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Effect of irrigation on the potato

Innocent Agwatu

Iowa State University

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Effect of irrigation on the potato

by

Innocent O. I. Agwatu

A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
the Requirements for the Degree of
MASTER OF SCIENCE
Major: Horticulture

Approved:

Signatures have been redacted for privacy

Iowa State University
Ames, Iowa
1977
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>iii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF THE LITERATURE</td>
<td>3</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>19</td>
</tr>
<tr>
<td>RESULTS AND DISCUSSION</td>
<td>27</td>
</tr>
<tr>
<td>SUMMARY AND CONCLUSION</td>
<td>51</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
<td>54</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>63</td>
</tr>
</tbody>
</table>
DEDICATION

To Chukwuma D. Agwatu,
the pioneer and bulwark
of higher education in
the Agwatu family.
INTRODUCTION

Iowa's water source is scarce and expensive. Rainfall is frequently erratic. The growing seasons of 1975 and 1976 were dry with temperatures above normal in July-August. Consequently, interest in irrigation has accelerated to elucidate means of judiciously managing this limited resource to offset the year to year yield and quality variations of such crops as the potato, a cool season and drought sensitive crop.

To perform at its best the root zone of the potato crop requires near field capacity moisture conditions. Mounting evidence indicates that of the methods of irrigation practiced, the trickle system comes close to maintaining near field capacity conditions, and so has aroused considerable interest. With its capacity of small volume, frequent irrigation application through small orifices, the trickle irrigation system has enhanced yield production with higher water efficiency. The sprinkler irrigation system, on the other hand, wets the cropland to field capacity only once a week or so. Excess water is expended because some areas without roots or root extensions are also wetted to field capacity. Coupled with this, there is the obvious loss of water in the form of run-off and high pumping energy.

Irrigation enhances root growth and development. More root growth increases demand on soil nutrients and this calls
for higher fertilization. Nitrogen fertilizer is a landmark in this regard because it is the most universally deficient of the soil derived nutrients for plants. In recent years, there has been a steady increase in the use of nitrogen fertilizer to achieve maximum potato yields. Higher fertilizer costs have created a need for additional research dealing with fertilizer usage in potato production, especially nitrogen.

Although nutrients may be present in the soil in sufficient quantities, they may become unavailable for crop use because the surface soil, the location for most nutrients, may be dry. In such a situation, crops may start to show nutrient deficiency symptoms even before they start to exhibit moisture stress.

The primary objective of this study was to determine if there is any advantage of trickle versus sprinkler irrigation to satisfy water requirements for the production of fresh market potatoes in Iowa. A second objective was to investigate how management of fertilizer nitrogen changes with the trickle irrigation system.
REVIEW OF THE LITERATURE

Irrigation

Irrigation is the practice of supplementing natural precipitation by applying water to the soil with a view to preventing and/or correcting plant water stress (23).

Irrigation offers adequate moisture for the rapid growth and development of the potato crop and results in increased tuber yield (18, 26, 27, 28, 44, 81). Galien (28) and Lucke (48) have established that irrigation helps to keep down insect damage. Working on the effect of supplementary sprinkler irrigation on cut worm damage of potatoes, Lucke (48) found that not only did the irrigated plots out-yield the non-irrigated controls (23t/ha vs. 13.4t/ha); but also there was more reduction in tuber damage by cut worm in irrigated than in non-irrigated plots (15.1% vs. 44.6%).

The rate of consumptive use of water by the potato in any particular locality is probably affected more by temperature than by any other factor. Abnormally low temperatures retard crop growth and unusually high temperatures produce dormancy (41). Irrigation cools through water evaporation from the cropland and the plant canopy. Since the potato requires a cool micro-climate for optimum performance (13, 44, 70), irrigation of some sort is decidedly necessary. Peterson and Weigle (68) have
established that mist irrigation, in cooling the plant canopy, causes the stomates to stay open longer, and other factors being equal, photosynthetic intensity is enhanced and more carbohydrates are consequently translocated to the tubers. Further, they showed reduced transpiration rate to be associated with lower temperatures.

The amount of water utilized by the potato crop increases with rise in temperature (94). If rainfall is uncertain during this period of increased moisture need, irrigation serves as a good substitute. Phene and Sanders (70) pointed out that as far as possible, potatoes should be grown at temperatures averaging 70°F, so as to produce tubers with high specific gravity and high starch content. Higher temperatures delayed tuber formation and lowered tuber quality.

Although irrigation prolongs maturation of the potato, thereby allowing more time for tuber bulking, the dry matter and the total nitrogen content of the tubers are lowered (12, 79). Also, excessive irrigation enhances the incidence of secondary growth and hollow heart. Quite often, immature tubers, containing more reducing sugars and less starch, are produced when compared with tubers grown under natural rainfall conditions.

Peterson and Weigle (68) pointed out that under mist irrigation conditions, the specific gravity is increased
rather than decreased. Challaiah (13), sharing the above viewpoint, stated that more frequent irrigation increased the specific gravity of tubers. However, decreasing soil water potential increases the number of misshapen tubers (23, 39, 45, 70, 76). Such tuber shape defects have been attributed to moisture tension. Maintaining a non-fluctuating soil materic potential in the root zone would help to minimize growth defects.

Different types of irrigation systems, some new, others old, have generally been employed to the advantage of some crop plants. While economics is the guiding factor as to which system to employ, other factors such as the crop to be irrigated, the topography of the land and the operating environmental conditions need to be considered. Surface, furrow, mist, sprinkler, and trickle irrigation are some of the systems that are generally employed.

Sprinkler irrigation

Sprinkler irrigation system has been employed to a greater advantage than some other systems. In rotating sprinkler irrigation, water is broken up into fine drops, sprayed into the air and distributed over the ground. Water then proceeds into the root zone by infiltration and capillary action. The amount of water that actually infiltrates depends on soil type. By capillary action water tends to creep from one soil particle to another because of its
attraction to the surfaces of the soil particles. This attraction may be multi-directional--upwards, lateral, and downwards.

The sprinkler irrigation system has been credited with the following benefits--yield increases, keeping air temperature within the plant canopy below 80°F throughout the growing season (44, 62), and decreasing the percentage of tubers with *Streptomyces scabies*. However, this irrigation system has certain obvious short-comings which may seem to overwhelm some of its benefits. Such short-comings include excessive wetting of the cropland which may result in anaerobic situations and lots of run-off water. Krogman and Torfason (44) have observed that with low volume sprinkler, a deposit of salt may accumulate on the leaves. Crop growth is impaired because the salt-deposits have a tendency to absorb water and therefore pull water out of the leaves. Salt deposits on leaves also result in high amounts of certain micro-elements, which otherwise the crop would require only in very small amounts. Thus, saline water should not be used with the sprinkler irrigation practice.

**Trickle irrigation**

The trickle irrigation system is, at least for now, the newest system in irrigation technology. It has been given different names in different countries, hence one oftentimes encounters such synonymous names as "trickle" which
originated in England; "drip" in Israel; "daily flow" in Australia, and dibble irrigation (41). Although trickle irrigation has been employed in the greenhouse for several years, its use in the field on vegetable and orchard crops has evolved only recently. While other systems may aim at correcting water stress, trickle irrigation tries to tackle the stress problem before it ever arrives, tries to prevent it.

Proponents of trickle irrigation claim that it could produce higher yields, improve quality of production, decrease water usage, decrease pumping energy, increase fertilizer efficiency, and reduce labor costs. There is accumulated data on higher yields resulting from trickle than from sprinkler or any other irrigation systems (11, 65, 70, 93). Bucks et al. (11) have claimed that through application of small quantities of water at frequent intervals by trickle irrigation, in contrast to larger, infrequent water application by conventional irrigation methods, a possible savings of 50-90% in water requirements may result. Kenworthy (42) pointed out that frequent light irrigations can be applied to crop plants to keep moisture available in a limited root zone, 26 percent, without wetting the soil beyond the extent of the root system. Thus, only small portions of the soil volume are irrigated, surface evaporation is decreased, water movement below the root zone is reduced, all culminating in
higher irrigation efficiency.

Phene and Beale (71) working in the sub-humid coastal plains have reported that controlled high frequency trickle irrigation can be used to accurately regulate soil matric potentials in the root zone without inhibiting the oxygen diffusion rate in soil and to minimize plant water stress of sweet corn (Zea mays). Other workers (2, 5, 42, 80) feel that widely spaced tree crops and orchard crops utilize the trickle irrigation system to more advantage than row crops, and have concentrated their work on such high value crops. The trickle system is also reputed for its ability to utilize saline water for irrigation over and above the other systems (42). As the crop is watered, moisture tends to soak the soil unilaterally so that the salt is precipitated at the edge of the wetted zone. As soil moisture in each field varies from year to year, highest profits are seldom realized by irrigations timed by calendar alone. Available soil moisture has to be predicted. Trickle irrigation has proved efficient. Sprinkler irrigation can over-wet the plots thereby giving rise to standing water or temporary flooding, puddling soil and consequent compaction. When soils stay wet in this manner for a long period of time, plant growth might be delayed. Such soils may run the risk of having their nitrogen leached out. Although irrigation has a tendency to check the incidence of disease (28, 48) allowing
standing water may enhance the severity of disease. Excess moisture also promotes anaerobic conditions which promote the proportion of raised lenticels on tubers, a depressing external quality, an unsightly and unappetizing scene to consumers.

Different researchers have various ideas as to when to start irrigating potatoes. Exponents of pre-planting irrigation (72) claim that such a timing is of advantage in reducing clotting, improving soil structure, and eventually leading to increased yield. They advise that water should also be applied to the field soon after planting, to hasten seed germination. Werner (93), however, does point out the necessity for adequate moisture in the early season in order to produce large plants with large leaf area necessary for a good crop of tubers. Large tops have to be produced as early as possible so that much of the tuber crop can be produced during the cool weather of early summer. Large leaf area is necessary for the manufacture of carbohydrates needed to produce a big crop of tubers. If growth is checked early in the season by moisture deficits, plant size will be reduced and yield will be correspondingly low. It is desirable, therefore, to have soil sufficiently moist at all times to assure growth at a continuous rate.

Other workers (26, 29, 33, 60, 61) examining morphological development stages of the potatoes, have found that
water consumption in potatoes is highest at the time the crop is fifty days old, or at flowering, stolon or tuber formation stage, depending on the planting date. During this stage, the potato is particularly sensitive to inadequate moisture supply. Similarly, Garay (29) demonstrated significantly higher yields with irrigation begun some fifty days after planting than with irrigation started seventy days after planting. Fuehring (27) has even observed that tuber yields increased with increase in number of irrigations during tuberization and tuber growth. Moisture stress applied to potato plants during early tuber set period increased the percentage of malformed tubers having pointed stem ends, bottle necks, and dumb-bell shapes, although total yield and grade of tubers was not significantly affected.

Evaluating the soil moisture content before switching on irrigation, Ivins and Milthorpe (33) felt that best results were obtained if irrigation water was applied when 50% of the available soil moisture had been used from the top 12 or 18 inches of soil. In so doing, the soil moisture content was brought back to field capacity or close enough, for optimum crop performance. Working on the same subject, Nyc (64) and others (66) pointed out that when the optimum soil moisture content is 75-80%, potatoes do not require irrigating as total yield, grade or tuber quality were not affected.

Irrigation needs of potatoes can be predicted by
moisture tensiometer readings, when the first symptoms of moisture stress are observed, or when indicated by a soil moisture budget involving estimated evapotranspiration. Comparing the above methods Dubetz and Krogman (20) and Krogman and Torfason (44) have confirmed that the moisture tensiometer method is the best of the three while evapotranspiration method is better than moisture stress procedure.

Although irrigation is a very useful practice, it is not desirable to continue to irrigate when its utility value starts to decline. One should stop irrigating as soon as potatoes are mature. Irrigating beyond this point would cause soil around the tubers to be wet, a situation which may induce poor tuber shapes and/or raised lenticel formation on the tubers. This, no doubt, helps to lower the quality of the tubers.

Lakes, dams, wells, streams, and springs have been in the past employed as sources of irrigation water. Although there have been no comparative studies of the above sources, it is however known that while trickle irrigation system can cope with saline water, sprinkler irrigation or any of the other systems cannot. Sprinkling with saline water causes leaf burn and reduced production, even though drip irrigation with same water causes no problem (6).
Nitrogen Fertilizer

Wilcox and Hoff (96) demonstrated that nitrogen fertilization of potatoes for early summer harvest yield and quality is determined by the number and size of tubers produced. The effect varies between localities and is probably due to differences in the growing season, temperatures, and light intensity. Gerdes et al. (32) and other workers (15, 72) claim that applied nitrogen promoted early potato top growth through increased branching, leaf number, and expansion. Potassium and phosphorus are known to enhance leaf expansion while phosphorus also aids in increased meristematic activity (72). Consequently, greater foliage is produced which could mean more photosynthetic area and activity leading to more carbohydrate manufacture, and culminating in greater translocations to the primary sink, tubers. Mineral nutrients are also known to affect the rate of dry matter production, chiefly by changing leaf area (15). As a result, the total dry weight yields of crops with different nutrient supply are closely related to the size of the leaf area, the seat of active photosynthesis and the basis for yield increases.

Nitrogen has been shown to increase the number of tubers set by allowing for the survival of tuber initiates and increasing the average tuber size by enhancing their rapid development (21, 34). Also, high rates of mineral fertilizer,
especially nitrogen have been shown to increase crop moisture content (22).

While some researchers (24, 49, 58, 59, 66, 73, 91, 95, 96) attribute N fertilization to increased scabiness, scurf, percentage of cracked tubers, and lowering of dry matter content of tubers, others (3, 12, 27, 30, 45, 58, 59, 66, 87, 91, 95) have found that nitrogen not only increases total tuber yields and the percentage of grade one tubers but also increases the nitrogen content of both foliage and tubers. Foliar nitrogen has been established to reflect the amount of applied nitrogen. The total nitrogen content of fresh tubers has also been shown to be directly and linearly related to the rate of nitrogen applied. Since these findings reflect ultimate yield increases, many growers tend to apply luxury levels of nitrogen. Unfortunately, however, not only do they waste nitrogen by so doing, they also create ideal conditions for tuber malformations, and lowering of specific gravity, chip quality, and storage life of the tubers produced. In addition, excess nitrogen can delay tuber initiation and can unduly prolong leaf area duration, thereby delaying crop maturity (59, 88).

Soltanpour (83) looking closely at the nutritional requirements of potato at different stages of development has established that maximum uptake of nitrogen occurred 60 to 90 days after planting; that nitrogen should be plentiful at
this stage of growth and not be depleted for several weeks; that maximum uptake by tubers occurred later in the season and that nearly all of this nitrogen is translocated from the vines. Investigating the effects of whole versus split nitrogen application Dimitov (17), working with alluvial meadow chernozen soil, has shown that all nitrogen applied at planting accelerated growth and tuber formation more than a split application. He also stated that these were more true of early than late cultivars. Svensson et al. (87), while not rejecting the foregoing concept, state that split applications with late supplementary dressings helped to increase the uniformity of tuber size, a necessary quality factor to consumers. Furthermore, split nitrogen application has been encouraged with croppings under irrigation or whenever a long season cultivar is involved, with or without irrigation. It has also been claimed that delay in harvesting early summer potatoes increases the effects of applied nitrogen by producing higher yield (1, 72). While some reports (12, 91) accept that no significant differences are obtained whether fertilizers are banded or broadcast, Painter and Augustin (66) point out that banding fertilizer produces more tubers having growth cracks, culls, and reduced yield of number ones when compared with broadcasting. Differing from the foregoing view, Vitosh (91) reports that banded and side-dressed nitrogen were more efficient than broadcast
nitrogen plowed down prior to planting.

Although the amount of fertilizer may well depend on soil type and its fertility status coupled with operating environmental factors, many growers tend to apply more nitrogen to early (spring) potatoes than to late (fall) potatoes because this element is usually less available early in the season. Evaluating the economic limits of nitrogen fertilization of potatoes, Gerdes et al. (32) have arrived at the economic rate of 150 kg N/ha. Such a nitrogen level produced greater leaf persistence, increased total yields with higher dry matter content, and increased yield of number one potatoes, as opposed to lower or higher levels of nitrogen. In a similar but separate research (12), economic level of nitrogen rate for potato production has been shown to be 180 kg N/ha.

Nitrogen fertilizer sources are variable, hence, nitrogen can be supplied to potatoes in a variety of forms, including ammonium nitrate, urea, potassium nitrate, ammonium sulphate, ureaform, calcium nitrate, anhydrous ammonia, and sodium nitrate. Some sources have proved more advantageous than others. Vitosh (91) has shown that equal yields were obtained with all nitrogen sources and that specific gravity was not affected, but that continued use of these nitrogen fertilizers would create soil pH problems which would ultimately affect tuber yield and specific gravity.
Lorenz and Johnson (47), in a comparative study of nitrogen source effect on potato production on a slightly alkaline coarse-textured soil in California, have reported that ammonium sulphate was much better than calcium or sodium nitrate for growing of potatoes. While some reports (77) have stated that potatoes, pineapples, and young stages of some cereals grow better on ammonium, others (10) point out that the ammonium ion would be detrimental to the growth and development of the potato plant and so conditions which favor the persistence of nitrogen in this form should be avoided.

Some nitrogen sources no doubt do tend to have apparent intermediate advantages over others, but the end product may well be the same. Slow release fertilizers as sulphur coated urea, for instance, are too costly to be applied to any economic advantage since the ultimate yield does not balance out the high costs.

Irrigation vs. Nitrogen

Irrigation and nitrogen fertilization separately or in combination are accepted practices that enhance potato production. In recent years, nitrogen fertilizers have been added as a variable to irrigation trials. Irrigation and nitrogen complement each other and, in fact, applications of low rates of nitrogen fertilizer in irrigation water lead to
increased yield. Fertilizing with nitrogen under irrigated conditions increases the reliability of the crops by enabling them to utilize more nitrogen, especially with long season cultivars, and leads to significant yield increases and percentage of large sized tubers when compared with fertilized but unirrigated plots (1, 32, 59, 81). Abel's data (1) show that in the dry regime, yields of potatoes receiving 336 kg N/ha were not significantly higher than those receiving only 56 kg N/ha under irrigation conditions. Irrigation, therefore, increases the efficiency of applied nitrogen. Also, fertilizing with 150 kg N/ha increased the dry matter content of the tubers from 18.1% to 22.1% while lower or higher fertilizer rates produced no significant difference (90). Mosley's data (58) show that under unirrigated conditions, nitrogen rates above 112 kg/ha are not economical while under irrigated conditions, up to twice the above rate or even more is still economical. Irrigating with nutrient solution has been credited with the advantage that the crop under such a system is being provided with its nutritional requirements at the time of need. Nitrate fertilizer, in such circumstances, would leach directly into the soil and would be almost immediately utilized via the roots. Evaluating the nitrate-nitrogen concentration of tissues of potatoes grown and fertilized under irrigation conditions, Carter and Bosma (12) have reported
that the nitrate-nitrogen concentration of the tissues were directly related to the level of applied nitrogen. However, when more water was applied at each irrigation, nitrate-nitrogen concentration of the tubers was less than at the lower level of applied water at each nitrogen rate. The nitrate-nitrogen concentration was even further reduced by the highest irrigation water level or by the application of nitrogen fertilizer in the slowly available form.

The loss of nitrogen is related to the amount of water percolating through the soil. High rainfall or excess irrigation early in the season when evapotranspiration (evaporation from soil plus transpiration from plants) is minimal can lead to loss of considerable amounts of nitrogen. However, if much of the nitrogen has been leached below the top two feet of soil, a side-dress application of nitrogen applied through the irrigation system may be very beneficial. Vitosh (91) has found that 125 kg N/ha applied at planting time was nearly sufficient for maximum production with the normal irrigation treatment. However, with excess irrigation, an additional 168 kg/ha of side-dress nitrogen would be required to obtain the same yield (92).
MATERIALS AND METHODS

The experimental site was the Iowa State University Horticulture Experimental Station, some ten miles northeast of Ames, Iowa. The soil type is Clarion-Nicollet loam with high water-holding capacity of 5 to 10%. A split plot design replicated four times was used, with treatments randomized within plots and subplots. The main plot consisted of three irrigation levels: check (natural conditions), sprinkler irrigation, and trickle irrigation. The subplots were three nitrogen fertilizer rates, 67, 135, and 202 kg/ha. At planting 112 kg/ha of phosphate (P₂O₅) and 112 kg/ha of potash (K₂O) was broadcast and incorporated into the experimental plots. The objective was to raise the soil level of these nutrient elements which tested low in available phosphorus (28 kg P/ha) and available potassium (162 kg K/ha). The soil pH was 7.05.

Certified seed of the long season Kennebec potato cultivar was procurred. Tuber seed pieces were cut to two ounces. This was achieved by using whole tubers of about this size and larger tubers cut to two-ounce sizes. Small, whole tubers saved labor for cutting, were less likely to rot in the ground, would not lose viability through bleeding and
drying, thereby giving better stand establishment. Tubers large enough to be cut in half were cut lengthwise. Tubers large enough for three, two-ounce pieces were cut, one piece off the stem end, while the remaining portion was split lengthwise. When it was necessary for a tuber to be cut into four pieces, the first cut was lengthwise followed by a crosswise one. This system of cutting was adopted because block-shaped pieces provide the minimum area of cut surface of a given weight of a seed piece. Less cut surface is desirable to avoid soil rot organisms. Preservation of the seed piece is important because sprout development is dependent upon it, and the young plant draws upon it for essential food material until it is a foot or more tall (94). Each seed piece has to have at least one eye (or bud) and two eyes was judged to be convenient, to assure sprouting. The prepared sets were then dusted with captan, a fungicide, to guard against rot organisms that could reduce sprouting vigor.

The seeds were planted on April 28, 1976 when the temperature had warmed up considerably (Table 1). Each row was 6.1 m long with seed pieces at 30.5 cm apart in the
row resulting in about twenty plants per row. Row spacing was 1.2 m. The depth of planting was about 7.5 cm. There were three rows per plot, but only the middle row was used for data collection and analysis. Weeds were controlled by cultivation and a pre-emergence application of Linuron (Lorox) two weeks after planting (May 11, 1976). Cultivation was discontinued as soon as the plants came into full bloom and the rows were closing up. At this time plants were hilled.

By June 1, 1976, crop establishment was excellent and two-thirds of the nitrogen rates were side-dressed using ammonium nitrate (34-0-0) approximately three inches to the side of each row and two to three inches deep. Before the stand filled in (June 23), the final one-third nitrogen application was side-dressed. In June a weekly, general, spray program of insecticides and fungicides was applied for the rest of the growing season.

April was a wet month and although May was not as wet (Table 1), the soil moisture content was still adequate for crop growth. By late June (after the full fertilizer rate had been applied), there was still a scarcity of
Table 1. Monthly rainfall and average temperatures during growing season of 1976

<table>
<thead>
<tr>
<th></th>
<th>Temperature (degrees F)</th>
<th>Rainfall (inches)</th>
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<tbody>
<tr>
<td></td>
<td>Deviation from Normal</td>
<td>Deviation from</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td>Normal</td>
</tr>
<tr>
<td>April</td>
<td>53.7</td>
<td>5.66</td>
</tr>
<tr>
<td></td>
<td>+4.3</td>
<td>+2.50</td>
</tr>
<tr>
<td>May</td>
<td>59.0</td>
<td>2.97</td>
</tr>
<tr>
<td></td>
<td>-1.5</td>
<td>-1.52</td>
</tr>
<tr>
<td>June</td>
<td>69.2</td>
<td>5.74</td>
</tr>
<tr>
<td></td>
<td>-0.3</td>
<td>-0.03</td>
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<tr>
<td>July</td>
<td>74.7</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>+1.1</td>
<td>-2.33</td>
</tr>
<tr>
<td>Aug.</td>
<td>71.4</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>-0.6</td>
<td>-3.38</td>
</tr>
<tr>
<td>Sept.</td>
<td>66.0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>+1.9</td>
<td>-3.28</td>
</tr>
</tbody>
</table>

aData reported from weather station, Ames, 8WSW.

rainfall. The plants were attaining full foliage and were flowering profusely. Tuberization had started. Maximum evapotranspiration losses had started to occur and would continue through July to August. Irrigation was therefore necessary from the end of June through the remainder of the season.

The trickle irrigation system, controlled by an automatic electric time clock and solenoid valves, was set to water the field evenly for ninety minutes each day, starting about noon when the temperature for the day was nearing its maximum. Irrigating at this time had a
cooling effect on the soil. The trickle system afforded application of water to the row crops through small orifices or emitters spaced 30.5 cm and designed to discharge water at the rate of 0.38 gallon per minute per 100 feet (or 30.5 m) row. Water was delivered to the orifices through plastic main and submains generally laid on soil surface. The rate of discharge was determined by the size of the orifice and the pressure in the pipelines. The complete trickle system included a 200-mesh screen for removing suspended particles from the water. Under the foregoing conditions, one inch of water was applied per week per acre. This worked out to be 30,000 gallons of irrigation water per week per acre of 283,590 l/ha.\(^1\) The sprinkler irrigation system supplied the same amount of water per week as the trickle irrigation system, but was applied once a week. The sprinkler system was switched on about noon when the temperature for the day was approaching maximum. Cooling of both the potato plants and the entire crop land was achieved. This effect could have been marked if the sprinkler system was switched on daily as was the case with Peterson and Weigle (68). Irrigating about noon, contributed to the cool microclimate the potato requires for optimal performance. Under such situations, the stomates remainder open for longer

\(^1\) 1 gallon/acre = 9.453 liters/hectare.
durations of time, thereby probably enhancing photosynthetic activity and promoting yield.

The plots continued receiving irrigation water at the prescribed rates until the tubers reached maturity. Irrigating beyond this stage was no longer economical. Irrigation was withheld after the first week of September. Tubers are of better cooking quality and are in better condition for harvesting if there was a slight moisture deficiency at harvest.

Leaf samples were taken on July 6, July 20, and August 3, 1976. These sampling dates coincided with 69, 83, and 97 days after emergence. Characteristically, leaf samples were taken at bloom on July 6. This, together with the biweekly sampling interval, were consistent with the sampling procedures of earlier workers (30, 67, 76). The plants were at about the 8-leaf stage at first sampling time. The first, whole (compound), mature, fully expanded leaf, generally judged to be the fourth or fifth from the shoot apex, was selected at random from five plants throughout each plot of some twenty plants. Altogether, five leaf samples from five different plants
were taken per plot. The samples were placed in paper bags, dried at 70°C in a forced air oven for 48 hours, and ground to pass through a 20-inch mesh screen (sieve) in a Wiley mill. The total nitrogen concentration of the samples was then determined by the micro-Kjeldal method.

Harvest took place on September 29, 1976, 154 days after planting. This period was consistent with other researches carried out with the long season Kennebec potato cultivar. At that time the tubers were mature and had attained their optimum starch content. More than 50% of the leaves had dried off and the stems had begun to do so. As the experiment was situated on a loam soil, there was fear of rain which would hamper harvest due to prolonged wet soil. After digging they were manually graded into the conventional U.S.A.'s, U.S.B.'s, and culls by passing them through screens. Potato tubers designated as U.S.A. are those that are greater than 1 7/8 inches (4.76 cm) in diameter. The U.S.B. class are those tubers that are less than 1 7/8 inches (4.76 cm) in diameter. The culls were made up of undersized tubers and larger tubers that were malformed, had secondary growths and cracks, or that were highly infected by hollow heart or scab. Sunburn was not included as one of the diagnostic characters of the culls.
The specific gravity of the tubers was determined to compare the percentage solids of the different treatments. Since the determination of solids by the laboratory method based on the loss of moisture after drying was not fast enough and had proved a costly exercise, an alternative way, the specific gravity method, was adopted to obtain a good estimate of total solids. The procedure requires the weight of sample in air and then in water. Hydrometer method uses direct comparison of weights in air and water. Tubers for specific gravity determination were representative of all locations in each plot; they were random samples with respect to size U.S.A., and were strictly clean (no soil sticking on them). Such measures were taken because soil on tubers would tend to raise the specific gravity reading while hollow heart disease, for example, would tend to lower it. The potato hydrometer method, devised by the American Potato Chip Institute, gives a direct specific gravity reading. Exactly eight pounds of potato tubers were weighed in air and placed in a basket (of known weight) suspended below the hydrometer. The assembly with the potatoes was then placed in a container of water, deep enough to float it. The specific gravity was then read directly from the scale on the hydrometer.
RESULTS AND DISCUSSION

For all the traits measured, the interaction between irrigation methods and nitrogen rates was not significant. This indicates that potatoes would respond to different nitrogen rates the same way with irrigation water application by sprinkler or trickle method or without irrigation. Similarly, potatoes would respond to different irrigation methods independent of fertilization (Table 2).

Variations in stand count were not significantly different (Table 3). Variations in stand count from one plot to the other were, if anything, minor. Differences in vegetative and/or tuber yield traits cannot, therefore, be attributed to plant population. Neither the irrigation types nor the nitrogen fertilizer rates influenced standability at any stage of plant development.

Irrigation

Yield

The analysis of variance for yield traits are consigned in Table 2. Although the total tuber yield of the different irrigation treatments was not significantly different the trickle irrigated plots tended to yield better than the sprinkler irrigated ones (Fig. 1 and Table 4).

The total tuber weight was then separated into U.S.A. and U.S.B. grades, and cull weight (Table 4). Though not
Table 2. Analysis of variance for yield traits (kg/ha) of Kennebec potato grown at the Horticultural Experimental Station, Ames, Iowa, 1976

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>M.S.</th>
<th>PROB F</th>
<th>M.S.</th>
<th>PROB F</th>
<th>M.S.</th>
<th>PROB F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>2</td>
<td>231147636</td>
<td>0.0704</td>
<td>22850360</td>
<td>0.5437</td>
<td>3577171.4</td>
<td>0.0332*</td>
</tr>
<tr>
<td>Blocks</td>
<td>3</td>
<td>33060337</td>
<td></td>
<td>42888040.4</td>
<td></td>
<td>7201467.5</td>
<td></td>
</tr>
<tr>
<td>Error A</td>
<td>6</td>
<td>54235869</td>
<td></td>
<td>25285181.4</td>
<td></td>
<td>563635.6</td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>2</td>
<td>2413855</td>
<td>0.9136</td>
<td>6649744.9</td>
<td>0.6378</td>
<td>2324299.2</td>
<td>0.1953</td>
</tr>
<tr>
<td>I * NR</td>
<td>4</td>
<td>1549741</td>
<td>0.9905</td>
<td>3896075.2</td>
<td>0.8896</td>
<td>101969.3</td>
<td>0.9851</td>
</tr>
<tr>
<td>Error B</td>
<td>18</td>
<td>26760931</td>
<td></td>
<td>14163257.2</td>
<td></td>
<td>1303273.7</td>
<td></td>
</tr>
</tbody>
</table>

*a Total tuber weight.

*b U.S.A.

*c U.S.B.

*d Total marketable weight.

*e Total marketable percent.

*f Cull weight.

*g Specific gravity.

* Significant difference at 5% level of probability.
<table>
<thead>
<tr>
<th>M.S.</th>
<th>PROB F</th>
<th>M.S.</th>
<th>PROB F</th>
<th>M.S.</th>
<th>PROB F</th>
<th>M.S.</th>
<th>PROB F</th>
</tr>
</thead>
<tbody>
<tr>
<td>42342982.5</td>
<td>0.3341</td>
<td>207.354</td>
<td>0.1496</td>
<td>78467090.2</td>
<td>0.0423*</td>
<td>0.000047</td>
<td>0.0743</td>
</tr>
<tr>
<td>20613451.2</td>
<td>88.228</td>
<td>12848014.9</td>
<td>0.000008</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31940119.2</td>
<td>78.311</td>
<td>13984422.2</td>
<td>0.000011</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1718731.8</td>
<td>0.9019</td>
<td>14.079</td>
<td>0.6559</td>
<td>2461007.9</td>
<td>0.6488</td>
<td>0.000017</td>
<td>0.1685</td>
</tr>
<tr>
<td>3094067.1</td>
<td>0.9407</td>
<td>48.043</td>
<td>0.2432</td>
<td>6960276.3</td>
<td>0.3156</td>
<td>0.000004</td>
<td>0.7199</td>
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<tr>
<td>16641621</td>
<td>32.008</td>
<td>5452744.7</td>
<td>0.000008</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Table 3. Analysis of variance for four plant vegetative traits of Kennebec potato grown at three levels of irrigation and three levels of Nitrogen fertilizer at the Horticultural Experimental Station, Ames, Iowa, 1976

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>M.S.(^a)</th>
<th>PROB F</th>
<th>M.S.(^b)</th>
<th>PROB F</th>
<th>M.S.(^c)</th>
<th>PROB F</th>
<th>M.S.(^d)</th>
<th>PROB F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>2</td>
<td>3.0278</td>
<td>0.2398</td>
<td>0.8424</td>
<td>0.0747</td>
<td>0.6516</td>
<td>0.1056</td>
<td>0.2401</td>
<td>0.6159</td>
</tr>
<tr>
<td>Blocks</td>
<td>3</td>
<td>4.5185</td>
<td>0.2645</td>
<td></td>
<td></td>
<td>0.7958</td>
<td></td>
<td>0.2450</td>
<td></td>
</tr>
<tr>
<td>Error A</td>
<td>6</td>
<td>1.6574</td>
<td>0.2045</td>
<td></td>
<td></td>
<td>0.1950</td>
<td></td>
<td>0.4511</td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>2</td>
<td>0.1944</td>
<td>0.7622</td>
<td>0.4455</td>
<td>0.0339</td>
<td>0.4431</td>
<td>0.0339</td>
<td>1.7930</td>
<td>0.0014 **</td>
</tr>
<tr>
<td>I * NR</td>
<td>4</td>
<td>1.6111</td>
<td>0.0958</td>
<td>0.0521</td>
<td>0.7546</td>
<td>0.06424</td>
<td>0.8403</td>
<td>0.0400</td>
<td>0.9181</td>
</tr>
<tr>
<td>Error B</td>
<td>18</td>
<td>0.6944</td>
<td>0.1094</td>
<td></td>
<td></td>
<td>0.1828</td>
<td></td>
<td>0.1759</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Standability.

\(^b\) Leaf Nitrogen on July 6.

\(^c\) Leaf Nitrogen on July 20.

\(^d\) Leaf Nitrogen on August 3.

* Significant differences at 5% level of probability.

** Significant differences at 1% level of probability.
Table 4. Planned comparison for six tuber yield traits of Kennebec potato summed across three levels of fertilizer nitrogen at the Horticultural Experimental Station in Ames, Iowa, 1976

<table>
<thead>
<tr>
<th>Irrigation Method</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>28564</td>
</tr>
<tr>
<td>Sprinkler</td>
<td>32270</td>
</tr>
<tr>
<td>Trickle</td>
<td>37308</td>
</tr>
</tbody>
</table>

Check vs. Irrigation: n.s.  n.s.  --*  n.s.  --*  n.s.
Sprinkler vs. Trickle: n.s.  n.s.  n.s.  n.s.  n.s.  n.s.

*Significant difference by t-test at 5% level of probability.
Figure 1. Tuber yields (total and marketable) of Kennebec potato grown under three irrigation levels at the Horticultural Experimental Station, Ames, Iowa, 1976
Figure 2. Effect of different irrigation methods on total yield, marketable yield, and cull weight of potato tubers
significantly different, the weight of U.S.A. tubers was highest under trickle irrigation and least under conditions of no irrigation.

With respect to U.S.B. tubers, trickle irrigated plots increased size B tubers 33% over the non-irrigated controls. All other treatments were not significant.

The yield of culls seemed to follow the same pattern as the yield of U.S.B. tubers. Trickle irrigation increased cull weight 76% over the check and 26% over sprinkler irrigation (Table 4, Fig. 2). Definitely, therefore, it is not just irrigation but rather trickle irrigation that is affecting these two tuber yield traits.

Similar to the findings of Krogman and Torfason in southern Alberta, Canada (44), the yield and quality of potatoes differed little whether sprinkler or trickle irrigated. In addition, there were no significant yield differences between the sprinkler irrigated plots and those left under rain-fed conditions. It does appear, therefore, that altering the aerial environment of the plants for a few hours per week in addition to replenishing soil moisture by sprinkling was inconsequential.

Even though sprinkler cooling once a week probably lowered the air temperature and evidently lowered leaf tissue temperature during the hot weather, yield differences among treatments means were small, when compared to check and
trickle irrigated plots. Although yields under sprinkler irrigating once a week were neither superior to those obtained with trickle frequencies and amounts, nor to those from check plots, the trend, however, preferentially indicates trickle, sprinkler, and check.

Peterson and Weigle (68) working at Muscatine, Iowa reported that sprinkler cooling applied daily between 11 a.m. and 4 p.m. whenever the temperature rose above 85°F, increased yield and quality of potatoes in two years when temperatures were near or above normal but produced no increase in one year when temperatures were below normal. Also, Sanders and Nylund (79) reported that in Minnesota, low volume sprinkling increased yields over non-irrigated plots only when temperature stress was rated high. Krogman and Torfason (44) working in southern Alberta, Canada, found that high temperature stress on the aerial parts of the plant was not a limiting factor in potato production as long as soil moisture was in good supply. Compared with the foregoing data from the present research indicate that the temperatures during the growing season were near or above normal (Table 1), that there was no incidence of moisture stress (as observed from the aerial parts of the plants) and that the soil moisture continued to be in good supply. These nonwithstanding the yield and quality gains of the sprinkler irrigated plots were not significantly different from those
of the plots left under rain-fed conditions only. This is probably so because of the high night temperatures in Iowa compared to those of other potato growing regions.

Large plants, warm summer and wet soil surface contribute to high consumptive use of water. These conditions occur during the middle of the growing season of potatoes. If the soil moisture in the root zone is depleted to near wilting point, malformed tubers may result. Total yield may decrease, coupled with decrease in yield of No. 1 tubers. As potatoes approach maturity, lower moisture levels will not harm yield or grade; however, soil moisture should not be depleted to the point where tubers may start dehydrating. More research needs to be conducted to determine the minimum soil moisture level during the maturity of the potato crop. Soil moisture level during the final days of the potato growing season is an important factor to be considered by potato growers as the amount of water in the root zone at maturity can affect the yield and quality of the crop.

The water holding capacity of the soil is the water held in the soil between wilting point and field capacity. Most agricultural soils have a water-holding capacity between 0.25 and 2.5 inches per foot of soil and Werner (93) has shown that potatoes procure more than 65% of their water requirement from the top foot of soil and about 25% from the second foot. So, as the potato plant grows, the
total amount of water available to it increases as the roots penetrate deeper into the soil. Also, Painter and Augustin (66) have shown that yield and grade of tubers did not vary significantly where supplementary irrigation water was applied when available soil moisture reached 65, 75, or 85%.

The specific gravity values are shown in Table 4. When compared, the tubers from the trickle irrigated plots gave the lowest specific gravity values while those from the check plots gave the highest. The sprinkler irrigated treatment yielded tubers with specific gravity values intermediate between the trickle irrigated and the control plots. Although these specific gravity differences were not significant, they however did depict a trend, namely, that the higher the soil moisture level, the more the tendency to lower the specific gravity of the tubers produced. These findings tend to agree with those of Sanders and co-workers (79) who had established that tubers from mist irrigated treatment tended to be lower in dry matter content than those from the non-irrigated controls. It seems probable that the higher levels of soil moisture during the season resulted in reduced dry matter content. Similarly, working on sweet potatoes at Baton Rouge, Louisiana, Roysell and co-workers (75) had found that as soil moisture levels increased, there was a significant
decrease in percent dry matter content of the sweet potato roots produced.

However, Krogman and Torfason (44) researching at Alberta, Canada reported significant differences between the specific gravity values of tubers from potato plots subjected to conventional irrigation of every seven days or so during July and August and only when the soil moisture suction exceeded a certain value, and those irrigated daily to offset the evapotranspiration of the previous 24 hours. The different methods of scheduling of irrigation by these workers is worthy of note. It needs to be stated, too, that the specific gravity values of potato tubers obtained in Canada under similar situations as the present study were relatively higher (1.095) when compared to values from the present work (Table 4) possibly because of the northernly location of Canada.

It should also be noted that Peterson and Weigle (68) have reported dry matter increases when potatoes grown in sand were mist-irrigated.
Leaf Nitrogen

Plant analysis is rapidly becoming a meaningful tool for better understanding of plant nutrition. Leaves were sampled and analyzed for their nitrogen content. This was done with a view to elucidating whether or not nitrogen supply was adequate to satisfy crop growth rate. Also as irrigation was a main treatment in this trial, the possibility of nitrogen leaching loss would not be ruled out. If nitrogen supply was found to be inadequate, then there would be time enough to apply supplementary nitrogen to the potatoes to utilize during the same growing season.

The different irrigation methods did not significantly affect percent leaf nitrogen at all stages of plant growth and development (Table 3). These results were at variance for the three irrigation treatments and showed no definite trend or pattern with the different irrigation levels. However, there was a tendency for percent leaf nitrogen to increase to a peak at mid-season of crop growth and thereafter to decrease (Table 3, Fig. 3). These findings are similar to those of Sanders et al. (78) who stated that leaves from different irrigation treatments did not differ consistently in their levels of total nitrogen and other nutrients; that the total nitrogen content of the leaves declined after attaining a peak, no matter the irriga-
Figure 3. Effect of irrigation method on leaf nitrogen content taken at different stages of development of Kennebec potato plants.
tion method and that this event occurred as the plants matured.

Nitrogen Rate

The analysis of variance for the tuber traits as they were affected by nitrogen fertilization is shown in Table 2. Kennebec potatoes did not respond to nitrogen fertilizer application (Fig. 4). However, the studies indicate a trend toward increased yields with increasing nitrogen rates up to 202 kg N/ha. These data are consistent with findings of Mosley (58) who worked on a sandy loam soil in Ohio but under non-irrigated conditions. It does appear therefore that the clarion-nicolet loam soil on which the present study was carried out was inherently rich enough in nitrogen to the extent of being able to support a crop of potatoes without recourse to supplementary heavy nitrogen application.

Maximum production of U.S.A. tubers and total marketable tubers occurred when ammonium nitrate was applied at 135 kg N/ha (Table 5). At this rate of fertilization also, the cull weight was the least. Although the highest nitrogen level, 202 kg N/ha yielded the greatest amount of U.S.B. tubers, the second nitrogen rate (135 kg N/ha) would still be preferred since with that rate of application the cull weight was kept down relative to total marketable weight. The total marketable percentage was also highest by
Figure 4. Tuber yields (total and marketable) of Kennebec potato.
Table 5. Effects of Different Nitrogen Levels on Yield, Grade, Tuber Size, and Sp. Gr. of Kennebec Potatoes, Ames, Iowa, 1976

<table>
<thead>
<tr>
<th>N-Rate kg/ha</th>
<th>Total Wt. kg/ha</th>
<th>U.S.IA</th>
<th>U.S.IB</th>
<th>Total Mktable Wt. kg/ha</th>
<th>Total Percentage</th>
<th>Culls</th>
<th>Sp.Gr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>67</td>
<td>32379</td>
<td>18875</td>
<td>4084</td>
<td>22955</td>
<td>71</td>
<td>9419</td>
<td>1.083</td>
</tr>
<tr>
<td>135</td>
<td>32539</td>
<td>20312</td>
<td>3400</td>
<td>23690</td>
<td>73</td>
<td>8849</td>
<td>1.084</td>
</tr>
<tr>
<td>202</td>
<td>33223</td>
<td>19259</td>
<td>4221</td>
<td>23480</td>
<td>71</td>
<td>9743</td>
<td>1.082</td>
</tr>
<tr>
<td>LSD.05</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td></td>
</tr>
</tbody>
</table>

LSD.05 not significant at the 0.05 level.
fertilizing at 135 kg N/ha. It may, therefore, neither be pertinent nor economical to apply nitrogen fertilizer under the conditions of this experiment or similar, at any rates greater than 135 kg N/ha. This figure is close enough to the 112 kg N/ha obtained under non-irrigated conditions by Mosley (58) and 180 kg N/ha found by Carter and Bosma (12), thereby making allowance for losses that may occur under irrigated conditions—leaching, denitrification, etc. Hence, the level of nitrogen required to produce a good crop of potatoes is usually applied, adding a little extra for possible losses that might occur. Also, the Idaho Fertilizer Guide recommends a nitrogen rate of 135 kg N/ha (120 lbs/acre) for potato production.

The rate of nitrogen to be used may at times depend on the grade of potatoes desired by the grower. If the grower has a good market for very large (U.S.A.) tubers it seems as if he has to strike a comfortable mean between the two higher rates. If, however, he desires only U.S.B., he undoubtedly has to go in for the 202 kg N/ha rate and/or reduce the spacing between plants.

The data showing the response of Kennebec potatoes to different nitrogen treatments do show that fertilizing with nitrogen for maximum yield may result in production of low grade tubers with undesirable characteristics for the fresh market or processing.
Increased nitrogen rates did not show any consistent pattern with respect to tuber specific gravity. The variations were, in fact, not significant (Table 5) although a slight decline appears to be evident at 202 kg N/ha. Earlier workers, Carter and Bosma (12), Mazur and Rzasa (49) and Painter and Augustin (66) have however, established that increased nitrogen rates decreased tuber specific gravity. It is to be noted that these foregoing workers not only sited their experiments on a different soil type (silt loam) from the present studies, but also applied much higher rates of nitrogen fertilizer. In addition, Toshkhodzhaev (89) has come up with a definite rate of 150 kg N/ha increasing tuber dry matter content from 18.1% to 22.1%. It is to be noted that from the data obtained from the present study (Table 5) tubers obtained from nitrogen fertilizer rate of 135 kg N/ha (which is close enough to 150 kg N/ha) gave a higher specific gravity value when compared to a lower or higher nitrogen rate.

Working on chernozemic soil (Cavendish sandy loam) in Canada and without irrigation, Dubetz and Bole (19) had shown that in their study specific gravity was not influenced by the relatively high levels of nitrogen and phosphorus.

Nitrogen fertilization has some influence on percent leaf nitrogen. Leaf nitrogen content reflects the amount of applied nitrogen. Higher nitrogen rates increased percent leaf nitrogen. These findings are consistent with the
results of earlier workers, Gardner and Jones (30), Mosley
(58), Painter and Augustin (66), and Soltanpour (83).
However, these influences appear to be limited to the early
and late stages of plant development (Fig. 5, Table 3).
Percent leaf nitrogen was relatively low early in the
season, recorded a peak at about mid-season, and decreased
rapidly as the season progressed and the plants matured
(Table 3). From early to mid-season, potato builds up the
nitrogen contents of its leaves only to translocate these
later to enhance the development of the tuber initiates. The
same fertilizer rate (135 kg N/ha) gave the highest total
marketable tuber weight (Table 5) and the greatest leaf
nitrogen content. It does appear, therefore, that applying
nitrogen fertilizer at any rate greater than 135 kg N/ha,
under the conditions of the present study should not be
encouraged. Also, with the lowest level of applied nitrogen,
percent leaf nitrogen content declined rapidly over the
season. This result is similar to the findings of Gardner
and Jones (30).

The application of 135 kg N/ha resulted in what may be
regarded as adequate percent leaf nitrogen throughout the
season, since a higher rate of nitrogen did not increase
leaf nitrogen. However, Gardner and Jones (30) working on
a similar subject at Idaho arrived at a figure of
202 kg N/ha. This higher figure could be probably
attributed to Idaho soils being more deficient in nitrogen than Ames soils or more nitrogen being lost on account of poor management, denitrification, leaching, etc.

Percent leaf nitrogen at early season through bloom (peak vegetative state) contributes to correlating leaf sampling dates and total yield. Hence, early and mid-season samplings are considered more accurate for predicting the nitrogen status of the potato plant (30, 58). Not only are they more reliable for predicting yield response to nitrogen fertilization, but they will often allow time for applying additional nitrogen fertilizer for use by the current crop, if the need is detected at these early sampling dates. If the total nitrogen content falls below a sufficiency level, an application of nitrogen is needed in order to avoid reductions in yield. With care and experience, percent leaf nitrogen can be used as a guide to more efficient use of nitrogen fertilizers in potato production.

In growing potatoes for chip manufacture, emphasis should be placed on cultural practices that produce tubers of maximum solid content. High solid content is especially important in growing potatoes for chips because the yield of chips is in direct proportion to their solids content. Also, chips made from potatoes of high solids content absorb less frying oil than those made from potatoes of low solids content. Tubers with high sugar content in place of starch
Figure 5. Effect of Nitrogen rates on leaf nitrogen content taken at different stages of development of Kennebec potato plants.
are indicative of physiological immaturity and such tubers produce dark-colored chips. Light-colored chips are much more preferred by consumers. Potato growers can similarly have a range of purposes for their potatoes; these include baking, mashing, cooking, or boiling. Some are even much more concerned with the production of certified seeds. Depending on the grower's particular purpose, he will be able to draw from the array of established cultural practices to suit his needs.

Looking closely at the need for irrigating potatoes from the crop standpoint, one would easily appreciate that potato, *Solanum tuberosum* L. is a herbaceous dicotyledonous annual, though sometimes regarded as a potential perennial because of its ability to reproduce vegetatively by means of tubers. With its above-ground stem herbaceous and erect in the early stages of development and later becoming spreading and prostrate or semi-prostrate, the potato canopy contributes to effective ground cover so that transpiration and not evaporation is more of the case in point. Also, the herbaceous succulent and fleshy nature of this crop aids in water conservation. Furthermore, observations during the course of the experiment showed that the potato plants never exhibited any signs of wilting whether temporary or permanent, the relative high temperatures and the intense sunshine notwithstanding. This goes to show that the crops
did not suffer from any moisture stress. The foregoing observations were true of all the irrigation treatments. It might be worthwhile, however, to add that mist or dew served as a source of moisture to the crop plants and that these were not measured. It would appear also that the plants were able to procure enough moisture from the early season rainfall to satisfy the yield levels obtained from the Clarion-Nicolet loam soil on which the experiment was sited.

A close look at the nature of the soil on which the experiment was carried out might perhaps be able to elucidate some other factors concerning irrigation and fertilization of potatoes. The principal soil series was Clarion-Nicolet resulting in a loam texture. Clarion is internally well-drained and Nicolet somewhat poorly. The experimental plots were able to retain a high percentage of moisture from the early season rainfall so much so that the effect of irrigation was not very pronounced. Poor drainage also raised problems of nitrogen losses by denitrification.

Irrigation of potatoes could be encouraged on sandy loam soils. It may not be that economical to irrigate potatoes grown on heavy soils with high clay content. However, the present work indicates that if need be at all, potatoes grown on heavy soils should be trickle and not sprinkler irrigated. In any event, one has to weigh the economics of applying such an expensive but efficient system
to such a low value crop as the potato. It does, however, not stand to be questioned that trickle irrigation has been profitably employed to other high value vegetable crops, fruit trees, and sugar cane.

Well-drained sandy loam soils produce crops with higher solids than heavy clay or poorly drained soils. Total solids are higher in potatoes grown on mineral soils than on muck or peat soils. Soils of low fertility (as a result of no fertilization or low rates of fertilization) often yield small crops, though their quality may be high. However, current agricultural competition does not permit growers with low yield to remain in business.
SUMMARY AND CONCLUSION

Irrigation could be a crucial input to potato production. Since water is crucial to the physiological processes of crops and considering that plant life evolved in an aqueous medium, this is not surprising. Irrigation is an important cultural practice and can be controlled by the potato grower. Knowledge of good irrigation practices is important as soil moisture levels can affect yield, grade, and resistance of tubers to bruising and certain diseases. It is important that the potato grower be aware of the relationship of water to his crop and soil, so as to obtain the best economic return. Although yield and water use efficiency of trickle irrigated potatoes were not significantly greater than those of the check and sprinkler irrigated plots probably because of the soil type on which the trial was conducted, similar trials conducted on sandy and sandy loam soils have shown these differences to be significant. Further work needs to be done to determine the most efficient method of water application for various types of soil in order to gain most from irrigation.

With increased concern over pollution and our environment, it becomes necessary to control the amount of nitrogen fertilizer application to agricultural crops, as nitrogen is the nutrient that is most suspect in contributing to pollution. This is so because the increased use of nitrogen
in the past few years, and in most cases in amounts greatly in excess of crop needs as one strives to maximize yields. Secondly, nitrogen is so highly mobile in the soil, moving through the profile in nitrate form alongside with water and accumulating and concentrating between the top 12 to 18 inches of soil by the end of the growing season.

Kennebec potatoes grown in a loamy soil in Ames requires 135 kg N/ha to produce a desirable yield of tubers. However, if the grower prefers U.S.B. tubers at the expense of U.S.A. and total marketable tubers, then applying 202 kg N/ha would be appropriate. The amounts of nitrogen in excess of the 135 kg N/ha adequate rate or actual needs of the potato did not contribute to increased yield or quality of potato tubers. If anything, they could be detrimental by contributing to pollution hazard and/or slightly lowering tuber specific gravity.

Relatively low yield levels were obtained from this study. This is probably not unusual for Iowa where the night temperatures are relatively high. If the trial were sited where the night temperatures were cooler, more nitrogen and more soil moisture would have been utilized by the potatoes and yield levels would have been relatively high.

In Iowa, potatoes are raised in Muscatine for early summer harvest, so as to earn high market values. To this end, only early-maturing or short-season cultivars (example
Norland, Superior) are grown. Muscatine soil is typically sandy. It not only warms up faster than other soil types in spring but also is an ideal soil for potato culture. These situations make high yield expectations of growers to come true. On the average the grower of long season Kennebec in Iowa is not reaping much profit unless his cropland is in northern Iowa on peat or muck land.

As this study was carried out for only one season, a repeat of it is desirable in order to confirm the results so far obtained. In doing so, it may be necessary to incorporate both early- and late-maturing cultivars.

Since potato is the "bread of the poor" and the demand for it is elastic, it would be worthwhile to carry out a number of studies with both short and long season cultivars on different soil types, utilizing various irrigation methods to establish the best culture for the potato crop under a given set of conditions.


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