Vegetable Research at the North Willamette Agricultural Experiment Station, 1987-1988

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VEGETABLE RESEARCH AT THE NORTH WILLAMETTE AGRICULTURAL EXPERIMENT STATION, 1987-1988

INTRODUCTION

A full-time program of vegetable crop research has been conducted at the North Willamette Experiment Station since 1976. The Station, a branch of the Oregon State University Agricultural Experiment Station, is just north of Aurora, a historic farming community 20 miles south of Portland. The land is provided by Clackamas County, with facilities owned and maintained by the University. Major vegetable research emphasis is on the needs of fresh-market growers in the Willamette River Valley, but research is also conducted on home garden and small farm intensive vegetable culture, and processed vegetable crops.

Many research projects reported here involved cooperation with research and Extension Service colleagues in the Oregon State University system and with area vegetable growers. Their contributions are gratefully acknowledged. The financial support of Kimberly-Clark, CDK International, the Oregon Processed Vegetable Commission, the Oregon Danvers Onion Commission, and the Oregon Potato Commission was essential to completing these projects and is greatly appreciated.

Ten crops from broccoli to tomato were involved in these experiments. This report is the sixth in a series of biannual reports initiated in 1979.

RESPONSE OF CRISPHEAD LETTUCE TO RATES OF NITROGEN AND POTASSIUM

Cooperators: N.S. Mansour, J.R. Baggett, Department of Horticulture

Introduction

Present crisphead lettuce varieties are not well-adapted to culture in the Willamette Valley, particularly in mid-summer. Oregon State University plant breeders N.S. Mansour and J.R. Baggett are attempting to develop well-adapted varieties based on crosses of 'Ithaca' x 'Salinas,' each of which has desirable characteristics. Qualities sought include good head size (about two pounds/head at maturity), resistance to bolting, uniform maturity, a moderately firm head with good color, and resistance to tipburn and rib blight (brown rib). The OSU release 'Summertime' has shown promise but its response to soil fertility is not well known. The purpose of these three trials was to study the yield and quality of 'Summertime," as compared to 'Salinas,' in response to various rates of N and K fertilizer.

Methods

For the first planting, 135 pounds P/acre as triple superphosphate was broadcast to the plot area. Potassium chloride was then applied to main plots (15 feet x 25 feet) at rates of 0, 83, and 167 pounds K/acre in a randomized block design with five replications of each rate. Fertilizers were then incorporated by rotary tillage. 'Salinas' and 'Summertime' were seeded with a belt planter at about five seeds/foot on 22 April, 1987, with two rows/bed on 16-inch centers, followed by an application of pronamide at 1.5 pounds/acre. The seedlings were thinned to about 12-inch in-row spacing on 13 May and the main potassium plots were split randomly by a sidedressed application of ammonium nitrate at 50, 100, or 150 pounds N/acre. The experimental design consisted of a split-split plot with K rates as main plots, N rates as subplots, and varieties as sub/subplots. Carbaryl was applied for insect control at weekly intervals at a rate of 1.0 pound/acre. Sub/subplot size was a single two-row bed of 4 x 10 feet. First harvest was on 1 July and all remaining heads were harvested on 6 July.

The methods for the second planting were similar except as follows. Seeding date was 21 May, 1987, and thinning and N application date was 12 June. The K rates were 0 and 167 pounds/acre; N rates were 30, 60, 90, and 120 pounds/acre, and there were four replications. First harvest was on 31 July. Remaining marketable heads were cut on 5 August.

Methods for the third planting were also similar except that 250 pounds/acre of ammonium sulfate was applied with the superphospate and potassium chloride. The lettuce was seeded on 15 June, 1988, and thinned on 29 June. The main K plots were then split by application of ammonium nitrate at 0, 50, 100, or 150 pounds N/acre, resulting in total N application rates of 50, 100, 150, and 200 pounds/acre. Sub/sub-plot size was a single two-row bed of 4 x 15 feet. First harvest was on 18 August, the second on 23 August.

Results and Discussion
First planting

Head size was small for the first planting even though heads were harvested when firm (Table 1). 'Summertime' matured earlier than 'Salinas' as evidenced by the higher percentage of heads cut at the first harvest. Head size 'Summertime' was unacceptably small, however, regardless of treatment. There was a trend, although not statistically significant, for greater head size of both varieties at higher rates of N. Rate of K had no consistent effect on head weight.

'Summertime' was much less susceptible to both rib blight and tipburn. Incidence of both disorders was higher at the second harvest for both varieties. Higher rates of N reduced rib blight at the second harvest, but this effect was not consistent over both harvests. Higher rates of K also reduced incidence of rib blight and tended to reduce tipburn.

All heads were cut at the second harvest in order to obtain a more accurate effect of N and K on head weight. Since the carton weights (weight of 24 heads) were unacceptably low for all treatments, essentially no treatment produced marketable size in this planting.

There were no significant two- or three-way interactions affecting yield or quality; only main effects are given in Table 1.

Second planting

Head size was greatly improved in the second planting, although most 'Salinas' heads were starting to bolt by the second harvest (Table 2). A much higher percentage of 'Summertime' than 'Salinas' heads were cut in the two harvests. Most 'Salinas' plants left unharvested were bolters. Bolting was not a problem in 'Summertime.'

Head size of 'Salinas' was again greater than for the 'Summertime.' Averaged across all fertilizer treatments, 'Summertime' carton weight was still only marginally acceptable. At the highest N rate, however, carton weight was acceptable (Table 3). Head weight increased with increasing N rate but was not affected by rate of K. 'Summertime' responded more to N rate than did 'Salinas' (Table 3). As in the first planting, 'Summertime' matured earlier than 'Salinas' and the high rate of K appeared to retard maturity (Table 2). Neither K nor N rate affected the percentage of heads cut in the two harvests.

Rib blight and tipburn were, again, less prevalent in 'Summertime' than in 'Salinas.' Rate of N had no effect on either disorder when averaged over K rates and varieties, but both were reduced with the high rate of K. This is consistent with the first planting. The interaction of variety and N rate was significant for rib blight. The greatest occurrence of blight was at low N for 'Summertime,' but at intermediate N rates for 'Salinas.'

Third planting

As with the first planting, there were no significant two-way or three-way interactions among K rate, N rate, and cultivar affecting any component of yield or quality. Thus, only main effects of treatments are presented.

Head size was again very small, particularly for 'Summertime' (Table 4). As in 1987, 'Summertime' matured earlier, as evidenced by the greater percentage of heads cut at the first harvest. Increasing rate of N tended to delay maturity of both lines and K rate had no significant effect.

Neither N nor K rate had any statistically significant effect on head weight at either harvest (Table 4). However, the trend was for applied K to reduce yield on this high potassium soil, and the 100 pound/acre N rate tended to be optimal.

As in the 1987 trials, 'Salinas' was much more susceptible to rib blight and tipburn than was 'Summertime' (Table 5). Also as in 1987, N rate had no significant effect on incidence of rib blight or tipburn, but rib blight was reduced by K application.

Observations were made on 4 August of the number of plants exhibiting a yellows disorder of the lower leaves. This disorder has been attributed to beet western yellows virus or perhaps to some other luteovirus. Neither N nor K rate had any effect on the disorder (Table 5), but the disorder occurred more often in 'Summertime.'

Results of these trials indicate that 'Summertime' is less susceptible to tipburn, rib blight, and bolting, under widely varying conditions of soil fertility, than is 'Salinas.' Rate of K had no effect on yield on this soil but high K rates appeared to reduce rib blight. The response to N was small, and 'Summertime' was marginal for head size. Rates of N up to 150 pounds/acre can be applied to 'Summertime' without reducing head quality. 'Summertime' heads may be excessively firm. A yellows disorder of the older leaves was more prominent in 'Summertime' than in 'Salinas.' This requires removing more leaves at harvest, increasing the difficulty of obtaining satisfactory head size in 'Summertime.'

Table 1. Main effects of N and K rates and cultivar on head weight, and rib blight and tipburn incidence in crisphead lettuce, first planting, 1987

Treatment	% heads cut., harvest 1	Mean head wt. (g)			Mean[z] carton wt. (lb)	Rib blight (%)			Tipburn		
		Harv. 1	Harv. 2	Mean		Harv. 1	Harv. 2	Mean	Harv. 1	Harv. 2	Mean
Cultivar											
Salinas	22.6	703	543	577	37.2	33.3	39.7	38.4	6.6	12.3	10.5
Summertime	42.7	567	413	483	30.0	0.7	13.5	7.3	0.6	4.6	3.1
	**[y]	**	**	**	**	**	**	**	*	**	**
N rate (lb/A)											
50	31.3	615	467	519	32.5	9.9	33.1	25.4	6.0	10.7	8.0
100	33.9	637	484	532	33.7	22.7	26.1	24.2	2.1	8.7	6.8
150	32.7	643	483	538	34.0	16.2	20.5	18.9	2.6	6.1	5.5
	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
K_2O rate (lb/A)											
0	29.9	654	473	526	34.6	15.9	33.5	27.6	4.7	9.2	7.2
100	35.4	636	499	545	33.6	17.8	27.6	24.6	3.8	10.5	8.4
200	32.6	615	462	518	32.5	17.4	18.6	16.4	2.3	5.7	4.7
	NS	NS	NS	NS	NS	NS	*	**	NS	NS	NS

[z]First harvest only.
[y]**, *, NS: significant differences among means at 1% level, 5% level, and no significant differences, respectively.

Table 2. Main effects of N and K rates and cultivar on head weight, and rib blight and tipburn incidence in crisphead lettuce, second planting, 1987

Treatment	% heads cut		Mean head wt. (g)			Mean carton wt.(lb)	Rib blight (%)[z]	Tipburn (%)[z]	No. cartons/acre[y]
	Harv. 1	Total	Harv. 1	Harv. 2	Mean				
Cultivar									
Salinas	18.5	80.3[x]	845	829	831	43.9	10.3	5.9	875
Summertime	45.7	96.8	773	780	776	41.0	2.3	1.4	882
	**	**	*	*	*	*	**	**	NS
N rate (lb/A)									
30	33.4	90.3	771	775	774	40.9	4.9	3.6	839
60	24.6	86.5	758	793	773	40.9	6.0	3.4	882
90	35.3	87.7	850	814	828	43.8	9.5	1.7	879
120	35.1	89.9	852	836	846	44.7	4.9	5.9	910
	NS	NS	NS	NS	*	*	NS	NS	NS
K_2O rate (lb/A)									
0	36.5	88.6	790	813	810	42.8	9.4	5.3	871
200	27.7	88.5	826	796	806	42.6	3.2	2.0	885
	**	NS	NS	NS	NS	NS	**	*	NS

[z]Second harvest only. No tipburn or rib blight at first harvest.
[y]24 heads/carton.
[x]Most heads not cut were bolting.

Table 3. Interaction of nitrogen rate and cultivar on mean head weight and rib blight incidence, second harvest of second planting, 1987

Cultivar	N rate (lb/A)	Mean head wt. (g)	Carton wt. (lb)	rib blight (%)
Salinas	30	811	42.9	3.5
	60	803	42.4	11.9
	90	854	45.1	16.9
	120	847	44.8	8.6
Summertime	30	740	39.1	6.3
	60	784	41.4	0.0
	90	774	40.9	2.0
	120	825	43.6	1.1
	LSD(0.05)	NS		10.0

Table 4. Main effects of N and K rates and cultivar on head weight and maturity of crisphead lettuce, 1988

Treatment	% heads cut		Mean head wt. (g)			Mean carton
	Harv. 1	Both	Harv. 1	Harv. 2	Mean	wt. (lb)
Cultivar						
Salinas	27.7	87.9	627	556	577	30.5
Summertime	40.2	91.9	565	483	518	27.4
	**	*	**	**	**	**
N rate (lb/A)						
50	42.0	93.2	598	510	550	29.1
100	36.7	92.8	612	528	561	29.7
150	30.2	90.1	574	525	540	28.5
200	26.9	83.4	598	515	539	28.5
	*	NS	NS	NS	NS	NS
K_2O rate (lb/A)						
0	37.4	92.4	601	530	561	29.7
200	30.5	87.4	591	509	534	28.2
	NS	NS	NS	NS	NS	NS

Table 5. Main effects of N and K rates and cultivar on disorders of crisphead lettuce, 1988

Treatment	Rib blight (%)			Tipburn (%)			% plants with
	Harv. 1	Harv. 2	Mean	Harv. 1	Harv. 2	Mean	yellows
Cultivar							
Salinas	71.7	62.4	63.6	33.1	70.7	59.1	11.5
Summertime	12.2	11.3	11.8	3.5	8.1	5.8	15.6
	**	**	**	**	**	**	*
N rate (lb/A)							
50	46.2	36.1	38.7	15.6	38.7	29.8	12.7
100	45.1	39.2	39.8	16.9	44.5	36.8	12.9
150	38.9	34.5	36.2	15.5	37.0	31.3	14.5
200	37.6	37.6	37.6	25.2	37.6	31.9	14.1
	NS	NS	NS	NS	NS	NS	NS
K_2O rate (lb/A)							
0	43.6	43.5	43.5	18.5	40.9	33.1	13.9
200	40.3	30.3	32.3	18.1	38.0	31.9	13.2
	NS	*	*	NS	NS	NS	NS

NITROGEN AND POTASSIUM RATES ON MINERAL SOIL ONION PRODUCTION

Introduction

Storage onion production in western Oregon has been almost exclusively on drained lake bottom soils which are high in organic matter. More recently, production of onions on mineral or "upland' soils has increased rapidly. Response of onions to nitrogen and potassium rates on mineral soils is not well understood. A trial in 1985 indicated that maximum yield and largest bulb size occur at 150 to 225 pounds N/acre on a Willamette silt loam. Onion yields did not respond favorably to K application, but some growers believe that high rates of K increase storage quality.

In 1986, yields of 'Granada' onion were greatest at 150 pounds N/acre while yields of 'Simcoe' were greatest at 250 pounds N/acre, on Willamette soil. In a grower field, 'Granada' yield did not vary significantly with N rates from 144 to 264 pounds/acre. In both experiments, rots and sprouting in storage were not affected by N rates. The 1987 and 1988 trials evaluated onion yield and keeping quality as a function of N and K rates.

Methods

After disking and harrowing, 500 pounds/acre of ammonium sulfate was applied to a Willamette silt loam, pH 5.9. Main plots of 30 x 15 feet were established by application of potassium chloride at 0, 100, or 200 pounds K_2O/acre with four replications of each treatment. The KCl was incorporated to a depth of four inches by rotary tillage and 5-foot-wide, 30-foot-long beds were seeded with three rows of 'Granada' onion with 20 inches between rows on 27 April, 1987. Propachlor herbicide was applied at 4 pounds/acre immediately after seeding, and was reapplied on 3 June and 2 July. Methomyl was applied at 0.45 pounds/acre for thrips control on 2 July.

Nitrogen rates of 0, 75, and 150 pounds N/acre (total N = 100, 175, 250 pounds/acre, respectively) as ammonium nitrate were applied to 5- x 30-foot subplots on 11 June. Plants were topped on 21 September and harvested on 23 September. Bulbs were size-graded into large (over 3-inch diameter) and small sizes. The large bulbs were collected for a storage trial and rated for basal and neck rots and sprouting on 25 February, 1988.

Methods were similar in 1988. Seeding date was 15 April. The propachlor was reapplied once on 20 May along with oxyfluorfen at 0.25 pounds/acre. The methomyl application was on 20 June. Nitrogen rate subplots were established on 11 June and harvest was on 12 October. The 1988 storage trial ended on 14 February, 1989.

Results

Neither N nor K rate greatly affected onion yield or bulb size in 1987. Yield and bulb weight tended to be greatest at 100 pounds N/acre

(Table 1). Mean bulb weight and percentage of large bulbs were significantly reduced at 250 pounds N/acre. Bulb size and yield also tended to be reduced at the highest rate of potassium application, perhaps due to the chloride provided by the KCl. As in 1986, the absence of significant rainfall during the April-June establishment period may have prevented leaching of nitrogen below the onion root zone.

The interaction of N and K rates significantly affected total yield (Table 2). Increasing the N rate decreased yield at the 0 and 100 pound rates of K_2O but increased yield at the high rate of K.

Neither N nor K rate consistently affected rots of the neck or basal plate after storage (Table 1). Increasing N rate significantly increased the degree of sprouting; increasing K tended to reduce sprouting (Table 1). The sprout inhibition effect at high rates of K was particularly pronounced at high rates of N (Table 3).

In 1988, there were no significant interactions of N and K rates on yield; only main effects are presented in Table 4. The greatest yield of large bulbs (over 3 inches) occurred with 175 pounds N/acre. Total yield and mean bulb weight also tended to be greatest at this N rate, but the differences were not significant (Table 4). The highest percentage of large bulbs occurred with 175 or 250 pounds N/acre. These results are in contrast to 1987, when onion yields were greatest at 100 pounds N/acre, but are in agreement with results obtained in 1985 and 1986.

Also in contrast to results of the previous experiments, application of a low rate of K tended to increase yield of large bulbs and mean bulb weight. However, K application decreased total yield and the high rate of K also decreased the yield and percentage of large bulbs. Although not statistically significant, the high rates of K and N tended to reduce stands slightly. Part of the yield effect of the fertilizers may be due to their effects on stands and competition among plants.

Increased K tended to reduce sprouting in 1988 but the effect was not significant. Application of K reduced basal plate rots. Rate of N had no effect on rot or sprouting.

The results of four years of fertilizer trials indicate that N applications should be moderate, in the range of 150 to 200 pounds/acre. Potassium application, even where soil test does not indicate a likely yield response, may lead to improved storage life.

Table 1. Main effects of N and K rates on yield and size of 'Granada' onion, 1987

Treatment	Yield (50 lb bags/acre)		Mean bulb wt. (g)		% large	% rot after storage		% sprouting
	Large bulbs	All bulbs	Large	All	bulbs	Basal	Neck	in storage
N rate (lb/acre)								
100	399	869	342	229	30.8	0.9	4.1	0.0
175	385	844	338	232	30.7	0.0	4.7	0.5
250	298	735	334	196	21.6	3.8	5.2	4.8
	NS[z]	NS	NS	*	*	NS	NS	**
K_2O rate (lb/acre)								
0	381	844	339	226	29.7	0	6.1	2.9
100	385	823	331	224	31.4	2.4	1.6	2.4
200	298	781	343	206	22.3	2.3	6.3	0.0
	NS	NS	NS	NS	NS	NS	NS	NS

[z]NS, *, **: no significant differences, significant at the 5% and 1% levels, respectively.

Table 2. Interaction[z] of N and K rates on total yield (bags/acre) of onions produced, 1987

N rate	K_2O rate (lb/acre)		
(lb/acre)	0	100	200
100	962	1003	643
175	799	928	805
250	772	538	895

[z]LSD (0.05) = 289 bags/acre. Interaction significant at P = 0.02.

Table 3. Interaction of N and K rates on onion sprouting in storage, 1987[z]

N rate (lb/acre)	K_2O rate (lb/acre) 0	100	200
100	0.0	0.0	0.0
175	0.9	0.6	0.0
250	7.9	6.6	0.0

[z]Rated on 2/25/88. LSD (0.05) = 5.0%.

Table 4. Main effects of N and K rates on yield and size of 'Granada' onion, 1988

Treatment	Bulb yield (50 lb bags/acre) Large	All	Mean bulb wt. (g)	% large bulbs	% rot after storage Basal	Neck	% sprouting in storage
N (lb/acre)							
100	136	783	164	9.3	0.7	1.0	2.0
175	238	885	186	15.1	0.3	1.0	2.0
250	211	817	185	15.3	0.3	1.3	3.7
Significance	*	NS	NS	*	NS	NS	NS
K_2O (lb/acre)							
0	204	881	176	13.0	1.3	0.7	3.7
100	253	819	186	17.7	0.0	1.0	2.7
200	128	785	172	9.0	0.0	1.7	1.3
Significance	*	NS	NS	*	*	NS	NS

NITROGEN FERTILIZER RATES AND BANDED PHOSPHORUS ON CARROT ROOT YIELD AND QUALITY

Cooperator: H.J. Mack, Department of Horticulture

Introduction

Higher yields and improved root quality are essential for processing carrot growers to remain competitive. Nitrogen fertilizer applications usually range from 50 to 100 pounds N/acre with most between 50 and 80 pounds. More research is needed to clarify yield response to N, especially at higher rates, and the influence of N on such root characteristics as diameter, length, splitting, and rots. Yield response to application of banded P fertilizer is also poorly understood.

In a trial in 1986, carrot yields tended to be greatest at 85 pounds N/acre, but did not vary greatly with N rate. Incidence of soft rot and root cracking increased with increasing N rate. Yield of large roots increased with banded P but this may have been caused by reduced stand on the banded P plots. The objective of the 1987 trial was to evaluate the effect of five N rates, both with and without banded P fertilizer, on yield and root characteristics.

Methods

A base fertilizer of 500 pounds/acre of a 10N-8.7P-8.3K fertilizer was disked into a Willamette silt loam on 27 April, 1987, and five-foot-wide beds were formed by rotary tillage. 'Nantes' carrot was seeded on 28 April at 15 seeds/foot, three rows per bed, with Planet Jr. seeders. Concentrated superphosphate was banded at 50 pounds P/acre approximately two inches beneath and one inch to the side of the row of appropriate plots at planting. Plot length was 15 feet. Linuron was applied at 1.0 pound/acre immediately after planting and was reapplied at 0.5 pounds/acre on 1 June. Fluazifop was also applied on 1 June at 0.25 pounds/acre.

The N rate variable was established on 5 June when ammonium nitrate was sidedressed at 30, 60, 90, or 120 pounds N/acre on the appropriate plots with four replications of each treatment in randomized block design. The P variable was restricted to three rates of N, for a total of eight treatments. Roots were harvested on September 24 and graded into three size categories (over 2-inch shoulder diameter, 1 to 2 inch, and less than 1 inch). Each root was visually inspected for cracking, and rots and defective roots were counted separately.

Results

The yield of roots in the large size category increased significantly with increasing N rate but most of the increase occurred between 50 and 110 pounds N/acre (R^2 = 0.80 linear, 0.89 quadratic). The increased yield was due to larger number of roots in this size category (Table 1). The increase in numbers of large roots also occurred mostly between 50 and 110 pounds N (R^2 = 0.84 linear, 0.92 quadratic). Yields of other size categories did not vary significantly with N rate. Total yield varied significantly with N rate, reaching a maximum at 140 pounds N/acre (R^2 = 0.70 quadratic, P = 0.04). The total number of roots recovered did not vary with N rate. Mean root weight also increased with N rate to a maximum at 140 pounds N/acre (R^2 = 0.72 quadratic, P = 0.03). Unlike 1986, the percentage of cracked and rotten roots did not vary significantly with N rate, but there was a strong trend for greater numbers of cracked roots at the higher N rates. The percentage of cracked roots was about tenfold higher in 1987 than in 1986, reflecting reduced plant population and the resulting increase in root size and maturity at harvest.

Banded P had no effect on any component of yield or quality. This is in contrast to 1986, when banded P reduced both yield and the percentage of rotted roots. Banded P reduced stands in 1986 but not in 1987.

These results indicate that, although root yields at low plant density may be increased by applying higher N rates, the increases are not of large magnitude and may be offset by increases in cracking. There was a trend, although not statistically significant, for fewer defect-free roots at higher rates of N.

Table 1. Main effects of N rates and banded P on yield and root characteristics of carrot, 1987

Treatment	Root yield (tons/acre)				No. roots/ foot	No. large roots/foot	Mean root wt. (g)	% cracked roots	% soft-rotted roots	No. of defect-free roots/foot
	Large	Med.	Small	Total						
N rate (lb/acre)										
50	2.4	27.7	2.9	33.0	11.4	0.3	131	21.3	8.0	8.8
80	3.5	31.9	2.6	38.0	12.1	0.5	139	19.8	5.6	9.8
110	6.6	28.7	2.5	37.8	11.0	0.9	148	32.2	10.4	8.1
140	7.0	34.6	1.7	43.3	11.4	0.8	167	33.6	15.8	7.8
170	7.2	29.7	3.4	40.3	12.0	1.0	150	33.6	8.8	7.8
Linear	*[z]	NS	NS	NS	NS	*	NS	NS	NS	NS
Quadratic	*	NS	NS	*	NS	**	*	NS	NS	NS
P rate (lb/acre)										
0	5.5	28.6	2.9	37.0	11.5	0.7	142	30.1	9.4	8.2
50	4.9	29.4	2.3	36.6	11.0	0.6	146	25.9	7.9	8.3
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]*, **, NS: significant differences at 5% and 1% levels, and no significant differences, respectively.

PLUG TRANSPLANTING OF ONIONS

Introduction

Transplanting onions is not a common practice in the United States, but bare-root transplants are used to establish stands of early maturing onions in a few growing regions. Use of plug-grown onion transplants is almost unknown. The primary reasons for transplanting are to obtain earliness, to obtain a stand when soil or weather conditions are unfavorable for direct seeding, or to allow for multiple cropping. Transplanting may provide a means for western Oregon growers to establish a stand on muck soils following spring fumigation for control of white rot and other diseases, weeds, and insect pests. The season is usually too short to allow spring fumigation followed by direct seeding.

Growing seedlings in cells or plugs in a greenhouse is expensive compared to direct seeding. One means to reduce this cost is to grow multiple seedlings per cell, a practice used to some extent in the United Kingdom. This practice could lead to excessive crowding of the plants in the row and deformed bulbs at harvest, particularly at the high plant populations (80,000 to 120,000/acre) common in production of bulb onions for storage.

The purpose of this preliminary trial was to investigate the effects of plug size, number of seedlings/plug, and spacing of the plugs in the row on yield and quality of storage onions. The trial was conducted on a mineral soil in the expectation that this would be a more difficult test of bulb shape and quality than with the same variety on a muck soil since the maturing bulbs are thought to spread apart more easily on muck.

Methods

'Granada' onion was seeded in an unheated greenhouse on 21 March, 1988, into two sizes of plugs or cells. The smaller plug size was a 256-plug tray from Growers' Transplanting, Inc. The 0.75-inch-square cells were filled with a peatlite medium to a depth of about 1 inch. The larger plug was a 2-inch-square plastic pot, filled to a depth of about 2.5 inches. Either 2, 4, or 5 seeds were placed in each plug. Seedlings were thinned to 1, 2, or 3 per plug at the first true leaf stage. The seedlings were irrigated daily as needed and fertilized weekly with a 10N-13P-16.7K soluble fertilizer at 100 ppm N.

The plugs were transplanted to a Willamette silt loam, pH 6.0, on 12 May. The treatments consisted of a factorial combination of the two cell sizes, the three populations per plug, and in-row spacing between plugs of 6 or 12 inches. In addition, a check treatment consisted of single seedlings grown in the small plugs and planted on 4-inch spacing. For all treatments, plot size was a 10-foot section of a 3-row bed with 15 inches between rows. Target plant populations per acre ranged from a low of 26,136 (1 plant/plug, 12-inch spacing) to a high of 156,816 (3 plants/plug, 6-inch spacing).

Propaclor herbicide was applied at 4 pounds/acre immediately after planting and was reapplied one month later at the same rate in combination with oxyfluorfen at 0.25 pounds/acre. Weeds were also hand-hoed once. Methomyl was applied at 1.0 pounds/acre for thrips control on 20 June, followed by an application of azinphosmethyl on 11 July. Treatments were rated for degree of bolting and percentage of tops down on 19 August. Bulbs were topped on 1 September and harvested on 8 September. Bulbs were separated into four size categories (less than 2-inch diameter, 2- to 3-inch diameter, 3- to 4-inch diameter, and 4- to 5-inch diameter), weighed, counted, and misshapen bulbs noted.

Results

Plant survival, expressed as the percentage of bulbs recovered at harvest compared to the number of seedlings planted, was increased by the larger plug, and by 1 or 2 seedlings/plug compared to 3 seedlings/plug (Table 1). In-row spacing between plugs had no significant effect on plant survival, but there was a trend toward greater survival at the 12-inch spacing. Thus, crowding of the seedlings reduced seedling survival. Seedlings in the smaller plugs and, especially, with multiple seedlings/plug, were noticeably less developed at time of transplanting. There were no significant interactions between plug size, seedlings/plug, and in-row spacing, so only main effects are given in the tables.

Maturity, as reflected in the percentage of tops down two weeks before harvest, was greater for the larger plug size, for 2 or 3 seedlings/plug as compared to 1 seedling/plug, and for the 6-inch in-row spacing (Table 1). Thus, higher plant populations favored earlier maturity. However, this was not strictly an effect of crowding, as plants from the larger, less crowded plugs, were also more mature. There were no significant interactions, so only main effects are given in the Table.

The percentage of bulbs forming seed stalks (bolting) was increased by large plug size, by increasing number of seedlings/plug, and by the closer in-row spacing (Table 1). The same factors affecting maturity were also apparently affecting seed stalk formation. Generally, crowding was associated with greater degree of bolting; however, the delayed maturity in the small plugs somewhat offset the effects of crowding.

Main effects of treatments on yield are presented in Table 2. The larger plug size, when averaged over the other treatments, produced more bulbs in the largest size category and reduced the number of bulbs in the smallest size categories. Total yield and mean bulb weight were greater for the larger plugs and there were fewer misshapen bulbs with the larger plugs.

Increasing the number of seedlings/plug increased the percentage of bulbs in the two smaller categories, at the expense of the larger bulbs, and mean bulb weight decreased markedly with increasing number of seedlings/plug. Nevertheless, total yield increased with increasing number of seedlings/plug as the much greater plant population more than offset the effect of reduced bulb size. The number of misshapen bulbs also increased sharply with multiple seedlings/plug.

Increasing the distance between plugs in the row greatly increased the percentage of bulbs in the larger-sized categories and increased mean bulb weight, but reduced yield as the effect of the larger bulbs was more than offset by the reduced plant population. Increasing the distance between plugs slightly reduced the percentage of misshapen bulbs.

There was a significant interaction of seedlings/plug and in-row spacing affecting the yield of large bulbs and mean bulb weight (Table 3). Increasing the number of seedlings/plug decreased large-bulb yield at 6-inch spacing, while the opposite was true with 12-inch spacing. The excessive crowding at 6-inch spacing and multiple seedlings/plug reduced bulb size. Bulb size decreased with increasing seedlings/plug much more at 6-inch spacing than at 12-inch spacing.

The interaction of all combinations of treatments on total yield, yield of large bulbs, mean bulb weight, and percentage of bolters and misshapen bulbs is given in Table 4. The greatest total yield occurred with the combination of large plugs, 3 seedlings/cell, and 6-inch spacing, but the percentage of bolters was also highest for this treatment and the percentage of misshapen bulbs was also very high. This combination of treatments produced the highest plant population. While the combination of small plugs, 3 seedlings/cell, and 6-inch spacing had the same target population, the actual number of bulbs recovered was higher for the large plugs due to greater seedling survival.

The greatest yield of large bulbs was with the combination of large plugs, 3 seedlings/plug, and 12-inch spacing, followed closely by small plugs, 2 seedlings/plug, 6-inch spacing, and large plugs, 1 seedling/plug, and 6-inch spacing. Generally, when the in-row plant population exceeded 4/foot, the yield of large bulbs was reduced dramatically.

Picking the best treatment depends on the total yield, the desired bulb size, and the economics of establishing the stand. No one combination of treatments can be considered the best, since the treatments producing the highest total yields were not necessarily those producing the greatest yields of large bulbs and acceptably low percentages of bolters and misshapen bulbs, nor were they necessarily the least expensive in terms of stand establishment.

Stand establishment costs are reduced with smaller plugs, greater numbers of seedlings/plug, and greater in-row spacing. The combination of small plug, 2 seedlings/plug, and 6-inch spacing, requiring 52,272 plugs/acre, and the combination of large plug, 3 seedlings/plug, and 12-inch spacing, requiring only 26,136 plugs/acre, produced essentially the same yield of both large bulbs and total bulbs and only a moderate amount of misshapen bulbs. This may appear to favor the latter treatment, since only half as many plugs are required. However, the large plugs require much more greenhouse bench space, 726 square feet for 26,136 plugs, versus only 204 square feet for the 52,272 small plugs.

This trial does establish the feasibility of using multiple seedlings per plug, as acceptable yields of well-formed, large bulbs could be obtained, as long as the population of bulbs did not exceed 4/foot. Several treatments produced yields of high quality, large bulbs that were greater than the yield obtained with the check treatment of 1 seedling/cell and 3 bulbs/row foot.

Table 1. Main effects of plug size, number of seedlings/plug, and in-row spacing between plugs on seedling survival, bolting, and maturity of transplanted onions, 1988

Treatment	Seedling survival (%)	% bolted	% tops down on 19 Aug.
Plug size			
Small	89	3.6	13
Large	99	12.4	24
	**	**	*
No./plug			
1	97	4.1	5
2	98	8.6	25
3	92	11.2	26
	*	**	**
Spacing			
6 inch	94	10.9	26
12	96	5.1	11
	NS[z]	**	**
Check[y]	92	7.3	15

[z]NS,*,**: Nonsignificant, significant at the 5% level, and significant at the 1% level, respectively.
[y]Small plug, 1 seedling/plug, 4-inch spacing.

Table 2. Main effects of plug size, number of seedlings/plug, and in-row spacing on yield and size distribution of transplanted onion, 1988

	% bulbs by number				Total yield	Mean bulb	Misshapen
	1-2"	2-3"	3-4"	4-5"	cwt/acre	wt. (g)	(% by number)
Plug size							
Small	6.5	27.8	59.7	6.1	437	333	7.6
Large	2.6	19.5	60.7	17.4	573	382	3.8
	NS	*	NS	**	**	**	*
No./plug							
1	0.0	4.2	67.5	28.3	404	485	0.0
2	2.0	26.8	66.2	5.3	521	325	2.6
3	11.6	39.9	46.9	1.6	590	263	14.3
	*	**	**	**	**	**	**
Spacing							
6 inches	8.7	32.3	51.9	7.2	610	325	7.1
12 inches	0.4	14.9	68.5	16.3	401	390	4.3
	**	**	**	**	**	**	*
Check	1.8	28.9	68.1	1.2	546	343	0.9

Table 3. Interaction of number of seedlings per plug and in-row spacing on yield by weight of large onions and average bulb weight of all bulbs, 1988

No./cell	Spacing	Yield of large bulbs[z] (cwt./acre)	Mean bulb wt. (g)
1	6 inches	524	487
2	6	441	280
3	6	288	209
1	12 inches	268	483
2	12	380	370
3	12	426	317
	LSD (0.05)	115	64

[z]3-5 inch diameter

Table 4. Interaction of plug size, number of seedlings/plug, and in-row spacing on yield and quality of transplanted onions, 1988

Plug size	No. / plug	Spacing	Plant population per acre	Bulb yield (cwt/acre) Large	All	Mean bulb wt. (g)	% bolted	% misshapen
Small	1	6 inch	52,272	500	516	489	3.4	0.0
		12 inch	26,136	246	251	463	3.5	0.0
	2	6 inch	104,544	553	577	267	5.0	5.4
		12 inch	52,272	307	349	319	4.4	2.8
	3	6 inch	156,816	135	509	177	3.3	21.9
		12 inch	78,408	296	424	281	2.3	15.6
Large	1	6 inch	52,272	549	553	485	9.2	0.0
		12 inch	26,136	290	296	503	0.7	0.0
	2	6 inch	104,544	520	688	292	19.0	2.1
		12 inch	52,272	452	471	420	6.0	0.9
	3	6 inch	156,816	440	817	240	25.6	13.2
		12 inch	78,408	557	612	351	13.9	6.5
Small[z]	1	4 inch	78,408	440	546	343	7.3	0.9
			LSD (0.05)	163	131	90	5.8	4.7

[z]Check

PLANT DENSITY AND IRRIGATION EFFECTS ON YIELD, HEAD ROT AND DOWNY MILDEW OF BROCCOLI

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Introduction

Head rot, caused by the soft rot bacterium *Erwinia carotovora*, and downy mildew, caused by *Peronospora parasitica*, are two serious diseases of broccoli in Oregon. Head rot is characterized by water-soaked lesions on heads which rapidly expand, resulting in a soft decay of the florets. Symptoms of downy mildew include light yellow lesions on the leaf surface and yellowing of the florets. Environmental conditions can play a major role in the development of these two diseases. Head rot is most prevalent when warm, moist conditions occur at the time of head formation whereas downy mildew is favored under cool, moist growing conditions. Because temperature and moisture are environmental parameters which can be influenced by plant population and irrigation practices, these studies were designed to evaluate the effect of plant populations and irrigation frequency and amount on yield, head rot, and downy mildew of broccoli.

Methods

In the 1987 plant population experiment, 'Gem' broccoli was seeded in 1.5-inch cells on 17 March, and placed in an unheated greenhouse. Seedlings were watered daily and fertilized with a soluble 20N-8.7P-16.7K fertilizer. The seedlings were transplanted to a Willamette silt loam on 16 April, 1987. The eight treatments included two between-row spacings (16 and 20 inches) and four in-row spacings (6, 8, 10 and 12 inches). Each plot was a four-row bed, 15 feet in length. The experimental design was a randomized block with treatments replicated six times. The plot area was treated with trifluralin at 0.75 pound/acre on 10 April and with propachlor at 4.0 pound/acre on 17 April. A diazinon drench at 1.0 pounds/acre was applied twice for maggot control. Total N applied in all the experiments was 250 pounds/acre. Following the establishment period, the plot area was irrigated by overhead sprinkler. At head initiation and one week later, a cell suspension of *Erwinia carotovora* was applied to the plants. Measurements of yield were taken from the middle two rows of each plot. Heads were harvested on 15 June and 23 June; weight and number of heads were recorded, and disease noted.

In the 1987 irrigation experiment, the two cultivars, 'Gem,' 'Citation,' and the breeding line 'OSU 86-3' were seeded on 24 June, 1987, and placed in a nonheated greenhouse. Seedlings were transplanted on 29 July and were spaced 10 inches apart within rows on 16-inch centers. Each plot consisted of a four-row bed, 12 feet in length. Cultivars were arranged in a randomized block design and replicated six times. Pest control was as in the previous experiment except that methomyl was applied at 0.25 lb/acre immediately after transplanting and *Bacillus thuringiensis* was applied at 0.25 lb/acre on 3 September for cabbage looper control. All plots received the same amount of water until two weeks prior to head initiation. At that time two line irrigation sources were established. One-half of the field was irrigated once a week for 7.5 hours while the other was irrigated three times a week for 2.5 hours each time. Three moisture levels were established within each frequency: high (0.75 inches/week), medium (0.5 inches/week), and low (0.25 inches/week). At head initiation and at weekly intervals, an aqueous suspension of *Erwinia carotovora* was applied to the plants with a pressurized, backpack sprayer.

Heads were harvested 28 September, and 6 and 12 October from the middle two rows of each plot.

In the 1988 population study, methods were similar to 1987 except that in-row spacings were 6, 9, and 12 inches, and the cultivar 'Gem' was seeded on 23 March, and 'OSU 86-3' on 9 March. Transplanting was on 26 April. The 12 combinations of between-row spacing, in-row spacing, and cultivar were replicated six times in randomized block design. Heads were harvested on 27 June, 5 July, 12 July, and 20 July.

In the 1988 irrigation study, methods were as in 1988, except that the seeding date was 23 June, transplanting date was 27 July, and harvests were on 6 October, 13 October, and 18 October. Water applied to each plot was measured with rain gauges located in each plot.

Results

In the 1987 population experiment mean head weight was significantly greater ($p = 0.05$) for the 20-inch between-row spacing than for the 16-inch between-row spacing. The average head weight was greatest at 10-inch in-row spacing. Yield increased from 6.6 tons/acre with a population density of 26,000 plants/acre to 10.1 tons/acre at 65,000 plants/acre (Table 1).

With hot, dry weather at harvest, head rot failed to develop. Downy mildew did occur naturally within the test plots, but no significant differences in disease incidence occurred among the different population densities (Table 1).

Table 1. Effect of plant population on 'Gem' of broccoli, spring 1987

Spacing		Population	Yield	Mean head	%
Between-row	In-row	per acre	(T/A)	wt. (g)	mildew
16	6	65340	10.0	181	6.4
20	6	52272	9.0	202	9.6
16	8	49005	8.0	211	7.5
20 (16)	8 (10)	39204	8.3	233	10.6
16	12	32670	6.8	239	7.0
20	10	31362	8.4	301	10.5
20	12	26136	6.6	277	3.6
		LSD(0.05)	2.4	58	NS[z]

[z]NS: no significant differences.

In the 1987 irrigation experiment, the amount of water applied had no effect on total yield in the high-frequency experiment, but did affect yield in the low-frequency experiment, with yields increasing with an increase in amount of water applied (Table 2). 'Gem,' the earliest maturing cultivar, had the greatest yield at the first harvest (data not shown). 'Citation,' which matured next, produced the highest yields during the second harvest. 'OSU 86-3' was late to mature and produced the highest yields at the last harvest, but total yield was still less than for the other two cultivars. However, if harvesting had been continued, yield of OSU 86-3 might have been comparable to the other two cultivars.

For all harvests, development of head rot was significantly affected by the amount of water applied in the low-frequency experiment. For both experiments, disease incidence tended to be higher in plots receiving high and medium amounts of water than in plots receiving a low amount of water (Table 3). There were no significant cultivar differences in susceptibility to head rot.

In contrast, the incidence of downy mildew was not significantly affected by the amount of water applied in either experiment, although there was a trend for an increase in amount of disease with an increase in amount of water applied. Cultivars, however, differed in their susceptibility to downy mildew. 'Gem' was the most susceptible cultivar.

The effects of amount of water on mildew and rot were most pronounced at the second harvest, the first in which significant disease occurred (Table 4). Both mildew and rot were more prevalent at the high rates and frequency of water application. In a separate experiment harvested once in late October, the percentage of rotten heads was 22.8 for the high frequency of irrigation but only 9.7 for the low frequency.

The fall weather was unusually dry and warm during this experiment. Despite unfavorable environmental conditions for extensive disease development, disease did occur. In plots receiving low amounts of water the incidence of head rot was reduced. When macroclimatic conditions are unfavorable for disease, a reduction in the amount of irrigation water applied could reduce the amount of disease. However, when the macroclimate is favorable for disease development, it is questionable whether a reduction in the amount of water applied would result in a decrease in the amount of disease.

Results of the 1988 population study were very similar to those of 1987 (Table 5). Mean head weight decreased with increasing plant population but yield increased up to 52,000 plants/acre as the greater number of heads more than offset the effect of reduced head size. Downy mildew incidence increased, and hollow stem incidence decreased, with increasing plant population. The degree of head rot did not vary significantly with plant population.

Table 2. Main effects of amount of water and cultivar on yield, head weight, and head width for two irrigation frequencies, 1987

Treatment	High frequency			Low frequency		
	Yield (T/A)	Head weight (oz)	Head width (in)	Yield (T/A)	Head weight (oz)	Head width (in)
Amount of water[z]						
High	7.6	9.4	4.4	9.3	10.3	4.7
Medium	7.6	10.4	4.8	7.2	10.0	4.9
Low	7.8	8.6	4.2	6.1	7.6	4.4
LSD(0.05)	NS	1.0	0.2	1.1	1.0	0.2
Cultivar						
Citation	8.9	10.4	4.8	8.5	9.8	4.8
Gem	7.7	8.8	4.4	8.2	9.1	4.6
OSU 86-3	6.4	9.1	4.3	5.9	9.0	4.5
LSD(0.05)	1.1	1.0	0.2	1.1	NS	0.2

[z]Low = 0.25 inches/week, medium = 0.50 inches/week and high = 0.75 inches/week.

Table 3. Main effects of amount of water and cultivar on incidence of head rot and downy mildew for two irrigation frequencies, 1987

Treatment	High frequency		Low frequency	
	Head rot %	Downy mildew %	Head rot %	Downy mildew %
Amount of water				
High	4.1	17.3	4.8	14.4
Medium	7.4	16.7	5.3	15.1
Low	2.3	13.2	0.9	8.6
LSD(0.05)	NS	NS	3.4	NS
Cultivar				
Citation	2.6	15.4	2.7	9.4
Gem	6.1	22.4	4.0	22.7
OSU 86-3	5.1	9.5	4.4	6.0
LSD(0.05)	NS	6.9	NS	5.9

Table 4. Main effects of amount of water applied, frequency of irrigation, and cultivar on head rot and downy mildew of broccoli, second harvest, October, 1987

Treatment	Head rot (%)	Downy mildew (%)
Amount of water		
High	4.8	22.3
Medium	4.9	18.2
Low	0.8	11.6
LSD(0.05)	3.5	6.6
Frequency		
Low	3.1	13.8
High	4.0	20.9
Cultivar		
Citation	3.1	13.9
Gem	5.1	32.8
OSU 86-3	2.3	5.4
LSD(0.05)	NS	6.6

Table 5. Main effect of plant population and cultivar on yield and disease of broccoli for spring planting, 1988

Treatment	Yield (T/A)	Head weight (oz)	Downy mildew (%)	Head rot (%)	Hollow stem (%)
Plants/acre					
65,340	8.5	6.4	15.2	15.3	24.4
52,272	8.6	7.3	10.0	17.7	29.9
43,560	8.3	8.0	8.2	19.1	43.9
34,848	6.8	8.3	12.3	26.2	37.6
32,670	7.8	8.6	6.5	13.4	53.2
26,136	6.8	9.7	7.3	16.9	59.9
	*	**	*	NS	**
Cultivar					
OSU 86-3	7.7	8.6	17.1	29.6	19.8
Gem	7.9	6.8	2.3	5.3	64.2
	NS	*	**	**	**

Head rot and mildew incidence were much greater in the OSU line than in 'Gem.' However, this is probably an effect of delayed maturity rather than a true difference in susceptibility. The 'OSU 86-3' heads were much slower to develop and were exposed to favorable conditions for disease development longer than were the 'Gem' heads. The OSU line had far fewer heads with hollow stems.

Laboratory tests were conducted to determine if 'Gem' and the OSU line differed in their susceptibility to head rot. Broccoli heads were inoculated with a cell suspension of *E. carotovora*, placed in large jars, sealed, and flushed with nitrogen to achieve an anaerobic environment. After six days, the heads were removed and the percent of rotted tissue was determined. No significant differences in susceptibility to head rot were observed. This indicates that the higher incidence of head rot in the OSU line in the field studies was due to the rot-promoting conditions at the time OSU heads were maturing.

Results of the two population experiments indicate that lowering plant density can not be used as a means of reducing disease incidence, at least with the range of populations used in this study. A previous experiment in 1986 indicated significant reduction in head rot with populations below 26,000/acre, but these are not economically reasonable populations for processing broccoli.

In the 1988 irrigation experiment, most of the 'Gem' heads were harvested during the first two harvests. 'Citation' matured later than 'Gem' with most of the heads harvested during the second and third harvests. The highest incidence of rot occurred in the second and third harvests of 'Gem' and the third and fourth harvests of 'Citation.' By the fourth harvest most of the heads of both cultivars were diseased (Table 6). Root maggot damage severely affected the OSU line but not the other cultivars. Data for the OSU line are not reported.

'Citation' had three times more head rot than 'Gem' (Table 6). In contrast, downy mildew was more severe in 'Gem' than in 'Citation.' Thus, there is not a positive correlation between head rot and downy mildew incidence, at least when compared between cultivars.

The incidence of head rot and downy mildew increased as the amount of water applied increased in the high-frequency experiment. In the low-frequency experiment, head rot did not vary significantly with the amount of water applied (Table 7).

Considerably less head rot developed in the low-frequency experiment compared with the high-frequency experiment. Downy mildew did not appear to vary with irrigation frequency. Total yield was not affected by irrigation frequency, but marketable yield was higher with the low frequency (Table 6). Because of the nature of the experimental design, the two frequencies can not be compared statistically.

Yield also increased with increased amount of applied water, although the plots closest to the irrigation lines (6 feet) tended to have the same yield as those 10 to 12 feet from the lines (Table 7). Gross yields did not vary with cultivar. The number of heads harvested was greater with 'Gem' but 'Citation' produced larger head size. Marketable yield (total yield minus the yield of diseased heads) also did not vary with cultivar or amount of applied water (Table 6).

Frequency of irrigation and amount of applied water should be minimized to avoid head rot problems. However, controlling the amount of water applied is probably not an effective management tool at this time, since the irrigation-yield relationship would have to worked out for different soil types, cultivars, and microclimates. Also, keeping the applied irrigation to the minimum required for economic yields will not protect against the effect of rain.

Table 6. Main effects of harvest date, cultivar, irrigation frequency, and amount of applied water on yield and disease incidence of broccoli, autumn, 1988

	Total yield (tons/A)	Marketable yield (T/A)	% Marketable	Mildew %	Head rot %
Harvest					
1	1.44	1.38	97	3	0
2	2.46	1.78	72	20	9
3	1.51	0.77	51	23	34
4	0.48	0.13	28	54	39
	**	**	**	**	**
Cultivar					
Gem	6.1	4.1	69	27	8
Citation	6.3	4.2	67	17	25
	NS	NS	NS	*	**
Frequency					
High	6.2	3.7	60	24	26
Low	6.1	4.6	75	19	7
Amount applied					
12-13 inches	6.6	4.0	61	25	21
10-12 inches	6.3	4.5	71	20	13
6-10 inches	5.4	3.9	72	18	14
	*	NS	*	*	NS

Table 7. Effects of irrigation frequency and amount of applied water on yield and disease incidence of broccoli, autumn 1988

Water applied (inches)	Total yield (T/A)	Marketable yield (T/A)	Mildew %	Rot %
	High frequency irrigation			
12.9	6.8	3.6	29	31
12.5	7.0	3.6	31	27
10.2	6.1	3.9	20	23
6.9	4.9	3.6	15	22
	**	NS	**	**
	Low frequency irrigation			
12.4	6.0	4.7	15	6
11.8	6.0	4.8	15	7
11.4	6.7	4.8	25	8
8.9	5.9	4.2	21	6
	*	*	NS	NS

MUSKMELON AND TOMATO PRODUCTION IN RESPONSE TO PLANT PROTECTION

Introduction

Tomato and muskmelon production in the Willamette Valley is limited by cool springs, a short growing season, and relatively cool nights, even during mid-summer. Cultural techniques to increase the mean air and soil temperature around plants, such as black plastic ground mulch, floating row covers, and tunnels, have hastened development and increased yield of both these crops.

Melons have nearly always responded favorably to row covers at the North Willamette Station, although in 1983, fruit size was reduced. Tomatoes have responded favorably to covers in most instances, but tomato yields have been reduced by covers during unusually warm seasons. Other plant protection devices, such as hotcaps and water-insulated shields, have not been compared directly to row covers for melon and tomato production. The purpose of these trials was to compare the effectiveness of several plant protection devices in increasing early and total yield of tomato and muskmelon, for both very early and normal transplant dates.

Methods

'Pikred' tomato was seeded in 2-inch pots in a heated greenhouse on 16 February and 13 March, 1987, and on 31 March, 1988. 'Goldstar' muskmelon was seeded on 8 April and 23 April, 1987, 'SuperStar' muskmelon on 20 April, 1988. The plot area was prepared by rotary tillage in late March following a broadcast application of 10N-8.7P-8.3K fertilizer at 1,000 pounds/acre. Black plastic mulch (0.04 mm x 1.2 m) was applied to the appropriate plots after laying drip irrigation tubing and the first transplanting of tomatoes was made on 2 April, 1987. The six plant protection treatments were applied immediately after planting with four replications in randomized block design. Each planting and crop was a separate experiment. Plot size was 3.7 m of row with five plants/plot. Between-row spacing was 2 meters.

Treatments for the early 1987 plantings consisted of a bare ground check, black plastic mulch, black plastic plus WallO'Water (water-filled tubes encircling the plant), black plastic plus Protecta-Cap (a self-venting hotcap installed in the vent-open position), black plastic plus Agryl P-17 (nonwoven polypropylene) floating cover, and black plastic plus Agryl P-17 supported by hoops at 1 meter intervals. Treatments for the other plantings were the same except that the row cover-tunnel material was Agronet M (coextruded polypropylene-polyamide). The second or "normal" planting date for tomato in 1987 was 28 April, still an early planting for the Willamette Valley. Tomatoes were transplanted on 10 May in 1988. Melons were transplanted on 4 May and on 14 May, 1987, and 17 May, 1988.

In 1987, air temperatures were sensed by thermocouples placed 2.5 cm above the soil surface and were recorded on a Speedomax multipoint recorder for three replications of each treatment of both tomato plantings and the first melon planting. The temperature record was maintained from 2 April until 26 May. Plant protectors, except black mulch, were removed from the first tomato planting on 14 May, the second tomato and first melon plantings on 26 May, and the late melon planting on 11 June, 1987. Plots were harvested at least weekly from first fruit ripening until 14 October. In 1988, air temperature was recorded from 25 May until 14 June, when the plant protectors were removed.

Results

Treatment effects on mean daily maximum and minimum air temperatures and heat unit accumulation are given in Table 1. All protectors increased maximum temperatures and heat units compared to bare ground in 1987. The floating cover always provided the warmest environment. Minimum temperatures were consistently increased by all protectors except the ground mulch. The WallO'Water had less effect on daytime temperatures for the later planting in 1987 and in 1988 than for the first planting of 1987. Algae growth in the tubes was greater late in the spring and produced some shading. Increased plant growth in the WallO'Water environment also produced shading. Minimum temperatures were always highest in the WallO'Water as the water-filled tubes released heat into the plant environment at night.

The WallO'Water and floating cover were particularly effective in reducing plant exposure to temperatures of less than 4°C (Table 1); the Protecta-Cap and tunnel also reduced exposure to low temperatures. The floating cover and tunnel treatments, whether Agryl P-17 or Agronet, resulted in the greatest number of days of temperatures considered excessively high (over 30°C) for tomatoes.

In 1987, the number of tomato flowers reaching anthesis at time of plant protector removal was greater than in the check for all treatments except the mulch (Table 2). Anthesis of perfect flowers of muskmelon tended to be earlier for all protectors, including the ground mulch (Table 4).

Time to first ripe tomato was reduced by most protectors in the first planting of 1987 but not for the other plantings (Table 2). Plant protectors tended to increase early yield for the first planting (Tables 2 and 3) of 1987 and in 1988. In the second planting of 1987, the Protecta-Cap did not increase yield and the percentage increase with the other protectors was smaller than for the first planting. For all plantings, early yields were higher with tunnels than with floating covers, perhaps because of excessive heat or abrasion under the floating covers. Early tomato yield did not correlate significantly with mean maximum or minimum temperatures or with heat unit accumulation in any planting.

Total yield for the season for the first planting of 1987 did not vary greatly among plant protectors, but was more than double the check plot yield. Black plastic mulch provided as great a total yield as any of the more expensive treatments (Tables 2 and 3). For the second planting, yield with plant protectors exceeded check yields and there were significant differences among protectors. The Protecta-Cap and WallO'Water plots had greater yields than did the other treatments. Unlike the first planting, the tunnel treatment was relatively low yielding. In 1988, total yields were lower because of the shorter, cooler growing season. The tunnel and WallO'Water treatments were the highest yielding. For all plantings, mean fruit weight did not vary greatly with treatment.

Days to first melon harvest were reduced markedly by ground mulch for all plantings (Table 4). Except for the Protecta-Caps in 1988, addition of the other plant protectors provided further reductions in days to first harvest. Earliest harvest was with the floating or hoop-supported cover for all plantings. In 1987, no ripe fruit were obtained by mid-August on bare ground; in 1988, check plots did not produce ripe fruit until September. Mulching produced a significant early yield and floating row covers or tunnels further increased early yield for the first planting.

For the entire season, mulch greatly increased yield for all plantings (Table 5). In the first planting of 1987, the cover treatments tended to increase total yield over that with mulch alone. In the second planting, the Protecta-Cap also increased total yield. In 1988, only the tunnel and WallO'Water increased total yield over that with mulch alone. Greatest mean fruit weight occurred with the mulch treatment for both plantings in 1987, but with the WallO'Water treatment in 1988. In all plantings, all protectors tended to increase mean fruit weight, although the differences were not usually significant. This is in contrast to results in 1983, when floating covers reduced fruit size compared to mulch alone.

The response of muskmelon to plant protectors other than mulch was generally more favorable than was the tomato response. The floating and hoop-supported cover treatments were particularly effective in increasing early and total yield. For both muskmelon and tomato in the Willamette Valley, row covers, hot caps, and other relatively expensive methods of plant protection should be compared to black plastic mulch rather than to bare ground for an accurate determination of costs and benefits.

Table 1. Effect of plant protection systems on air temperatures and heat unit accumulation, 1987 and 1988

Treatment	Mean air temp. (°C)[z] Daily max.	Daily min.	Heat units[y] (degree days)	Days under 4°C	Days under 10°C	Days over 30°C	Days over 38°C
First tomato, 1987							
Bare ground	27.1	6.9	258	12	31	15	5
Mulch	29.7	6.8	327	12	32	23	6
WallO'Water[x]	30.8	8.7	394	7	32	29	7
Protecta-Cap[x]	32.7	7.8	404	9	29	33	13
Floating cover[x]	41.5	8.3	566	7	29	37	28
Tunnel[x]	36.9	8.1	474	9	30	36	17
LSD (0.05)	3.1	0.5	56				
Second tomato, 1987							
Bare ground	30.4	8.9	199	4	15	13	5
Mulch	32.7	8.8	295	4	15	14	5
WallO'Water	31.4	11.7	317	0	10	14	6
Protecta-Cap	34.2	10.2	348	0	13	23	9
Floating cover	41.7	10.7	449	0	11	27	22
Tunnel	39.6	10.5	411	0	13	26	17
LSD (0.05)	3.3	0.4	50				
First melon, 1987							
Bare ground	31.1	9.4	156	4	12	11	2
Mulch	34.2	8.8	244	4	12	16	5
WallO'Water	32.7	11.8	253	0	7	11	4
Protecta-Cap	36.0	10.3	284	0	10	22	7
Floating cover	43.6	10.5	356	0	10	23	20
Tunnel	41.4	10.2	339	0	10	23	15
LSD (0.05)	3.2	0.6	43				
Melon, 1988							
Bare ground	24.1	5.1	93	9	21	3	1
Mulch	27.3	5.1	130	9	21	6	1
WallO'Water	21.7	6.7	91	2	20	1	0
Protecta-Cap	24.1	5.8	107	6	21	1	0
Floating cover	37.4	6.0	244	6	21	18	9
Tunnel	32.2	6.6	199	5	20	13	3
LSD (0.05)	6.3	0.7	69				

[z]Recorded 2.5 cm above the soil.
[y]Summation of the difference between the daily mean temperature and 10°C for the measured period.
[x]Treatment also included ground mulch.

Table 2. Effect of plant protectors on plant development and yield by number of grade No. 1 'Pikred' tomato

Treatment	No. flowers/plant[z] Planting 1st	2nd	Days to first harvest[y] Planting 1st	2nd	3rd	Early yield (No. fruit/plant)[x] Planting 1st	2nd	3rd	Total yield (No. fruit/plant) Planting 1st	2nd	3rd
Bare ground	2.6	6.0	110	86	77	0.7	1.0	1.0	26.3	23.7	16.4
Black mulch	2.6	7.2	110	87	86	1.2	1.5	1.2	50.5	47.5	35.2
WallO'Water	8.0	9.8	105	84	88	4.2	3.3	2.0	47.8	64.9	38.1
Protecta-Cap	6.6	8.4	109	93	81	2.1	0.2	1.3	52.5	57.6	43.2
Floating cover	4.2	7.8	103	90	90	2.5	1.5	1.9	56.7	53.1	38.0
Tunnel	6.6	10.6	101	84	86	7.1	2.9	3.3	60.3	40.9	51.9
LSD (0.05)	4.1	3.8	5	6	NS[w]	3.2	1.4	0.9	18.3	16.2	6.7

[z]At removal of plant protectors, 1987.
[y]Days from transplanting to first ripe fruit harvest.
[x]No. of fruit harvested through 31 July, 1987; 17 August, 1988.
[w]NS: no significant differences ($P = 0.05$).

Table 3. Effect of plant protectors on total yield by weight and mean fruit weight of 'Pikred' tomato

Treatment	Early yield[z] (kg/plant) Planting 1st	2nd	3rd	Total yield (kg/plant) Planting 1st	2nd	3rd	Mean fruit wt. (g) for season Planting 1st	2nd	3rd
Bare ground	0.2	0.3	0.2	6.3	3.6	5.2	158	184	197
Black mulch	0.4	0.4	0.3	12.6	7.8	11.4	141	185	210
WallO'Water	1.0	0.8	0.4	12.2	9.7	13.7	138	169	225
Protecta-Cap	0.5	0.2	0.2	13.5	8.5	13.8	146	176	176
Floating cover	0.8	0.4	0.3	13.7	8.2	13.0	160	201	187
Tunnel	1.9	0.7	0.5	14.2	11.0	8.8	149	176	188
LSD (0.05)	0.8	0.3	0.2	3.7	1.6	2.8	NS[y]	NS	25

[z]Through 31 July, 1987; 17 August, 1988.
[y]NS: no significant differences ($P = 0.05$).

Table 4. Effect of plant protectors on plant development and early yield of muskmelon

Treatment	No. flowers per plant[z]	Days to first harvest			Early yield per plant[y]					
		Planting			1st planting		2nd planting		3rd planting	
		1st	2nd	3rd	No.	Mean wt. (g)	No.	Mean wt. (g)	No.	Mean wt. (g)
Bare ground	0.2	142	130	112	0.0	-	0.0	-	0.0	-
Black mulch	2.3	87	99	98	1.4	1016	0.0	-	0.9	1690
Wall0'Water	1.6	84	95	92	1.2	1081	0.2	1350	1.1	1917
Protecta-Cap	1.3	84	93	104	1.3	966	0.1	1365	1.4	1768
Floating cover	3.0	82	86	95	2.1	901	0.5	1243	1.3	1876
Tunnel	5.9	82	87	89	2.5	1034	0.7	1232	1.9	1851
LSD (0.05)	1.7	4	5	7	1.1	NS[x]	0.4	NS	0.8	NS[x]

[z]Perfect flowers at anthesis by 26 May, 1987, early planting.
[y]Through 15 August, 1987; 31 August, 1988.
[x]NS: no significant differences (P = 0.05).

Table 5. Effect of plant protectors on total yield of musk-melon

Treatment	Total yield per plant					
	1st planting		2nd planting		3rd planting	
	No.	Mean wt. (g)	No.	Mean wt. (g)	No.	Mean wt. (g)
Bare ground	0.4	950	0.2	1040	0.9	968
Black mulch	3.9	1207	2.3	1278	2.8	1811
Wall0'Water	3.9	1151	2.7	1207	3.5	2069
Protecta-Cap	3.5	1089	3.9	1336	2.6	1888
Floating cover	4.3	977	4.3	1257	2.7	1847
Tunnel	5.6	1061	3.7	1212	3.6	1817
LSD (0.05)	1.4	214	1.3	NS	1.1	365

THE USE OF FLOATING ROW COVERS TO PREVENT APHID TRANSMISSION OF VIRUS TO POTATO SEED STOCK

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Introduction

Control of virus-vectoring insects, particularly aphids, is essential in seed potato production to exclude viruses such as potato virus Y and leaf roll. Seed production fields are heavily treated with insecticides to prevent virus transmission but control is often inadequate. Floating row covers might protect plants from insect attack, reducing the need for insecticides. A preliminary trial in 1986 with three types of single-row covers indicated that covers were far more effective than the standard insecticide treatment in reducing virus transmission. Gross yields tended to be reduced, however, because of growth restriction or excessive temperatures under the covers.

The objective of the 1987 and 1988 trials was to evaluate the effect of one row cover fabric, in both single- and multiple-row widths and for several covering intervals, on yield and potato virus Y (PVY) transmission in potato. The polypropylene-polyamide material chosen for the 1987 trials had the least effect on mean daily temperatures in 1986 and was very effective in preventing virus transmission.

Methods

The trials were conducted on a Willamette silt loam, pH 5.8, to which was applied 1,000 pounds/acre of 10N-8.7P-16.7K fertilizer. In 1987, nuclear virus-tested, stem-cut, seed stock 'Norgold Russet' pieces were planted 1 foot apart in rows spaced 4 feet apart. Every fifth row was planted with PVY-infected seed. In the experiment with wide covers, plots consisted of four rows, 18 feet long. The row covers were applied over the four rows of virus-free seed, leaving the infected rows uncovered. In a separate experiment with single-row covers, plot size was an 18-foot section of a single row. In both experiments, treatments were replicated five times in a randomized block design. Planting date for both experiments was 5 May, 1987, and an additional 50 pounds N/acre was applied as ammonium nitrate on 20 May.

Alachlor and linuron were applied at 2.5 pounds and 1.0 pounds/acre, respectively, one week after planting. The rows were hilled on 25 May and covers were applied the next day. In the wide-cover experiment, the factorial combination of six treatments consisted of uncovered check, 21-foot-wide Agronet M removed on 1 July, and Agronet M removed on 11 August, both with and without insecticide treatment. The insecticide-treated plots were sprayed at biweekly intervals with acephate at 1.0 pounds/acre. In the single-row cover experiment, 6-foot wide Agronet was applied on 26 May and removed for a two-week period starting on either 11 June, 1 July, or 15 July. In addition, a fourth treatment consisted of delaying the initial covering date to 1 July. All covers were removed again on 11 August.

The foliage was rated for viral symptoms on 12 August and diquat (0.25 pounds/acre) was applied for vinekill on 14 August. The diquat was reapplied on 19 August. All plots were harvested on 9 September. A sample of 25 tubers from each plot was submitted for a winter test evaluation of PVY and leaf roll viruses.

In 1988, cultural methods were similar except as follows. Nuclear virus-tested 'Russet Burbank' seed pieces were planted on 19 May. Every third row was planted with virus-infected seed. The row cover plots consisted of a pair of virus-tested rows, 20 feet long. The plots were hilled at initial shoot emergence on 6 June and 100 pounds N/acre as ammonium nitrate was banded on the hills on 7 June. Ten-foot-wide covers of polypropylene-polyamide were applied to the appropriate plots on 8 June. Of 18 treatments, replicated four times, 16 were covered on 8 June. Of the remaining two treatments, one was covered on 21 June, and the other was left uncovered for the entire growing season. Dates of uncovering and recovering for all treatments are listed in Table 3. A different treatment was uncovered each week during the growing season. Immediately after recovering, plots were drenched with acephate at 1.0 pounds/acre to kill any aphids invading the plot during the period of uncovering. All plots still covered were uncovered on 13 September. All plots were sprayed with diquat on 13 September and again on 16 September. Tubers were dug on 5 October. Greenhouse evaluation of virus symptoms was completed on 6 February, 1989.

Results and Discussion

The cover edges remained buried throughout the growing season but holes and tears developed during the season, primarily from snagging by spray equipment. Small holes were not repaired but major tears were patched or covers were replaced. A few aphid colonies were found on covered plants at cover removal, particularly at the final cover removal in August. It could not be determined whether these aphids entered through holes in the covers or hatched beneath the covers.

In 1987, there was very little difference among treatments in the degree of foliar damage caused by diabrotica and flea beetle. Nevertheless, both in-field and greenhouse foliar symptoms of aphid-vectored PVY infection were much greater on plants without covers than on those covered at some time during the season (Tables 1 and 2). In the wide-cover experiment, there was no significant difference in foliar viral symptoms between plants uncovered on 1 July and those uncovered just before vinekill (Table 1). In the single-row cover experiment, PVY foliar symptoms were much more prevalent in plants uncovered during June than in those uncovered during July (Table 2). Results of both experiments indicate that the critical period for viral transmission is early in the season. Any negative effects of covers on yield due to heat stress might be avoided by removing the covers during the warmest portion of the growing season. A late-season infection, while not obvious from foliar systems, might still move to the tubers, however.

A very low incidence of possible leaf roll symptoms was observed in the field (Tables 1 and 2). No leaf roll was observed in the greenhouse test. The virus source rows of potatoes in the field also failed to exhibit leaf roll symptoms.

The Agronet M covers had only a small effect on air temperatures (Table 1). Daily maxima were increased less than 8°F, daily minima by slightly more than 1°, during the measurement period. Although not statistically significant, the wide covers tended to increase the number of tubers harvested, mean tuber weight, and gross yield (Table 1).

In contrast to 1986, the insecticide program did not increase yield, nor did it reduce foliar virus symptoms. The single-row cover experiment had no uncovered check, but yields were comparable to those in the wide-cover experiment. This indicates that, in contrast to 1986, the narrow covers had no adverse affect on tuber production.

The most surprising aspect of the 1987 trials was the lack of effect of the insecticide program on viral symptoms in the field or in the greenhouse-grown plants. Since the spray program was even more rigorous than the one normally used by growers, virus transmission was expected to be reduced significantly. Leaving half the uncovered plants as well as the virus source rows unsprayed may have insured survival of large numbers of vectors. This would not be typical of a commercial seed field situation. However, it also makes the great reduction in virus symptoms on covered plants all the more impressive.

In 1988, row covers reduced the yield of potato tubers compared to vines which were never covered, primarily by reducing the number of tubers harvested. The mean weight per tuber was not significantly affected by covers (Table 4). The highest-yielding treatment was the no-cover check. The second-highest treatment was No. 5, which was covered at emergence, but uncovered early in the season and left uncovered. Treatment 9, uncovered at midseason and left uncovered, also yielded slightly higher than the average for all treatments. These results are in contrast to results obtained in 1987 when yields tended to increase with row covers, but are in agreement with 1986 results.

In Table 5, the treatments in which plots were uncovered for a week and then recovered are grouped into three 3-week categories, consisting of plots uncovered during the first, second, and last third of the growing season, respectively. Yield of plots uncovered early in the season tended to be higher than those uncovered late in the season, or never uncovered. This may be because covers were applied more loosely at recovering, allowing more room for plant growth.

Estimates of plant senescence and aphid infestation were made on 12 September (Table 3). Senescence tended to be greater for plants uncovered early in the season. Vines uncovered early and left uncovered and those never covered had the lowest degree of senescence. There was a strong positive correlation between degree of senescence and degree of aphid infestation ($R_{xy}=0.572$, $p=0.001$). Plots uncovered early and recovered had a greater degree of infestation than did plots uncovered later in the season. Plots uncovered early and left uncovered or never covered had the lowest degree of aphid infestation, presumably because predator insects were not excluded from these plots. These results re-emphasize that, while row covers may exclude aphids, aphids finding their way under the covers are then protected in a favorable environment.

Senescence and yield were negatively correlated ($R_{xy}=-0.422$, $p = 0.001$) since the prematurely senescent plants did not produce as many tubers. However, within those treatments which were initially covered, uncovered, and recovered, the correlation between senescence and yield (or aphid infestation and yield) was positive, although not significant. In this case, the effect of cover replacement and more growing room may have been more important than the tendency for premature senescence to reduce yield.

As in previous trials, covers significantly reduced virus transmission in 1988 (Tables 4 and 5). Mosaic (mostly PVY) incidence ranged from 91 percent for tubers from plots that were never covered to the 4 to 11 percent range for plots covered the entire season. Plants uncovered during the third through the fifth weeks after shoot emergence produced tubers with a greater degree of mosaic infection than those uncovered later in the season. Leaf roll symptoms also tended to be highest for plots uncovered early in the season.

The tendency for covers to reduce yields in two out of three growing seasons at the North Willamette Station and to reduce yields at the Hermiston Station (data not shown), indicates the need for further research on the causes of the yield reduction. Assuming that the cause may be heat stress, abrasion of growing points, or lack of growing room, it will be important to establish whether early cover removal will significantly reduce virus transmission without having a deleterious effect on yields.

Table 1. Main effects[z] of wide row covers and insecticide on yield and virus symptoms in potato, 1987

Treatment	No. of[x] leaf roll plants/plot	No. of[x] PVY plants/plot	Total yield (tons/acre)	No. of tubers harvested	Mean tuber wt. (g)	Mean temperatures[y] Max.	Mean temperatures[y] Min.	Percent tubers with PVY	Percent tubers with Leaf roll
Row cover									
No cover	0.6	23.6	10.0	360	168	95.0°	50.1°	83.4	0.0
Early cover removal	0.3	0.6	11.3	381	179	102.6	51.3	3.1	0.0
Late cover removal	0.3	0.5	11.6	389	178	-	-	1.5	0.0
LSD(0.05)	NS[w]	**	NS	NS	NS	*	**	**	NS
Insecticide									
None	0.5	7.1	11.1	385	174	-	-	29.0	0.0
Sprayed	0.3	9.3	10.8	369	176	-	-	29.7	0.0
	NS	NS	NS	NS	NS			NS	NS

[z]No significant row cover x insecticide interactions.
[y]Recorded for the period 1 June - 10 June, 1987 at 1.0 inch above the soil surface.
[x]Total plants/plot = 72.
[w]NS, *, **: No significant differences, differences significant at 5% and 1% levels, respectively.

Table 2. Effect of covering intervals with single-row covers on yield and virus symptoms in potato, 1987

Period Uncovered	No. leaf roll plants/plot	No. PVY plants/plot[z]	Total yield (tons/acre)	No. tubers harvested	Mean tuber wt. (g)	Percent tubers with PVY	Percent tubers with Leaf roll
Planting - 1 July	0	10.0	9.7	89	166	98.7	0.0
11 June - 26 June	0	3.7	10.6	101	159	64.1	0.0
1 July - 15 July	0	0.3	11.4	104	165	47.0	0.0
15 July - 30 July	0	0.4	11.9	106	170	30.5	0.0
	NS	**	NS	NS	NS	*	NS

[z]Total plants/plot = 18.

Table 3. Uncovering and recovering dates for the treatments in the virus exclusion trial, degree of aphid infestation and vine senescence, 1988

Treatment	Date uncovered	Date recovered	Aphid infestation[z]	Senescence[y]
1	6/21	6/28	2.3	3.3
2	6/28	7/05	3.0	3.5
3	7/05	7/12	2.8	4.3
4	7/12	7/19	2.8	3.0
5	7/19	Never	1.0	1.3
6	7/19	7/26	1.8	2.8
7	7/26	8/02	1.3	2.5
8	8/02	8/09	1.5	2.5
9	8/09	Never	1.3	1.3
10	8/16	8/23	1.0	2.3
11	8/23	8/30	1.3	2.5
12	8/30	Never	1.3	2.8
13	9/13	Never	2.0	2.8
14	9/13	Never	2.3	3.3
15	9/13	Never	2.0	2.8
16	9/13	Never	1.8	2.8
17[x]	9/13[x]	Never	2.0	3.0
18	Never covered		1.0	1.8
		LSD (0.05)	0.8	1.2

[z] 3 point scale; 3=most severe, 1=least severe (no aphids present).
[y] 5 point scale; 5=most severe, 1=least severe (no senescent vines).
[x] This treatment initially covered on 21 June, 13 days later than treatments 1 through 16. Emerging shoots were exposed for approximately one week before covers applied.

Table 4. Effect of row cover treatments on yield and virus infection of potato tubers, 1988

Treatment	Yield (tons/acre)	No. tubers harvested/plot	Mean tuber wt. (g)	% tubers with Mosaic	% tubers with Leaf roll
1	16.0	405	121	39	8
2	16.3	430	114	32	16
3	16.3	425	115	51	40
4	17.7	449	119	58	26
5	18.2	412	135	63	7
6	15.3	381	120	49	1
7	15.6	399	117	9	6
8	15.6	380	124	5	0
9	16.6	432	115	9	11
10	15.3	431	106	14	0
11	15.1	402	113	16	1
12	15.4	395	118	5	14
13	15.8	395	121	9	3
14	15.5	398	118	5	3
15	15.5	395	118	10	13
16	16.6	406	123	4	0
17	14.6	392	112	11	18
18	21.4	565	115	91	5
Mean	16.3	416	118	26	9
LSD (0.05)	1.9	58	NS	20	NS

Table 5. Effect of early, mid-, and late season uncovering intervals on yield, aphid infestation, senescence, and virus infection of potato, 1988

Uncovering period	Mean yield (tons/acre)	Mean aphid rating	Mean senescence rating	Mean % Mosaic	Mean % Leaf roll
Early season	16.2	2.7	3.7	41	21
Mid-season	16.2	1.9	2.8	39	11
Late season	15.3	1.3	2.4	12	3
Never uncovered	15.8	2.0	2.9	7	5
Never covered	21.4	1.0	1.8	91	5[z]
Early, not recovered	18.2	1.0	1.3	63	7
Mid, not recovered	16.6	1.3	1.3	9	11
Late, not recovered	15.4	1.3	2.8	5	14
Mean, all treatments	16.3	1.8	2.7	26	9

[z]Difficult to read leaf roll symptoms because of severity of mosaic.

EFFECT OF CULTIVAR, SOIL PH, AND INSECTICIDE ON
FOLIAR DISORDERS AND GROWTH OF SPINACH

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Introduction

Willamette Valley spinach growers have complained of a yellows disorder or chlorosis affecting the crop. Possible causes include *Fusarium* wilt, which causes a general chlorosis and wilting of the plant as the vascular system is invaded by the fungus; various insect-vectored viruses; and suboptimal pH accompanied by Mn or Al toxicity. In this trial, *Fusarium*-resistant varieties of spinach as well as non-resistant varieties were seeded on plots of soil with pH from 4.9 to 6.5. Half of each soil pH plot was treated with insecticide in an attempt to pin down the likely cause of yellows/chlorosis problems observed by growers.

Methods

In 1974, lime was applied to 40- x 45-foot plots of Willamette silt loam at rates of 0, 4, and 8 tons/acre, and sulfur was applied at 1.0 ton/acre. The four soil pH treatments were replicated four times in randomized complete block design. Soil pH at time of planting in 1987 ranged from 4.9-5.0 for the sulfur treatment to 6.4-6.6 for the 8-ton lime treatment. On 26 May, 1987, 700 pounds/acre of 10N-8.7P-8.3K fertilizer was applied to all plots. On 28 May, six cultivars of spinach were seeded on the pH plots with a single row of each cultivar and 3.0 feet between rows. Cultivars were randomized within each pH main plot. The main plots were split by an insecticide spray program, with half of each plot (22.5 feet) receiving biweekly applications of both carbaryl and acephate at 1.0 pounds/acre. Chlorpropham at 2.0 pounds/acre was used for weed control on all plots. Plots were irrigated and cultivated as necessary. An additional 35 pounds N/acre as ammonium nitrate and 25 pounds N/acre as calcium nitrate were sidedressed on 16 June and 9 July, respectively. Yields were not determined but all plots, except for the pH 4.9-5.0, were rated for quality characteristics and yellowing or chlorosis on 17 July.

Results

Possible viral symptoms were identified with the help of Alf Christensen Seed Co. pathologist Margaret Savage. Viruses present in plant samples were identified by Dr. Paul Koepsell. Beet western yellows virus was found in leaf tissue showing typical bright yellow marginal chlorosis. Cucumber mosaic virus was isolated from leaves showing a chlorotic mottle characterized by light green or yellow spots and small (1 mm diameter) raised areas on the leaf surface.

Fusarium wilt symptoms were confined primarily to the cultivar 'Giant Nobel,' which is not resistant to this disease.

The spinach plants grew very poorly on the sulfur-treated plots. These plots were not rated for quality characteristics. Plant growth, as measured by plant width and height of the tallest leaf, increased with rate of lime application (increasing soil pH) for all varieties (Table 1). Soil pH had no consistent effect on leaf color, degree of bolting, chlorotic mottle, or marginal yellowing (beet western yellows symptom). The insecticide treatment, when averaged over lime rates and cultivars, had no effect on plant growth and overall color, but reduced the severity of chlorotic mottle, a possible symptom of cucumber mosaic virus. This indicates that the chlorotic mottle is a symptom of insect injury or virus infection. There was a significant interaction of lime rate and insecticide treatment on plant width. The insecticide improved plant growth at high soil pH but not at low pH (Table 2).

Among cultivars, the most vigorous and long-standing plants were of 'Olympia.' This cultivar also had the best overall color rating. The chlorotic mottle symptoms were most severe on 'Skookum.'

These results indicate the need for more exact descriptions of yellows disorders in spinach, as a number of factors may be involved, including low N fertility, low soil pH, several viruses, and *Fusarium*. The chlorotic mottle observed in this trial, and in a commercial field at the same date, may be a symptom of cucumber mosaic virus or other insect-transmitted virus or mycoplasm. The mottle may also be simply a wound response to injury by leaf hoppers or other sucking insects, the so-called "hopper burn."

Table 1. Main effects of lime, cultivar, and insecticide treatment on quality of spinach, 1987

Treatment	Plant width (cm)	Plant height (cm)	Color[z]	Degree of bolting[y]	Chlorotic mottle[x]	Marginal yellowing[x]
Lime rate (tons/acre)						
0	17.3	14.4	2.5	3.1	2.8	2.3
4	22.9	18.4	2.7	3.2	3.0	2.6
8	24.8	18.9	2.8	3.1	2.8	2.2
LSD(0.05)	2.5	1.8	NS[w]	NS	NS	0.3
Insecticide						
Unsprayed	20.7	16.7	2.7	3.0	3.4	2.3
Sprayed	22.6	17.9	2.7	3.3	2.3	2.4
	NS	NS	NS	*	**	NS
Cultivar						
Baker	20.4	17.6	2.3	4.2	2.4	2.6
Giant Nobel	20.7	16.0	2.7	3.3	3.0	2.6
424	19.2	16.9	1.8	4.3	2.8	1.9
Jake	22.9	17.5	3.0	2.8	2.7	2.1
Olympia	24.8	17.8	3.3	1.3	3.0	2.5
Skookum	22.0	17.8	3.1	3.0	3.3	2.4
LSD(0.05)	3.6	NS	0.5	0.4	0.4	0.5

[z]Five point scale with 1 = palest, 5 = darkest green.
[y]Five point scale with 1 = no elongation of seedstalk, 5 = male flowers shedding pollen.
[x]Five point scale with 1 = no symptoms, 5 = severe symptoms. Probable symptom of beet western yellows virus.
[w]NS, *, **: no significant differences and significant at 5% and 1% levels, respectively.

Table 2. Interaction of lime and insecticide treatment on spinach plant width, averaged over cultivars, 1987

Lime rate (tons/acre)	Plant width (cm) Sprayed	Plant width (cm) Unsprayed
0	16.4	18.2
4	25.5	20.2
8	25.8	23.8
Interaction LSD(0.05) = 3.6		

VIRUS CONTROL IN LETTUCE AND SPINACH

Introduction

Lettuce, spinach, and other leafy greens in western Oregon suffer from a complex of yellows disorders which do not appear to be related to plant nutrition or fungal pathogens. In 1987, a spinach variety trial at the Station eliminated soil pH and *Fusarium* yellows as the cause of two yellows disorders observed in the planting. One disorder, characterized by a pale, chlorotic mottling of the leaf blade, was reduced by regular applications of acephate insecticide. The other disorder, characterized by a bright yellow interveinal coloring, particularly on older, lower leaves, was not affected by insecticide, soil pH, or cultivar. Affected plants, and similarly yellows-affected plants from other sites and grower fields, were determined to carry beet western yellows virus (BWYV) in 1987.

Insect-vectored viruses, particularly those spread by aphids, have been controlled by excluding the vector from the plants with row covers. The purpose of this trial was to attempt to reduce the yellows disorder in spinach and lettuce with either row covers, or a combination of row covers and acephate, an effective aphicide.

Methods

A Willamette silt loam, pH 6.2, was prepared for transplanting by rototilling in 1,000 pounds/acre of 10N-8.7P-16.7K fertilizer. Half the field was treated with 3.0 pounds/acre of cycloate herbicide, which was incorporated in preparation for planting spinach. Three cultivars each of lettuce and spinach were seeded on 25 July into trays consisting of 0.75-inch-square cells and containing a commercial peatlite medium. The transplants were set out on 16 August with a single row of each cultivar per 10-foot-long bed. Between-row spacing was 2.5 feet and in-row spacing was 1.0 foot. The lettuce cultivars were 'Summertime,' 'Salinas,' and 'Waldmann's Green.' The spinach cultivars were 'Grandstand,' 'Liberty,' and 'Olympia.' Immediately following planting, the lettuce area was treated with pronamide herbicide at 2.0 pounds/acre.

On 18 August half the plots of each species were covered with Agronet row cover. The 10 foot wide covers covered a single 3-cultivar bed. On 22 August, half of both the covered and uncovered plots were treated with acephate at 1.0 pound/acre and carbaryl at 1.0 pound/acre, at 40 pounds/square inch pressure and 100 gallons per acre total volume. Thus, the treatments consisted of a factorial combination of cover (+ or -) and spray (+ or -) treatments, with the four treatment combinations in randomized complete block design with four replications for lettuce and three replications for spinach. Individual cultivars were subplots of these main plot treatments. The insecticide treatments were reapplied on 6 September. Plots were uncovered and rated for yellows disorder on 13 September.

Results

The insecticide sprays were associated with an increase in bright yellow coloring of the older leaves of lettuce while row covers decreased the number of plants showing symptoms by 50 percent (Table 1). Cultivars did not vary significantly in the percentage of plants showing symptoms. There were no significant 2- or 3-way interactions of insecticide, row cover, and variety, so only main effects are shown in the Table.

For spinach, neither insecticide, row cover, nor cultivar had any significant effect on the expression of the disorder (Table 1).

These results do not provide strong evidence that the observed yellows disorder was caused by an insect vector or that row covers will be an effective means of control. Tissue samples were not submitted for ELISA test of BWYV infection, but plants from test plots at the Vegetable Research Farm at Corvallis, showing similar symptoms, did not test positive for BWYV in 1988. However, lettuce samples from a grower's field near the North Willamette Station, also showing lower leaf yellowing, did test positive for BWYV. Obviously, further research is needed to pin down the cause and possible control measures for this yellows disorder(s), which has caused serious losses in commercial fields in both 1987 and 1988. Perhaps more than one luteovirus is involved, which would explain the lack of consistency in positive tests for BWYV.

Table 1. Main effects of row covers, insecticides, and cultivar on lower leaf yellowing symptoms in three cultivars of lettuce and spinach, 1988

	Percent plants showing symptoms		
Treatment	Lettuce		Spinach
- Insecticide	16.6		25.8
+ Insecticide	31.7		19.2
	*[z]		NS
- Cover	32.2		21.6
+ Cover	16.1		23.4
	*		NS
'Summertime'	22.4	'Grandstand'	20.8
'Salinas'	20.1	'Olympia'	28.4
'Waldmann's'	29.9	'Liberty'	18.2
	NS		NS

[z]*,NS: difference significant at the 5 % level, and nonsignificant, respectively.

ROW COVERS ON OVERWINTERED VEGETABLES

Introduction

Overwintered vegetables, seeded in late summer or early autumn for harvest the following spring, are important new alternative crops in the Willamette Valley. These crops offer a source of cash flow in the spring, present the opportunity for three crops in two years, and may be less expensive to grow because of reduced needs for insecticides and irrigation. Cauliflower, onions, and spinach have shown the most promise as overwintered crops.

Recent cold winters have shown that these crops are marginally hardy in the Willamette Valley and might benefit from an inexpensive means of winter protection in some years. For all three crops, yield and quality decline when winter minima fall below 15°F. Temperatures in the low teens occur about every other winter on the average.

The objective of this trial was to determine whether these three overwintered crops would benefit from application of floating row covers, either shortly after planting or later in the autumn, for both early and late-seeded crops.

Materials and Methods

Cultivars used in this trial were 'Sweet Winter' Onion, 'Inca' cauliflower, and 'St. Helens' spinach. For all three crops, plot preparation before planting included disking, harrowing, application of 1,000 pounds/acre of 10-20-10 fertilizer and rotary tillage. The row covers used were a nonwoven polypropylene, Kimberly Farms, from Kimberly-Clark and a coextruded polypropylene-polyamide, Agronet, from Beghin Say-Kaysersberg. A summary of planting, covering, uncovering, and harvest dates for each crop is contained in Table 1.

Plot size was 20 feet of a three-row bed for spinach and onions, and 15 feet of a single row for cauliflower. Between-row spacing for cauliflower was 5 feet, within-row spacing was 1.5 feet. Cauliflower was transplanted from greenhouse-grown cell packs at 5 weeks after seeding. The spinach and onions were direct-seeded.

Herbicides used at planting (pounds/acre) were propachlor (4.0) for onions; chloro-IPC (1.5) for spinach, trifluralin (0.75) and propachlor (4.0) for cauliflower. The onions received applications (pounds/acre) of chloroxuron (3.0) on 2 December 1986, oxyfluorfen (0.10) on 15 December 1986, chloroxuron (3.0) and oxyfluorfen (0.12) on 11 March 1987. No insecticides or fungicides were used.

Additional fertilizer was applied as follows (pounds/acre): ammonium nitrate (50) to all crops on 3 February 1987, ammonium sulfate (50) to all crops on 10 March 1987, and urea (50) to onions on 8 May 1987.

Table 1. Dates of planting, row cover application, row cover removal, and harvest dates for cauliflower, onion, and spinach, 1986-1987

	Cauliflower		Onion		Spinach	
	Early	Late	Early	Late	Early	Late
Planting date	08/27/86^z	09/18^z	09/02	10/08	10/08	10/29
First cover applic.	10/14	10/14	09/30	10/08	10/08	10/31
Second cover applic.	11/02	11/02	10/20	10/20	11/05	12/02
Cover removal	02/23/87	02/23	03/23	03/23	03/30	03/30
Harvest	03/23-04/20	03/23-04/20	07/07	-	04/09	04/09

^{z}Transplant dates. Seeding dates were 7/24 and 8/21, respectively.

Results and Discussion

Cauliflower

The winter of 1986-1987 was unusually warm and dry. The lowest recorded temperature was 22°F, insufficient to affect yield of these crops. Thus, the covers would not be expected to provide significant yield benefit but might still enhance quality. However, the percentage of Grade No. 1 heads (white, free of defects, 1.0 pound minimum) for the uncovered check plots in the early planting was the highest that has been obtained in 10 years of trials at this site (Table 2).

The Kimberly Farms cover reduced total yield, mean head weight, and percentage of Grade No. 1 heads (Table 2) for the early planting. Two factors may have contributed to the reduced yield and quality. The growing plants completely filled the available space under the covers and growth may have been restricted. However, the Agronet cover was similar in its restriction of growth but did not significantly reduce yield or quality. The greater temperatures under the Kimberly Farms cover may have stressed the plants either in the autumn or in early spring. This cover also advanced maturity by 7 to 9 days, indicating a warmer environment. This would be a distinct advantage in a colder winter. Plant size and appearance did not vary with treatment after cover removal.

For the second planting the yield of No. 1 heads and mean head weight tended to increase with row covers. Maturity was advanced only slightly by covering. The late covering dates for this planting may have prevented heating under the covers, leading to improved yield and quality.

Spinach

Onset of cold, wet weather indicated that applying covers immediately after planting might encourage earlier emergence and greater stands. This did not prove true. Stands and yields were lower when covers were applied at planting than when applied a month later (Table 4). With heavy rains and wet soil, the covers tended to stick to the soil surface rather than float and stands were reduced. A yellows disorder, probably *Fusarium*, was more pronounced on covered plots, perhaps because of more favorable temperatures for disease development. Where the covers did not stick to the soil surface, the spinach was cleaner and free of insect damage, compared to check plots.

Table 2. Effects of planting date, cover application dates, and type of row cover on yield and maturity of overwintered cauliflower, first planting, 1986-1987

	Yield (tons/acre)		Mean head wt. (pounds)		%	Harvest period		
Treatment	No. 1	Total	No. 1	Total	No. 1	First	Peak	Last
No cover	6.7	8.0	2.9	2.8	82	3/30	4/17	4/20
KF, first applic.[z]	2.6	4.9	1.6	1.6	54	3/23	4/08	4/20
KF, second applic.	2.6	6.1	2.3	2.1	38	3/23	4/08	4/17
Agro, first applic.	5.4	8.2	2.6	2.6	65	4/08	4/14	4/20
Agro, second applic.	5.9	7.9	2.7	2.7	74	3/23	4/14	4/20
LSD(0.05)	2.0	1.4	0.6	0.5	21			
Significance:								
Cover vs. check	**[y]	NS	*	*	**			
First vs. second applic.	NS	NS	*	*	NS			
KF vs. Agro	**	**	*	**	**			

[z]KF = Kimberly Farms, Agro = Agronet.
[y]**, *, NS: differences significant at 1% or 5% levels, or nonsignificant, respectively.

Table 3. Effects of planting date, cover application dates, and type of row cover on yield and maturity of overwintered cauliflower, second planting, 1986-1987

	Yield (tons/acre)		Mean head wt. (pounds)		%	Harvest period		
Treatment	No. 1	Total	No. 1	Total	No. 1	First	Peak	Last
No cover	1.2	2.4	2.3	1.2	47	4/08	4/17	4/20
KF, first applic.	1.3	1.9	1.6	1.3	61	4/08	4/17	4/20
KF, second applic.	1.4	3.2	1.7	1.5	33	3/23	4/08	4/27
Agro, first applic.	1.5	2.8	1.5	1.4	57	4/08	4/14	4/20
Agro, second applic.	1.4	2.0	2.1	1.3	48	4/08	4/08	4/20
LSD(0.05)	NS	NS	0.5	NS	NS			
Significance								
Cover vs. check	NS	NS	*	NS	NS			
First vs. second applic.	NS	NS	NS	NS	NS			
KF vs. Agro	NS	NS	NS	NS	NS			

Table 4. Effect of planting dates, cover application date, and type of row cover on yield and maturity of overwintered spinach, 1986-1987

Treatment	Yield (tons/acre) First planting	Yield (tons/acre) Second planting	Yellows rating[z]
No cover	1.8	0.1	2.0
KF, first applic.	0.1	0.1	3.2
KF, second applic.	0.5	0.2	3.7
Agro, first applic.	0.2	0.4	3.8
Agro, second applic.	0.7	0.8	3.0
LSD(0.05)	0.8	NS	0.9
Significance			
Cover vs. check	*	NS	*
First vs. second applic.	*	NS	NS
KF vs. Agro	NS	NS	NS

[z]First planting only. 0 = no yellow present, 5 = all older leaves affected.

Onion

Onion stands were reduced by the row covers, particularly in the second planting (Table 5). Onions are slow to emerge and lack vigor. The seedlings did not support the covers, which tended to become muddy and stick to the ground. The effect was less pronounced with Agronet as the seedlings tended to grow through the covers.

Vigor and stands for the second planting were so poor that it was abandoned in April. Row covers tended to reduce weed control in the first planting. Oxyfluorfen and chloroxuron were applied through the covers at 40 psi and 50 gallons/acre; the sprays tended to run off where the covers were supported by weeds or onions. The covers also provided a more favorable environment for weed growth. Nevertheless, some weed kill occurred under the covers and weed populations were maintained at an acceptable level.

Onion plant vigor was increased by Agronet but not by Kimberly Farms when rated in March. The vigor ratings mainly reflect plant height. Foliar color of covered onions in May was paler than that of check plot onions (Table 6), perhaps indicating that the covers interfered with even distribution of the spring-applied fertilizer. The covers tended to shed the fertilizer to the alleyways between plots. The tendency for reduced vigor on previously covered plots when rated in May, may also indicate uneven fertilizer distribution.

Row covers reduced yield of both jumbo and all grades of onions (Table 6). This was attributable both to the reduced stand and to smaller bulb size. Bulb size and yields were greater with Agronet than with Kimberly Farms.

Table 5. Effects of planting date, cover application date, and type of row covers on stand and vigor of onion, and weed control rating, 1986-1987

Treatment	Stand/20 feet First planting	Stand/20 feet Second planting	Weed control rating[z] First planting	Weed control rating[z] Second planting	Vigor rating[y] 30 Mar.	Vigor rating[y] 11 May
No cover	98	48	7.3	5.8	4.3	4.8
KF, first applic.	59	0	5.5	6.0	3.3	4.0
KF, second applic.	68	0	5.0	7.2	3.8	4.4
Agro, first applic.	74	18	4.5	4.5	5.0	4.2
Agro, second applic.	83	24	5.0	5.0	5.0	4.3
LSD(0.05)	NS	23	1.7	NS	0.9	NS
Significance						
Cover vs. check	NS	**	*	NS	NS	NS
Applic. date	NS	NS	NS	NS	NS	NS
KF vs. Agro	NS	NS	NS	NS	NS	NS

[z]Rated on 30 Mar. 1987. 0 = no control, 9 = no weeds present.
[y]First planting only. 5 = most vigorous, 0 = least vigorous.

Table 6. Effects of planting date, cover application date, and type of row cover on yield of overwintered onion, first planting, 1986-1987

Treatment	Yield (tons/acre) Jumbo[z]	Yield (tons/acre) Total	Mean bulb wt.(oz)	% Jumbo by number	Foliar color on 11 May
No cover	4.7	20.9	5.3	12.8	dark green
KF, first applic.[b]	1.4	10.2	4.3	7.3	pale
KF, second applic.	0.3	8.5	3.0	1.5	very pale
Agro, first applic.	3.0	14.5	4.8	9.0	pale
Agro, second applic.	1.5	15.0	4.4	4.3	pale
LSD(0.05)	4.0	5.0	1.4	NS	
Significance					
Cover vs. check	*	**	*	NS	
Applic. date	NS	NS	*	NS	
KF vs. Agro	NS	*	*	NS	

[z]Jumbo = at least 3 inch diameter.

Conclusions

The winter of 1986-1987 did not provide an adequate test of row cover effects on plant survival, yield, or quality. However, a few conclusions can be made. Postemergence weed control chemicals can be applied through the covers but pressures or coverage may need to be adjusted to compensate for the partial barrier. Cauliflower might benefit greatly from wide covers which would not restrict foliar growth. Fertilizer distribution would be less of a problem on this crop since the roots extend over a large area.

Both onions and spinach appear poorly adapted to covering immediately after planting in high rainfall conditions. Covers could be applied later in areas where weather permits, or hoop-supported structures could be used.

RESPONSE OF LILY TO MULCH, ROW COVERS, DISBUDDING AND CUT FLOWER HARVEST

Cooperator: G.L. Reed, Hermiston Experiment Station

Introduction

Black plastic ground mulch and row covers have enhanced the growth and yield of many crops. Lily bulb production in the Pacific Northwest takes place on bare ground. The objective of this research was to study the effects of a ground mulch and a hoop-supported row cover (tunnel), as well as flower bud removal and cut flower harvest, on bulb growth and bulblet production of Asiatic lily.

Methods

In 1987, 20-inch-wide raised beds of Willamette silt loam, pH 5.5, were formed on 6-foot centers after broadcast and incorporation of 800 pounds/acre of 10N-8.7P-8.3K fertilizer. Lily bulbs were planted 6 inches deep with two rows per bed and 8 inches between bulbs. Main plots consisted of a factorial combination of three mulch treatments (bare ground, mulch, mulch plus row cover) and two disbudding treatments (flower buds removed or left intact) in randomized block design with four replications. These main plots were split by five subplots consisting of the cultivars 'Campfire,' 'Debutante,' 'Impact,' 'Moonfire,' and 'Snowcap.' Including border areas, subplots were 10 feet in length and were planted with 11 bulbs. The 1.5 mil, 4-foot-wide, black polyethylene mulch was installed before bulbs were set. Bulbs were planted on 16 March, 1987, and covers were applied to the appropriate plots on 1 April. The initial covers were 6-foot-wide polypropylene-polyamide (Agronet M) and were supported loosely by 5-foot hoops. Bare ground areas were treated with chloro-IPC at 5.0 pounds active/acre.

Covers were removed on 13 May, the appropriate plots were disbudded, and 10-foot-wide Agronet covers were installed. Alleyways were mechanically cultivated and bare-ground treatment beds were hand-weeded twice during the growing season. Bulbs were dug on 17 September. Bulblets were removed from the stems and counted and weighed separately.

The following changes were made in 1988. The main plots were a factorial combination of two mulch treatments (bare soil or block mulch), two cover treatments (no cover on 10-foot Agronet) and three disbudding treatments (check, disbudded at first bloom, or stem-cut at bloom to 4 inches above ground). Twelve-bulb subplots consisted on 'Connecticut King' or 'Enchantment' cultivars. Bulbs were planted on 22 April and the appropriate plots were immediately covered. The disbudding was on 14 July, cut flower harvest on 22 July. Bulbs were harvested on 22 September.

Results and Discussion

1987

An original objective of this research had been to investigate the use of the row covers to prevent insect-vectored virus transmission in the lilies. The planting stock was found to be virus-infected, however, and this aspect of the project was not pursued. Nevertheless, the row covers remained in place for the entire growing season except during disbudding.

In 1987, black plastic mulch increased the percentage of bulbs producing shoots before 29 April, 1987, by 15 percent (Table 1). Row covers provided no additional benefit.

At harvest in 1987, the number of bulbs recovered was greatest with mulch, least on bare ground. Mean bulb weight was also greatest with mulch and least on bare ground. The number of bulblets produced on each stem tended to be increased by mulch or mulch plus cover. Mean bulblet weight was also increased by the mulch treatments. The mulch plus cover treatment did not increase bulb weight or bulblet production beyond that obtained with mulch alone.

Disbudding the shoots to remove flower buds increased bulblet production but not mean bulblet weight. The number of bulbs recovered also increased with disbudding, as did the mean bulb weight.

The cultivars 'Moonfire' and 'Snowcap' produced fewer bulblets than did the other three cultivars. Bulblets of 'Debutante' and 'Impact' were largest when averaged over main plot treatments. 'Campfire' produced the largest bulbs, 'Snowcap' the smallest.

There was a significant interaction of disbudding and cultivar affecting the number and weight of bulblets produced (Table 2). Disbudding increased bulblet formation for three cultivars but did not affect bulblet formation for 'Campfire' and 'Snowcap.'

There was also a significant interaction of mulch-cover treatment and disbudding affecting mean bulblet weight (Table 3). Neither mulch nor mulch plus cover treatments affected mean bulblet weight for disbudded plants. Mulch and mulch plus cover increased bulblet size for plants which were not disbudded.

The combination of mulch and disbudding produced the largest weight and number of bulblets and the greatest mean bulb weight. Mean bulblet weight was greatest with mulch but no disbudding.

1988

In contrast to 1987, mulch decreased the number of emerged shoots (Table 4) of the cultivar 'Connecticut King' in 1988. However, the number of bulbs recovered at harvest was not affected by mulching (Table 4). The planting date was more than a month later than in 1987. Cooler soils may have been a limiting factor in shoot emergence in 1987 and mulch is known to increase soil temperature. Tunnels had no effect on shoot emergence in 1988 (data not shown).

Just prior to disbudding, all plots were rated for flower bud development (Table 5). Mulch had no consistent effect on the number of flower buds present, but the tunnels reduced the number of buds significantly, perhaps through abrasion of the growing point. Nevertheless, tunnels also advanced the date of first bloom for 'Enchantment' (Tables 5 and 6).

In 1988, there was a trend toward higher bulb weight with mulch, but the effect was not significant (Table 7). As in 1987, the tunnel tended to reduce bulb weight, and disbudding, but leaving the stem intact, tended to increase bulb weight. However, these effects were not statistically significant in 1988. As expected, cut flower harvest, where most of the stem is removed at bloom, reduced bulb size. There were no significant 2-, 3-, or 4-way interactions of mulch, tunnel, disbudding treatment, or cultivar affecting bulb size at harvest, hence only main effects are shown in Table 7.

In 1988, mulch again increased the number of bulblets per stem (Table 7). Tunnels and cut flower harvest tended to reduce bulblet production and disbudding to increase bulblet production, but these effects were not significant. 'Enchantment' produced 3.4 bulblets per stem versus only 1.9 for 'Connecticut King' when averaged over all treatments.

Mulch markedly increased mean bulblet weight. Disbudding had no effect and tunnels tended to decrease bulblet mean weight. Cut flower harvest, not surprisingly, also decreased mean bulblet weight. There were no significant 2-, 3-, or 4-way interactions affecting number of bulbets per stem or mean bulblet weight. 'Connecticut King' produced slightly larger (1.4 g vs. 1.0 g) bulblets than did 'Enchantment.'

The greatest increase in bulb weight occurred with the combination of mulch and disbudding, but no tunnel (+24 g). The greatest number of bulblets per stem also occurred with this combination, but greatest mean bulblet weight was favored by the combination of mulch, no tunnel, and no disbudding. Treatments favoring large bulbs also generally produced more and larger bulblets as bulblet formation increases with maturity. The correlation coefficient for number of bulblets produced versus mean bulb weight was 0.59 ($p \leq 0.001$); the correlation coefficient for mean bulblet weight versus mean bulb weight was 0.61 ($p \leq 0.001$).

The practices of using a ground mulch and disbudding clearly favor production of larger lily bulbs and increased bulblet production. In addition, mulch provides soil moisture control and weed control. It may, however, be difficult to plant at the high densities normal in the lily industry when using a plastic mulch.

Table 1. Main effects of mulch and row cover, disbudding, and cultivar on bulb size and bulblet formation in lily, 1987

Treatment	No. plants emerged/plot	No. bulbs recovered	Mean bulb wt. (g)	No. bulblets per stem	Mean bulblet wt. (g)
Bare ground	9.2	9.0	68.7	5.7	1.9
Black mulch	10.6	10.2	88.1	6.4	2.3
Mulch + cover	10.5	9.8	75.9	6.6	2.2
LSD (0.05)	0.9	0.8	6.8	NS[z]	0.3
Disbudded	9.9	10.0	80.2	6.8	2.2
Allowed to bloom	10.2	9.3	74.9	5.6	2.1
	NS	*	NS	**	NS
Cultivar					
Campfire	10.8	9.7	109.5	9.8	2.0
Debutante	10.2	9.6	77.9	8.5	2.5
Impact	10.5	9.7	86.6	10.2	2.4
Moonfire	9.8	10.3	69.5	1.2	2.2
Snowcap	10.0	9.0	44.2	1.6	1.7
LSD (0.05)	NS	NS	8.7	1.6	0.3

[z]NS, *, **: no significant differences; differences significant at 5% and 1% levels, respectively.

Table 2. Interaction of disbudding and cultivar on the number and weight of lily bulblets produced, 1987

Treatment	Cultivar	No. of bulblets/stem	Weight of bulblets (g/plot)
Allowed to bloom	Campire	9.8	202
	Debutante	7.1	173
	Impact	8.1	182
	Moonfire	0.9	18
	Snowcap	1.6	20
Disbudded	Campfire	9.7	188
	Debutante	9.9	243
	Impact	12.1	304
	Moonfire	1.4	38
	Snowcap	1.6	27
	LSD (0.05)	2.2	65

Table 3. Interaction of mulch or cover and disbudding on average bulblet weight of lily, 1987

Treatment	Mean bulblet wt. (g)[z] Allowed to bloom	Disbudded
Bare ground	1.7	2.2
Mulch	2.4	2.2
Mulch + Cover	2.2	2.2

[z]LSD(0.05) = 0.4

Table 4. Interaction of mulch and cultivar on lily shoot emergence and bulb recovery at harvest, 1988

Treatment	No. shoots/plot	No. bulbs harvested/plot
Conn. King, bare soil	11.8	11.7
Enchantment, bare soil	11.9	11.5
Conn. King, mulched	10.9	11.5
Enchantment, mulched	11.8	11.5

Table 5. Interaction of mulch and tunnel on flower development, 1988

Treatment	No. flower buds/shoot	Days to first bloom (anthesis)
Bare soil	2.8	90.4
Mulch	2.9	89.5
Tunnel	2.4	87.7
Both	1.6	85.4
LSD (0.05)	0.6	4.5

Table 6. Interaction of mulch, tunnel, and cultivar on days to anthesis

Treatment	Cultivar	
	'Connecticut King'	'Enchantment'
Bare soil	93.3	87.5
Mulch	94.0	85.0
Tunnel	93.5	81.8
Both	91.3	79.5
	NS	4.1

Table 7. Main effects of mulch, tunnel, disbudding, and cut flower harvest on bulb size and bulblet production, 1988

Treatment	Mean bulb weight (g)	No. bulblets per stem	Mean bulblet weight (g)
Bare soil	24.3	1.9	1.0
Mulch	27.9	3.4	1.5
	NS	**	**
No cover	28.9	2.8	1.3
Tunnel	23.4	2.4	1.2
	NS	NS	NS
Check	28.7 a[z]	2.7	1.3 a
Disbudded	29.8 a	2.9	1.4 a
Cut flower	19.9 b	2.2	0.9 b
	*	NS	*

[z]Mean separation with columns by Duncan's MRT, 5% level.

ROW COVER EFFECTS ON MINIMUM AIR TEMPERATURES

Introduction

Row covers increase daily mean and maximum air temperatures, but their effect on minimum air temperatures is not clear cut. Manufacturers of these materials often claim that covers provide a significant degree of frost protection. However, M. H. Keveren (Plastics in horticultural structures. Rubber and Plastics Research Assoc. of Great Britain, 1973) has established that, on cool nights, temperatures under plastic row covers may be lower than the ambient. This "temperature inversion" was related to the thermal conductivity of the plastic, the degree of condensation on the cover, and the amount of air movement.

Temperature measurements have been made under row covers at the North Willamette Experiment Station for several years, both in winter and in spring. In every experiment, row covers increased the mean minimum air temperature recorded for the length of the experiment. However, there were exceptions to this trend, primarily on cool, clear nights. The following is a compilation of mean minimum temperatures recorded in each of these experiments, along with every instance of exceptions to the general trend.

Table 1. Effect of floating row covers on minimum air temperatures, 14 April-1 June, 1983. Crop: muskmelon

Date	Soil	Mulch	Mulch+Reemay	Mulch+Vispore	Mulch+Xiro
Mean	44.1	44.1	47.4	46.7	46.6
4/15	NR	34	34	37	34
4/16	NR	38	39	40	38
4/23	NR	39	38	40	39
4/30	NR	48	48	52	51

All temperatures measurements made 1.0 inch above the soil surface.

Table 2. Effect of floating row covers on minimum air temperatures, 5 April-1 July, 1984. Crop: muskmelon

Date	Soil	Mulch	Mulch+Reemay	Mulch+Vispore
Mean	46.6 c	47.2 bc	47.5 ab	48.0 a
5/08	43	43	42	43
5/13	44	39	43	41
5/22	46	43	46	46
5/25	52	51	51	51
5/27	52	53	51	52
6/04	50	50	48	51
6/10	53	52	52	57

All temperature measurements made 1.0 inch above the soil surface.

Table 3. Effect of Kimberly Farms row tunnels on minimum temperatures, 7 May-23 June, 1986. Crop: tomato, melon, broccoli

Date	Mulch	Mulch+Tunnel
Mean	48.8	52.6 **
5/12	40.0	39.8 NS
5/16	43.0	40.0 *

Temperature measurements made 6 inches above the mulch surface.

Table 4. Effect of floating row cover materials on minimum air temperatures, 10 June-19 June, 1986. No crop

Date	Soil	Agronet	Reemay	Vispore	Agryl P-17	Kimberly Farms
Mean	49.3 d	49.8 cd	52.7 a	51.5 bc	52.0 ab	52.4 a
6/18	50.0	49.5	51.5	52.5	50.5	52.0

Temperature measurements made 1.0 inch above the soil surface.

Table 5. Effect of floating row covers and black mulch on minimum air temperatures, 9 May-6 June, 1986. Crop: cucumber

Date	Soil	Mulch	Reemay	Vispore	Reemay+Mulch	Vispore+Mulch
Mean	49.1 c	49.3 c	51.4 a	50.7 b	50.7 b	51.3 a
5/10	39	39	42	41	40	37
5/11	36	35	41	39	37	36
5/12	39	39	41	39	38	38
5/13	48	48	47	48	48	49
5/23	47	47	48	46	53	48

Temperatures measurements made 1.0 inch above the soil or mulch.

Table 6. Agryl P-17 floating cover and tunnel effects on minimum air temperatures, 8 April-22 May, 1987. Crop: muskmelon

Date	Soil	Mulch	Floating	Tunnel
Mean	44.1 b	43.9 b	46.8 a	46.2 a
4/08	45.7	46.0	46.0	45.7

Temperatures measured 1.0 inch above the soil or mulch surface.

Table 7. Agronet floating cover effects on minimum air temperatures, 1 June-10 June, 1987. Crop: potatoes

Date	Soil	Agronet
Mean	49.8	51.1 **
6/02	54.0	53.3 *

Temperatures measured 1.0 inch above the soil surface.

Table 8. Effect of covers on minimum air temperatures, 26 November, 1986-21 January, 1987. Crop: ornamental nursery stock

Date	Check	Agronet	AgrylP-17	Lutradur	Reemay	Tufbell	Vispore
Mean	30.3 d	32.2 c	33.5 b	34.4 a	34.7 a	32.9 c	33.1 b
12/17	28	28	30	30	30	29	29
12/18	30	30	30	32	33	32	31
01/10	29	29	30	31	31	30	29
01/15	29	29	30	31	31	30	29

Temperatures measured 9 inches above surface of can yard, in plant canopy.

Table 9. Effect of covers on minimum air temperatures, 10 December, 1987-22 February, 1988. Crop: ornamental nursery stock

Date	Check	4-mil white poly	Typar	Agryl P-17
Mean	34.0 c	35.0 b	35.9 a	35.4 b
12/26	28.5	28.5	29.0	28.5
01/01	30.5	31.0	30.5	31.5
01/03	32.5	31.5	30.0	33.0
01/05	30.5	31.5	30.5	30.0
01/06	31.5	32.5	31.0	33.0

Temperatures measured 9 inches above surface of can yard, in plant canopy.

Temperatures were recorded for a total of 403 nights during these experiments. On 30 occasions, equal or lower temperatures were recorded under row covers than over bare soil. Usually the differences were very small and may not have exceeded experimental error. However, in three instances the temperature was 2 or more degrees F lower under a cover. Although not occurring often, these instances tend to confirm the findings of Keveren. "Temperature inversion" under covers did not appear to be related to the type of cover as instances occurred both with polyethylene and non-woven fabric materials. Higher-weight materials generally gave more protection.