UNIVERSITY OF SASKATCHEWAN

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Date
A PRELIMINARY
IRRIGATION STUDY WITH VEGETABLES
IN SASKATCHEWAN

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfilment of the Requirements
for the degree of
Master of Science
in the Department of Horticulture
University of Saskatchewan

by
Charles Oliver Green
Saskatoon, Saskatchewan
October, 1963.

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ACKNOWLEDGMENTS

The financial assistance, without which this thesis would not have been possible, was provided by the Saskatchewan Research Council and is gratefully acknowledged.

The writer also wishes to express his sincere appreciation and thanks to Mr. D. H. Dabbs, Assistant Professor, Department of Horticulture, University of Saskatchewan, Saskatoon under whose very helpful and encouraging guidance the experiments in the field were conducted and the writing and completion of this thesis was made possible.

Sincere appreciation and thanks is also extended to Dr. S. H. Nelson, Head, Department of Horticulture, University of Saskatchewan, Saskatoon for his encouragement and very capable assistance especially during the preparation of this manuscript.

Sincere thanks is also extended to Dr. D. M. Gray of the Department of Agricultural Engineering, University of Saskatchewan, the third member of the examining board, for his services in this capacity.

The helpful assistance of Mr. L. G. Sonmor of the Canada Agriculture Research Station, Saskatoon in providing equipment and guidance during the course of the experiment
and in making available many research articles and other
bulletins from his personal library is gratefully acknowledged.
Thanks is also extended to the other members of his staff for
the assistance they provided in the field.

Sincere thanks is extended to the staff of the Depart­
ment of Agricultural Engineering, University of Saskatchewan
for the facilities and assistance they provided.

The photographs used in this thesis were obtained
through the courtesy of the Canada Department of Agriculture
and are gratefully acknowledged.

The encouragement and assistance provided by the
staff of the Department of Horticulture, University of
Saskatchewan, particularly in the field and in gathering the
data, is also appreciated very much and is gratefully
acknowledged.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>3</td>
</tr>
<tr>
<td>Advantages of Irrigation:</td>
<td>3</td>
</tr>
<tr>
<td>Soil</td>
<td>4</td>
</tr>
<tr>
<td>The Water Supply</td>
<td>5</td>
</tr>
<tr>
<td>Methods of Irrigation:</td>
<td>6</td>
</tr>
<tr>
<td>Determining Time and Frequency of Irrigation:</td>
<td>15</td>
</tr>
<tr>
<td>Relation of Stage of Development to Irrigation:</td>
<td>22</td>
</tr>
<tr>
<td>Extraction of Soil Moisture:</td>
<td>26</td>
</tr>
<tr>
<td>Effect of Irrigation on Growth and Development:</td>
<td>29</td>
</tr>
<tr>
<td>Effect of Irrigation on Yield:</td>
<td>36</td>
</tr>
<tr>
<td>Effect of Irrigation on Quality:</td>
<td>40</td>
</tr>
<tr>
<td>Effect of Irrigation on Storage of Vegetables:</td>
<td>45</td>
</tr>
<tr>
<td>Irrigation, Disease and Insects:</td>
<td>45</td>
</tr>
<tr>
<td>Interaction of Soil Moisture, Fertilizer and Plant Population:</td>
<td>49</td>
</tr>
<tr>
<td>MATERIALS AND METHOD</td>
<td>52</td>
</tr>
<tr>
<td>South Plot:</td>
<td>52</td>
</tr>
<tr>
<td>North Plot:</td>
<td>56</td>
</tr>
</tbody>
</table>
## EXPERIMENTAL RESULTS AND DISCUSSION 61

### Effect of Irrigation on:

- **South Plot:** 61
- **Beans:** 64
- **Corn:** 68
- **Peas:** 74
- **Potatoes:** 80
- **North Plot:** 92
- **Cabbage:** 95
- **Carrots:** 97
- **Celery:** 101
- **Lettuce:** 108
- **Onions:** 111
- **Rutabagas:** 114

### SUMMARY AND CONCLUSIONS 123

### LIST OF REFERENCES 125

### APPENDIX 134
LIST OF TABLES

TABLE 1: South Plot - Crop, Date of Planting, Eventual Spacing, Fertilizer Treatment and Rate of Application. 55

TABLE 2: North Plot: Crop, Date of Planting, Date of Pricking Out, Date of Transplanting and Eventual Spacing. 59

TABLE 3: Monthly Precipitation from May to October, 1962, and the 60-Year Average for these Months at Saskatoon. 62

TABLE 4: Time and Amount of Irrigation Water and Rainfall Received by the Respective Crops in the South Plot. 63

TABLE 5: Yield Data for Beans Grown at Three Moisture Levels. 65

TABLE 6: Yield and Measurements of Corn Produce Grown at Three Levels of Moisture. 72

TABLE 7: Yield and Related Data for Peas Grown at Three Moisture Levels. 78

TABLE 8: Yield, Number and Diameter of Potato Tubers Produced by Three Moisture Levels. 87

TABLE 9: Time and Amount of Irrigation Water and Rainfall Received by the North Plot. 94
TABLE 10: Yield and Diameter of Cabbage Heads Produced at Three Moisture Levels.

TABLE 11: Yield and Related Data of Carrots Grown at Three Moisture Levels.

TABLE 12: Yields and Pertinent Measurements of Celery Grown at Three Moisture Levels - Actual Data per Sub-Plot.


TABLE 14: Yields and Pertinent Measurements of Celery Grown at Three Moisture Levels - Only Replicates 2 and 3.

TABLE 15: Yield, Average Diameter and Number of Marketable and Unmarketable Heads of Lettuce Produce Grown at Three Moisture Levels.

TABLE 16: Yield and Diameter Measurements of Onions Grown at Three Levels of Soil Moisture.

TABLE 17: Yields and Diameters of Rutabagas Produced at Three Moisture Levels - Actual Data Per Sub-Plot.

TABLE 18: Yields and Diameters of Rutabagas Produced at Three Moisture Levels - Corrected Data.

TABLE 19: Yields and Diameters of Rutabagas Produced at Three Moisture Levels - Only Replicates 2 and 3.
<table>
<thead>
<tr>
<th>FIGURE</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The South Plot.</td>
<td>54</td>
</tr>
<tr>
<td>2</td>
<td>The North Plot.</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>Bean Produce; Treatments are, Left to Right, Wo, W₁, W₂. (July 31)</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>Corn - Wo Treatment. Note Height, Ground Cover and Leaf Curl. (August 20)</td>
<td>69</td>
</tr>
<tr>
<td>5</td>
<td>Corn - W₁ Treatment. Note Height, Ground Cover and Absence of Leaf Curl. (August 20)</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>Corn - W₂ Treatment. Note Height, Ground Cover and Absence of Leaf Curl. (August 20)</td>
<td>70</td>
</tr>
<tr>
<td>7</td>
<td>Peas - Wo Treatment. Note Height and Lack of Foliage Compared to the other Two Treatments. (August 2)</td>
<td>75</td>
</tr>
<tr>
<td>8</td>
<td>Peas - W₁ Treatment. Note Height, Abundant Foliage and Good Ground Cover. (August 2)</td>
<td>75</td>
</tr>
<tr>
<td>9</td>
<td>Peas W₂ Treatment. Note Height, Abundant Foliage and Good Ground Cover. (August 2)</td>
<td>76</td>
</tr>
</tbody>
</table>
FIGURE 10: Potatoes - Wo Treatment. Note Height, Wilting and Lack of Foliage. (August 20)

FIGURE 11: Potatoes - W1 Treatment. Note Height, Complete Ground Cover and Absence of Wilting. (August 20)

FIGURE 12: Potatoes - W2 Treatment. Note Height, Complete Ground Cover and Absence of Wilting. (August 20)

FIGURE 13: Potatoes - Wo Treatment at Harvest. Note Maturity of Plants. (September 13)

FIGURE 14: Potatoes - W1 Treatment at Harvest. Note Senescing of Plants. (September 13)

FIGURE 15: Potatoes - W2 Treatment at Harvest. Note Healthy Appearance of Plants. (September 13)

FIGURE 16: Cabbage Produce; Treatments are Left to Right, Wo, W1 and W2. (August 9)

FIGURE 17: Rutabagas - Wo Treatment at Harvest. Note Size and Yield. (September 6)

FIGURE 18: Rutabagas - W1 Treatment at Harvest. Note Size and Yield. (September 6)

FIGURE 19: Rutabagas - W2 Treatment at Harvest. Note Size and Yield. (September 6)
INTRODUCTION

On July 25, 1958, the construction of the South Saskatchewan River Dam was authorized by the governments of Canada and Saskatchewan at an estimated cost of 96 million dollars. The dam will rise 210 feet above the bed of the river and, together with a dam in the Qu'Appelle Valley, will create a reservoir 140 miles long with about 475 miles of shoreline. The reservoir will impound 8,000,000 acre feet of water over an approximate area of 109,600 acres. The objectives of this dam and reservoir are to permit full use of the river water for power development, rural and urban water supply, recreation, flood control and irrigation.

The proposed irrigation system may ultimately provide for the irrigation of some 500,000 acres of land at an estimated cost of 50 million dollars to the provincial government. The area to be irrigated will include both sides of the South Saskatchewan River between Elbow and Saskatoon, and the Qu'Appelle Valley extending east of Elbow, to the Manitoba border.

Grain, hay and pasture crops are expected to be the main crops of the irrigation project during its initial stages. Specialty crops, however, such as potatoes, peas, corn, and
other fresh vegetables as well as canning crops and sugar beets may eventually be grown under irrigation.

To date, there has been very little research on the irrigation of vegetable crops in Saskatchewan. Consequently, much information is required on all aspects of irrigation, if vegetables are to be grown economically in Saskatchewan. It was for this purpose that the present study with ten vegetable crops was undertaken in the Department of Horticulture at the University of Saskatchewan, Saskatoon. This investigation was designed to determine whether irrigation, and which level of irrigation, would significantly increase the yield and quality of the particular vegetables involved. It must be remembered, however, that the results reported herein are preliminary, based only on one year's data.
Advantages of Irrigation:

Erwin and Haber (17) suggested that the advantages of irrigation were as follows:

(a) To carry the crop through periods of drought which may otherwise wipe out or materially reduce yields.

(b) To make possible, through moisture control, the production of larger yields.

(c) To insure continuous growth of vegetables which is necessary for high quality.

(d) To obtain a good start for vegetables transplanted into dry soil.

(e) To obtain prompt and uniform germination of seed at sowing time.

(f) To prepare the ground which, without irrigation, would be too dry to work properly.

(g) To protect certain crops from light frost injury by the use of sprinkler irrigation.

In Saskatchewan, Murray and Stewart (52) stated that drought was the limiting factor in the production of cereal and forage crops in most of the southern prairie region of western Canada. The average annual precipitation available
to plant growth in south-central Saskatchewan ranged from ten
to twelve inches, and assuming suitable soil, land preparation,
correct irrigation and efficient management, they suggested
that the economic advantages of irrigation could be shown.

Soil:

According to Olson and Kapusta (54), soils classed as
irrigable were lighter-textured and better drained than non-
irrigable soils. They reported that these soils did not hold
water as well as heavier, non-irrigable soils and thus, crop
production on them was often limited by drought. In their
work, these lighter soils demonstrated the greatest yield
increases when irrigation water was applied to them.

Luetkemeier and Kohnke (44) suggested that supplementary
irrigation was good for light textured soils even under normal
moisture conditions since these soils had a low available
water holding capacity and good aeration. For medium textured
soils, they suggested that supplementary irrigation was good
insurance against adverse, dry periods during the growing
season, whereas on heavy soils, the value of irrigation was
found to be questionable since these soils had a high water
holding capacity as well as poor aeration. They also suggested
that factors, other than water, appeared to be responsible for
the limited production on the heavier type of soil. Other
sources of information agreed with these statements (31, 43,
52, 82).

3. The Water Supply:

There are numerous sources of water for irrigation, such as, wells, lakes, rivers, streams and dugouts (43, 52). Murray and Stewart (52), however, stated that unless wells and dugouts yielded large quantities of water, their use for irrigation purposes would not be feasible, except for small garden areas or lawns.

The water supply must be not only adequate but also relatively free from alkali salts (hardness) so as not to render the soil unproductive as a result of increased alkalinity (43). Murray and Stewart (52) stated that normal river water on the prairies contained 300 parts per million of dissolved salts whereas water from lakes, dugouts, streams and wells contained over 1,000 parts per million. Furthermore, they emphasized that water containing under 700 parts per million of dissolved salts was considered safe for irrigation purposes but a slightly higher concentration was tolerable on light, well-drained soils.

Wilcox (100), expressing mineral salt content in terms of electrical conductivity (expressed as mhos x 10^5), stated that a conductivity of 75 or less was safe for irrigation water whereas a value between 75 and 100 was only suitable for sandy soils. Water, with a value over 100 was considered by
him to be unsafe for any soil. In the same article, he stated that irrigation water with a pH value over 8.5 should not be used for irrigation purposes.

Barnes and Peele (3) found that snap beans (*Phaseolus vulgaris* L.) were very sensitive to sodium chloride concentrations in the irrigation water but concentrations of 500 parts per million were found to be safe. They also found that the yield, specific gravity and chipping quality of Sebago potatoes (*Solanum tuberosum* L.) were not affected by concentrations of 2000 parts per million of this salt. In the same experiment, tomatoes (*Lycopersicum esculentum* Mill.) and sweet corn (*Zea mays* L.) were not injured by 1,500 to 2,000 parts per million of sodium chloride nor did water with 1,500 parts per million affect the germination or growth of beet (*Beta vulgaris* L.), cabbage (*Brassica oleracea*, var. *capitata* L.), lettuce (*Lactuca sativa* L.), onion (*Allium cepa* L.) or turnip (*Brassica rapa* L.).

Wharton and McGeorge (95) reported that soluble salts became concentrated in the upper layer of soil on raised beds of lettuce and other vegetables grown under furrow irrigation. These soluble salts, according to them, were mainly chlorides, nitrates, and to a lesser extent sulfates.

Ayers et al. (1) reported that a salt concentration giving a conductance of 4.4 millimhos caused a potato yield reduction of 33 per cent whereas a conductance of 6 millimhos resulted in a 50 per cent reduction in yield. There was no
significant difference, however, in the salt tolerance of the six varieties tested by them. These workers also found that lettuce had a moderate salt tolerance. They concluded that the growth responses attributable to salinity was due primarily to physiological scarcity of water rather than to any derangement in mineral nutrition. Wadleigh et al. (90) supported these findings, stating that, as the moisture content of a saline soil decreased, the concentration of the soil solution increased causing plant growth to be inhibited. They found this inhibition was caused by higher osmotic pressures rather than ion toxicity until, at an osmotic pressure of 15 atmospheres, plants wilted. According to them the retention of water at this tension occurred as a result of the osmotic pressure of the solution as well as "capillary" forces of soil particles.

According to Israelson (31) lettuce, carrots (Daucus carota L.) and onions had moderate salt tolerance but peas (Pisum sativum L.), celery (Apium graveolens L.), cabbage, potatoes and green beans had low salt tolerance.

Methods of Irrigation:

Irrigation has been applied by the four general methods listed below (31, 82):

1. Flooding.
2. Sub-irrigation.
4. Furrows.

To this list, Murray and Stewart (52) added corrugations which were merely small, shallow furrows placed close together. Flooding was the method by which all of the land surface was submerged in water (31, 82). According to these authors, borders, basins, contour ditches and checks have been most frequently used for this purpose. This system has been best suited to the irrigation of forage, pasture and feed grain crops (52), although basin irrigation has been used in orchards to some extent (31, 82).

Sub-irrigation was a method designed to supply water to plants from below the soil surface by controlling the elevation of the water table so as to continually supply capillary moisture to the root zone (82). Although this method required suitable soils which were of limited extent, where it could be used, it has been adapted to many crops (82). Parks (56) suggested that sub-irrigation on muckland soils was less wasteful and a more effective method of irrigation than any other method. According to Israelson (31), soils for sub-irrigation had to permit free lateral movement of water in the soil, rapid capillary movement in the root zone and very slow downward movement in the subsoil.

Sprinkler irrigation was a method designed to supply water to vegetative growth similar to rain (28, 31, 82). Wilcox (99) suggested that sprinkler irrigation had the
following advantages and disadvantages:

Advantages.

1. Caused less soil erosion.
2. Could be used on sloping soil with no leveling required.
3. Soil could be kept properly wetted more easily.
4. Frequently increased yields and some times quality.
5. Required less water, especially on sandy soils.
6. With proper management there was less trouble from run-off and deep percolation.
7. Required less labour if orchards and small vegetables were being irrigated.
8. Resulted in a better germination of vegetable seed.
9. Could be used to apply soluble fertilizers.

Disadvantages.

1. Initial costs were high.
2. Water had to be under pressure which increased fuel costs.
3. Water had to be clean so as not to plug the nozzles.
4. The spray was easily disturbed by wind.
5. Sprinkler irrigation was not adapted to a variable flow of water.
6. Wetting of the leaves has been shown to increase injury as well as the incidence and spread of disease in some cases.

7. The operator was more likely to have muddy feet.

Wilcox (99) reported further that if pressure for sprinkler irrigation could be obtained from gravity, as occurred in some parts of British Columbia, then the cost of sprinkler irrigation was likely to be lower than for surface irrigation.

The estimated initial cost of sprinkler irrigation as suggested by Murray and Stewart (52) ranged from 50 to 70 dollars per acre and the cost of operation, labour, interest on investment and depreciation was at least two dollars per acre-inch of water applied. They also reported that winds above 15 miles per hour rendered sprinkler irrigation impractical.

Parks (56) added that sprinkler irrigation permitted more accurate control of water and allowed a lighter application to be given than by furrow irrigation, but found that sprinkler irrigation could also impede the aeration of heavy soils.

Certainly, where uneven topography and sandy soils were prevalent, sprinkler irrigation was best (28, 31, 51, 52, 82).

Furrow irrigation, which wets only part of the ground surface, has been shown to be best suited to fruits and vegetables when grown as row crops (82). Israelson (31)
suggested that only one-half to one-fifth of the soil surface was wetted by this method. This reduced evaporation losses and lessened the puddling of heavy soils (31, 82).

On relatively flat slopes, furrows were usually run down the slope but on steeper slopes the furrows were run across the slope or along the contour (52, 82). On very steep slopes, however, furrow irrigation was inadvisable since the banks of the furrow may overflow causing a complete loss of water control (31). Parks (56) suggested that a grade of one to two inches per one hundred feet (0.08 - 0.17%) was ideal for furrow irrigation of potatoes. Israelson (31) suggested that slopes of 10 to 30 feet per 1000 (1.0 - 3.0%) were preferable but on some soils, slopes of 100 to 150 feet per 1000 (10.0 - 15.0%) could be irrigated successfully if only a small flow was used to avoid erosion.

Furrows measuring 300 to 350 feet in length were most common according to Israelson (31), although they varied from less than 100 feet for gardens up to one-quarter mile for field crops depending on the soil. He reported that excessive, deep percolation and soil erosion occurred near the upper end of the furrow if the furrows were too long. Hill and Palmer (28), in Alberta, stated that the usual length of a furrow was 300 to 600 feet. They also suggested that an irrigation flow of two cubic feet per second usually supplied 40 to 50 furrows in a sugar beet field on a medium textured
soil with a moderate slope.

The spacing of the furrows was ordinarily determined by the spacing of the row crop (31, 82). One reference (83), however, stated that the furrows should be no farther apart than twice the depth of the principal plant roots, i.e., the furrows should be closer together for shallow-rooted crops than for deeper rooted crops.

Israelson (31) suggested that furrows eight to twelve inches deep would facilitate the control of water and the penetration into soils of low permeability for orchards and some furrow crops, whereas three-to five-inch furrows were best suited to root crops, such as, sugar beets under similar conditions. He also suggested that it was desirable to have the furrows deep enough and the level of water low enough so that water could not come in contact with the plant.

Although water may be brought to the area by wood or concrete flumes as well as concrete pipe under ground, the most common method of distributing it to the furrows has been the earth supply ditch (31, 43). According to the same authors, water was usually diverted into the furrows either by making small openings in the bank of the supply ditch, by miniature culverts, by siphons or by gated pipe. They also reported that the use of gated pipe has increased substantially in recent years since it allowed more uniformity of application by overcoming the problems of regulating the total volume of
water applied and adjusting the water level in the ditch. This was done by adjusting the small, sliding gates in the pipe (31, 43). Israelson (31) suggested that rates of flow from one gallon per minute up to ten gallons per minute or more could be delivered by gated pipe. In addition, he stated the aluminum pipe, being relatively light, facilitated easy handling.

Israelson (31) also suggested that the entire furrow should be wetted quickly and then the flow reduced so that just enough water entered the furrow to keep it wet until irrigation was complete. Korven and Blakely (43) suggested that the flow should be slow enough to allow sufficient time for the water to soak into the soil. They also suggested that a stream was flowing too fast if there were ripples in the water and dry soil between the furrows. They, however, made no mention of wetting the furrow quickly at the beginning.

Korven and Blakely also (43) stated that garden vegetables would not stand more than a few hours of ponded water. Murray and Stewart (52) reported that excess water resulted in waterlogged soils and salt accumulation which could restrict or even kill plant growth. Consequently, they suggested that these flooded areas should be drained by temporary ditches. Murray and Stewart (52) continued by stating that this flooding problem could be overcome by proper land leveling, by better water control, by reducing the grade and by better drainage.
There have been a number of reports comparing sprinkler irrigation to furrow irrigation of vegetable crops (5, 7, 23, 38, 41, 73, 83, 99, 100, 101). As a result of favourable conditions for sprinkler irrigation in British Columbia, Wilcox (100, 99) estimated that 50 per cent of the fruit and vegetable land in the southern interior was being irrigated by sprinklers in 1952. In a later publication, Wilcox and Ferries (101) found that, for adequate irrigation, sprinkler systems cost more per acre than furrow systems but that the annual costs of irrigating, including interest and depreciation, was less for sprinkler systems, without pumps, than for furrow systems. Blake et al. (7) also reported that the cost per inch of water was greater with sprinklers than with furrow irrigation.

It was shown that furrow irrigation of peas was superior to sprinkler irrigation since sprinkling caused the pea vines to lie down and become moldy (83). Haddock and Linton (23), however, obtained satisfactory yields of canning peas with both furrow and sprinkler irrigation.

In 1954, Beljak (5) reported that sprinkler irrigation was more effective than furrow irrigation of cabbage. Somas (74), however, reported that flooding was better than sprinklers for winter cabbage.

Studies with potatoes in Utah (83) have shown that furrow irrigation required 30 to 50 per cent more water than sprinkler irrigation when the soil was maintained in a moist
condition. In addition, the yields of Russet Burbank potatoes were 20 per cent higher under sprinkler irrigation than under furrow irrigation in the same experiment. Jannaccone (38) found that sprinkler irrigation matured potatoes earlier than furrow irrigation. Kar (41) also found that sprinkler irrigation was superior to furrow irrigation of potatoes.

In British Columbia, Wilcox (99) recommended the use of surface irrigation for beans grown for seed and for potatoes in humid areas since sprinkler irrigation could cause a greater spread of disease. Where there was evidence of soil erosion, however, he recommended sprinkler irrigation, except for these two crops.

Haddock (22), working with potatoes, found that furrow irrigation required more water than sprinkler irrigation but that there were no significant differences in yield between the two treatments nor were there any differences in quality. Corey and Myers (13) reported similar results. They stated that yields and grades of potatoes depended on a continuous water supply and it did not matter if the water was supplied by furrow or sprinkler irrigation.

Determining Time and Frequency of Irrigation:

Israelson (31) stated that the available water for plant growth was the moisture content of a soil at field capacity less the moisture content at permanent wilting. An
extensive review of the literature substantiated Kattan and Fleming's (42) statement that the relative availability of this soil moisture at various levels between field capacity and permanent wilting was still in dispute. On one side were Hendrickson and Veihmeyer (27), MacGillivray and Doneen (47), and Veihmeyer and Hendrickson (34, 35) who reported that all moisture between field capacity and permanent wilting point was equally and readily available for plant use and that as long as any of this moisture was available there was no check in plant growth. On the other side were Ayers et al. (2), Bradley and Pratt (8), Fulton and Murwin (20), Howe and Rhoades (29), Jacob et al. (32), Majmudar and Hudson (48), Stanhill (75), Wadleigh et al. (90), and Woodhams and Kozlowski (102) who have all indicated that soil moisture was not equally available for plant growth over the entire range from field capacity to wilting point.

According to Israelson (31), readily available water must be stored in the soil since all growing plants required water continuously. He stated further that the capacity of a soil to store available water influenced the amount of water to apply and the interval between each irrigation. According to him, if more water was applied in each irrigation than could be retained by the soil the excess would be wasted. Conversely, he reasoned if less water was applied than the soil would hold, the plants might wilt before the next
irrigation. Consequently, Israelson (31) concluded that, for maximum irrigation efficiency, water had to be applied when needed and in sufficient amount to fill the soil reservoir to field capacity, while at the same time, not using more water than was required.

Thus, according to Robertson and Hames (62), to avoid over-irrigation, it was necessary to determine the amount of water held in a soil at field capacity. Field capacity has been defined by them as the water held in the small spaces between soil particles after excess water was drained away from the larger pore spaces. A method for determining field capacity has been described by Israelson (31). He suggested that soil moisture determinations should not be made until two to five days after an irrigation since it takes this long for a soil to reach field capacity after an adequate irrigation.

Ingram (30) stated that maximum yields would be obtained by keeping the soil near field capacity while the plant root system was developing its maximum volume early in the growing season. Taylor (79) reported that crop growth was best if soil moisture tension was kept low, i.e., if the soil was kept moist. Similar recommendations were made by Bean (4) who added that, if a soil was irrigated to a point beyond field capacity, there was a tendency for flooding to occur and the soil to become water-logged. This, according to Bean (4), caused the plants to die from lack of air and also caused
other bacterial and chemical processes to cease.

At the other end of the soil moisture range, the water content of the soil should not be allowed to drop to the wilting point (52). Robertson and Holmes (62) defined the permanent wilting point as the minimum amount of soil moisture which was available to plant growth.

Bean (4) stated that, at the permanent wilting stage, not only did the plant wilt, but the existence of useful bacteria also became precarious. These conditions were reported by him to check continuous growth and permanently affect the health of the plant. He advised that water should be applied before this wilting stage was reached. Others (4, 52) gave the same recommendation.

Since soil moisture must be kept between field capacity and the permanent wilting point either by rainfall or supplemental irrigation, there have been several methods of determining time of application and quantity of irrigation water needed to keep soil moisture within these limits (19).

Heeney and Rutherford (26) have suggested three methods of scheduling irrigation:

1. Irrigation according to schedule.
2. Irrigation according to soil moisture content.
3. Irrigation according to meteorological data.

The methods listed by Fulton (19) generally agreed with these.

Irrigation according to schedule was based on the
calendar (19, 26). For example, Fulton (19) recommended one inch of water every seven days for early potatoes on sandy loam soils. He based this schedule on the average daily use of water and the average interval between irrigations for optimum production. He admitted, however, that the use of irrigation schedules resulted in applying more water than the exact requirement during cool weather and less during hot weather. Murray and Stewart (52) reported that most Saskatchewan soils could store three to four inches of water which would be used by a crop of alfalfa at the rate of one-quarter inch per day under hot dry conditions and necessitated irrigation every two weeks or less.

Irrigation based on soil moisture content, according to Heeney and Rutherford (26), was the simplest and easiest to understand. The Bouyoucous available moisture meter with its companion gypsum block was the instrument most widely used in research to determine soil moisture content (19).

Fulton (19) described the tensiometer as another instrument used effectively in coarse sandy loam soils to determine soil moisture. This instrument, however, only gave an accurate reading in sandy loam soils, if the available soil moisture was over 75 per cent of the total and according to him, this seriously limited its use.

Soil moisture could also be determined from soil samples as described by Israelson (31). This was the most common
method of determining soil moisture and was the basic technique against which the moisture values determined by instrumental methods were compared (50).

Another method of determining soil moisture was by measuring the scattering of neutrons in the soil (50). By this method a group of high energy neutrons were emitted into a soil mass where hydrogen atoms of the water molecule caused the neutrons to lose their energy and the number of low energy neutrons returning to the counter was a measure of the soil moisture content.

Murray and Stewart (52) have given a table in their bulletin for determining the approximate water content of the soil by feel and appearance of the soil.

Several authors (26, 62, 82) have suggested that it was time to irrigate when about one-half of the total available moisture in the root zone had been used.

Irrigation according to meteorological data required the acceptance of certain fundamental concepts (62). This method assumed that the soil merely acted as a reservoir for moisture and that the only source of water for this reservoir was from either rain or irrigation whereas water could only be removed by evaporation and transpiration (50, 62). According to these authors, a soil moisture balance sheet could be set up which would record the day to day changes in soil moisture and when the soil moisture was depleted to a pre-
determined level, irrigation water could be added.

Rainfall and irrigation could easily be measured, but evapotranspiration was much more difficult, although several systems have been developed for estimating it (62). According to Robertson and Holmes (62), Thornwaite had developed the concept of potential evapotranspiration which postulated that the combined total daily rate of evaporation and transpiration from a given land area was independent of the crop and was determined solely by certain meteorological factors, provided that the crop was growing, completely covered the ground and had an adequate moisture supply. Heeney and Rutherford (26) reported, however, that Thornwaite's method of determining potential evapotranspiration was unreliable since it did not consider air movement and to this Robertson and Holmes (62) added sunshine and vapor pressure.

According to Robertson and Holmes (62), Penman had also developed an equation for determining potential evapotranspiration but they reported that his method, even though it was effective, was very cumbersome.

These same authors (62) listed several instruments designed to determine evapotranspiration, which include the four-foot diameter open water tank, Piché atmometer, the Livingstone porous spherical bulb atmometer, the Wright and the Summerland evaporation pans and the black Bellani plate atmometer (62). These authors felt that these instruments
had limited use, however, since they measured only the drying ability of the air rather than potential evapotranspiration. The black Bellani plate, however, has proven to be a useful instrument for measuring the drying ability of the air or, preferably, latent evaporation (62). The black Bellani plate as described by Heeney and Rutherford (26) as well as Rutherford and Holmes (62) was a flat, black, porous plate which was kept moist and fully exposed to sunshine and wind. The water evaporating from the surface of the plate was termed latent evaporation from which the potential evapotranspiration could be calculated (26, 62).

The amount and frequency of irrigation could have been a topic in itself and the treatment of the subject in this thesis was by no means complete. It is hoped, however, that the material presented here will give the reader some insight into the problem and its complexities.

Relation of Stage of Development to Irrigation:

Kattan and Fleming (42) believed that, in order to determine the true benefits of irrigation and to utilize available water resources at maximum efficiency, it was essential to investigate the various stages of plant development in regard to their magnitude of sensitivity to soil moisture. They concluded that, in order to obtain maximum yield and quality of snap beans, it was essential to maintain available
soil moisture from flowering to pod development. Allowing the soil moisture to be depleted to the wilting point stunted early plant growth but, according to them, did not reduce total yields or impair quality, providing the available soil moisture was above 50 per cent after flowering. Janes and Drinkwater (37) agreed that the greatest injury from lack of soil moisture occurred in the later stages of growth but that lack of moisture at any time would reduce the yield of beans. Rahn (61) working with lima beans (Phaseolus limensis Macf.) found that a single irrigation applied at the time of bloom did not increase yields significantly, except when a hot, dry spell coincided with this stage of development.

With dry beans Robins and Howe (65) reported that a soil moisture deficiency prior to bloom delayed plant development and also extended the interval of pod formation which delayed harvest, lowered quality and increased losses through shattering. Robins and Domingo (64) added that the number of pods were reduced by this treatment. They also reported that a soil moisture deficiency during blooming resulted in a fewer number of pods per plant, fewer beans per pod and shortened pods while a deficiency prior to harvest only reduced the average weight per bean and hastened ripening. Sistrunk et al. (72) reported that high soil moisture stress during pod development was not only detrimental to yield and size of pods but also to quality.
Janes and Drinkwater (37) reported that a prolonged condition of low soil moisture at any time during growth of a cabbage crop reduced yields but was most harmful during the latter part of the growing season.

Evans et al. (18) found that for the best yield of sweet corn, high levels of soil moisture were required throughout the growing season, especially during the stages of rapid plant growth which occurred just before tasseling was complete. They also suggested that an irrigation was highly desirable when the corn was one foot high. MacGillivray (45) stated that corn required adequate water at the time of ear setting. Cordner (12) arrived at the same conclusion.

Janes and Drinkwater (37) stated that lettuce apparently had a low water requirement. Schwalen and Wharton (70) reported that lettuce grown in soil near or above field capacity produced the heaviest heads. They also reported that soil moisture reductions early in the season greatly decreased head weight whereas the same moisture reductions late in the season did not have the same effect, if followed by an irrigation during harvest. Veihmeyer and Holland (86) suggested that irrigation need not be more frequent than once every thirty days after thinning.

An irrigation immediately after the transplanting of onions was more beneficial than delaying the irrigation until ten days later (25). Jones and Johnson (40) found that with-
holding water during the first one-third of the onion's growing period was not as detrimental as withholding water in later periods. Erwin and Haber (17) reported that moist soil was essential for growing onions during the filling out stage but dry soil was essential for curing the bulb. Continuing, they stated that irrigation after the bulbs had begun to ripen resulted in water soaked bulbs with poor keeping quality. Janes and Drinkwater (37) added that this treatment also delayed maturity and increased the number of defective onions whereas dry soil, especially during the period of rapid growth, resulted in small onions with poor keeping quality.

Results obtained by Salter (66, 67) showed that irrigation between sowing and flowering increased haulm weight but not yield of shelled peas whereas irrigation after flowering, as the pods were swelling, increased yield of marketable pods as well as yield of shelled peas. Heeney and Rutherford (26) obtained similar results.

MacGillivray (46) stated that potato plants should be kept actively growing in moist soil until tubers were nearly full size or mature. Higher potato yields were obtained when this soil moisture was kept over 50 per cent of field capacity than when allowed to go below 50 per cent (13, 19, 20, 32). Corey and Myers (13) recommended that the first irrigation should come within forty days after planting to avoid pointed-end and bottle-neck tubers. Edmundson (16) reported that
an irrigation prior to the beginning of tuber formation increased the number of tubers. Palmer (55) found that, in dry years, yields were increased by irrigating soon after the plant started to bloom and by giving two or more subsequent irrigations at intervals of three weeks.

Stanhill (76), working with turnips, found that different yield responses as a result of a three-week period of daily irrigation at different growth stages could be related to three distinct phases of growth of these plants as reported below. During the first phase, when the plants were seedlings, this wet treatment increased the weight of leaves as well as edible roots at harvest. The wet treatment applied during the second phase, when the roots began to swell, depressed yields. This was attributed to changes in nitrogen utilization within the plant. The third phase extended to harvest, during which time a wet treatment produced the greatest increase in final yield of edible roots.

Extraction of Soil Moisture:

Cordner (12) stated that the volume of soil occupied by the root system greatly affected the total amount of water available to the plant. He stated that the amount of water available also depended on soil characteristics, spacing of plants, depth of soil occupied by the roots and the amount of water lost by evaporation.
Robins and Howe (65) found that, when bean plants emerged, the roots extended three to four inches into the soil whereas at the time of bloom, the roots were well developed in the first foot with some roots beyond two feet and finally, at the time of pod ripening, the root system occupied the top three feet of soil with some extending down to the four-and five-foot level. They added that bean plants used two-thirds to three-quarters of the total water available for plant growth in the top foot of soil, but only used one-half of the total available at lower depths. The results obtained by Robins and Domingo (64) coincided with the above observations. They found that visible stress of bean plants during bloom was first evident when 10 to 20 per cent of the available moisture was left in the top foot of soil and that there was no extraction of soil moisture from the one to two foot level. Janes and Drinkwater (37) reported that the largest portion of water used by beans came from the top eight to ten inches with some extraction from the twelve-inch depth.

These workers (37, 64) also found that cabbage plants removed moisture from a depth greater than six inches, in spite of the fact, that most of the root activity was centered at that point.

Janes (36) working with celery found, five weeks after planting, that the root system was shaped like an inverted cone four inches in diameter and six inches deep with some
roots extending out twelve inches each way. By the seventh week, he found that the V-shape was lost and by the tenth week, the roots were penetrating all areas of the topsoil with a few roots down to the 30-inch depth, but the area of greatest root activity occurred at the nine- to twelve-inch level. In this experiment, there was no visual difference between topsoil and subsoil roots nor in the number of roots produced by irrigated and non-irrigated plants. He also found that moisture was removed from each successive layer of soil only after the moisture in the level above was reduced to near 50 per cent of the total moisture available.

MacGillivray (45) stated that sweet corn had a shallow root system. Vittum et al. (89) found that irrigated sweet corn extracted very little water from below a depth of sixteen inches and non-irrigated sweet corn extracted all the water it required from the top twenty-four inches of soil.

Veihmeyer and Holland (86) reported that lettuce roots penetrated to a depth of at least two feet and Schwalen and Wharton (70) found that the majority of feeder roots were contained in an inverted cone thirty inches in diameter and fifteen to eighteen inches deep with some roots penetrating to a depth of forty to fifty inches. Janes and Drinkwater (37), however, found that lettuce roots were largely in the top twelve inches of soil. Veihmeyer and Holland (86) reported that lettuce roots did not permeate throughout the
soil to reach the soil moisture but that water must be brought to them by irrigation.

Onion roots were reported to be concentrated in the top seven inches of soil with a few extending down to thirty inches (15). In their experiment, as well as work by Jones and Johnson (40), the greatest amount of soil moisture extraction was from the top six to eight inches. Drinkwater and Janes (15) also reported that the greatest extension of onion roots occurred under conditions of heavy and frequent irrigation and that roots of large diameter narrowed at the topsoil/subsoil interface but smaller roots terminated when they reached the subsoil.

Potatoes extracted most of the water they required from the top twelve inches of soil (40, 56) although some roots were reported to extend to a depth of four to five feet (56).

Stanhill (75) found that non-irrigated turnips produced the deepest root system whereas plants grown in soil rewetted to field capacity each day had most of their roots in the top six inches of soil. He also found that the water requirements of a turnip plant could be satisfied by only a small portion of the total fibrous root system.

Effect of Irrigation on Growth and Development:

Wilcox (99), basing his conclusions on tree fruits,
reported that, if the soil was allowed to dry out to the wilting point at any time during the growing season, the photosynthesis was reduced and many absorbing rootlets were killed. Schneider and Childers (69) added that not only were photosynthesis and transpiration decreased but the rate of respiration was also increased. Woodhams and Kozlowski (102) stated that returning soil moisture to field capacity did not restore photosynthesis to its previously observed rate.

They (102) added that height, growth, dry weight of foliage, dry weight of stems, dry weight of roots as well as the sugar and starch content in leaves, stems and roots of beans decreased as the soil moisture approached the permanent wilting point. Returning the soil moisture to field capacity, according to them, caused a marked increase in starch but no corresponding increase in reducing and non-reducing sugars. They concluded that the varying degrees of water availability were a major factor in bringing about the observed responses in starch content and suggested that these responses may have been due, in part, to starch hydrolysis through increased amylolytic activity. Wadleigh et al. (90) also found that starch disappeared during soil desiccation. Sistrunk et al. (91) observed that pods were more mature from non-irrigated plots which accounted for the higher percentage of pectin in the non-irrigated beans. They stated, however, that protopectin was not influenced by irrigation treatment.
Robins and Domingo (64) as well as Robins and Howe (65) reported that as soil moisture became deficient, bean foliage changed from a light succulent green to a dark blue-green. As plants matured, however, these authors noted that this color change became more difficult to detect.

According to Hawthorn (24) various soil moisture levels had no measurable effect on the color of carrot foliage but high soil moisture content did increase plant height.

Celery plants were shorter, had poorer quality and lower weight per plant when the soil moisture was depleted to 40 per cent of field capacity than when moisture was maintained at higher levels (36).

Sweet corn was reported to have a shallow root system and under conditions of soil moisture depletion wilted easily and the weight and height of the plant being proportional to the amount of irrigation water applied (45). In this experiment, the effect of inadequate moisture was not noticed until thirty to forty days after planting. In addition, MacGillivray (45) reported that the number of tassels per plant; the number of ears with silks per plant; and the number of suckers was less on plants grown in non-irrigated plots. Zuber and Decker (103) reported that irrigated corn tasseled two days earlier, silked earlier, produced fewer sterile tassels, had better timing between tasseling and silking as well as more plants with silks than non-irrigated corn. Robins and
Domingo (63) obtained somewhat similar results except they found tasseling and silking was delayed four to five days and plants, under dry conditions, did not cease to elongate at the internodes until three to four days prior to tasseling. Cordner (12), however, found that three irrigations prior to silking delayed silking by one day and increased plant development. Robins and Domingo (63) also found that there was a lower water usage by plants on the dry plots which probably occurred as a result of a reduction in leaf area and because there was less moisture in the soil. Sweet corn matured 2.2 days later when grown under irrigation (89).

Veihmeyer and Holland (86) reported that time of marketability, firmness of head, moisture content and the apparent eating quality of lettuce was not changed by different irrigation treatments whereas Schwalen and Wharton (70) obtained opposite results. The latter found that a uniform high soil moisture content throughout the growing season resulted in early maturity, a lower percentage of split heads, an increased amount of slime, maximum solidity or compactness, less leafiness and a lower percentage of wrapper leaves than if there was a low moisture content in the soil.

The foliage of irrigated onions was a yellowish-green whereas the foliage of non-irrigated onions was a much deeper green in color (25). It was suggested by the same person
that the light color of the foliage on plants in the irrigated plots resulted from a lack of nitrogen which may have been leached from the soil by frequent waterings. Seedstalk formation was not associated with irrigation treatment although there did appear to be fewer seedstalks on less frequently irrigated plants (14).

Heeney and Rutherford (26) as well as Salter (67) stated that irrigation of peas delayed maturity. Salter (67) added that pre-flowering irrigation also increased the amount and weight of haulm produced. Masefield (49) agreed with this finding and also found that irrigation increased the number, the size and the weight of nodules produced by the crops broad beans (*Vicia faba* L.), peas and beans.

Werner (94) found that seed potatoes grown in dryland areas were distinctly superior when compared to seed potatoes grown under irrigation. It was generally agreed that inadequate soil moisture for the growth of potatoes resulted in reduced growth and dark green foliage whereas adequate water caused the foliage to be light green in color which indicated continuous growth (16, 46, 56). Edmundson (16) compared adequate irrigation, i.e., throughout the growing season, to irrigations in the later stages of plant development. He found that the early irrigation treatment had no effect on the number of stolons but did increase growth and development, caused shorter stolons and brought about an earlier set of
tubers than in those plants grown on the late irrigated plots.

Working with early turnips Stanhill (76) compared a wet treatment in which the soil moisture was restored to field capacity each day and a dry treatment in which no irrigation was applied. He found that those plants receiving the wet treatment made less efficient use of the water than those plants in the dry treatment. In addition, he found that leaf weights (fresh and dry), the leaf area and the mean evapotranspiration were increased but the number of leaves per plant was lowered by the wet treatment. As the plant cover increased, however, the increase in the mean evapotranspiration became less and less in his experiment. Thus, he concluded the increased evapotranspiration was caused by increased evaporation rate from the wet bare soil more so than from increased transpiration rate of the foliage. The water content of the leaves and bolting of the plants was not affected by either treatment in his work.

Reporting on the relation of irrigation to foliar diagnosis, Thomas et al. (81) stated that foliar diagnosis gave valuable information concerning the nutrition of the plant and even suggested that foliar diagnosis could be a more accurate index of the effect of irrigation and fertilizer than yields. Thomas et al. (81), working with snap beans, found that nitrogen, calcium oxide (CaO) and magnesium oxide (MgO) decreased whereas phosphorous pentoxide (P2O5) and
potassium dioxide (K₂O) progressively increased in the leaves obtained from plants under irrigation treatment. They stated that high yields were related to a high intensity of nutrition, characterized by high potassium dioxide (K₂O), high phosphorous pentoxide (P₂O₅) and low nitrogen content in the leaves. They found that this occurred under conditions of high fertilizer and high irrigation and that not only was intensity important in producing high yields but equilibrium or balance was also equally important. This corresponded to statements made by Haddock (22).

Working with potatoes, Haddock (22) reported that nitrogen and phosphorous decreased significantly with increasing amounts of irrigation water whereas the potassium content increased. With petioles, the nitrate nitrogen content appeared to be decreased with increased irrigation water but he found that phosphorous did not appear to be consistently associated with soil moisture.

Haddock (22) also reported that the yield and quality of tubers was significantly increased as the nitrogen content in the leaf blade was lowered and the potassium content was increased by irrigation. Thus, as frequency and amount of irrigation increased, in his experiment the nutrient composition came into balance which resulted in increased yield and quality of tubers in spite of the decreased uptake in total nutrients. Haddock (22) also suggested that the nitrogen to
potassium (N/K) ratio was a sensitive indicator of nutrient status where phosphorous was not a controlling factor since nutrient balance was brought about by relative changes in nitrogen and potassium. According to him, the ideal nitrogen to potassium (N/K) ratio appeared to be 2:1. The total soluble nitrate nitrogen, phosphorous and potassium in the petioles appeared to be one-half the total concentration of these nutrients in the leaf blade so he suggested that the petioles could serve as a useful tissue in appraising the nutritional status of the plant.

With celery Cannel (9) found that concentrations of calcium, magnesium, manganese and nitrogen increased under conditions of moisture stress whereas boron, molybdenum, phosphorous, potassium and sodium decreased with drier moisture treatments.

Effect of Irrigation on Yield:

Rahn (61) found that, by maintaining soil moisture over 75 per cent of field capacity, bean yields were increased by 35 per cent. Robins and Howe (65) found that a delay of irrigation for more than seven to ten days after the foliage turned a dark bluish-green significantly reduced yields. Nettles et al. (53) and Sistrunk et al. (72) also obtained higher yields of beans under irrigation. Sistrunk et al. (72) added that pods from bean plants which received no irrigation
during pod development were small, malformed, poor in color and contained a larger percentage of seed than was obtained from pods on plants under irrigation. Conversely, Erwin and Haber (17) obtained no yield increases as a result of irrigation.

Results for cabbage indicated that the maintenance of soil moisture above 50 per cent of field capacity in the top twenty-four inches of soil significantly increased yields and the average weight per head but there was no effect on the percentage of split heads (88). Janes (35) as well as Janes and Drinkwater (37) also obtained yield increases for cabbage under irrigation. Janes (35) found that yield increases, as a result of irrigation, were caused by increases in the size of heads.

Cannel et al. (9) obtained significant yield increases with celery under irrigation.

There have been many reports of irrigation increasing the yields of sweet corn (12, 45, 53, 87, 93). Increased number of marketable ears per plant, increased weight per marketable ear, and increased percentage of useable corn cut from the ear accounted for the increased gross yield of unhusked ears and net yield of cut corn in Vittum's (87) experiment, in which the soil moisture in the top twenty-four inches of soil was maintained above 50 per cent of field capacity. Similar reasons for yield increases were given
by Ware and Johnson (93), Nettles et al. (53) and MacGillivray (45).

Jones and Johnson (40) obtained maximum yields of onions when the soil moisture was maintained over 80 per cent of field capacity, but irrigation at the 60 to 80 per cent level may have been more economical. They found that irrigation at the 40 per cent level was found to be detrimental to onion yields. Others have also obtained higher yields of onions under irrigation (14, 15, 17, 37, 89). Curry (14) reported that the maximum yields of top grade onions were obtained from plots which received heavy irrigation.

According to Salter (67), irrigation prior to flowering had no beneficial effects on yield of marketable pods or yield of shelled peas but did increase the weight of shelled peas slightly. Post-flowering applications, however, did increase yields significantly in his experiment. According to him, the yield increases occurred as a result of an increased number of pods and an increased mean weight and size of shelled peas in the pods. Heeney and Rutherford (26) found that maximum pea yields were only obtained when the soil moisture was kept over 50 per cent of the total available moisture. Haddock and Linton (23) also obtained increased pea yields under irrigation treatment.

Guthrie (21) reported that potato seed-pieces planted in irrigated soil failed to increase yields when compared to
yields obtained from seed-pieces planted in dry soil. He attributed this to the stimulating effect of soil moisture on the parasitic activity of certain pathogens.

From the literature reviewed, it was shown that significant increases in the yield of potato tubers occurred when the plants received irrigation water (6, 7, 8, 11, 13, 16, 19, 20, 22, 32, 40, 46, 54, 55, 59, 60, 78, 92). Most workers reported that available soil moisture should be kept over 50 per cent in order to obtain the most profitable potato yields (7, 8, 13, 19, 20, 32, 40, 42). The main cause of increased yields was an increase in the size of tubers (8, 13, 16, 20, 46, 59, 78). Pratt et al. (59) reported that the number of tubers set was also increased but others (8, 13, 16, 20) found that this was not the case and that only the number of larger tubers was increased. Corey and Myers (13) found that non-irrigated potato plants produced a higher percentage of pointed-end or bottle-neck tubers. They reported that the percentage of knobby tubers remained constant regardless of treatment whereas MacGillivray (46) found that the irrigation of potatoes caused more knobs to appear. Knobs were produced by a cessation of growth followed by good growing conditions (46, 55). Thus an irregular moisture supply throughout the growing season would be one cause of excess knobbiness in potatoes (11, 99).

Stanhill (75, 76) reported that irrigation significantly increased the yield of early turnips. Although he found
a significant increase in total fresh weight, only a non-significant trend in favor of irrigation could be established for dry weight and dry matter data.

Effect of Irrigation on Quality:

Sistrunk et al. (72) found that high soil moisture stress in non-irrigated plots of green beans was detrimental to quality. They also reported that alcohol-insoluble solids, reducing and total sugars as well as protopectin was not affected by irrigation in fresh beans but starch and pectin was higher in beans from non-irrigated plots. He found that canned beans from irrigated plots had a lower percentage of sloughed skins and had a higher resistance to shear (harder beans). In addition, he reported that the water-soluble constituents in the liquid of canned beans were lower with produce from irrigated plots than from non-irrigated plots. Janes (34) reported that the dry matter content of snap beans was higher under conditions of low soil moisture than under irrigation. Although he found a difference in chemical composition on a fresh-weight basis, this difference was not evident when calculated on a dry-weight basis.

Janes (35) found a number of irrigation effects on the quality of cabbage and these are discussed in the following paragraph. On a fresh-weight basis acid hydrolyzable carbohydrates, acid-insoluble residue, ascorbic acid, ash dry matter,
reducing sugars, calcium, iron, nitrogen, magnesium, manganese, phosphate, potassium and sulfate were highest in cabbage from non-irrigated plots and lowest in cabbage from frequently irrigated plots. Sodium was not affected by either treatment. On a dry-weight basis, however, reducing sugars decreased while acid-hydrolyzable carbohydrates and nitrogen increased in cabbage from non-irrigated plots. The increase in acid-hydrolyzable carbohydrates was less than the decrease in reducing sugars so that the net effect was one of carbohydrate reduction with less irrigation. Also on a dry-weight basis, the sulphate and potassium levels were lowered and the sodium level raised in samples obtained from plots receiving the medium level of irrigation. The percentage of iron and magnesium increased with a decrease in irrigation while the percentage of ash, calcium, phosphate and manganese became insignificant between water treatments. Janes (35) concluded with the observation that, if appearance and succulence was used as a basis of quality, cabbage from frequently irrigated plots had the better quality since cabbage from these plots had a higher moisture content.

Erwin and Haber (17) found that the quality of carrots was greatly improved by irrigation as indicated by the absence of tough fibrous roots.

The quality of sweet corn was also improved by irrigation (89). Although Vittum et al. (89) reported that
Irrigation treatment had no effect on the percentage of moisture in the cut corn. MacGillivray (45) found that insufficient moisture in the non-irrigated plots increased the percentage of dry matter, sugar and nitrogen in sweet corn. Luetkemeier and Kohnke (44) found that dry matter was produced more efficiently in corn plants on irrigated plots.

Veihmeyer and Holland (86) reported that neither the firmness of lettuce heads, their moisture content nor their apparent eating quality was changed by the different irrigation treatments. Conversely, Schwalen and Wharton (70) found that lettuce plants grown on plots deficient in moisture prior to harvest and then irrigated had loose heads which were undesirable for market. They concluded that the highest yield of quality lettuce was obtained from plots with a uniformly high soil moisture content throughout the growing season.

MacGillivray and Doneen (47) found that the quality of sweet Spanish onions did not vary significantly between non-irrigated plots and plots with three levels of irrigation. Drinkwater and Janes (15) showed that the pungency of Australian Brown onions, based on volatile sulfur tests, was increased under conditions of irrigation. Ervin and Haber (17) reported that the irrigation of onions caused rapid continuous growth which resulted in a milder flavor and better color.

Dry matter content of shelled peas was higher from plants which were irrigated prior to harvest than from plants
which were not irrigated prior to harvest (67).

It has been generally shown that irrigation also improved the quality of potatoes (22, 32, 56) although Palmer (55) found that potato quality was not significantly affected by irrigation treatment. Prince and Blood (60) reported that the specific gravity of tubers was lowered by irrigation but probably not enough to affect marketability. Smith and Nash (73) also found that the specific gravity was lowered by irrigation whereas Jacob et al. (32) reported that irrigation seldom reduced the specific gravity of tubers and was more likely to increase it. Corey and Myers (13) found that the specific gravity definitely was increased by irrigation treatment. They believed that this occurred as a result of a higher starch content in the tubers. Haddock (22) found that starch content was positively correlated with yield and quantity of irrigation water applied. He further stated that the starch content was highly correlated with good cooking quality or mealiness. Thiessen (80) reported mealy potato varieties were less mealy when grown under irrigation. Smith and Nash (73) reported, however, that there was no difference in texture between irrigated and non-irrigated potatoes. Under high rates of fertilizer, however, they found that tubers from irrigated plots were less mealy.

Smith and Nash (18) as well as Widstoe (97) found that the percentage of dry matter in the tubers was lowered by
Irrigation treatment. MacGillivray (46) reported that tubers from irrigated potato plants usually had a lower percentage of dry matter, a higher water content, a smaller percentage of nitrogen and exhibited large whitish appearing lenticels on their surface. Palmer (55) also found the presence of large whitish lenticels on the skins of many tubers obtained from plots receiving more than four irrigations during the season. Widstoe and Stewart (98) reported that the water content of tubers was not affected by the amount of irrigation water applied. He added that irrigated potatoes had a higher ash and protein content. The degree of blackening was not influenced by irrigation treatment (73).

Salunke et al. (68) found that irrigation did influence chip color, the irrigated tubers giving darker colored chips than non-irrigated tubers.

Irrigation treatment also affected the quality of turnips (75, 76). According to this author, turnips receiving irrigation treatment had the smoothest texture, the highest moisture content and the mildest flavor, although the differences in flavor were not significant. Working with turnip greens, Sheets (71) found that the calcium content was higher in plants which were not irrigated whereas the phosphorous content was higher in irrigated plants. He also stated that nitrogen, dry matter, ascorbic acid and iron varied independent of irrigation.
Effects of Irrigation on Storage of Vegetables:

The keeping quality of lettuce was reported to show no difference which could be attributed to different irrigation treatment (86).

Curry (14) found that water applied to onions at weekly intervals resulted in bulbs with better keeping quality, with less shrinkage and fewer culls when compared to bulbs obtained from plants which received irrigation water at ten-day intervals or irrigation when it appeared the plants needed water. Erwin and Haber (17) showed that, when irrigation was applied after bulbs started to ripen, numerous water-soaked onions of poor keeping quality resulted. Janes and Drinkwater (37) found that onions from the non-irrigated plots lost a higher percentage of the original stored weight than onions from any irrigation treatment, but the keeping quality was not affected.

MacGillivray (46) reported that irrigation treatment did not appreciably affect loss of weight in potato tubers kept in storage.

Irrigation, Disease and Insects.

Menzies (51) studied the effect of irrigation on the spread of four bacterial diseases of beans, namely, common bacterial blight (*Xanthomonas phaseoli* (E.F. Sm) Dowson), bacterial leaf spot of lima beans (*Pseudomonas syringae* V.
Hall), halo blight (*Pseudomonas phaseolicola* (Burk) Dows) and bacterial wilt (*Corynebacterium flaccumfaciens* (Hedges) Dows). He found that none of these diseases occurred when the beans were furrow irrigated but, under sprinkler irrigation, these diseases appeared late in the season and damage was negligible. Menzies (51) concluded that the results could best be explained on a temperature basis rather than a moisture basis. According to him, viable inoculum did not survive between sprinkler irrigations in high enough concentrations as a result of the warm weather and only a low level of inoculum, sufficient to carry the disease through until the cool weather in the fall, was obtained. Wilcox (99), however, reported that sprinkler irrigation increased the spread of bacterial blight of beans where it was present.

Blackheart of celery was significantly increased in non-irrigated plots under high fertilizer treatment (9). According to this author, irrigation treatments did not reduce this infection in the plots receiving the higher fertilizer treatment but did in the lower fertilizer rate. He continued by suggesting that the rate of growth may influence the susceptibility of plants to blackheart.

Wilcox (99) reported that sprinkler irrigation sometimes increased the amount of slime on the outer wrapper leaves of lettuce and cabbage. He also noted that sprinkler irrigation had no harmful effects on corn providing the sprinkler
risers were above the stand of corn.

It was reported by Jenkins (39) that brown rib of lettuce, also referred to as red rib, rib blight, pink rib, rib discoloration and rib breakdown, was a physiological disorder caused by environmental conditions similar to those causing tipburn. He found that this disorder usually developed in warm weather, near maturity, and often resulted in a type of soft rot which was moderate to severe with furrow irrigation. Daily applications of sprinkler irrigation during the latter part of the season significantly reduced brown rib and tipburn which, he suggested, was probably a result of the cooling effect of the water. Even though overhead irrigation kept the temperature seven degrees F. lower than normal he did not consider it a practical method of controlling this disorder.

Curry (14) found that there was no difference in the amount of pink rot on onions as a result of irrigation treatment.

Both Passlow (57) and Hawthorn (25) found that irrigation reduced the status of thrips as a pest since unthriftty plants rather than vigorous ones carried the large thrip population.

The larvae of the weevil *Sitona lineata* which attacked the nodules of broad beans and peas was effectively controlled by irrigation and, therefore, the life of the nodules,
according to Masefield (49), was prolonged. Higher quantities of irrigation water also resulted in some root rot of peas which somewhat curtailed yield of vines and peas (23).

Fulton (19) reported that insects and disease were no greater on irrigated plots of potatoes than on non-irrigated plots and recommended spraying for the control of potato beetle, flea beetle, leafhopper and blight regardless of irrigation practice. Pratt et al. (59) and Wilcox (99) found, however, that sprinkler irrigation, when late blight was present, greatly increased the infestation. Verticillium wilt disease (Verticillium albo-atrum (Reinke and Berth), when present, was also aggravated by irrigation (60). Corey and Myers (13) reported similar results for verticillium wilt. They also found that over irrigated or poorly drained soils provided ideal conditions for the fungus causing water rot or pink rot (Phytophthora erythroseptica (Pethy)). Starr et al. (77) reported that the most potato scab (Actinomyces scabies Thax (Guss) occurred on those plots receiving the most irrigation water. Erwin and Haber (17), however, found that irrigation reduced radish scab caused by the same organism.

It was also reported that blossom end rot of tomatoes was reduced by irrigation treatment (17, 26). Wilcox (99) has reported other effects of sprinkler irrigation on the incidence and spread of disease in apples, pears, cherries, raspberries, strawberries and tomatoes.
Interaction of Soil Moisture, Fertilizer and Plant Population:

Ware (91) stated that an irrigation experiment planned without due regard to the influence of certain fertility factors may fail in determining the value of irrigation, i.e., at low fertility levels the extra cost of irrigation may not be justified whereas it may be justified at high fertility levels. He continued by saying that maximum increases in yields of beans, onions, potatoes and turnips were obtained only when irrigation and organic matter were used in combination with each other, rather than when each was used separately.

Nettles et al. (53) tested three levels of fertilizer on the cabbage variety, Copenhagen Market. They obtained a yield increase when a side-dressing was applied seven to ten weeks after planting but not when the amount of nitrogen applied at planting time was increased. In addition, they found no significant interaction between irrigation and fertilizer treatment. Vittum and Peck (88) found that doubling the normal fertilizer application significantly increased the average weight per head but this increased the amount of splitting so that the marketable yields were only slightly increased. In the same experiment, close spacing was found to increase yields but the average weight per head and amount of splitting were decreased.

With celery, Cannel et al. (9) found that two tons per acre of 10-10-10 fertilizer gave higher yields than one or four tons per acre of the same fertilizer formulation.
was no interaction between moisture and fertilizer treatment on yield but the interaction of fertilizer and moisture on blackheart was highly significant (see page 46).

Ware and Johnson (93) found that the increase in yield of sweet corn, derived from the use of organic matter, was greater when used with irrigation than without irrigation. Vittum et al. (89) reported that doubling the normal rate of fertilizer caused no significant change in the number of plants per acre, the average weight per ear, the gross yield, the percentage of cut corn or the percentage of moisture in the cut corn. Evans et al. (18) found that increasing the rate of nitrogen from 50 to 100 or 200 pounds per acre significantly increased the yield of unhusked and husked ears as well as the total number of ears but 100 pounds of nitrogen per acre, however, appeared to be most economical. Both sources (18, 89) reported that there was no interaction between irrigation and fertilizer treatment, although, Evans et al. (18) pointed out that, if sweet corn was irrigated for optimum production, it must also be fertilized for optimum and economical production.

With closer plant spacing of corn, it was found that the number of ears produced per acre was increased but the weight per ear was decreased (53). Others found similar results (18, 89). A spacing of twelve inches in three-foot rows or one plant per three square feet was recommended (18,
Vittum et al. (89), however, found that this response to spacing was independent of irrigation and fertilizer treatment.

Lettuce grown at close plant spacings was found by Majmudar and Hudson (48) to have the highest total fresh weight and dry weight yields but lettuce grown at widest spacings had the highest fresh and dry weight per head. They also found that maturity was retarded at the closer spacing.

Celestino (10) found a greater response in bulb size of onions to fertilizer was obtained from irrigated plots than from non-irrigated plots.

Haddock and Linton (23) reported that the yield of both pea vines and canning peas was increased by phosphorous applied as superphosphate fertilizer (44 lbs. P.) whereas nitrogen fertilizer applied as ammonium nitrate (80 lbs. N.) had very little influence on yield.

Working with potatoes, Ware (92) found that neither irrigation nor organic matter used separately resulted in as large a yield as when they were used in combination. White-Stevens and Wessels (95) obtained similar results with a commercial fertilizer. Jacobs et al. (33) determined the nitrogen, phosphorous and potash requirements of six potato varieties with and without irrigation.
In the summer of 1962, two separate irrigation experiments were conducted with ten vegetable crops at Saskatoon. The first experiment was concerned with the effect of three levels of irrigation on beans, corn, peas and potatoes. This experiment was carried out with the assistance of Mr. Sonmor of the Canada Department of Agriculture, Canada Agriculture Research Station, Saskatoon in the Department of Horticulture's plot area. This area, situated approximately one-quarter mile east of the university campus, will be hereinafter designated as the South Plot.

The second experiment was conducted in conjunction with the Department of Agricultural Engineering, University of Saskatchewan, on their irrigation farm about one-quarter mile north of the university campus. The vegetables grown on this plot were cabbage, carrots, celery, lettuce, onions and rutabagas. This area was designated as the North Plot and will be referred to as such in the remainder of this thesis.

South Plot:

In 1954, this area was sown to a mixture of brome and alfalfa which remained as a hay and pasture crop until the spring of 1961. During this time, the area was frequently
manured. The sod was broken in the spring of 1961 and the area was summerfallowed for the remainder of the year.

In the spring of 1962, a relatively level site was chosen for the plot area. A split-plot design was used in this experiment. Three levels of irrigation, replicated three times, were used for each crop. The irrigation treatments included a \( W_0 \) treatment which received only natural precipitation, a \( W_1 \) treatment which was irrigated each time the available soil moisture was depleted to 35 per cent of field capacity and a \( W_2 \) treatment which was irrigated each time the available soil moisture dropped to the 70 per cent level. Water, obtained from the city water mains, was applied by the furrow method of irrigation with the use of gated pipe. Irrigation applications were scheduled by Mr. Sonmor of the Canada Department of Agriculture from data obtained from both soil samples and a black Bellani plate.

There were six 40-foot rows spaced three feet apart and twelve furrows in each sub-plot. The furrows were approximately six to eight inches wide and five to six inches deep. The two outer rows and five feet of row on both ends of the other four rows were considered guard material. The data obtained from the two 30-foot rows on the inside (\( R_1 \)) were kept separate from the data on the next two outer rows (\( R_2 \)). A diagram of the area showing the location of each sub-plot and its respective water treatment, along with the topography, is given in Figure 1.
Prior to planting, the plot area was worked and treated with aldrin (20% emulsible) at the rate of three gallons per acre to control wireworms. After this, commercial fertilizers
at the rates given in Table 1 were applied. In order to insuare a level soil surface for furrow irrigation, the area was leveled by means of a land planer. The area was subsequently harrowed and rototilled to prepare a suitable seed bed.

The variety of each crop used, as well as the date of planting, plant spacing and fertilizer treatment are also given in Table 1.

TABLE 1: South Plot: Crop, Date of Planting, Eventual Spacing, Fertilizer Treatment and Rate of Application.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Date of Planting</th>
<th>Planting (in inches)</th>
<th>Spacing (in inches)</th>
<th>Fertilizer</th>
<th>Rate (lbs/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>beans</td>
<td>Dwarf Green</td>
<td>May 23</td>
<td>4</td>
<td>11-48-0</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stringless</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>peas</td>
<td>Homesteader</td>
<td>May 23</td>
<td>4</td>
<td>11-48-0</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Lincoln)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>corn</td>
<td>Golden</td>
<td>May 22</td>
<td>12</td>
<td>16-20-0</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Beauty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>potatoes</td>
<td>Norland</td>
<td>May 24</td>
<td>12</td>
<td>11-48-0</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

During the growing season the height of the crop was measured periodically. Any color differences and differences in the amount of foliage were also noted. At harvest, the yield of edible produce from each crop was determined. Appropriate measurements for each crop, such as, the size of the produce and the quantity produced per sub-plot were also taken. The only quality determinations made, other than tasting the
produce from each crop, were the chipping quality and specific gravity of potatoes. A sample of potatoes from each treatment was also put in storage.

For convenience, all yields were converted to hundred-weight per acre. The data obtained were subjected to an analysis of variance to determine if there were significant differences between treatments. When significance was found, the least significant difference method was used to determine the treatments that were significantly different from each other.

North Plot:

Prior to the spring of 1958, this area had been virgin soil. At that time, the area was broken and summerfallowed for the rest of the summer. Oats were sown in the area in 1959, 1960 and 1961.

In 1962, a site with a relatively steep slope to the north was chosen for the North Plot. A split-plot design, similar to the design on the South Plot, was also used for this experiment. The three water treatments, replicated three times for each of the six crops were identical to the treatments on the South Plot.

The water used to irrigate this Plot was obtained from the main irrigation canal which was filled by pumping water directly from the South Saskatchewan River. Since the Plot was below the level of the canal, the six-inch gated pipe was easily filled by means of gravity. When the pipe was full,
the gates were opened from approximately one-quarter to one-half inch which allowed each furrow to be filled to capacity in about twenty minutes. Personnel of the Department of Agricultural Engineering did the soil sampling and took the readings on the black Bellani plate in order to determine when irrigation was required.

Each sub-plot contained six 40-foot rows spaced three feet apart as in the South Plot. A diagram of the plot area showing each sub-plot and its respective water treatment is given in Figure 2. There were only six furrows per sub-plot.

![Figure 2: The North Plot.](image-url)
in contrast to the South Plot which had twelve. Each furrow measured approximately eight to ten inches deep and 14 to 16 inches wide at the surface. The two outermost rows and five feet on both ends of the other four rows were used as guard material. The data obtained from the two 30-foot rows in the center of the sub-plot (R1) were kept separate from the data from the next two outer rows (R2).

This plot area was slightly uneven in the spring of 1962 so that some cut and fill was required, especially on replicate 1. Immediately afterwards, the area was furrowed by means of a commercial ditcher. No fertilizer was applied. An application of dieldrin (50% wettable) was applied after planting in order to control a serious infestation of wireworms. Later in the season, Atox (rotenone) was dusted on the cabbage to control the cabbage butterfly and larvae.

The variety, date of planting, date of pricking out and transplanting and the eventual plant spacings are given in Table 2.
A V-belt seeder was used to sow the carrot, onion and rutabaga seeds directly into the sub-plots. Cabbage, celery and lettuce seeds were sown into a mixture of sand and peat moss (1:1 ratio) in seed pans in the greenhouse. When the first true leaves appeared, they were pricked out and transplanted into flats containing a mixture of soil, sand and peat moss (2:1:1 ratio). Prior to transplanting into the field, these flats were placed in portable, plastic greenhouses outdoors for a hardening-off process. The plants were subsequently set out in the field and watered immediately. A few plants were replaced a few days later since some plants

# TABLE 2: North Plot: Crop, Date of Planting, Date of Pricking Out, Date of Transplanting and Eventual Spacing.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Date of Planting</th>
<th>Date of Pricking Out</th>
<th>Date of Transplanting</th>
<th>Plant Spacing (in in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cabbage</td>
<td>Copenhagen</td>
<td>April 24</td>
<td>May 1</td>
<td>June 6</td>
<td>18</td>
</tr>
<tr>
<td>carrots</td>
<td>Red Cored</td>
<td>May 29</td>
<td>N.A.</td>
<td>N.A.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Chantenay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>celery</td>
<td>Utah No. 15</td>
<td>March 24</td>
<td>April 16-19</td>
<td>June 8</td>
<td>12</td>
</tr>
<tr>
<td>lettuce</td>
<td>Premier Great</td>
<td>April 18</td>
<td>April 25-27</td>
<td>June 6-8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Lakes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>onions</td>
<td>Autumn Spice</td>
<td>May 28</td>
<td>N.A.</td>
<td>N.A.</td>
<td>3</td>
</tr>
<tr>
<td>rutabaga</td>
<td>Laurentian</td>
<td>May 29</td>
<td>N.A.</td>
<td>N.A.</td>
<td>6</td>
</tr>
</tbody>
</table>
failed to establish or were damaged by cutworms.

During the growing season, data such as the height and appearance (especially color) were obtained periodically for each crop. At harvest, the yields of edible produce for each crop were obtained. The size factor was also considered and measurements were taken accordingly. In addition, the amount of bolting and soft rot in lettuce for the different treatments was determined. No quality determinations were made, except by tasting samples from the three treatments. Representative samples of carrots, onions and rutabagas were also placed in storage to study their keeping ability.

The data obtained from the North Plot were treated and analyzed similar to the data from the South Plot.

Precipitation data were not obtained on either plot area but measurements recorded by the Department of Physics, University of Saskatchewan were used.

Both plots were given a general sprinkler irrigation, when the seed was planted, to insure germination. This was not counted as a treatment in the experiment.
EXPERIMENTAL RESULTS AND DISCUSSION

Effect of Irrigation on:

South Plot

Analysis by the Canada Department of Agriculture revealed that the South Plot area consisted of a soil that varied from a loam to a heavy clay-loam. At field capacity it held 17.4 inches of water (at 1/3 atm.) to a depth of three feet and at the permanent wilting point, the moisture content was 9.4 inches to the three-foot depth. Although a rich loam soil would have been preferred, it was not available in the Department of Horticulture's plot area.

As stated previously, no precipitation data were recorded in the South Plot. Consequently, in order to compare the precipitation for 1962 with the long time average, data from the Department of Physics, University of Saskatchewan were used. These data were collected from meteorological equipment situated on the university campus. It is assumed that these data were the same as the data that would have been obtained for both the South Plot and the North Plot area since the meteorological equipment was located between and not too distant from the two plots. The total precipitation by month at Saskatoon from May to October, 1962, is given in Table 3
along with the 60-year average.

TABLE 3: Monthly Precipitation from May to October, 1962, and the 60-Year Average for these Months at Saskatoon.

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation for 1962 (in inches)</th>
<th>60-Year Average (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>.75</td>
<td>1.37</td>
</tr>
<tr>
<td>June</td>
<td>1.40</td>
<td>2.54</td>
</tr>
<tr>
<td>July</td>
<td>3.41</td>
<td>2.33</td>
</tr>
<tr>
<td>August</td>
<td>1.90</td>
<td>1.73</td>
</tr>
<tr>
<td>September</td>
<td>.94</td>
<td>1.38</td>
</tr>
<tr>
<td>October</td>
<td>.19</td>
<td>.78</td>
</tr>
<tr>
<td>Total</td>
<td>8.59</td>
<td>10.13</td>
</tr>
</tbody>
</table>

Substantial rainfalls of over one-quarter inch occurred only on May 29; June 4 and 7; July 1, 9, 18 and 21; August 26 and 27; and September 1. Thus, in the months of May, June, September and October, the precipitation was much below normal, whereas July and August were the only months in which the rainfall exceeded the long-time average.

Since moisture was not supplied by rain in sufficient quantity to keep the moisture content of the soil above the required treatment levels, irrigation was required. The number of irrigations along with the interval between planting and irrigation, as well as the estimated amount of water applied are presented in Table 4.
TABLE 4: Time and Amount of Irrigation Water and Rainfall Received by the Respective Crops in the South Plot.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Plot Number</th>
<th>Times between Planting and Irrigation (in days)</th>
<th>Estimated Amount of Rain (in inches)</th>
<th>Amount of Water Received (in inches)</th>
<th>Total Amount of Water Received (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans</td>
<td>Wo</td>
<td>0</td>
<td>0</td>
<td>5.91</td>
<td>5.91</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>2</td>
<td>35.76</td>
<td>2.14</td>
<td>5.91</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>3</td>
<td>35.58,79</td>
<td>3.21</td>
<td>5.91</td>
</tr>
<tr>
<td>Corn</td>
<td>Wo</td>
<td>0</td>
<td>0</td>
<td>8.31</td>
<td>8.31</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>2</td>
<td>35.76</td>
<td>2.14</td>
<td>8.31</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>3</td>
<td>35.71,89</td>
<td>3.21</td>
<td>8.31</td>
</tr>
<tr>
<td>Peas</td>
<td>Wo</td>
<td>0</td>
<td>0</td>
<td>5.91</td>
<td>5.91</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>2</td>
<td>35.63</td>
<td>2.14</td>
<td>5.91</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>3</td>
<td>35.58,76</td>
<td>3.21</td>
<td>5.91</td>
</tr>
<tr>
<td>Potatoes</td>
<td>Wo</td>
<td>0</td>
<td>0</td>
<td>8.31</td>
<td>8.31</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>2</td>
<td>34.70</td>
<td>2.14</td>
<td>8.31</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>3</td>
<td>35.62,78</td>
<td>3.21</td>
<td>8.31</td>
</tr>
</tbody>
</table>

It was observed that the seedlings of beans, corn, and peas emerged very unevenly. This has been attributed to the fact that the V-bolt seeder used to plant the seed was continuously jumping over large chunks of sod and manure which caused the seed to be placed at varying depths.
Beans:

Bean plants began to emerge on June 11, nineteen days after planting. They did not require any thinning as less than the required number of plants per row emerged. The most probable explanation for this was that not enough seed was sown by the V-bolt seeder rather than the lack of good germination.

The plants grown under the Wo treatment were observed to be shorter than plants grown on either the W1 or W2 treatment. Those receiving the W2 treatment were tallest. In addition, plants receiving irrigation were more uniform in height and had slightly more foliage. The foliage on plants in the W2 treated sub-plots remained a light green in color throughout the season whereas the foliage on non-irrigated plants remained dark green. The W1 treated plants were dark green except for a few days after receiving an irrigation treatment at which time they became light green in color. These observations are similar to those reported by Robins and Domingo (64).

Irrigation significantly increased the yield of beans in this experiment (Table 5). Nettles et al. (54) as well as Sistrunk et al. (72) also obtained higher yields under irrigation but Erwin and Haber (17) found this not to be the case in their experiment. The yield from the W1 and W2 treated sub-plots was significantly greater than from the non-irrigated sub-plots but there was no statistical significance between the
W₁ and W₂ treatments although the yields from the sub-plots receiving the intermediate moisture (W₁) were slightly higher. These beans were harvested seven times from July 31 to August 20 (69-89 days after planting).

The first three and the last four harvests were also analyzed separately (Table 5). Considering the yields from the first three harvests only, there was no significant difference between any of the treatments although they exhibited the same pattern as the total yield data. Conversely, the results for the last four harvest dates proved to be very significant (1% level). The yields from the W₁ and W₂ treatments were significantly greater than those from the non-irrigated sub-plots. These results would appear to prove that irrigation not only increased yields but also delayed the maturity of beans as well. These results are in agreement with Sistrunk et al.'s (91) findings.

**TABLE 5: Yield Data for Beans Grown at Three Moisture Levels.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield in Cwt/Acre</th>
<th>Average Number of Pods/Plant</th>
<th>Average Weight/Pod (in grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First Three Harvests</td>
<td>Last Four Harvests</td>
<td>Total</td>
</tr>
<tr>
<td>W₀</td>
<td>19.88</td>
<td>28.65</td>
<td>48.53</td>
</tr>
<tr>
<td>W₁</td>
<td>27.30</td>
<td>59.50</td>
<td>86.80</td>
</tr>
<tr>
<td>W₂</td>
<td>26.27</td>
<td>60.47</td>
<td>86.74</td>
</tr>
<tr>
<td>L.S.D.</td>
<td>N.S.</td>
<td>7.70</td>
<td>13.70</td>
</tr>
</tbody>
</table>

5% Level
As shown in Table 5, the increased yields from the use of irrigation resulted from an increased number of beans per plant as well as from an increase in the weight per pod. The increase in the weight per pod from the W1 and W2 treatments was highly significant (1% level) over the W0 treatment whereas the increase in the number of beans per plant was only significant (5% level). In both cases, there was no significant difference between the W1 and W2 treatments. More pods per plant were obtained from the W2 treated sub-plots but the greatest weight per pod occurred on the W1 treated plants.

The beans from the W2 treated sub-plots also appeared to be more uniform in size when compared to either of the other two treatments. This is shown in Figure 3 which also shows the size difference between the three treatments. These observations coincided with the results obtained by Sistrunk et al. (72) who stated that non-irrigated plants produced pods which were small, malformed, poor in color and contained a large percentage of seed.
FIGURE 3. Bean Produce; Treatments are, Left to Right, Wo, W1 and W2. (July 31)

There appeared to be no difference in the length of string as a result of different water treatments. When a pod was broken in half, the length of string averaged from one-quarter to one-half inch in length regardless of treatment.

No equipment was available for quality determinations. Consequently, samples of the produce could only be tasted to determine the effects of irrigation on quality. Analyzing the raw beans in this manner indicated that beans from the Wo treatment were tough, flat, poor tasting and lacked a high moisture content. Beans from both of the irrigated treatments,
however, had a higher moisture content and were more pleasant tasting than non-irrigated beans. This higher moisture content (lower dry weight) was also found by Janes (34) in his experiment.

It was shown, in this experiment that both the W1 and W2 treatments were equally effective in producing the highest yield of good quality beans. The W1 treatment, however, appeared to be slightly superior in producing higher yields but beans from the W2 treatment were slightly superior in quality. It was obvious though, since the results were nearly identical for the W1 and W2 treatments, that maintaining the soil moisture at the higher level was not warranted.

Corn:

The corn planted in this experiment emerged seventeen days after planting, on June 8. On July 9, forty-six days after planting, these plants were large enough to be thinned to a 12-inch spacing. At this time, there were only slight differences in height and appearance between the W0 treated plants and the irrigated plants. Certainly, the differences were not as marked as those reported by MacGillivray (45) as early as thirty to forty days after planting.

As the season progressed, however, these differences became much more pronounced. The W0 treated plants remained the shortest throughout the season whereas the plants receiving
the W2 treatment were the tallest. These differences can be observed in Figures 4, 5 and 6. The curling of the leaves as a result of a lack of moisture in the non-irrigated sub-plots is especially noticeable in Figure 4. Only slight leaf curl was observed on plants receiving the other two treatments, as can be noted in Figures 5 and 6. In other words, plants grown on the non-irrigated sub-plots wilted severely whereas irrigated plants did not wilt nearly as severely. These observations are in agreement with MacGillivray (45) who also found that non-irrigated corn wilted easily. It was also observed in this experiment that the ground cover on the irrigated sub-plots was much greater than on the Wo treated sub-plots. This is also evident in Figures 4, 5 and 6.

FIGURE 4. Corn - Wo Treatment. Note Height, Ground Cover and Leaf Curl. (August 20)
FIGURE 5. Corn - W1 Treatment. Note Height, Ground Cover and Absence of Leaf Curl. (August 20)

FIGURE 6. Corn - W2 Treatment. Note Height, Ground Cover and Absence of Leaf Curl. (August 20)
There were no obvious differences in color early in the season. Later in the season, however, those plants receiving the Wo treatment appeared to be a dull, greyish-green in color whereas the foliage on plants receiving the W1 and W2 treatments were still a dark green. There did not appear to be any difference in color between the W1 and W2 treatments.

By visual observations, it was noted that irrigated plants produced tassels and silks much earlier than those plants which received no irrigation. Again, there did not appear to be any difference between the W1 and W2 treatments.

These results were in agreement with Zuber and Decker (103) as well as Robins and Domingo (63) but not with Cordner (12) who reported the opposite by stating that irrigation delayed silking.

There were five harvests of corn between August 29 and September 15 (68-85 days after planting). Results showed a highly significant difference (1% level) in yield of unhusked corn between treatments when weighed immediately (Table 6). Plants receiving the W1 treatment produced the greatest yield followed closely by the W2 treatment, with the Wo treatment producing the least corns. Results, similar to those obtained for unhusked corn, were obtained after the cobs of corn had been husked (Table 6). Although no similar work has been reported for Saskatchewan conditions, these results are not surprising when the reports (12, 45, 53, 87, 93) from other
locations are considered.

**TABLE 6: Yield and Measurements of Corn Produce Grown at Three Levels of Moisture.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield in Cwt/Acre</th>
<th>Number of Ears/Plant</th>
<th>Average Diameter of Ears/Plant (in inches)</th>
<th>Average Overall Length of Husked Corn/Ear (in in.)</th>
<th>Average Number of Rows of Husked Corn/Ear</th>
<th>Average Number of Rows of Corn/Ear</th>
<th>Average Average Average Average Diameter Overall Length Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>36.1</td>
<td>23.9</td>
<td>.55</td>
<td>1.48</td>
<td>6.51</td>
<td>5.73</td>
<td>12.2</td>
</tr>
<tr>
<td>W1</td>
<td>128.6</td>
<td>80.1</td>
<td>1.50</td>
<td>1.59</td>
<td>7.18</td>
<td>6.32</td>
<td>12.3</td>
</tr>
<tr>
<td>W2</td>
<td>117.8</td>
<td>70.6</td>
<td>1.37</td>
<td>1.60</td>
<td>7.04</td>
<td>6.17</td>
<td>12.2</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>5.15</td>
<td>6.53</td>
<td>.22</td>
<td>.007</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

The yield differences between treatments occurred as a result of an increased number of ears per plant. As shown in Table 6, the greatest number of ears was found on the plants in the W1 treated sub-plots whereas the non-irrigated treatment produced the least number of ears. The above differences between irrigated and non-irrigated treatments were highly significant (1% level). These results coincided with those obtained by MacGillivray (45), Nettles et al. (53), Vittum (87) as well as Ware and Johnson (93).

There was also a significant difference (5% level) in the average diameter of the husked ear (Table 6). Ears from the W2 treatment were significantly larger in diameter than
those from the $W_1$ treatment which, in turn, were significantly larger than the husked ears from the non-irrigated (Wo) sub-plots.

Conversely, there was no significant difference in the overall length of ears or in the edible length of corn on the ears between the different treatments (Table 6). Likewise, as shown in Table 6, there was no difference in the number of rows of edible corn per ear.

At each harvest, representative cobs of corn from each treatment were cooked and subsequently tasted. Corn from the Wo treatment seemed to taste flat, was apparently less succulent and in some samples was less tender than the produce from both of the irrigation treatments. There appeared to be very little difference between the $W_1$ and $W_2$ treatments. Corn from these latter treatments was tender, rather sweet and fairly succulent. Thus, one would suspect, although it was not confirmed by analysis, that the highest sugar content occurred in corn grown on the $W_1$ and $W_2$ treated sub-plots. These results did not, however, coincide with those obtained by MacGillivray (45) who found that non-irrigated corn had the highest percentage of dry matter, sugar and nitrogen. Vittum et al. (89), on the other hand, found that the dry weight or the percentage of moisture was not affected by irrigation treatment although irrigation did improve quality in their experiment.

Finally, it was apparent that the $W_1$ treatment was
best suited for the production of good quality corn under the conditions of this experiment.

**Peas:**

Peas emerged sixteen days after planting and did not receive thinning for reasons previously described for beans.

Data for height measurements taken periodically throughout the growing season showed that plants receiving the W₁ and W₂ treatments were taller, more uniform in growth, had more foliage and better ground cover than plants grown on the non-irrigated sub-plots. This can be readily observed by comparing Figures 7, 8 and 9. There was very little difference in height, uniformity, and ground cover, however, between the W₁ and W₂ treatments. These differences between irrigated and non-irrigated sub-plots were similar to those found by Masefield (49) and Salter (67).

Prior to maturity, the foliage of plants on the Wo treated sub-plots was a dark green, whereas plants receiving the W₁ and W₂ treatments were a light green in color. As maturity approached, however, the Wo treated plants became a lighter green in comparison to the W₁ and W₂ treated plants. This probably resulted from senescence which would indicate that non-irrigated plants matured earlier than those being irrigated. This was substantiated by the findings of Heeney and Rutherford (26) as well as Salter (67).
FIGURE 7. Peas - Wo Treatment. Note Height and Lack of Foliage Compared to the Other Two Treatments. (August 2)

FIGURE 8. Peas - W1 Treatment. Note Height, Abundant Foliage and Good Ground Cover. (August 2)
FIGURE 9. Peas - W₂ Treatment. Note Height, Abundant Foliage and Good Ground Cover. (August 2)

Earlier maturity of plants receiving the W₀ treatment was also indicated in this experiment by the fact that plants receiving the W₀ treatment stopped flowering earlier than those plants receiving the W₁ and W₂ treatments.

An infestation of powdery mildew and aphids occurred on the plants late in the season. Although powdery mildew occurred on all plants, it appeared to be most severe on those plants receiving irrigation water. Aphids were severe regardless of treatment. These infestations of powdery mildew and aphids did not occur until near the last harvest, so that any detrimental effects on yield or quality was probably negligible.

There were seven harvests between July 31 and August 21 (69-90 days after planting). Since the number of plants per sub-plot was variable, the yield of peas in the pod was
corrected to seventy-seven plants per row and subsequently converted to hundredweight per acre. The analysis of variance indicated significance (5% level) between irrigated and non-irrigated yields (Table 7). There was no significance, however, between the \( W_1 \) and \( W_2 \) treatments although the yield from the \( W_1 \) treated sub-plots was slightly higher. Haddock and Linton (23) as well as Heeney and Rutherford (26) similarly found that irrigation increased pea yields.

When considering the yields from the first three harvest dates alone, there was no significance (Table 7). The highest yield, however, was obtained from plants receiving the \( W_0 \) treatment whereas plants being treated with the intermediate moisture level produced the lowest yields. Conversely, a highly significant difference (1% level) between yields was obtained when the last four harvests were considered. The data for these harvests, which is shown in Table 7, were similar to the total yield data. These results further substantiated the observation made previously that plants receiving the non-irrigation treatment matured earlier than irrigated plants.
TABLE 7: Yield and Related Data for Peas Grown at Three Moisture Levels.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield in Cwt/Acre</th>
<th>Number of Pods/Plant</th>
<th>Weight of Shelled Peas/Plant (grams)</th>
<th>Weight of Pod (in grams)</th>
<th>L.S.D. 5% Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First</td>
<td>Last</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wo</td>
<td>30.62</td>
<td>25.22</td>
<td>55.84</td>
<td>137</td>
<td>4.96</td>
</tr>
<tr>
<td>W1</td>
<td>21.62</td>
<td>66.09</td>
<td>87.71</td>
<td>183</td>
<td>5.75</td>
</tr>
<tr>
<td>W2</td>
<td>25.09</td>
<td>60.94</td>
<td>86.03</td>
<td>183</td>
<td>5.75</td>
</tr>
<tr>
<td>L.S.D.</td>
<td>N.S.</td>
<td>9.96</td>
<td>8.62</td>
<td>18.90</td>
<td>0.18</td>
</tr>
</tbody>
</table>

An increased number of pods per plant, similar to Salter's (67) results, was partly responsible for the increased yields as a result of irrigation (Table 7). The number of pods per plant produced on the irrigated sub-plots was significantly greater (5% level) than those produced on the Wo treated sub-plots but there was no significance between the W1 and W2 treatments.

Another factor contributing to the higher yields on the irrigated sub-plots was the weight per pod (Table 7) which was also significantly different (1% level) between irrigated and non-irrigated treatments. Plants on the irrigated sub-plots yielded pods with the greatest weight compared to pods from plants grown on the non-irrigated sub-plots. There
was no significant difference, however, between the W1 and W2 treatments. The above differences must have occurred largely as a result of an increase in the size and weight of the pod rather than an increase in the size and weight of shelled peas. Although the greater weight of shelled peas obtained from the irrigated plants may have contributed to the above significance, there was no significance between any of the treatments either in the average weight of shelled peas per pod or the average weight of shelled peas per plant (Table 7). The average weight of shelled peas per pod and per plant, however, was greatest from the W1 treated sub-plots with the non-irrigated plants producing the least amount of shelled peas. These results do not agree with Salter (67) who found that the higher mean weight of shelled peas was one of the major factors responsible for the increased yields from irrigated plots.

At each harvest, a sample of raw peas from each replicate was tasted to determine if the irrigation treatment had any effect on the sweetness and tenderness of the peas. By using this method of determining quality, it was found that there were no striking differences between peas from the W1 and W2 treatments. Shelled peas from both treatments were sweet, tender and seemed to have a fairly high water content. Peas from the non-irrigated sub-plots, however, were tough, often slightly bitter to taste and seemed to
have a low moisture content. Based on this apparent moisture content, these results would seem to be in disagreement with Salter (67) who found that the dry matter content was higher in shelled peas from irrigated plants than from non-irrigated plants.

Considering the yield of peas in this experiment, one could state that it was desirable to irrigate peas since higher yields were obtained with irrigation. It was evident though, that these higher yields occurred largely as a result of an increase in the size and weight of the pod. Although the weight of shelled peas was also greater from irrigated plants, the increase was not significant. The seemingly better quality produce obtained from the irrigated plants also indicated the beneficial effect of irrigation. Since slightly lower yields were obtained from the W2 irrigation treatment, however, it was obvious, in this experiment, that it was not feasible to maintain the soil moisture at the higher level.

Potatoes:

Potato plants began to emerge nineteen days after planting. Noticeable differences between plants on the irrigated and the non-irrigated sub-plots occurred very early. Those on the irrigated sub-plots were taller, more uniform in growth and had more foliage than the non-irrigated plants. There was no appreciable difference, however, between the W1 and W2 treatments. As the season progressed these trends
became more noticeable and, as well, the W2 treated plants became slightly taller than the rest. Eventually the ground cover was complete on the W1 and W2 treated sub-plots but there was only partial ground cover on the non-irrigated sub-plots, even at the end of the season. These differences, mentioned above, can be seen in Figures 10, 11 and 12. Wilting which occurred frequently and severely on plants receiving the Wo treatment can also be seen in Figure 10. Similar observations on the growth of potatoes under irrigation were made by Edmundson (16), MacGillivray (46) and Parks (56).

These authors also reported foliage color differences noted in this experiment. The color of foliage on plants receiving the Wo treatment remained a dark green throughout the season, until the time of senescence. By comparison, the color of plants grown on the W2 treated sub-plots was a light green throughout the season. The foliage on the W1 treated plants fluctuated between a light green just after irrigation to a dark green just before the next irrigation.

By visual observations, it was apparent that the irrigated plants produced more blossoms than the non-irrigated plants and that the W2 treated plants produced considerably more bloom than the W1 treated plants. Plants receiving the W2 treatment also carried a greater number of seed balls than plants being given the intermediate moisture treatment whereas those plants receiving no irrigation water had very few seed balls.
FIGURE 10. Potatoes - Wo Treatment. Note Height, Wilting, and Lack of Foliage. (August 20)

FIGURE 11. Potatoes - W1 Treatment. Note Height, Complete Ground Cover and Absence of Wilting. (August 20)
At harvest time, on September 13, one hundred and twelve days after planting, those plants receiving the Wo treatment were obviously mature. Most of the foliage had died on these sub-plots and the stems were falling over. This is evident with the plants which had not been dug up at the time the photograph (Figure 13) was taken. In Figure 14, the plants receiving the W1 treatment were obviously in a state of senescence but had not died at the time of harvest. The plants which were given the W2 treatment (Figure 15) were still healthy and actively growing at harvest time. It was apparent from the above results that the irrigation treatments delayed the maturity of potatoes grown in this experiment.

Figures 13, 14, and 15 also illustrate the differences
FIGURE 13. Potatoes - Wo Treatment at Harvest. Note Maturity of Plants. (September 13)

FIGURE 14. Potatoes - W1 Treatment at Harvest. Note Senescing of Plants. (September 13)
in yield of tubers as a result of the different treatments. Considering the total yield of all tubers, the irrigated sub-plots (W1 and W2) significantly (1% level) outyielded the non-irrigated sub-plots (Table 3). The total yield from the W2 sub-plots was slightly higher than the yield from the W1 sub-plots, but the difference was not significant. These results are in agreement with many other workers (6, 7, 8, 11, 13, 16, 19, 20, 22, 32, 40, 46, 54, 55, 59, 60, 78, 92) who obtained similar results.

Not all of these tubers, however, would be considered marketable since small tubers are undesirable. Consequently, all those tubers measuring over two and one-quarter inches in diameter were kept separate from the smaller tubers. There
was a high degree of significance (1% level) between all treatments when only the yield of marketable tubers (over 2 1/2 inches in diameter) was analyzed. Yields obtained from the W2 treated sub-plots were significantly higher than the yields from the W1 treated sub-plots and it, in turn, yielded significantly higher than the non-irrigated sub-plots (Table 8). Some of the workers mentioned previously (7, 8, 13, 19, 20, 32, 40) have also found that the most profitable potato yields were only obtained at a high available moisture level (over 50% of field capacity).

The yield of tubers measuring under two and one-quarter inches in diameter were also significantly different (5% level) between treatments. This time, however, as shown in Table 8, the W0 treated plants gave the highest yield, followed by the W1 and finally the W2 treated plants.
TABLE 8: Yield, Number and Diameter of Potato Tubers Produced at Three Moisture Levels.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield in Cwt/Acre</th>
<th>Average Diameter/Tuber</th>
<th>Average Diameter/Tuber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marketable (over 2½&quot;)</td>
<td>Unmarketable (under 2½&quot;)</td>
<td>Total Diameter (in inches)</td>
</tr>
<tr>
<td>Wo</td>
<td>62.56</td>
<td>32.59</td>
<td>95.15</td>
</tr>
<tr>
<td>W₁</td>
<td>292.82</td>
<td>20.57</td>
<td>313.39</td>
</tr>
<tr>
<td>W₂</td>
<td>330.98</td>
<td>11.61</td>
<td>342.59</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>37.25</td>
<td>7.17</td>
<td>40.81</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Tubers/Sub-Plot</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 2½&quot; in diameter</td>
<td>Under 2½&quot; in diameter</td>
<td>Total in diameter</td>
</tr>
<tr>
<td>Wo</td>
<td>101</td>
<td>186</td>
</tr>
<tr>
<td>W₁</td>
<td>239</td>
<td>100</td>
</tr>
<tr>
<td>W₂</td>
<td>272</td>
<td>78.</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>26.57</td>
<td>3.39</td>
</tr>
</tbody>
</table>

From the above results and the analysis of variance carried out on the diameter of all tubers, it was evident that the yield increases occurred as a result of an increase in the size of tubers. This observation was well substantiated by the findings of other workers (8, 13, 16, 20, 46, 59, 78). As shown in Table 8, tubers from the W₂ treated sub-plots had a larger average diameter than those from the W₁ treated.
sub-plots which, in turn, had a larger average diameter than the tubers from the non-irrigated sub-plots.

There was no significant increase in the total number of tubers produced per sub-plot under the irrigation treatments, in spite of the fact that the greatest number of tubers were found on the irrigated sub-plots (Table 3).

As previously inferred in marketable yield discussions, there were differences, however, in the number of tubers over two and one-quarter inches in diameter and in the number of tubers under two and one-quarter inches in diameter between the different treatments. As shown in Table 3, more of the larger tubers and fewer of the small tubers were found on the irrigated sub-plots whereas more of the smaller tubers and fewer of the large tubers were found on the non-irrigated sub-plots. These size differences are also apparent in Figures 13, 14 and 15. These results seem to be intermediate between the various reports in the literature. Although the highest level of moisture tended to produce the greatest number of tubers, similar to work reported by Pratt et al. (59), these data were not significant in this experiment. Based on statistical analysis, these results are also very similar to results obtained by other workers (8, 13, 16, 20) who found that only the number of larger tubers was increased by irrigation.

Representative samples of tubers from each treatment were tasted raw as well as cooked. There was very little
difference in the taste of the raw tubers from the different sub-plots, with the exception that those tubers from the Wo treated sub-plot were a little less crisp and a little more bitter than the others. When cooked, the tubers were scored for texture, color, flavor, sloughing and discoloration after standing. There was no difference between treatments in color, flavor or sloughing. The W2 treated plants, however, produced tubers which were much more mealy than tubers from either of the other two treatments. Tubers from the non-irrigated sub-plots were the least mealy. These results are in disagreement with others (22, 32, 56) where the quality, using mealiness as an indicator of good quality, has been improved by irrigation. Thiessen (80) has reported opposite results whereas Smith and Nash (73) reported that irrigation had no effect on mealiness.

Slight blackening occurred after standing on some of the tubers from the W2 treated sub-plots, but it was not serious. These results are not in agreement with Smith and Nash (73) who found that the degree of blackening was not influenced by irrigation treatment.

A sample of tubers from each treatment was also placed in storage at 55 degrees F and, at a later date, removed to a warm storage place (70°F) in the dark. About one week later the potatoes were sliced and made into chips (Saratoga type) in the recommended manner. In each case, the tubers
from the $W_2$ treated sub-plots produced the darkest chip, indicating a higher sugar content. A higher glucose content in tubers from the $W_2$ treated sub-plots was also indicated by the "Chip Color Tester" tape. There appeared to be no difference in the chipping quality between the tubers from the Wo and $W_1$ treatments. A similar darkening of chips as a result of irrigation was reported by Salunke et al. (68) but the level of moisture in the soil was not specified.

The three treatments had no visible effect on the keeping quality of the above tubers kept in warm storage. Furthermore, there was no visible deterioration in quality which could be attributed to the different irrigation treatments when the potatoes were stored at 35 to 36 degrees F. over winter. Similar results have been reported by MacGillivray (46).

Since equipment was not available to determine the specific gravity of tubers at harvest time, these determinations had to be delayed until July 12, of 1963, at which time the above tubers kept in cold storage were used. There was no significant difference in the specific gravities between treatments at this time. As shown in Table 8, tubers from the irrigated treatments were identical in their specific gravities and had a lower specific gravity than tubers from the Wo treated sub-plots. Prince and Blood (60) as well as Smith and Nash (73) reported similar results whereas Jacob
et al. (32) found that the specific gravity was seldom reduced and more likely increased by irrigation and Corey and Myers (13) stated that irrigation definitely did increase the specific gravity of potato tubers.

Irrigation was essential for maximum potato yields under the conditions of this experiment. Since potato plants receiving the W2 treatment produced the highest significant yield of marketable tubers (over 2½ inches in diameter), it was apparent that irrigation at the higher irrigation level was the most satisfactory for the production of potatoes. It is obvious, however, that potatoes produced specifically for the chipping industry are unfavorably affected by this high moisture and lower levels should be studied.
North Plot:

The soil contained in this area was a loam to a sandy loam soil as determined by personnel in the Department of Soil Science, University of Saskatchewan. Determinations made by personnel in the Department of Agricultural Engineering, University of Saskatchewan, indicated that it held 18.63 inches of water to a depth of three feet at field capacity whereas the soil moisture content at the permanent wilting point was 8.77 inches to the same depth.

As stated previously, some cut and fill was required especially on the first replicate. This resulted in a ten-foot wide strip, extending through the most easterly row of sub-plots, being filled with topsoil whereas the remainder of these sub-plots had mostly subsoil exposed on the surface. Three other sub-plots in the first and second replicates were similarly affected. This caused very uneven growth, i.e., in the places where the topsoil had been removed the growth was very poor whereas the growth was much better on those areas which contained abundant topsoil. Celery, rutabagas and onions were the crops most seriously affected. The data obtained for these crops were treated in a different manner than the data obtained for the other crops. The procedure of analyzing data will be discussed later under the respective crops.
The amount of precipitation for the 1962 growing season was considered to be the same as the amounts given for the South Plot area and will not be repeated here. Like the South Plot area, the soil moisture periodically fell below the 35 and 70 per cent level. Consequently, irrigation water was necessary to keep the moisture content of the soil above these levels. These irrigations are recorded in Table 9 along with the amount and frequency of water received by each sub-plot.
# TABLE 9: Time and Amount of Irrigation Water and Rainfall Received by the North Plot

<table>
<thead>
<tr>
<th>Crop</th>
<th>Plot Number</th>
<th>Times Between Planting and Irrigation</th>
<th>Estimated Amount of Rain (in inches)</th>
<th>Amount of Water Received (in inches)</th>
<th>Total Amount Received (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabbage</td>
<td>Wo</td>
<td>0</td>
<td>4.61</td>
<td>4.61</td>
<td>4.61</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>2 50, 68</td>
<td>3.75</td>
<td>4.61</td>
<td>8.36</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>5 21, 37, 50, 61, 68</td>
<td>9.38</td>
<td>4.61</td>
<td>13.99</td>
</tr>
<tr>
<td>Carrot</td>
<td>Wo</td>
<td>0</td>
<td>7.14</td>
<td>7.14</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>3 58, 76, 87</td>
<td>5.63</td>
<td>7.14</td>
<td>12.77</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>6 29, 45, 58, 69, 76, 84</td>
<td>11.25</td>
<td>7.14</td>
<td>18.39</td>
</tr>
<tr>
<td>Celery</td>
<td>Wo</td>
<td>0</td>
<td>6.66</td>
<td>6.66</td>
<td>6.66</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>3 48, 66, 77</td>
<td>5.63</td>
<td>6.66</td>
<td>12.29</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>6 19, 35, 48</td>
<td>11.25</td>
<td>6.66</td>
<td>17.91</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Wo</td>
<td>0</td>
<td>4.22</td>
<td>4.22</td>
<td>4.22</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>1 49</td>
<td>1.88</td>
<td>4.22</td>
<td>6.10</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>3 20, 36, 49</td>
<td>5.63</td>
<td>4.22</td>
<td>9.85</td>
</tr>
<tr>
<td>Onion</td>
<td>Wo</td>
<td>0</td>
<td>8.31</td>
<td>8.31</td>
<td>8.31</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>3 59, 77, 88</td>
<td>5.63</td>
<td>8.31</td>
<td>13.94</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>6 30, 46, 59, 70, 77, 85</td>
<td>11.25</td>
<td>8.31</td>
<td>19.56</td>
</tr>
<tr>
<td>Rutabaga</td>
<td>Wo</td>
<td>0</td>
<td>8.04</td>
<td>8.04</td>
<td>8.04</td>
</tr>
<tr>
<td></td>
<td>W1</td>
<td>3 58, 76, 87</td>
<td>5.63</td>
<td>8.04</td>
<td>8.04</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>6 29, 45, 58, 69, 76, 84</td>
<td>11.25</td>
<td>8.04</td>
<td>19.29</td>
</tr>
</tbody>
</table>
Cabbage:

Early in the growing season, there was no noticeable difference in growth of the transplanted cabbage between the three different treatments. Later in the season, however, plants grown on the \( W_1 \) and \( W_2 \) treated sub-plots gradually increased in size more than those from the \( W_0 \) treated sub-plots. There was also more ground cover on the irrigated sub-plots.

There was no noticeable difference in the color of the foliage between the three treatments from the time of transplanting until harvest.

The heads were harvested, when they were reasonably firm, between August 9 and 22 (sixty-four to seventy-seven days after transplanting). There did not appear to be any difference in the date of maturity between treatments. Although there was no significant difference in the total yield of cabbage between treatments, the irrigated sub-plots did produce higher yields (nearly double) than non-irrigated sub-plots, with the \( W_2 \) treatment resulting in the highest yield (Table 10). These results, although they were not significant, were similar to those found by others (35, 37, 88).
TABLE 10: Yield and Diameter of Cabbage Heads Produced at Three Moisture Levels.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total Yield (in Cwt/Acre)</th>
<th>Average Diameter of Heads (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>581.14</td>
<td>4.4</td>
</tr>
<tr>
<td>W₁</td>
<td>1,039.88</td>
<td>5.6</td>
</tr>
<tr>
<td>W₂</td>
<td>1,080.05</td>
<td>5.8</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

The reason for the higher yields obtained from the W₁ and W₂ treated sub-plots was obviously from an increase in the size of head (Table 10). Although these results again were not significant, they were in agreement with those reported by Janes (35). A representative head from each treatment showing this relative difference in size between irrigated and non-irrigated treatment is displayed in Figure 16. It can be seen from this photograph that heads from the irrigated plots were the largest whereas heads from the remaining treatment (Wo) were much smaller.

When representative samples of cabbage from each treatment were placed in cold storage at 35 to 36 degrees F for two weeks, no visible difference in their keeping quality resulted. A few outer leaves turned brown on cabbage from all treatments and some mold occurred on the cut surface of the stems but otherwise there was no visible deterioration.
FIGURE 16: Cabbage Produce; Treatments are left to right, W₀, W₁ and W₂. (August 9)

Even though the analysis of variance did not show significance, the double yields on the irrigated sub-plots showed a positive trend. Further work on this crop is needed and it would appear as if the extra use of water to keep the soil at a high level of moisture is not warranted.

Carrots:

Carrots which emerged two weeks after planting were large enough to be thinned to the recommended three-inch spacing six weeks after planting. Small gaps occurred within the row in numerous places as a result of stopping to refill the V-belt seeder with seed and starting again which left a space in the row with no seed. The average number of plants
per row, however, varied only slightly.

There was no difference in growth between treatments early in the season. Later, however, differences in height, amount of foliage and color were noticeable. It was evident that the W1 treated plants were slightly taller than plants on any of the other sub-plots except in replicate 1 in which the majority of the W1 treated sub-plot had subsoil exposed to the surface. Consequently, these plants in this sub-plot were shorter than the W2 treated plants although taller than those in the non-irrigated sub-plot. These results were in agreement with Hawthorn (24) who also found that high soil moisture increased plant height although he did not stipulate the level of moisture.

Plants from both the W1 and W2 treatments had more foliage and covered the ground more than plants receiving the Wo treatment. There was very little difference, however, between the W1 and W2 treatments.

Shortly after an irrigation treatment, the foliage on both the W1 and W2 treated sub-plots became a light green, although the difference in color was not great. A few days later, the foliage returned to its normal dark green color. Plants on the non-irrigated sub-plots remained relatively dark green throughout the season. In contrast to the above observations, Hawthorn (24) found that the color of carrot foliage was not affected by irrigation treatment.
The carrots in this experiment were harvested on September 11, one hundred and five days after planting and there was a significant difference in yield. As shown in Table 11, the W1 treatment resulted in significantly (1% level) higher yields than was obtained from either the Wo or W2 treatment. The yields obtained from the Wo and W2 treatments were nearly identical.

**TABLE 11: Yield and Related Data of Carrots Grown at Three Moisture Levels.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield of Carrots (in Cwt/Acre)</th>
<th>Average Equatorial Diameter of Carrots (in inches)</th>
<th>Average Length of Carrots (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>98.77</td>
<td>1.37</td>
<td>4.65</td>
</tr>
<tr>
<td>W1</td>
<td>136.01</td>
<td>1.58</td>
<td>5.07</td>
</tr>
<tr>
<td>W2</td>
<td>99.14</td>
<td>1.40</td>
<td>4.68</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>6.94</td>
<td>0.08</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

Significantly higher yields on the W1 treated sub-plots occurred as a result of a significantly (5% level) greater average equatorial diameter (Table 11). Conversely, the average equatorial diameter of carrot roots produced on Wo and W2 treated sub-plots was significantly lower and nearly identical to each other. There was no significant difference, however, in the average length of the carrots between the different
treatments although the average length of carrots from the W1 treated sub-plots was slightly greater as shown in Table 11.

Raw carrots from the W1 treatment were crisp and sweet whereas carrots from the Wo treatment were not as crisp or sweet and tasted slightly stronger than those from either of the other two treatments. Carrots from the W2 treated sub-plots were crisp, although not as sweet as those from the W1 treated sub-plots. Even when cooked, those carrots receiving the Wo treatment seemed to have a stronger carrot taste although they were sweeter than when tasted raw. Carrots from the W1 treated sub-plots were sweet and most pleasing to the taste when cooked. Carrots given the W2 treatment, however, tasted flat and watery when cooked and were not as pleasant to taste as those from the other treatments. It would appear that these results were similar to those reported by Haddock and Linton (17) even though they did not mention the level of irrigation which improved quality in their experiment.

There were also differences noted in the color of the core between treatments. The Wo treated carrots had a much superior core. The color of the stele was almost identical to the color of the cortex and the line of demarcation between the stele and cortex was hardly noticeable. The other two treatments, however, had cores which were more distinct, being lighter in color than the rest of the carrot. The line separating the stele from the cortex was also very distinct.
There was no difference, however, in the color of the cortex between treatments.

Since the stored carrots were only placed in paper bags, most of them showed some dessication and a few were slightly infected with rot. There were no visible differences, however, that could be attributed to irrigation treatment.

Since the W₁ treatment resulted in the best growth of carrots, the largest yields and the best taste of both raw and cooked carrots, it is apparent under the conditions of this experiment that soil moisture could drop to 35 per cent of field capacity before water was applied. The extra number of irrigations required for the W₂ treatment was definitely not warranted in this experiment since the results obtained from the W₂ sub-plots were nearly identical to the results obtained from the Wo or non-irrigated sub-plots.

Celery:

No particular difficulties were encountered with the celery transplants although a few plants had to be replaced. Slight damage was caused by rabbits but this did not appear to check the growth of the young transplants.

This was one of the crops which was seriously affected as a result of cut and fill in the first replicate and in one sub-plot in the second replicate. As stated previously, where subsoil was exposed to the surface, growth was very poor.
The W2 treated sub-plot in the first replicate appeared to be affected the most. Early in the season, the height of plants in this sub-plot was lower than the height of plants in the other two treatments of this replicate. Later, near maturity, the height of the W2 treated plants was still lower than the W1 treated plants but about equivalent to the Wo treated plants. In all treatments of this replicate, the height of plants grown on the low spots, which had been filled with topsoil, ranged from six to twelve inches higher than the rest of the sub-plot.

On the other two replicates, where the growth was more uniform, the W1 treatment resulted in the greatest height of celery plants, followed by the W2 treatment with the Wo treated plants being the shortest throughout the season. These results opposed those obtained by Janes (36) who found that celery plants were shorter when the soil moisture was maintained at 40 per cent than when maintained at 80 per cent of field capacity. Towards the end of the season a nearly complete ground cover was obtained on the irrigated sub-plots of the second and third replicate but a somewhat less ground cover occurred on the Wo treated sub-plots.

The color of the foliage on the W1 and W2 treated sub-plots became a light green shortly after each irrigation. A few days later, however, the color returned to its normal dark green color so that very little difference in the color of the foliage was evident between treatments. The plants
grown where subsoil was exposed to the surface became very yellow, especially late in the season near harvest time.

The celery plants were harvested on October 1, one hundred and fifteen days after transplanting into the field. They were weighed immediately without trimming. Since growth was variable in the first replicate and in one sub-plot in the second replicate, the plants grown on the topsoil, which included about ten plants, were kept separate from the poorer ones which had developed on subsoil.

The actual total yield per sub-plot was converted to hundredweight per acre (Table 12) and analyzed. There was no significant difference in yield between any of the treatments by doing the statistics in this manner. Yields from the W1 treated sub-plots, however, were much higher than the yields from the other two treatments. The Wo treatment produced the least celery.

TABLE 12: Yields and Pertinent Measurements of Celery Grown at Three Moisture Levels - Actual Data Per Sub-Plot.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield of Celery (Cwt/Acre)</th>
<th>Average Overall Length of Celery Plants (in inches)</th>
<th>Average Edible Length of Celery Stalks (in inches)</th>
<th>Average Stalk Diameter (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>156.98</td>
<td>16.9</td>
<td>10.5</td>
<td>.51</td>
</tr>
<tr>
<td>W1</td>
<td>310.85</td>
<td>25.3</td>
<td>14.8</td>
<td>.68</td>
</tr>
<tr>
<td>W2</td>
<td>230.83</td>
<td>20.4</td>
<td>12.9</td>
<td>.57</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>N.S.</td>
<td>3.36</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>
Since the yield per sub-plot of celery grown on subsoil was seriously lowered in the first replicate, only the data obtained from the better plants in each sub-plot was used in a second analysis of variance. These yields were corrected to sixty plants per sub-plot and subsequently converted to hundredweight per acre (Table 13). The analysis of variance again showed no significant difference between treatments. The \( W_1 \) treated sub-plots again outyielded the \( W_2 \) treated sub-plots which, in turn, outyielded the \( W_0 \) treated sub-plots.

**TABLE 13: Yields and Pertinent Measurements of Celery Grown at Three Moisture Levels - Corrected Data.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield of Celery (Cwt/Acre)</th>
<th>Average Overall Length of Celery Plants (in inches)</th>
<th>Average Edible Length of Celery Stalks (in inches)</th>
<th>Average Diameter Stalks (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_0 )</td>
<td>205.34</td>
<td>18.74</td>
<td>11.7</td>
<td>.57</td>
</tr>
<tr>
<td>( W_1 )</td>
<td>342.35</td>
<td>24.29</td>
<td>15.4</td>
<td>.71</td>
</tr>
<tr>
<td>( W_2 )</td>
<td>277.50</td>
<td>22.22</td>
<td>13.2</td>
<td>.64</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>N.S.</td>
<td>1.46</td>
<td>.25</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

A third analysis of variance (Table 14) was carried out using only the actual data obtained for the second and third replicates. This time a significant difference (5% level) in yield, similar to that found by Cannel et al. (9)
was found between treatments. Similar to their results, the yield data obtained in this experiment from the irrigated sub-plots were significantly higher than the yields from the non-irrigated sub-plots. There was no significance between the W1 and the W2 treatments, although higher yields were obtained from the W1 treated sub-plots.

TABLE 14: Yields and Pertinent Measurements of Celery Grown at Three Moisture Levels - Only Replicates 2 and 3.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield of Celery (Cwt/acre)</th>
<th>Average Overall Length of Celery Plants (in inches)</th>
<th>Average Edible Length of Celery Stalks (in inches)</th>
<th>Average Stalk Diameter (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>88.90</td>
<td>17.9</td>
<td>11.0</td>
<td>.53</td>
</tr>
<tr>
<td>W1</td>
<td>210.22</td>
<td>24.1</td>
<td>15.2</td>
<td>.69</td>
</tr>
<tr>
<td>W2</td>
<td>190.13</td>
<td>22.5</td>
<td>14.3</td>
<td>.64</td>
</tr>
<tr>
<td>L.S.D.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The same three methods of calculation were used on the subsequent data and will be referred to as the first, second and third analysis of variance in the remainder of this thesis.

The first (Table 12) as well as the second (Table 13) method of analysis indicated that there was a significant difference (5% level) in the overall length of celery between treatments. The overall length was considered to be the distance from the base of the stalks to the tip of the plant.
In the first case (Table 12), both the W₁ and W₂ treated plants were longer than the Wo treated plants but there was no significant difference between the W₁ and the W₂ treatment. In the second case (Table 13), however, there was significance (5% level) between all treatments. Plants grown on the W₁ treated sub-plots were significantly longer than those grown on either the Wo or W₂ treated sub-plots and plants grown on the W₂ treated sub-plots were significantly longer than those from the Wo treated sub-plots. There was no significant difference between treatments, as shown in Table 14, when only the second and third replicates were considered. The differences, however, showed the same trends as before. The W₁ treated plants were the longest followed by the W₂ treated plants, with the Wo treatment producing the shortest plants.

The edible length of the celery stalk which was measured as the distance from the base of the plant to the second node, did not vary significantly between treatments in the first (Table 12) or third (Table 14) method of analysis but did in the second analysis (Table 13) in which case there was a high degree of significance (1% level) between treatments. The W₁ treatment produced the longest edible stalk of celery, as expected from data mentioned previously, followed by the W₂ treatment and finally the Wo treatment.

The diameter of the stalk was also measured for a determination of the size of the edible stalks produced.
The width of the largest stalk three inches below the first node was the measurement used. As seen in Tables 12, 13 and 14, there was no significance found between treatments in any of the three methods of analysis used. In all cases, however, the largest stalks were found on plants from the W1 treated sub-plots. Plants receiving the Wo treatment were found to have the smallest stalks.

Since the stem diameters and the length of the celery plants were not significantly different between treatments in the third method of analysis, it was assumed that the significant increase in yields from the irrigated sub-plots resulted from an increase in each of these two factors (i.e., stem diameters and length of plants). Both the W1 and the W2 treated plants had longer stalks with larger diameters than plants receiving the Wo treatment.

A representative sample from each sub-plot was rated from one to three, as to taste, in an attempt to determine if irrigation treatment had any effect on quality. The sample from each W1 treated sub-plot rated one (superior) whereas the produce which had received the Wo treatment rated the poorest (three). The plants from the Wo treated sub-plots were very stringy whereas those from the irrigated sub-plots were much less stringy. Plants receiving the Wo treatment were also very strong and bitter to taste. Plants from the higher moisture treatment were also bitter although not as
noticeable as those from the non-irrigated sub-plots. The W1 treated celery was somewhat milder and a little sweeter than celery from both of the other treatments but not sufficiently mild and sweet to be pleasant tasting. Consequently, as a result of these undesirable tastes all the celery produced in this experiment would probably not have been marketable.

It was apparent that celery was a poor choice of plant material. The poor quality found in this experiment would suggest that celery should not be attempted as a commercial crop. It is apparent, however, that irrigation would be advantageous if varieties suitable to the area were developed.

Lettuce:

Unfortunately, no action was taken prior to transplanting lettuce on June 6, 7 and 8, to control wireworms and although these transplants established well, they became severely infested with wireworms six days later. The wireworms attacked the lettuce stems below ground level, burrowed into the center of the stem and ate their way to the apex of the plant. This seriously weakened and eventually killed the plants. The treatment with dieldrin, as stated previously, was apparently effective in controlling them. A few remained alive, especially those already in the lettuce stem, but their activity was practically nil after treatment. Dead and severely affected plants were replaced and no further damage was observed.
As a result of the short growing season of lettuce and the relatively few irrigation treatments applied (Table 9), no visible differences in height, growth or color was noted between treatments.

All plants appeared healthy until near harvest at which time a considerable amount of soft rot and bolting began to appear. These developed very rapidly and there were very few marketable heads (Table 15) at harvest time which was from July 26 to August 1 (forty-nine to fifty-four days after transplanting). The total yield from the three Wo treated replicates was fifty-seven marketable heads whereas a total of forty-six and forty-one marketable heads were obtained from the three W1 and W2 treated replicates, respectively. These differences, however, were not significant.

The remainder of the heads on these sub-plots were unmarketable (Table 15). The three sub-plots of Wo, W1 and W2 produced a total of 315, 328, and 329 unmarketable heads, respectively, although, as before, the differences were not significant. Any head which was evidently bolting, infected with soft rot or misshapen was considered unmarketable. The majority of these unmarketable heads, however, were infected with soft rot whereas there were very few misshapen heads and an intermediate number of heads bolted. Although the differences, as shown in Table 15, were not significant, there were approximately one and two-thirds more heads infected with rot from
the W₁ and W₂ treated sub-plots than from the Wo treated sub-plots. The number of heads bolting, also shown in Table 15, was about equal under each treatment with a few less on those plots receiving the W₂ treatment.

**TABLE 15:** Yield, Average Diameter and Number of Marketable and Unmarketable Heads of Lettuce Produce Grown at Three Moisture Levels.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield in Cwt/Acre</th>
<th>Average Diameter of Marketable Heads (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marketable</td>
<td>Unmarketable</td>
</tr>
<tr>
<td>Wo</td>
<td>19.93</td>
<td>102.20</td>
</tr>
<tr>
<td>W₁</td>
<td>17.87</td>
<td>104.71</td>
</tr>
<tr>
<td>W₂</td>
<td>16.82</td>
<td>93.58</td>
</tr>
<tr>
<td>L.S.D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% Level</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

Although the cause or source of this soft rot was not determined, it was believed that it may have been equivalent to the physiological disorder called brown rib or tipburn.
described by Jenkins (39). Brown rib, as described by him, developed in warm weather near maturity and often resulted in a type of soft rot. In this experiment, the environment was very warm throughout the season and the soft rot did not appear until near maturity.

Although other data are shown in Table 15, the very low per cent of marketable produce in this experiment precludes any further discussion on irrigation treatments. Brown rib or soft rot is apparently the limiting factor to head lettuce growing in this region.

Onion:

Onions emerged on June 11, two weeks after planting and a relatively even germination was obtained. All plants were fairly uniform in height until just prior to harvest, at which time the W₁ and W₂ treated plants were approximately four inches taller than the Wo treated plants. There was no difference, however, between the W₁ and W₂ treatments. It also appeared that a slightly denser stand of foliage was obtained on the W₁ and W₂ treated sub-plots than on the Wo treated sub-plots. The color of the foliage did not appear to vary between treatments during the early part of the growing season. Just prior to harvest, however, plants receiving the Wo treatment became a light green whereas the W₁ and W₂ treated plants were still dark green. In contrast to these results, Hawthorn (25)
found that opposite color differences between irrigated and non-irrigated onions occurred throughout the season and that the yellowish green color prevalent in irrigated onions resulted from a lack of nitrogen. The non-irrigated plants in this experiment, however, were obviously senescing since the plants were not only beginning to yellow but the stems were also starting to fall over. The irrigated plants, however, were still in a state of active growth and none of the stems were falling over. It was obvious from the lack of plant maturity that the planting date, which had to be delayed because of site preparation was much too late for this crop.

In spite of the fact that the W₁ and W₂ treated plants were not mature, all onions were harvested on September 25, one hundred and twenty days after planting since it was feared the crop would have been destroyed by frost if they were left in the field. The entire plant was weighed immediately and these data, referred to as the immature yields, are presented in Table 16. Although the W₁ and W₂ treated sub-plots out-yielded the W₂ treated sub-plots, the difference was not significant. These onions were subsequently cured, the tops removed and the onion bulbs weighed. These yields were referred to as mature yields and are also presented in Table 16. Again, the irrigated sub-plots showed a higher yield than the non-irrigated sub-plots, but, as before, the differences were not significant between any of the treatments, even though the W₁
treated sub-plots had a slightly greater yield. These results were in disagreement with five other workers (14, 15, 17, 55, 89) as well as with Jones and Johnson (40) who found that irrigation at the 60 to 80 per cent moisture level was most economical for the production of onions whereas irrigation at the 40 per cent level was detrimental to onion yields.

**TABLE 16: Yield and Diameter Measurements of Onions Grown at Three Levels of Soil Moisture.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield in Cwt/Acre</th>
<th>Average Equatorial Diameter (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immature</td>
<td>Mature</td>
</tr>
<tr>
<td>Wo</td>
<td>170.76</td>
<td>112.82</td>
</tr>
<tr>
<td>W1</td>
<td>218.39</td>
<td>118.92</td>
</tr>
<tr>
<td>W2</td>
<td>216.28</td>
<td>117.83</td>
</tr>
<tr>
<td>L.S.D. 5% Level</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

The average equatorial diameter of the onions from each treatment was identical. In each case, as shown in Table 16, the diameter averaged 1.92 inches.

No obvious differences, however, were noted in the flavor or texture of these onions (raw or cooked). These results were in agreement with results obtained by MacGillivray and Doneen (47) but did not agree with Erwin and Haber (17) who found that irrigated onions had a milder flavor and better color than non-irrigated onions.
No differences were observed when the onions were stored which was in contrast to results reported by Curry (14) as well as Janes and Drinkwater (37) who both found that irrigated onions had better keeping quality than non-irrigated onions. The onions in this experiment, although slightly dessicated at the end of the storage period in the spring of 1963, were still edible even though they had been held at a relatively warm temperature. No rotting occurred.

It should be remembered, however, the lateness of planting and subsequent lack of maturity may have seriously affected these results in this experiment.

Rutabaga:

The rutabagas in this experiment emerged on June 6, one week after planting. Very early, the young seedlings suffered from some flea-beetle damage, however, the dieldrin application apparently controlled them and no subsequent infestation was noted.

Rutabagas were similar to celery in that they too were seriously affected by cut and fill. The Wo, W1 and W2 treated sub-plots in the first replicate and the W2 treated sub-plots in the second replicate were the sub-plots most seriously affected. The better growth on those areas filled with topsoil only occurred on a five-foot section in each row. Growth on the remainder of the second and third replicates indicated
that plants on the irrigated sub-plots were much taller than those on the non-irrigated sub-plots. There was not too much difference, however, between the W1 and W2 treatments although the W1 treated plants were slightly taller. There was also a difference in ground cover. On both the W1 and W2 treated sub-plots, ground cover was complete about a month prior to harvest. The Wo treated sub-plots, however, never became completely covered with foliage not even by harvest. There was very little or no difference in ground cover between the W1 and W2 treatments in the last two replicates.

Considerably more wilting during the heat of the day was noted with this crop than with any other crop. Wilting was particularly severe on the Wo treated sub-plots with some on the W1 treated sub-plots. Although slight wilting was also noted on the W2 treated sub-plots, especially just prior to an irrigation treatment, it was by no means as severe as on the non-irrigated sub-plots.

Early in the growing season, there was no difference in the color of the foliage between the three treatments. Later, near maturity, however, there were differences. Those plants receiving the Wo treatment appeared to be a light greyish-green in color whereas plants on the irrigated plots were still a dark green, except just after an irrigation, at which time they became light green in color. Also near maturity, there were a large number of dead leaves on plants receiving
the Wo treatment whereas very few dead leaves were found on the W1 and W2 treated sub-plots. Consequently, it appeared that the irrigation treatments delayed the maturity of rutabagas.

The rutabagas were considered sufficiently mature to be harvested on September 6, one hundred days after planting. As stated previously, there was considerable variation in growth on all sub-plots in the first replicate and on one sub-plot in the second replicate. Consequently, data for the five-foot section of good growth was kept separate from the data for the remainder of the sub-plot. There were three methods of calculation similar to the methods used for celery.

Using the first method of analysis (actual yields), no significant differences in yields (Table 17) were found between treatments, although the yields from both the W1 and W2 treated sub-plots were higher than from the Wo treated sub-plots. Furthermore, the yields from the W2 treated sub-plots were slightly higher than from the W1 treated sub-plots. No significant differences in yields were found between any of the treatments by using either the second or third method of analysis (Tables 18 and 19, respectively). In both cases, the relationship between treatments was the same as for the first method of analysis. Although these yield results were similar to those reported by Stanhill (75, 76), he found significant yield increases with irrigation whereas no significance was found here.
TABLE 17: Yields and Diameters of Rutabagas Produced at Three Moisture Levels - Actual Data Per Sub-plot.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (in Cwt/Acre)</th>
<th>Average Equatorial Diameters (in inches)</th>
<th>Average Polar Diameters (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>181.02</td>
<td>2.93</td>
<td>3.43</td>
</tr>
<tr>
<td>W₁</td>
<td>334.06</td>
<td>3.69</td>
<td>3.85</td>
</tr>
<tr>
<td>W₂</td>
<td>340.98</td>
<td>3.70</td>
<td>3.92</td>
</tr>
<tr>
<td>L.S.D.</td>
<td></td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>5% Level</td>
<td></td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

TABLE 18: Yields and Diameters of Rutabagas Produced at Three Moisture Levels - Corrected Data

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (in Cwt/Acre)</th>
<th>Average Equatorial Diameters (in inches)</th>
<th>Average Polar Diameters (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>258.39</td>
<td>3.29</td>
<td>3.66</td>
</tr>
<tr>
<td>W₁</td>
<td>395.92</td>
<td>3.93</td>
<td>3.99</td>
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<tr>
<td>W₂</td>
<td>469.49</td>
<td>4.23</td>
<td>4.16</td>
</tr>
<tr>
<td>L.S.D.</td>
<td></td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>5% Level</td>
<td></td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>
TABLE 19: Yields and Diameters of Rutabagas Produced at Three Moisture Levels - Only Replicates 2 and 3.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (in Cwt/Acre)</th>
<th>Average Equatorial Diameter (in inches)</th>
<th>Average Polar Diameter (in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wo</td>
<td>121.05</td>
<td>1.94</td>
<td>2.35</td>
</tr>
<tr>
<td>W1</td>
<td>253.62</td>
<td>2.56</td>
<td>2.66</td>
</tr>
<tr>
<td>W2</td>
<td>302.08</td>
<td>2.82</td>
<td>2.81</td>
</tr>
<tr>
<td>L.S.D.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% Level</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

These yield differences are well illustrated in Figures 17, 18 and 19. These photographs also show the differences in size between the three treatments.

The largest average equatorial diameter was obtained from the W2 treated sub-plots whereas rutabagas from the non-irrigated sub-plots were the smallest and the W1 treated rutabagas were intermediate in size. This was evident regardless of the method of analysis used. None of these methods, however, indicated significance between any of the treatments. The data for each of the first, second and third method of analysis are shown in Tables 17, 18 and 19, respectively.

Similar results were obtained when the average polar diameters were considered. In all cases (Tables 17, 18 and 19), the rutabagas from the W2 treated sub-plots had the largest average polar diameter whereas the Wo treatment resulted in
FIGURE 17. Rutabagas - Wo Treatment at Harvest. Note Size and Yield. (September 6)

FIGURE 18. Rutabagas - Wl Treatment at Harvest. Note Size and Yield. (September 6)
FIGURE 19. Rutabagas - W₂ Treatment at Harvest. Note Size and Yield.  (September 6)

rutabagas with the smallest diameter and those from the W₁ treated sub-plot were intermediate, but again, the difference was not significant.

There was no difference between treatments in the thickness of skin. Rutabagas from all treatments had skins which measured approximately one-eighth inch in thickness. The color of the flesh was also nearly identical between all three treatments. In all cases, it was a typical whitish-orange to a whitish-yellow in color.

It was very difficult to determine differences in raw taste of rutabagas between treatments, but, it seemed that those from the W₁ treated sub-plots were slightly sweeter and not as bitter as those from the other two treatments. The
Wo treated rutabagas seemed to lack the sweetness and were also slightly more bitter than those from the irrigated sub-plots. None of the rutabagas had a woody texture and all were crisp and palatable. These observations opposed those made by Stanhill (75, 76) who found that irrigation treatment produced turnips with the smoothest texture, the highest moisture content and the mildest flavor.

The taste of cooked rutabagas followed the same trends. Those from the \( W_1 \) treated sub-plots were superior, being much sweeter and more tender than any of the others. Rutabagas receiving the \( W_2 \) treatment tasted flat and were not as sweet as those from the \( W_1 \) treated sub-plots. The Wo treated rutabagas were fairly bitter and not as sweet as those from either the \( W_1 \) or the \( W_2 \) treatment. There were still no differences in the color or texture of the flesh between treatments after being cooked.

The representative sample of rutabagas from each treatment, placed in cold storage (35 - 39°F) shortly after harvest, had sprouted somewhat by July 22, 1963, but they were still relatively firm. There were no obvious differences in their keeping quality which could be attributed to the three moisture treatments.

Although no statistical yield differences were found, the very obvious trends of higher yields under irrigation would suggest further work with this crop. Since there is
no difficulty of maturing rutabagas in this climate, it is possible that, with the soil variation removed, significant results could be obtained.

It is obvious from the results of this experiment that land leveling which will be necessary in many parts of Saskatchewan is going to severely affect the uniformity of production in the first year. It is assumed, with proper management, that these differences will be eliminated under subsequent rotation of cropping.
SUMMARY AND CONCLUSIONS

A furrow irrigation study with ten vegetables was initiated at the University of Saskatchewan, Saskatoon in the spring of 1962. Water for the irrigation of four of these crops, namely, beans, corn, peas and potatoes grown on a loam to a heavy clay loam soil was taken from the city water mains whereas the remaining crops, namely, cabbage, carrots, celery, lettuce, onions and rutabagas grown on a loam to sandy loam soil were irrigated with water obtained directly from the river. As well as a non-irrigated treatment, irrigation was applied at two levels. In one, the moisture was restored to field capacity when it dropped to the 70 per cent level and in the other, the moisture was allowed to reach the 35 per cent level before field capacity was restored by irrigation.

Analysis of yields from the crops on the heavier soil showed that irrigation was beneficial but indicated that the low irrigation treatment was sufficient for bean, corn and pea production whereas the high level of irrigation was most desirable for potatoes.

Primarily, increases in the yield of irrigated beans occurred as a result of an increase in the number of pods per plant and in the average weight per pod whereas increases
in the number of ears per plant and in the average diameter of the ear were responsible for the higher corn yields under irrigation. The superior potato yields resulted from an increase in the average size of tubers.

Although there was considerable variability in the lighter soil, it was found that carrots and celery produced higher yields under irrigation, with the low level of irrigation being most suitable. Similar, though not significant, trends were found for cabbage and rutabagas.

An increase in the equatorial diameter was primarily responsible for the higher cabbage and carrot yields whereas rutabagas had an increase in both equatorial and polar measurements. Although all celery was of poor quality, the longer and larger stalks were responsible for the yield increases.

The high incidence of soft rot in lettuce precluded any recommendations, whereas the lack of significant differences with onion may have been caused by a lack of maturity.

From the data presented herein, it is apparent that beans, carrots, corn, peas and potatoes respond to irrigation and can be successfully grown in Saskatchewan. Variability with cabbage, onions and rutabagas would suggest further work since they tended to respond to irrigation. Finally, celery does not appear to be suitable for commercial production in Saskatchewan and head lettuce under irrigation should be avoided until brown rib or soft rot can be eliminated.
LIST OF REFERENCES


## APPENDIX A

Total Yield of Marketable Produce per Treatment and per Replicate in the South Plot. (Cwt/Ac).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Treatment</th>
<th>Rep. 1</th>
<th>Rep. 2</th>
<th>Rep. 3</th>
</tr>
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<tbody>
<tr>
<td>Beans</td>
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<td>80.15</td>
<td>106.48</td>
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<td></td>
<td>(W_1)</td>
<td>212.19</td>
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<td></td>
<td>(W_2)</td>
<td>183.92</td>
<td>175.40</td>
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<td>Corn</td>
<td>(W_0)</td>
<td>61.0</td>
<td>50.1</td>
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<td></td>
<td>(W_1)</td>
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<td>165.5</td>
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<td>(W_2)</td>
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<td>Peas</td>
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<td>Potatoes</td>
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<td>(W_1)</td>
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<td>(W_2)</td>
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## APPENDIX B

**Total Yield of Marketable Produce per Treatment and per Replicate in the North Plot. (Cwt/Ac).**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Treatment</th>
<th>Rep. 1</th>
<th>Rep. 2</th>
<th>Rep. 3</th>
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<tr>
<td>Cabbage</td>
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<td>209.99</td>
<td>161.89</td>
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<td>198.92</td>
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<td>Celery</td>
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<td>Lettuce</td>
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<tr>
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<td>184.26</td>
<td>232.61</td>
<td>260.06</td>
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<tr>
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<td>317.55</td>
<td>201.90</td>
<td>194.06</td>
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<td>215.63</td>
<td>239.15</td>
<td>252.21</td>
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<tr>
<td>Rutabaga</td>
<td>W</td>
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<td>361.84</td>
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<td>935.38</td>
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