AN ABSTRACT OF THE THESIS OF

Mary Beth Graham for the degree of Master of Science

in Horticulture presented on May 2, 1988 .

Title: MANAGEMENT EFFECTS ON WATER USE AND CABBAGE (BRASSICA OLERACEA) YIELD IN A PERENNIAL RYEGRASS (LOLIUM PERENNE) LIVING MULCH

Abstract approved: Garvin Crabtree

Living mulch systems can benefit soils and crops. Competition between the crops for nutrients and water must be minimized if benefits are to be realized.

The effects of management practices on water use and yield of cabbage (Brassica oleracea) in monocultures and living mulch systems were compared in a field study. Five water application levels (20, 35, 65, 83 and 100% of 33.3 cm), imposed by a line source, were factorially combined with five interrow treatments. Cabbage spaced at 30 x 80 cm had 40 cm strips of grass between rows managed by mechanical (two mowings), chemical (one application at .17 kg ai/ha of fluazifop-P ((R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]-oxy]phenoxy]-propanoic acid)) or no suppression. Cabbage monocultures had bare ground between rows or another row of cabbage, doubling the crop density.

Compared to bare ground, interrow cabbage decreased the yield of the remaining cabbages as much as the mowed and unsuppressed grass, by 14% at the 100% water level,

though total marketable yield for the double density plots was 64% higher than for the low density monoculture. Compared with the low density monoculture, chemically suppressed grass decreased the yield as much as the other treatments at the 65% water level, less so at the 83% water level, and was no different at the 100% water level. Chemical suppression reduced the competitive ability of the grass against cabbage, but also against weeds.

Weekly readings were made from gypsum blocks placed at 15, 30, 60 and 90 cm depths at locations in the cabbage row, under the interrow treatment, and midway between the cabbage row and the center of the interrow at the 65% water application level. Treatment by location, location by date, and treatment by date interactions for water potential were significant. Most water was depleted from the 15 and 30 cm depths within the cabbage row. Grass or cabbage in the interrow caused more water to be depleted in the cabbage row as well as in the interrow. Chemically suppressed grass did not deplete soil water as much as the other interrow treatments. Interactions with date were significant because treatment and location differences developed later in the season as the plants grew.

Results suggest that competition was mainly for water. This study indicated that when water is the limiting factor, a living mulch system may yield as well as a monoculture if grass suppression and added water are sufficient.

MANAGEMENT EFFECTS ON WATER USE AND CABBAGE (*BRASSICA OLERACEA*) YIELD IN A PERENNIAL RYEGRASS (*LOLIUM PERENNE*) LIVING MULCH

by

Mary Beth Graham

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed May 2, 1988

Commencement June 1988

APPROVED:

Professor of Horticulture in charge of major

Head of Department of Horticulture

Dean of the Graduate School

Date thesis presented May 2, 1988

Typed by Mary B. Graham

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

MANAGEMENT EFFECTS ON WATER USE AND CABBAGE (BRASSICA OLERACEA) YIELD IN A PERENNIAL RYEGRASS (LOLIUM PERENNE) LIVING MULCH

Chapter 1

INTRODUCTION

In Oregon's Willamette Valley, cabbage matures during the rainy season when excessive soil moisture makes harvesting with heavy machinery difficult. A living mulch may prevent soil damage.

A living mulch is a cover crop grown simultaneously with the main crop in a reduced tillage system. It may reduce erosion and weed invasion. A grass living mulch can improve water infiltration, trafficability and soil structure.

The addition of another crop usually causes yield decreases and maturity delays in the main crop that are most often attributed to competition for nutrients or water. Regulation of a living mulch is necessary to minimize competition between the crops. Management strategies include improving plant spacing for optimal use of resources, providing more of limiting resources, and reducing the growth and resource use of the mulch.

Development of effective management systems requires an understanding of the needs of the crop and the susceptibility of the mulch to management, and experience with the interaction between the crops.

A cabbage and perennial ryegrass living mulch system was studied in a field experiment with several water and mulch management regimes. The objectives of the experiment were to evaluate some management programs for living mulch systems and to gain a better understanding of the role of water in an intercrop situation.

Chapter 2

REVIEW OF THE LITERATURE

LIVING MULCH SYSTEMS

The use of living mulches has been reviewed by several authors. Wiles reviewed living mulch systems for row crops (39), Peterman reviewed potential advantages of living mulches (30), Cooper discussed mulch selection and regulation (10), and Butler reviewed grass characteristics relevant to their use as living mulches (7).

Living mulches offer several possible improvements over conventional tillage: less erosion, nutrient leaching, tillage, weed invasion, splashing of soil onto crops, and the addition of organic matter to the soil (7,14). The modified environment may reduce pest problems (31,40). Grass specifically has been credited with improving soil structure, trafficability and water infiltration (7). Improved trafficability is a main goal of living mulch systems in cabbage, as late season harvest is difficult for heavy machinery on wet soil.

Maturity delays and reduced crop yields are common in living mulch systems (14,20,25) and are usually attributed to competition for nutrients and/or water (1,8,17,18,31). Yield decreases not attributable to competition for the major resources of water, nutrients or light have been observed (6). Successful living mulch systems usually depend on high levels of fertility and water (1,8,13), though with lower plant density, adequate rainfall, or leguminous crops addition of resources to the system is less critical (13,20,25,31).

Selection and management of living mulches has been geared at reducing their competition with the main crop. Water has been identified as a limiting factor, but a poor understanding of its role and the nature of competition in an intercrop hinders the development of efficient living mulch systems. Creating a successful system requires an understanding of its components and how they interact.

CABBAGE GROWTH AND REQUIREMENTS

The addition of a living mulch to a cropping system can change the resource use of the main crop and is in some ways similar to placing plants closer together or having weed invasion. Selection and management of a mulch crop is better accomplished with information about the growth and requirements of the main crop. For a crop that has rarely been grown with living mulches, information about its response to weed invasion and various spatial arrangements is often the only evidence of its ability to handle competition.

Cabbage is a fast growing crop that doubles its weight every nine days during head formation (26). It requires high levels of water and nutrients for maximum yields (15,29,37). Excessive moisture can cause head splitting (37) and yield decreases possibly due to nutrient leaching

(24), but depletion of even 25% of the available soil water can cause yield decreases (11). The later in the season water stress occurs, the more severe is the decrease in cabbage yield (11,32,35).

Cabbage is sensitive to both interspecific and intraspecific competition. Higher density spacing decreases individual head size but increases total yield (16,37). Additional water and fertilizer can improve individual head size and total yield (11,15). In comparing several studies, Zimdahl noted no critical period of competition from weeds (42). Though there is a limit on the length of time that early or late season weeds will be tolerated without yield reductions, in one study a single weeding at three weeks from planting was sufficient to allow maximum cabbage yields.

The majority of cabbage roots are within 10 cm of the surface of the soil, with lateral spread exceeding depth increases during head formation (28). Water extraction depends on factors other than root density. One study showed 95% of cabbage roots within 15 cm of the soil surface, but 40% of the water was extracted from the 15 to 30 cm depth (12). Rooting habit depends in part on soil conditions such as bulk density and moisture and may be altered by irrigation which, if frequent, favors shallow rooting systems (28).

Selection and management of a living mulch should focus on avoiding competition for water in the shallow root zone of the cabbage.

GRASS SELECTION AND MANAGEMENT

Desireable living mulch characteristics are low growth, fast germination and cover, weed resistant cover, wear resistance (7), manageability and minimal resource use. Cook recommends perennial ryegrass as the species most favorable for the Willamette Valley (9). Though warm season grasses use less water (5), they do not grow well enough in this area to fulfill the other requirements of a living mulch (7).

Established grass roots spread deeper into the soil than cabbage, but they are also somewhat concentrated near the soil surface (4).

Several cultural and chemical techniques have been shown to influence the growth and water use of turf and forage grasses. Water use has been correlated to grass root and top growth (23,36). Frequent irrigation or compacted soil layers will cause roots and water extraction to be concentrated near the soil surface (2,22,27). Frequent mowing at lower heights decreases rooting (7), while aeration increases rooting (21). Water use increases with frequent irrigation, frequent mowing (34), mowing with a dull blade, traffic (3), low levels of potassium, and some diseases such as stripe smut (33). The most effective cultural techniques for decreasing water use of turfgrasses are lower cutting height and decreased nitrogen fertilization (5,9,19,21,34).

Chemical suppression of grass living mulches has often been inadequate, with competition causing yield decreases, or excessive, allowing weed invasion (14,20,23). Perennial ryegrass growth has been reduced for up to eight weeks without stand reduction by fluazifop-P and sethoxydim ((2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one)) (39,41). The ability of these herbicides to consistently suppress grass makes them the most likely chemicals to provide a balance between keeping the living mulch competitve against weeds and limiting its ability to compete with the main crop.

Chapter 3

MANAGEMENT EFFECTS ON WATER USE AND CABBAGE (BRASSICA OLERACEA) YIELD IN A PERENNIAL RYEGRASS (LOLIUM PERENNE) LIVING MULCH

INTRODUCTION

Harvest of fall crops such as cabbage can be a problem in rainy areas. Excessive soil moisture makes harvesting with heavy machinery difficult and the soil may be damaged for the following crop.

A grass living mulch can improve trafficability, water infiltration, and soil structure and may reduce erosion and weed invasion (7). Living mulch systems commonly cause yield decreases and maturity delays which are most often attributed to competition for nutrients or water (1,8,20). Mulch dry matter production has been negatively correlated to cabbage yield (25).

Management strategies for regulation of a living mulch system include improving plant spacing for optimal use of resources, providing more of limiting resources, and reducing the growth and resource use of the mulch.

Cultural factors such as mowing height and fertilization level can significantly influence the water use of a turfgrass (34). Sublethal rates of grass herbicides can suppress grass growth for up to eight weeks (41).

In this study management strategies involving water regulation and grass suppression were evaluated by comparing water applied, soil moisture, and cabbage yield.

MATERIALS AND METHODS

This experiment was conducted in 1986 at the Oregon State University Vegetable Research Farm near Corvallis, Oregon, on a Cumulic Ultic Hapoxeroll, mixed mesic (Chehalis silty clay loam) soil.

Five water application levels, imposed by a line source, were factorially combined with five interrow treatments. Cabbage was spaced 30 x 80 cm in plots sized 240 x 270 cm. In the three living mulch treatments 40 cm strips of grass between the cabbage rows were managed by mechanical, chemical, or no suppression. The cabbage monocultures had bare ground between rows, or another row of cabbage, doubling the crop density.

Plots were arranged in eight complete blocks with systematic water application levels and randomized interrow treatments. Analysis is similar to that for a split-plot design because the water application levels are not randomized. The line source generates a pattern of water distribution from no water at the distal end of the block to a high level of water proximal to the line.

Prior to planting, holes were dug with a power auger for the placement of gypsum blocks and neutron meter access tubes (Fig. 3.1). Aluminum neutron meter access tubes were placed between plants in a cabbage row in both the unsuppressed grass plots and the low density cabbage monoculture plots at each water level in four of the blocks. Water from both irrigation and precipitation was measured in catchcans placed on top of or next to each neutron meter access tube.

Gypsum blocks were placed at two or four depths (15, 30, 60, and 90 cm) at six locations per plot for each treatment at the middle water level in four blocks. The six locations were as follows: beneath a cabbage plant, between two cabbage plants in a row, in the center of the grass or bare ground strip across from the gypsum blocks in the cabbage row, and midway between the first two pairs of gypsum blocks. Blocks were placed at all four depths in locations under or across from cabbage. Blocks between plants and across from those were placed at the 15 and 30 cm depths. For data analysis locations were grouped into three sections: in the cabbage row, under the interrow treatment, and midway between the cabbage row and the interrow. Thus, there are twice as many observations for the 15 and 30 cm depths as for the 60 and 90 cm depths.

728 kg/ha of fertilizer (8N-10.6P-6.6K) was banded in the cabbage rows prior to hand seeding of 'Market Victor' on 11-12 June. Cabbage was thinned to a 30 cm spacing on 16-17 July and sidedressed with 56 kg N/ha of ammonium nitrate. Double density cabbage plots received twice as much fertilizer as other plots because fertilizer was banded for each row.

'Manhattan II' perennial ryegrass was planted at 22.4 kg/ha on 12 June and 44.8 kg N/ha of ammonium sulfate was broadcast over the grass area the next day.

Irrigation was uniform until the grass was established. Weekly line source irrigation began 14 July. The amount of water to be applied weekly was calculated from neutron meter readings to raise the soil moisture level in the plots adjacent to the line source to field capacity.

Gravimetric soil water and bulk density measurements taken at the time of access tube placement and after harvest were used to calibrate the neutron meter for volume percent water. In addition to several early season measurements, readings were taken at 15, 30, 60, and 90 cm depths on the day before line source irrigation and two days later throughout the season. In calculating the amount of water in the soil profile from the surface to a depth of 105 cm, it was assumed that the 15 cm reading represented 0 to 20 cm, the 30 cm reading represented 20 to 45 cm, the 60 cm reading represented 45 to 75 cm, and the 90 cm reading represented 75 to 105 cm.

After one early season reading on 3 July, gypsum block readings were taken weekly on the day before line source irrigation. Readings were converted to matric potential with the manufacturer's calibration curve.

Soil temperature at 10 cm depth was measured on 20 July in each plot at the middle water level in all blocks at the edge of the grass, or, in the cabbage monocultures, at the same distance from the cabbage plant.

On 14 July .17 kg ai/ha of fluazifop-p-butyl was applied for the chemical suppression treatment with a carbon dioxide pressured backpack sprayer. Mechanically suppressed plots were mowed to approximately 4 cm on 23 July and 14 August.

Fonofos was incorporated into the soil prior to planting. Carbaryl, Bacillus thuringienis, and diazinon were applied as needed to control insects. All weeding was by hand or hoe.

On 29 August, approximately 14 heads of cabbage per plot were harvested from the two rows adjacent to the center of the plot. Guard plants were excluded. Plants were counted, weighed, and trimmed to marketable condition. All heads of marketable size were counted and weighed.

All data were analyzed by an analysis of variance. Correlation between water applied and marketable yield was determined by regression.

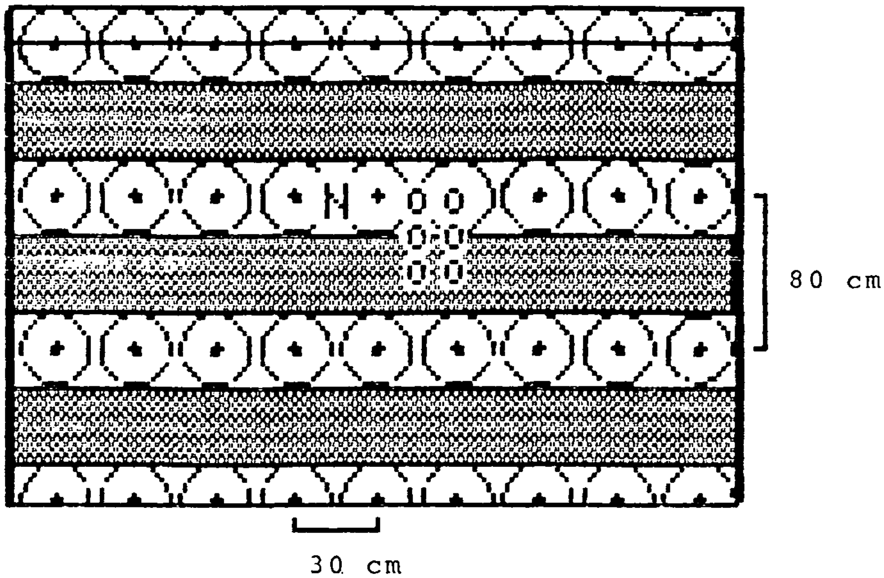

Figure 3.1. Locations of gypsum blocks (o), and neutron meter access tubes (N) within a plot. Circles represent cabbage plants. Shaded area represents the interrow treatment: bare ground, grass, or another row of cabbage. Figure shown represents one complete 240 x 270 cm plot.

RESULTS AND DISCUSSION

Catchcan measurements indicate that an average of 33.3 cm of water was applied throughout the season, as rainfall and irrigation, at the high water application level. The other water application levels, in increasing distance from the line source, were 83, 65, 35, and 20% of the highest water application level.

Cabbage yield was the primary criterion for evaluating the various management systems. As cabbage yield relationships were the same for total weight and marketable weight, only the results for marketable weight will be presented. Figure 3.2 shows the marketable weight means for each treatment at each water level. Two lines represent the double density cabbage system. One is the total marketable weight for that treatment. The other ignores the yield of the added rows of cabbage, considering them only as an interrow treatment, and in effect measures their influence on the other rows of cabbage. Regression equations for the five treatments are in Table 3.1. Ignoring the lowest water level allows a regression curve that better describes the relationship between yield and added water (Table 3.2). The 35% water level can be considered a threshold level below which no significant cabbage growth occurs.

Yields for all treatments were similarly low at the two lowest water application levels. Significant treatment differences occurred only at the three highest water application levels.

The double density plots yielded 64% higher than the low density monoculture at the highest water application level. Doubling the number of plants more than compensated for decreased head size at the two highest water application levels.

Cabbage yields in the unsuppressed and mechanically suppressed grass treatments were significantly lower than the low density monoculture at all water application levels with treatment differences. The difference was 14% at the highest water application level.

Cabbage in the chemically suppressed grass yielded the same as the other grass treatments at the 65% water application level, better at the 83% water application level, and as well as the low density monoculture at the highest water application level.

Comparison of the yields of cabbage under various interrow treatments with yields of the low density monoculture, which had bare ground as the interrow treatment, was used to assess the relative competitive ability of each of the interrow treatments. In this case competitive ability is defined as the ability to reduce cabbage yield.

Interrow cabbage in the double density treatment reduced the yield of the remaining cabbage as much as the unsuppressed and mowed grass at all water application levels that have significant treatment differences. This indicates that cabbage and perennial ryegrass compete equally well with cabbage. Mechanical suppression at two mowings per season had no effect on the competitive ability of the grass. The reduction in water use through cultural techniques that Shearman and Beard report utilized more frequent mowing and reduced grass fertilization (34). In this experiment grass was adequately fertilized to prevent competition for nutrients.

Chemical suppression reduced the competitive ability of the ryegrass slightly at the 65% water application level and more so at the higher water application levels. For all treatments, the degree of competition lessened as more water was applied and at the highest water application level competition between cabbage and the chemically suppressed grass was eliminated. Further evidence of the reduced competitive ability of the chemically suppressed grass was the greater number of weeds observed than in the other grass plots.

It is unclear from these data whether the addition of water alone would eventually eliminate all competition, but it seems that under the conditions of this study competition was mainly for water. Competition for nutrients, if it did exist, would likely be for water soluble, soil mobile nutrients and therefore dependent on soil moisture. The addition of any interrow treatment to the low density monoculture increased the amount of water required to achieve a given yield, though the effect of chemically suppressed grass was less than the other treatments.

Soil moisture determinations support the hypothesis that cabbage yield decreases were due to competition for water. Gypsum block readings of water potential showed a significant location by treatment interaction at the 15 and 30 cm depths (Table 3.3). Graphic representations of the gypsum block readings for each treatment are presented in figures 3.3 - 3.7. Less soil water was available (the matric potential was higher) in the lower yielding treatments: unsuppressed grass, mechanically suppressed grass, and cabbage as an interrow treatment. The matric potential of the chemically suppressed grass treatment was midway between the low density monoculture and the other interrow treatments. In the low density cabbage monoculture most of the water is used (the soil is dryer) in the cabbage row, less is used in the middle section and very little is used in the bare ground area between cabbage rows. In other treatments the interrow area was as dry as or dryer than the cabbage row. The middle section tended not to be as dry as areas directly below cabbage or grass.

All treatments had similarly wet soil after uniform early season irrigation. Differences between treatments and locations developed later in the season as the plants grew. The treatment by date interaction was significant at the 15, 60 and 90 cm depths (Table 3.4) and the location by date interaction was significant at all but the 90 cm depths (Table 3.5).

It appears that cabbage uses water mainly from the cabbage row and the middle section. Grass in the interrow uses water mainly from the interrow and probably from the middle section. As more water is used from the interrow and middle sections by grass, cabbage uses more water from the cabbage row. Cabbage, even if it acquires as much water as in the low density monoculture treatment, is forced to extract that water from a limited area.

Neutron meter measurements did not detect significant differences between volumetric soil water content of the two treatments monitored, perhaps because the neutron meter measures soil water for a larger volume of soil than the gypsum blocks. There may also be smaller differences in the soil water content as measured by the neutron meter than in the soil matric potential as measured by the gypsum blocks. The neutron meter measurements were not made at the location that had the largest differences in soil moisture. The neutron meter measurements were made in the cabbage row. Judging by the gypsum block results, treatment differences might have been better detected if the neutron meter access tubes had been placed between cabbage rows, directly below the different interrow treatments. However, Vomocil was unable to detect seasonal water use differences between soil in grape rows and between rows under various tillage systems using the neutron meter (38). Differences in soil water content were apparent over time and different irrigation levels (Figure 3.8).

Soil temperature was significantly different between treatments on the date measured (Table 3.6) Higher soil temperatures roughly correspond to higher cabbage yields. The differences in soil temperature are probably due to the amount of ground cover. As the temperature was measured late in the season, part of the difference in ground cover was due to different sized cabbage plants. Earlier measurements would be better indicators of any effect on cabbage yield.

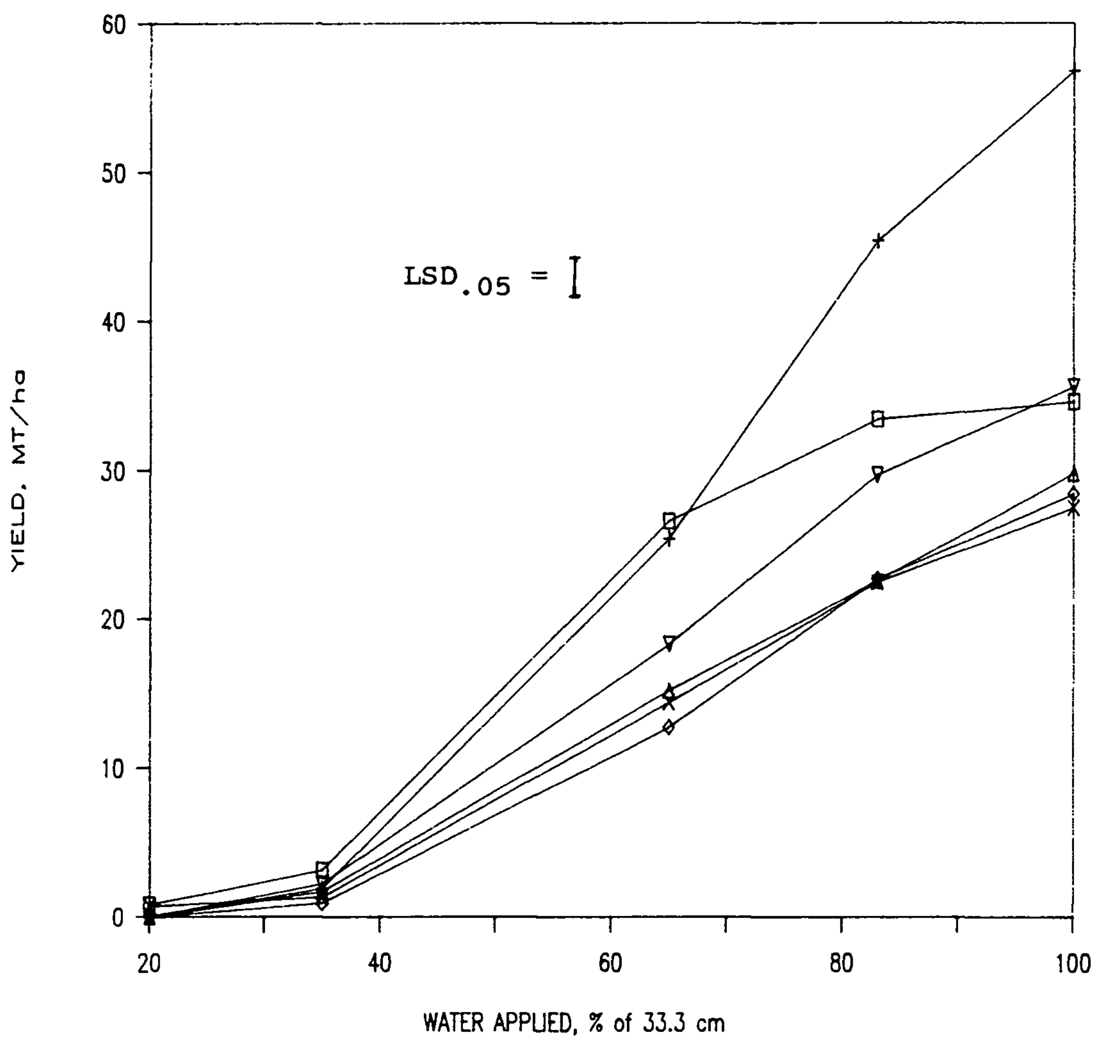

Figure 3.2. The effect of interrow treatment and water applied on market weight of cabbage. Treatments are as follows:

+ = Double density cabbage
□ = Low density cabbage
▽ = Chemically suppressed grass
Δ = Unsuppressed grass
× = Mowed grass
◇ = Cabbage as an interrow treatment

Table 3.1 Regression equations for cabbage yield vs.water applied.

Treatment	Regression Equation	R^2
Low density cabbage	Yield (MT/ha) = $(\%H_2O)^{.7228}$	.95
Chem. suppressed grass	Yield (MT/ha) = $(\%H_2O)^{.6963}$	.96
Unsuppressed grass	Yield (MT/ha) = $(\%H_2O)^{.6512}$	.95
Mowed grass	Yield (MT/ha) = $(\%H_2O)^{.6127}$	.92
Double density cabbage	Yield (MT/ha) = $(\%H_2O)^{.8055}$	.98

Table 3.2. Regression equations for cabbage yield vs.water applied from the 35 to 100% water application levels.

Treatment	Regression Equation	R^2
Low density cabbage	Yield (MT/ha) = $(\%H_2O\text{-}35)^{2.05}$	.95
Chem. suppressed grass	Yield (MT/ha) = $(\%H_2O\text{-}35)^{1.97}$	.97
Unsuppressed grass	Yield (MT/ha) = $(\%H_2O\text{-}35)^{1.83}$	.96
Mowed grass	Yield (MT/ha) = $(\%H_2O\text{-}35)^{1.80}$	.97
Double density cabbage	Yield (MT/ha) = $(\%H_2O\text{-}35)^{2.21}$	.97

Table 3.3. The effect of treatment and location on water potential (kPa) as measured by gypsum blocks. Averaged over all dates.

		Treatment[2]				
Depth[1]	Location	1	2	3	4	5
	Cabbage	901	1399	1324	1153	1430
15 cm	Midway	630	802	902	1133	931
	Interrow	271	786	1393	1147	1430
	Cabbage	686	538	630	570	768
30 cm	Midway	252	275	297	430	333
	Interrow	79	103	465	457	768
	Cabbage	166	189	175	173	251
60 cm	Midway	32	60	70	184	57
	Interrow	18	35	22	21	251
	Cabbage	20	72	30	43	116
90 cm	Midway	19	19	31	21	22
	Interrow	18	18	19	18	116

[1]Mean separation within each depth:
15 cm means are significantly different at p = .01, LSD (.05) = 360.
30 cm means are significantly different at p = .05, LSD (.05) = 296.
60 and 90 cm means are not significantly different.

[2]Treatment numbers are as follows:
1 = Low density cabbage
2 = Chemically suppressed grass
3 = Unsuppressed grass
4 = Mowed grass
5 = Double density cabbage

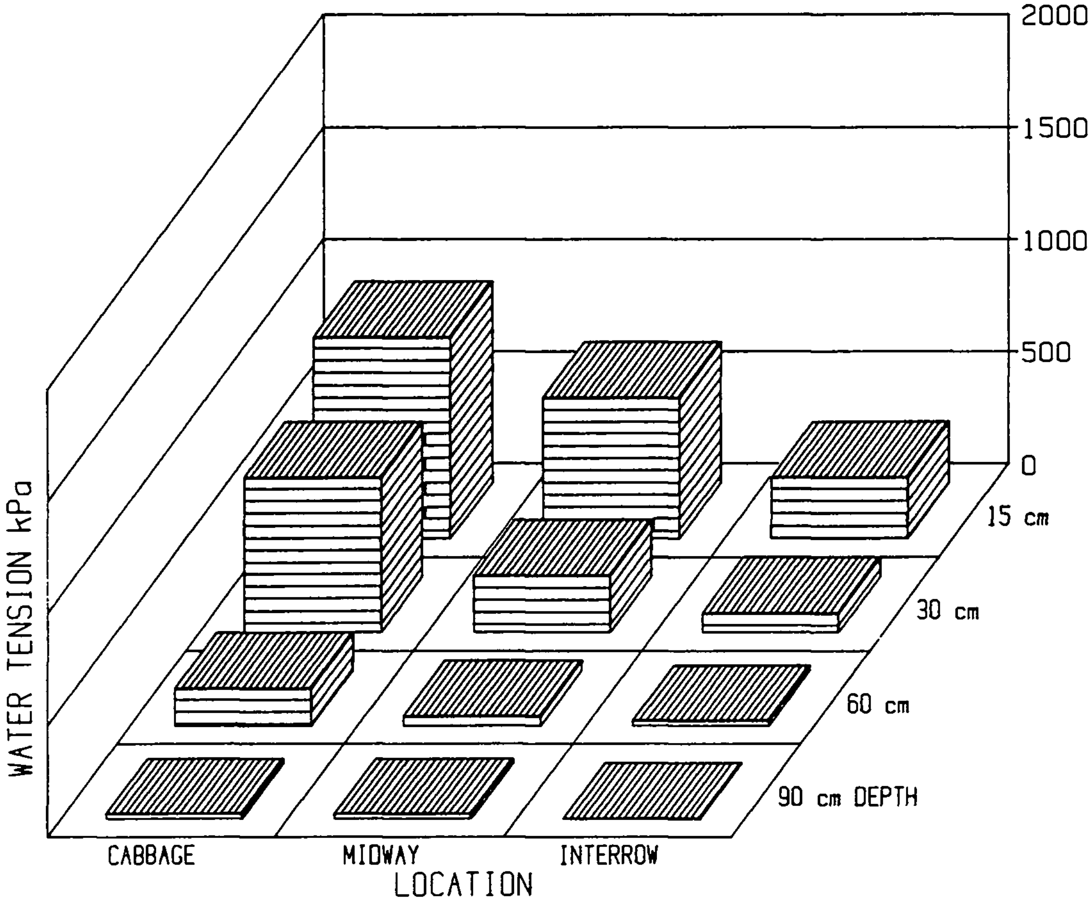

Figure 3.3. Seasonal average water tension (kPa) as measured by gypsum blocks in the low density cabbage treatment.

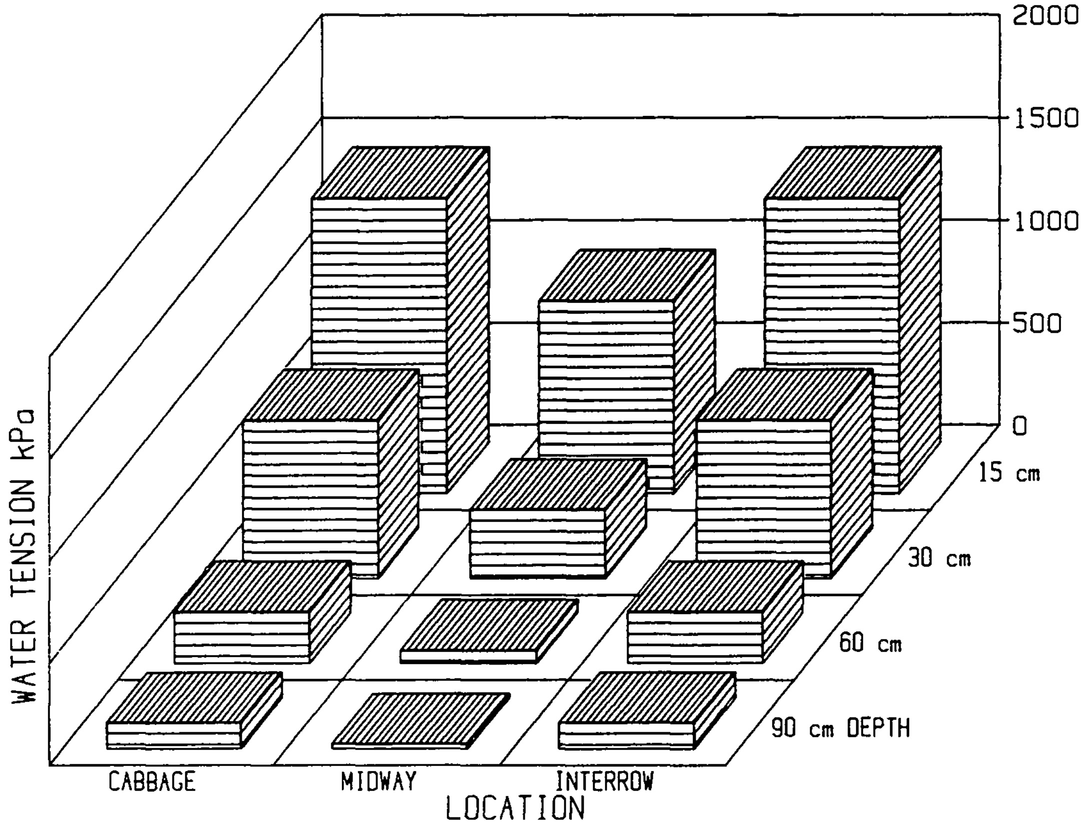

Figure 3.4. Seasonal average water tension (kPa) as measured by gypsum blocks in the double density cabbage treatment.

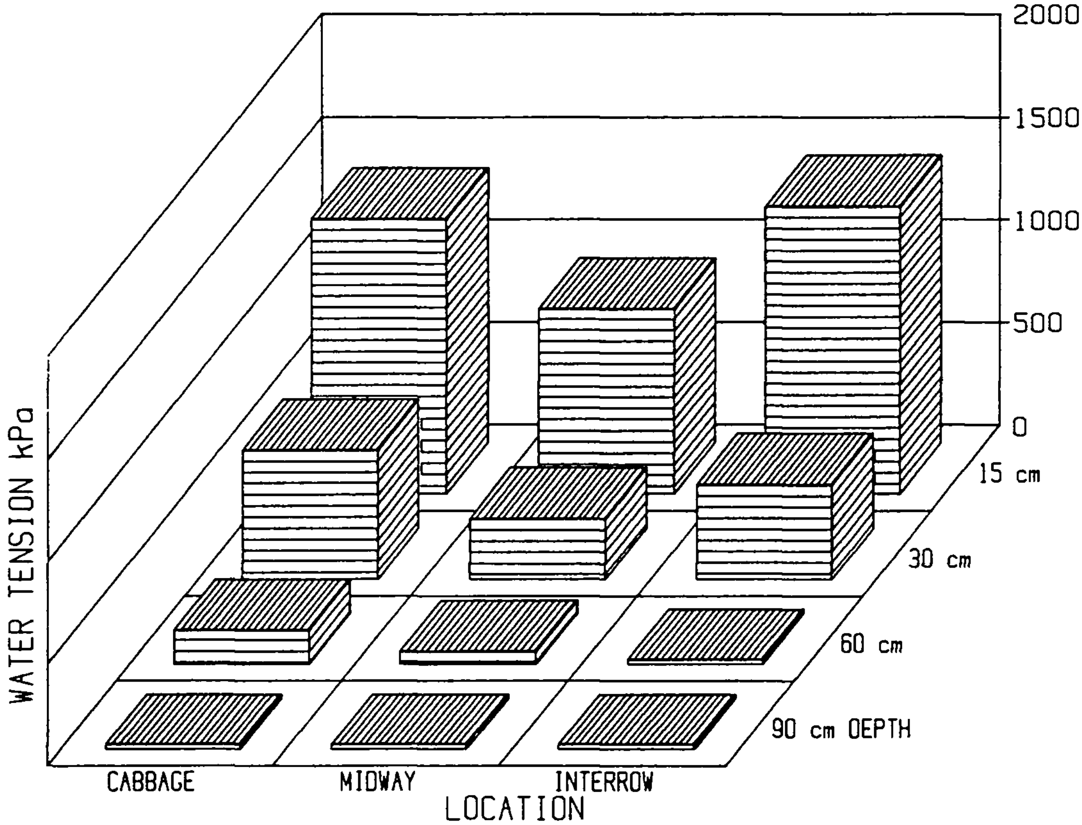

Figure 3.5. Seasonal average water tension (kPa) as measured by gypsum blocks in the unsuppressed grass treatment.

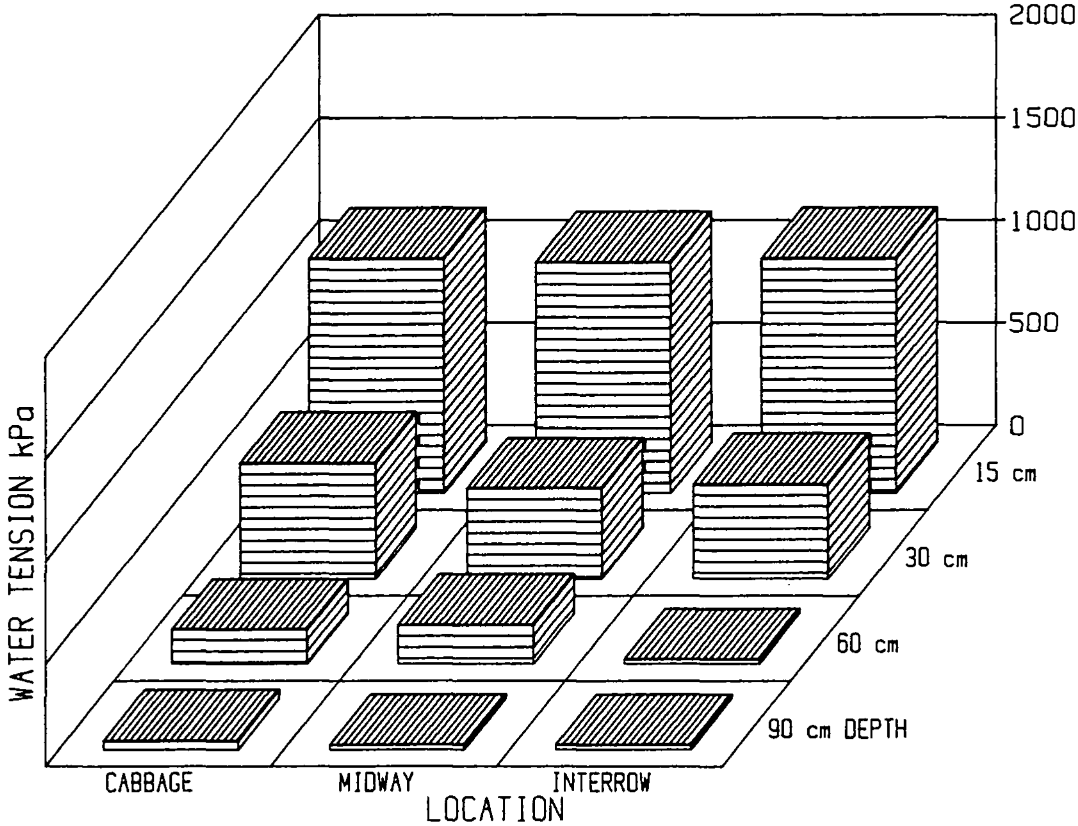

Figure 3.6. Seasonal average water tension (kPa) as measured by gypsum blocks in the mowed grass treatment.

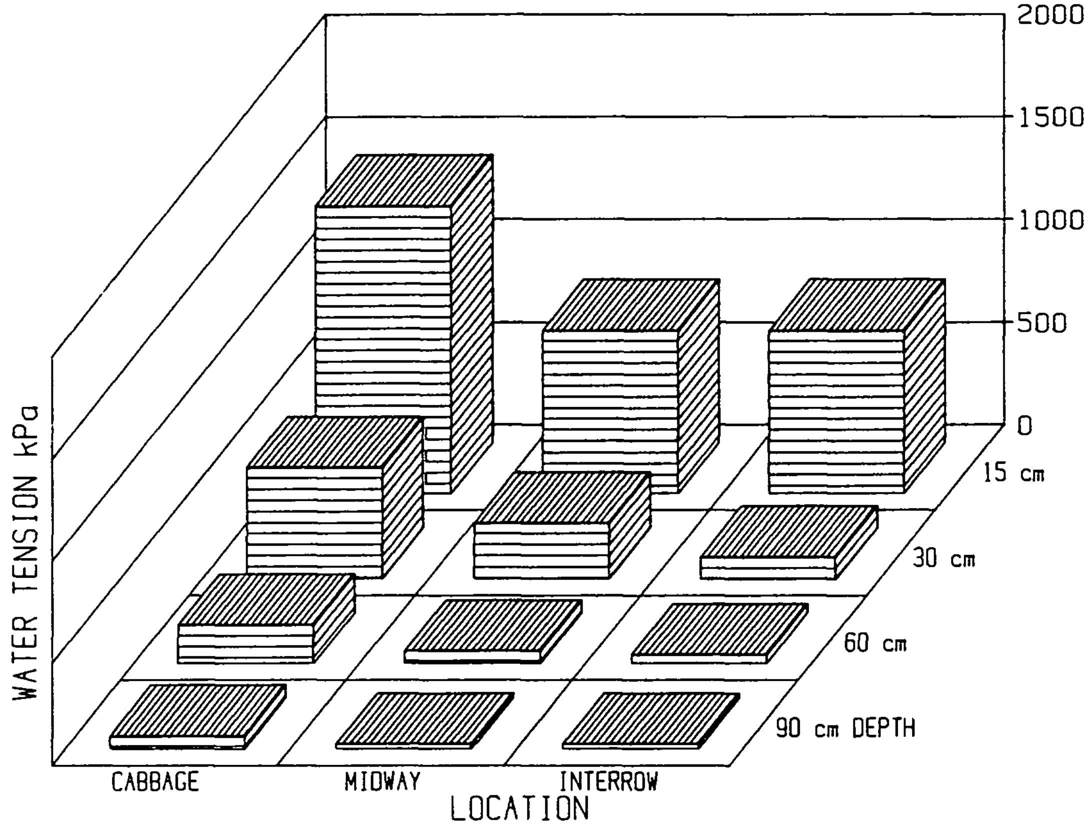

Figure 3.7. Seasonal average water tension (kPa) as measured by gypsum blocks in the chemically suppressed grass treatment.

Table 3.4. The effect of treatment and date on water potential (kPa) as measured by gypsum blocks. Averaged over locations.

Depth[1]	Date	Treatment 1	2	3	4	5
15 cm	July 3	47	33	33	25	29
	July 13	519	740	812	746	1111
	July 20	785	1450	1566	1579	1488
	July 27	1359	1802	1938	1852	1878
	August 3	452	1172	1551	1598	1246
	August 10	561	997	1469	1339	1279
	August 17	452	838	1155	932	1418
	August 24	630	934	1127	1084	1659
30 cm	July 3	19	18	17	20	17
	July 13	141	84	149	40	200
	July 20	189	293	357	495	660
	July 27	737	683	1038	999	1211
	August 3	627	505	861	839	1071
	August 10	478	478	751	810	829
	August 17	163	135	140	193	217
	August 24	358	250	398	489	778
60 cm	July 3	18	19	18	18	19
	July 13	19	18	18	19	19
	July 20	19	19	18	19	20
	July 27	20	22	23	23	22
	August 3	106	41	72	105	114
	August 10	184	275	204	309	535
	August 17	90	174	159	218	317
	August 24	121	190	198	296	444
90 cm	July 3	19	18	19	19	19
	July 13	18	18	20	18	19
	July 20	19	18	19	19	19
	July 27	20	19	19	19	19
	August 3	17	19	18	17	45
	August 10	19	44	21	19	182
	August 17	20	62	33	45	137
	August 24	21	93	65	64	241

[1]Mean separation within each depth:
15 cm means are significantly different at p = .01, LSD (.05) = 365.
30 cm means are not significantly different.
60 cm means are significantly different at p = .05, LSD (.05) = 95.
90 cm means are significantly different at p = .01, LSD (.05) = 47.

Table 3.5. The effect of location and date on water potential (kPa) as measured by gypsum blocks. Averaged over treatments.

		Location		
Depth[1]	Date	Cabbage	Midway	Interrow
15 cm	July 3	46	23	31
	July 13	1099	455	804
	July 20	1371	1243	1506
	July 27	1784	1706	1808
	August 3	1342	872	1398
	August 10	1482	836	1069
	August 17	1378	789	709
	August 24	1428	1114	719
30 cm	July 3	17	18	20
	July 13	261	24	84
	July 20	562	199	436
	July 27	1143	735	924
	August 3	1130	516	695
	August 10	980	519	509
	August 17	300	132	77
	August 24	716	396	252
60 cm	July 3	19	18	19
	July 13	18	19	19
	July 20	18	19	19
	July 27	25	20	20
	August 3	176	40	46
	August 10	520	211	173
	August 17	328	134	113
	August 24	420	182	147
90 cm	July 3	19	19	19
	July 13	19	18	19
	July 20	18	19	19
	July 27	19	19	19
	August 3	27	18	26
	August 10	85	19	67
	August 17	100	24	53
	August 24	163	44	83

[1]Mean separation within each depth:
15 cm means are significantly different at $p = .01$, LSD (.05) = 283.
30 cm means are significantly different at $p = .01$, LSD (.05) = 218.
60 cm means are significantly different at $p = .01$, LSD (.05) = 74.
90 cm means are not significantly different.

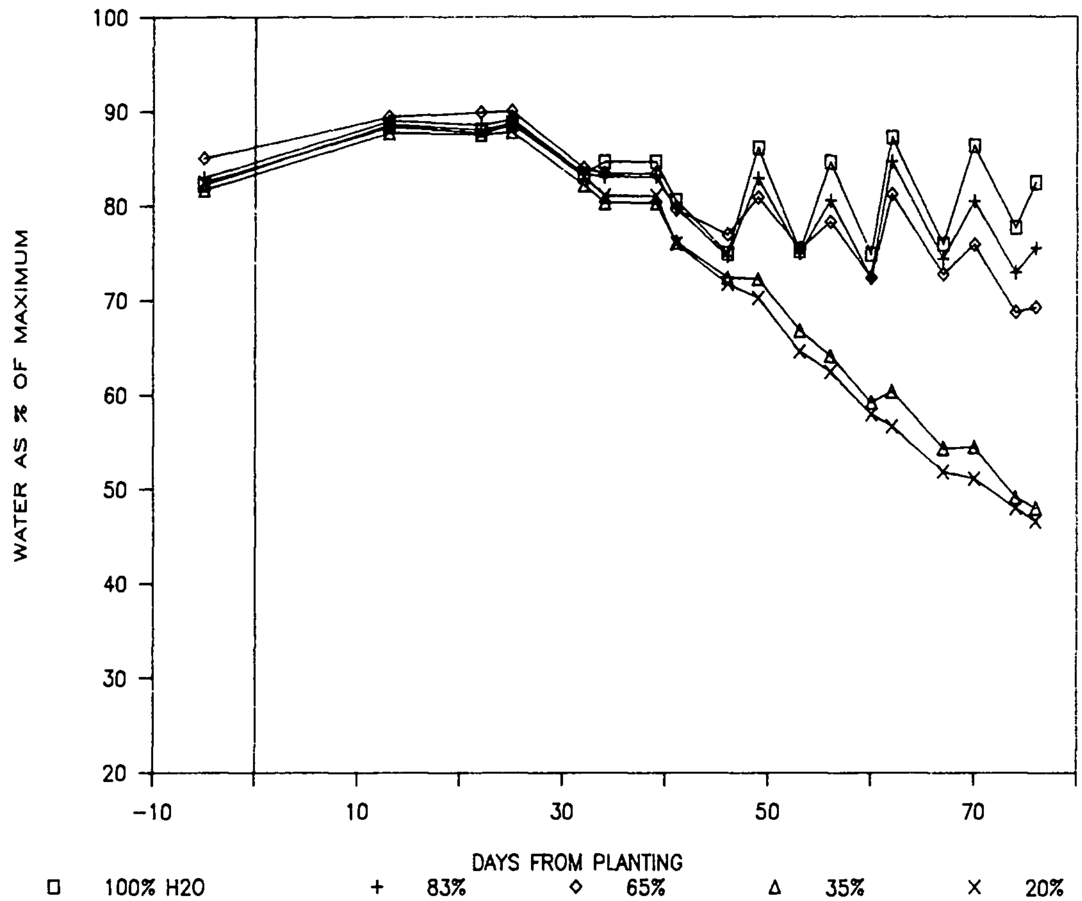

Figure 3.8. The effect of water applied on the amount of water in the 105 cm soil profile as measured over the season by the neutron meter. Average of both interrow treatments. Water is expressed as a percent of the maximum measurement.

Table 3.6. Mean soil temperature at 10 cm depth on 20 August at the 65% water level.

Treatment	Soil Temperature ^{o}C
Low density cabbage	18.89 bc
Chemically suppressed grass	17.94 a
Unsuppressed grass	18.22 ab
Mowed grass	18.70 bc
Double density cabbage	18.99 c

Numbers followed by the same letter are not significantly different from each other at p = .05.

BIBLIOGRAPHY

1. Adams, W. E., J. E. Pallas, Jr. and R. N. Dawson. 1970. Tillage methods for corn-sod systems in the Southern Piedmont. Agron. J. 62:646-649.

2. Agnew, M. L. and R. N. Carrow. 1985. Soil compaction and moisture stress preconditioning in Kentucky bluegrass. I. Soil aeration, water use, and root responses. Agron J. 77:872-878.

3. Beard, J. B. 1973. Turfgrass: Science and Culture. Prentice-Hall, Inc. Englewood Cliffs, N.J.

4. Bennett, O. L. and B. D. Doss. 1960. Effect of soil moisture level on root distribution of cool-season forage species. Agron. J. 52:204-207.

5. Biran, I., B. Bravdo, I. Bushkin-Harav and E. Rawitz. 1981. Water consumption and growth rate of 11 turfgrasses as affected by mowing height, irrigation frequency and soil moisture. Agron J. 73:85-90.

6. Box, J. E., Jr., S. R. Wilkinson, B. N. Dawson and J. Kozachyn. 1980. Soil water effects on no-till corn production in strip and completely killed mulches. Agron. J. 72:797-802.

7. Butler, J. D. 1986. Grass interplanting in horticulture cropping systems. HortScience 21(3) 394-397.

8. Carreker, J. R., J. E. Box, Jr., R. N. Dawson, E. R. Beatty and H. D. Morris. 1972. No-till corn in fescuegrass. Agron. J. 64:500-503.

9. Cook, T. 1982. The potential of turfgrasses as living mulches in cropping systems. p. 23-25. In: Proc. Crop Prod. Using Cover Crops and Sods as Living Mulches. Oregon State University, Corvallis.

10. Cooper, A. S. 1985. Sweet corn (Zea mays) production in a white clover (Trifolium repens) living mulch: the establishment year. M. S. Thesis. Oregon State University. Corvallis, Oregon.

11. Drew, D. H. 1966. Irrigation studies on summer cabbage. J. Hort. Sci. 41:103-114.

12. Goodman, D. and D. J. Greenwood. 1976. Distribution of roots, water and nutrients beneath cabbage grown in the field. J. Sci. Fd. Agric. 27:28-36.

13. Harper, L. A., S. R. Wilkinson and J. E. Box, Jr. 1980. Row-plant spacing and broiler litter effects on intercropping corn in tall fescue. Agron. J. 72:5-10.

14. Hughes, B. J. and R. D. Sweet. 1979. Living mulch: a preliminary report on grassy cover crops interplanted with vegetables. Proc. NE Weed Sci Soc. 33:109.

15. Janes, B. E. and W. O. Drinkwater. 1959. Irrigation studies on vegetables in Connecticut. Storrs Ag. Exp. Sta. Bull. 338.

16. Knavel, D. E. and J. W. Herron. 1981. Influence of tillage system, plant spacing, and nitrogen on head weight, yield, and nutrient concentration of spring cabbage. J. Am. Soc. Hort. Sci. 106(5):540-545.

17. Knavel, D. E. and J. W. Herron. 1985. Effect of sudan grass on yield and elemental content of cabbage. HortScience 20(4):680-681.

18. Knavel, D. E. and J. W. Herron. 1986. Response of vegetable crops to nitrogen rates in tillage systems with and without vetch and ryegrass. J. Am. Soc. Hort. Sci. 111(4):502-7.

19. Kneebone, W. R. and I. L. Pepper. 1982. Consumptive water use by sub-irrigated turfgrasses, under desert conditions. Agron. J. 74:419-423.

20. Loy, S. J. W. 1984. Competition of bush winter squash and bell pepper with permanent cover crops in strip tillage cultural systems. M. S. Thesis. University of New Hampshire.

21. Madison, J. H. and R. M. Hagan. 1962. Extraction of soil moisture by Merion bluegrass turf, as affected by irrigation frequency, mowing height, and other cultural operations. Agron. J. 54:157-60.

22. Mantell, A. 1966. Effect of irrigation frequency and nitrogen fertilization on growth and water use of a kikuyugrass lawn (<u>Pennisetum</u> <u>clandestinum</u> Hochst.) Agron. J. 58:559-61.

23. Mathias, E. L., O. L. Bennett, G. A. Jung and P. E. Lundberg. 1971. Effect of two growth regulating chemicals on yield and water use of three perennial grasses. Agron. J. 63:480-483.

24. Nettles, V. F., F. S. Jamison, B. E. James. 1952. Irrigation and other cultural studies with cabbage, sweet corn, snap beans, onions, tomatoes and cucumbers. Fla. Ag. Exp. Sta. Bull. 495.

25. Nicholson, A. G. and H. C. Wien. 1983. Screening of turfgrasses and clovers for use as living mulches in sweet corn and cabbage. J. Am. Soc. Hort. Sci. 108(6):1071-6.

26. North, C. 1957. Studies in morphogenesis of Brassica oleracea L. I. Growth and development of cabbage during the vegetative phase. J. Exp. Bot. 8(23):304-12.

27. O'Neil, K. J. and R. N. Carrow. 1983. Perennial ryegrass growth, water use, and soil aeration status under soil compaction. Agron J. 75:177-180.

28. Portas, C. A. M. 1973. Development of root systems during the growth of some vegetable crops. Plant and Soil. 39:507-518.

29. Peck, N. H. 1981. Cabbage plant responses to nitrogen fertilization. Agron. J. 73:679-684.

30. Peterman, M. K. 1985. Sweet corn (Zea mays) production in a white clover (Trifolium repens) living mulch: the second year. M. S. Thesis. Oregon State University. Corvallis, Oregon.

31. Ryan, J., M. F. Ryan and F. McNaeidhe. 1980. The effect of interrow plant cover on populations of the cabbage root fly, Delia brassicae (Wiedemann). J. Applied Ecol. 17:31-40.

32. Salter, P. J. and J. E. Goode. 1967. Crop responses to water at different stages of growth. Commonw. Bur. Hort. and Plant. Crops. East Malling Res. Rev. No. 2. p. 87-89.

33. Shearman, R. C. Undated. Water usage by the turfgrass plant. Univ. of Nebraska, Lincoln.

34. Shearman, R. C. and J. B. Beard. 1973. Environmental and cultural preconditioning effects on the water use rate of Agrostis palustris Huds., cultivar Penncross. Crop Science 13:424-7.

35. Singh, R. and R. B. Alderfer. 1966. Effects of soil-moisture stress at different periods of growth of some vegetable crops. Soil Sci. 101:69-80.

36. Trimmer, M. C. and D. L. Linscott. 1985. Herbicide effects on water use by grass sod and red clover (Trifolium pratense) establishment. Weed Science. 34:48-51.

37. Vittum, M. T. and N. H. Peck. 1957. Response of cabbage to irrigation, fertility level and spacing. Bull. NYS Ag. Exp. Sta., Geneva. No. 777.

38. Vomocil, J. A. 1986. The effect of cover crops on availability of water to grape vines in the Willamette Valley in 1985. Wine Advisory Board Research Report.

39. Wiles, L. J. 1986. Managing growth and competition of a perennial ryegrass (Lolium perenne) living mulch in a vegetable cropping system. M. S. Thesis. Oregon State University. Corvallis, Oregon.

40. William, R. D. 1981. Complementary interactions between weeds, weed control practices, and pests in horticultural cropping systems. HortScience 16(4):508-13.

41. William, R. D. and L. K. Brenner. 1985. Living mulch suppression using postemergence grass herbicides. Abstr. Weed Sci. Soc. Am. p. 32.

42. Zimdahl, R. L. 1980. Weed Crop Competition: A Review. Int. Plant Protection Center. Corvallis, Oregon.