5-1977

An Evaluation of Using In-Field Evaporation Pans to Schedule Irrigation on Potatoes

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Recommended Citation

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AN EVALUATION OF USING IN-FIELD EVAPORATION PANS TO SCHEDULE IRRIGATION ON POTATOES

by

Michael J. Tremblay

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Soils and Biometeorology
(Soil Science)

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1977

ACKNOWLEDGEMENTS

I wish to express my utmost appreciation to those who helped me attain this degree. My thanks to David Stoll, who initiated the idea of applying to USU and to Dr. James L. Taylor who recommended me to the Soil Science Department and gave patient and unending moral support.

I would sincerely like to thank Dr. R. J. Hanks, the committee and Department Head for his unselfish patience and guidance. His unwavering faith in me fostered my own self-confidence and his advice was invaluable. I would also like to thank D. W. James and H. H. Wiebe, my committee members, for their patience and advice.

My office partners, Jim Wolf and Vel Sorenson gave moral support and generally made life more enjoyable. Steve Zsiray was considerable help in teaching me how to use the Wang.

Recognition and many thanks goes to Sandy Gillies for her patience and determination in deciphering my writing and typing my thesis.

Finally, I wish to thank the two people who essentially made all of this possible.

I wish to thank my father, A. Todd Tremblay, one of the innovators of farm consulting in Idaho, for introducing the field to me. His support is evidenced by the freedom he gave me in working for his company while simultaneously researching my thesis.

My wife, Connie, showed me the same understanding and support during this period of my schooling as she had during all my years of school. This undertaking at USU would not have succeeded without her assistance.

Michael J. Tremblay

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

ABSTRACT

An Evaluation of Using In-Field Evaporation Pans to Schedule Irrigation on Potatoes

by

Michael J. Tremblay

Utah State University, 1977

Major Professor: Dr. R. J. Hanks
Department: Soil Science and Biometeorology

This research project was undertaken to determine if an evaporation pan would accurately predict evapotranspiration when placed in an actual irrigated field situation. Two potato fields in Southern Idaho with different micro-climates and soil types were used in this study. The in-field evaporation pan method was compared with the gravimetric method and the Jensen-Haise and modified-Penman climatic methods. Yield and quality responses were evaluated by varying the amount of sprinkler-applied water so that three distinct moisture regimes were evaluated. It was also necessary to evaluate recent crop coefficient (K_c) curves on potatoes to see if the K_c values predicted evapotranspiration (Et) accurately when related to the evaporation pan or climatic methods.

The results showed that the in-field evaporation pan method predicted Et as well as or better than the climatic methods. During July and August, the evaporation pan reading times a K_c of 0.95 predicted Et extremely well when compared with measured actual Et. Crop coefficient curves were developed for both fields by dividing measured actual Et by the evaporative pan reading. The two K_c

curves were very similar for the entire growing season. Established K_c curves did not predict actual Et with accuracy or consistency.

Yield and quality was definitely correlated with the amount of applied water. The dry moisture regime for both fields received 37 percent less water than the normal plots (which were watered to gravimetric and evaporation pan depletion levels) and resulted in a yield reduction of 34 percent. The quality (percent number one potatoes) was decreased by about 50 percent with reduced water.

(79 pages)

INTRODUCTION

Since the amount of tillable land in the world is limited, increases in yield per acre are needed to meet an increasing food demand. World production of potatoes was 330.6 million tons in 1972 second only to grain in total tonnage (Martin et al., 1976). However average yield is only about 230 cwt. per acre in the U.S. in Southern Idaho. With proper soil and environmental conditions up to 600 cwt. can be produced (Wright and Jensen, 1974; Painter and Augustin, 1976). Potato production is particularly difficult because of the extreme sensitivity of the plant to moisture stress. Delaying an irrigation by 48 or even 24 hours in some cases may lower yield or seriously affect the quality (Robins et al., 1967). Since the potato tuber is the product marketed, appearance is of crucial importance for maximum profits. Proper soil moisture control and fertility are some of the factors that can be managed to promote maximum yields and quality (Thompson and Kelly, 1956).

With the advent of modern irrigation systems soil moisture control for potatoes has been considerably refined. Determining when to irrigate and how much water to apply are very important goals of good irrigation farm management. These goals can now be attained with sprinkler systems. However these goals are not always properly approached because of (1) lack of knowledge on how to schedule irrigations by the farmer or (2) lack of proper moisture measuring devices or (3) lack of time or incentive. The average farmer can be advised on when to irrigate and how much to apply only in extremely simple language, preferably requiring neither calculations nor delicate equipment (Linacre and Till, 1969). Thus many farm management services have developed to convert technology into easily understood farm irrigation management suggestions.

Two general methods are employed for irrigation scheduling: Direct soil moisture monitoring and evapotranspiration (Et) monitoring. Soil moisture monitoring requires measurement of soil water content and matric potential changes in the soil with water content. When a pre-determined soil water content or status is reached, depending on the crop, stage of growth, etc., then irrigation water should be added to bring the soil back to field capacity. Gravimetric soil measurements, tensiometers, gypsum blocks, neutron probes and calcium carbide bomb methods have all been used to estimate the soil water content or potential to predict when and how much to irrigate (Pair, 1975).

Et monitoring consists of multiplying a crop coefficient (k_c) by the measured or calculated Et potential (Et_p) to get a predicted Et actual (Et_A) value. The predicted Et_A represents the total amount of soil water that the soil is losing to the combined effects of evaporation and transpiration. The predicted Et_A values can be directly related to soil moisture depletion if the amount of available water holding capacity of the soil is known, provided irrigation, rain and drainage are known also. Climatic estimators, lysimeters, and evaporation pans are some of the common methods for Et monitoring.

Little information is available concerning the use of in-field pans to schedule irrigations. The in-field pan has several advantages: (1) it reflects the specific microclimate of the field in question,

(2) it has low initial cost and maintenance and (3) it measures both input from irrigation and rain and output from evaporation. The main disadvantages are: (1) that each field has to be monitored separately instead of on a broad scale as is done with the climatic methods, (2) a crop coefficient needs to be applied to relate Et_p to Et_A, so that error can occur if the right k_c is not used, (3) problems may arise from faulty pan readings because of human or animal interferance with the pan, (4) excess irrigation water application may cause the pan to overflow, (5) rapidly growing foliage can grow over and into the pan and (6) improper pan siting can cause faulty readings.

In an actual field situation, irrigation input from the sprinkler system fills the pan to the desired level needed to refill the soil moisture reservoir, then after irrigation is shut off is depleted by evaporation until a pre-determined amount of water is lost from the pan before turning the water on again. This reflects the amount of available water lost from the soil profile through Et after a k_c depending upon stage of growth is applied. Wolfe and Evans (1964) reported using in-field pans on irrigated pasture to catch applied sprinkler water. The pan evaporation represented the amount of soil water depletion. When the pan had evaporated one-half of its depth then irrigation water was applied to fill the pan to the point of overflowing. They claimed that this procedure could be adapted to other crops by adjusting the depth of water that could be depleted. This specific case is the only example of using an in-field pan to schedule irrigations under sprinkler irrigation that was found in the literature.

This concept of using in-field pans for measurement of soil water depletion was adapted for use on potatoes in 1973 by Magic Valley Enterprises, Inc., an Idaho agricultural consulting firm. This present study was proposed to evaluate the in-field pan method for scheduling irrigation for potatoes.

OBJECTIVES

The main objective of this study was to evaluate the reliability of scheduling irrigations by using in-field pans. More specific sub-objectives were:

1. To determine the correlation between E-pan and Et_A during different stages of growth.

2. To determine the relation between water use efficiency and potato crop production (tuber set, yield, and quality) with varying moisture levels.

3. To compare the E-pan method with gravimetric and climatic methods of irrigation scheduling.

LITERATURE REVIEW

Soil Moisture Control for Potatoes

Salter and Goode (1967) have grouped the factors affecting water relations of plants and their growth and yield response into four groups as follows:

1. Soil factors: Soil water content, texture, structure, depth, salinity, fertility, aeration, temperature and drainage.

2. Plant factors: Type of crop, density and depth of rooting, rate of root growth, aerodynamic roughness of the crop and drought tolerance.

3. Weather factors: Sunshine, temperature, humidity, wind and rainfall.

4. Miscellaneous factors: Soil volume and plant spacing, crop and soil management factors.

Long days, high temperatures, high amounts of nitrogen fertilizer and a uniform moisture supply favor rapid growth of plants and prolong the growing season. Days of intermediate length, cool temperatures, and ample nitrogen and soil moisture favor maximum tuber growth (Martin et al., 1976).

The potato plant is a shallow rooted plant with 70 percent of its roots in the top foot of soil, thus it is very sensitive to moisture stress (Kunkel, 1957). The potato plant is very specific in its moisture needs. Adequate soil moisture throughout the entire growing season is needed for maximum yields (Singh, 1969).

For maximum production, soil moisture must be maintained in a range that permits absorption of the water by the roots at a rate comparable to Et losses (Pair, 1975). Reducing crop Et by decreasing the irrigation supply or extending the irrigation interval beyond the period during which soil water is freely available to the crop is particularly critical during times when the crop is sensitive to water stress. Some crops, such as potatoes which are grown for fresh weight production, are sensitive in any period of growth to prolonged water stress conditions. At any time soil water stress may have a lasting effect and could drastically reduce yields (Robins et al., 1967; Jensen et al., 1970; Doorenboos and Pruitt, 1975).

When water deficits occur, greatest water loss is from the growing tissue of the potato plant. Rapidly developing tissues, specifically the tuber, is hurt by water deficits. Water stresses cause the growth processes to proceed abnormally by upsetting the internal water balance of the plant tissues (Gates, 1968).

Steineck (1958) defined three definite stages of potato growth which are very sensitive to moisture stress. The first stage is that of stolon formation (8-10 leaf) which takes place about 2-3 weeks after emergence. Adequate soil moisture is necessary for a maximum number of stolons to develop. The second stage of tuber setting, which occurs 4-5 weeks after emergence, requires constant adequate moisture so that each stolon will set on a tuber. The third stage of tuber growth lasts from tuber formation until maturity. This stage is decisive in determining the individual tuber weight and size. Moisture stress or interrupted growth during this stage will cause undersize, malformed tubers.

Nelson and Hwang (1975) include a fourth stage of senescene and tuber ripening. This final stage is characterized by a marked reduction in water use primarily because of lower transpiration and loss of functioning foliage. Overirrigation in this stage can reduce yield because of water rot. Thus irrigation amount and frequency should be reduced. The soil should be allowed to dry out more than in the previous stages.

Most authors agree that moisture stress during the stolonization and tuberization stages has a greater effect on yield and quality reduction than late season moisture stress (Thorne and Petersen, 1954; Corey and Myers, 1955; Ohms, 1961; De Lis, 1964; Haddock et al., 1974). The poor quality is attributed to a higher percentage of malformed tubers having pointed stem ends, bottlenecks and dumbell shapes. Yields are reduced because maximum tuber size is reduced (Painter et al., 1975; Painter and Augustin, 1976). Specifically, the first irrigation is designated as the most important in determining quality and yield by Ohms (1961) and Larsen (1963).

Thompson and Kelly (1956) and Robins and Domingo (1956) blame the problem of tuber abnormalities on a widely fluctuating moisture supply in which tuber regrowth occurs after dry soil conditions. If the soil moisture is low then the cells will mature. A sudden soil moisture increase will cause enlargement at the growing tip while the older portion will remain stunted. Tuber malformations and cracking will result.

High soil temperatures can also cause tuber malformations. Light frequent irrigations are recommended by Corey and Myers (1955) to help keep the temperature at a lower level. Specific gravity, important in processed potatoes, was markedly increased by increasing the frequency of irrigations (Corey and Myers, 1955 and Haddock, 1961).

Bradley and Pratt (1955) found that a high moisture level resulted in better top growth, earlier tuber set and a greater net tuber weight than lower available moisture levels. The greater foliage growth caused increased carbohydrate production which led to increased tuber size.

Low soil moisture reduced total vine growth and delayed canopy closure by about 20 days (Corey and Myers, 1955 and Enrödi and Rÿtema, 1961). The reduced foliage development will cause less carbohydrate production which will cause decreased tuber size.

Most of the older literature has specified that the soil moisture should never fall below about 50 percent available (Cykler, 1946; Jacob et al., 1952; Bradley and Pratt, 1954, 1955; Blake et al., 1955; Corey and Myers, 1955; Fulton and Murwin, 1955; Ohms, 1961; Prince and Blood, 1962; Struchtemeyer et al., 1963; Dunton, 1968; and Singh, 1969).

However, more recent workers have suggested that 65 percent available soil moisture is the level at which to irrigate (Jensen and Middleton, 1970; Dubetz and Krogman, 1973; Haddock et al., 1974; Painter et al., 1975; Painter and Augustin, 1976).

Some authors have claimed that highest yields were obtained when soil water depletion was never allowed to drop to less than 80 percent available (Kunkel, 1957; Jones and Johnson, 1958; Hobbs et al., 1963). However a recent extensive study (Painter and Augustin, 1976) found no difference in total yield, grade or tuber quality when irrigating at 75 or 85 percent available instead of 65 percent.

With increasing use of sprinkler irrigation there is a need to determine more precisely the amount and frequency of irrigation on a potato crop (Blake et al., 1955; Jensen et al., 1970). In areas of relatively high evapotranspiration (0.25 to 0.35 inches per day) this may necessitate irrigating every two or three days on a coarse-textured soil and every three to four days on medium-textured soils (Robins et al., 1967).

The best irrigation frequency for potatoes is a function of the irrigation system, consumptive use rate, soil water holding capacity, maximum and minimum soil depletion and the water extraction patterns of the plant (McMaster, 1969).

What is good irrigation management?

A good irrigation scheduling scheme should be able to predict when to irrigate and what quantity of water to apply before any plant stress has occurred which will reduce yield and quality of the crop (Jensen, 1972; Taylor and Ashcroft, 1972). Technical competence of the fieldman and close, personal communications with the farmer are essential for proper irrigation management.

Even with modern irrigation systems, water is not applied at an application uniformity of 100 percent (Pair, 1973). Some part of the field will be underirrigated and some parts of the field will be overirrigated. Thus irrigations should be applied to satisfy the average moisture requirements of the entire field. After irrigations are applied, the field should be checked to see that irrigation has been adequate in refilling the soil water reservoir (Jensen et al., 1970; Pair et al., 1973).

An estimate of applied irrigation should be attained from sprinkler irrigation "catch cans" or the in-field pan. When this is related to soil water depletion, drainage or underirrigation can easily be determined.

Two primary goals of increased net income and greater water use efficiencies should be realized by a farmer who seeks the aid of an irrigation management service (Jensen, 1972).

Gravimetric method of irrigation scheduling

To determine the actual soil water content of the soil, the gravimetric method is generally used. This method is simple and accurate if proper soil sampling and handling of the sample is practiced. For an accurate soil moisture sample, samples should be taken from several field locations and immediately be stored in airtight containers until the soil can be weighed and dried in the lab. This method is commonly used to figure soil water depletion.

It is convenient to convert the gravimetric measurements (θm) to available soil water content per two feet of soil. Two feet is assumed the effective rooting depth for potatoes. Available moisture = percent moisture at field capacity minus percent moisture at the permanent wilting point times the bulk density of the soil times the rooting depth. To illustrate the procedure the following example is given. The soil has a FC of 10 percent, a pwp of 4 percent and a B.D. of 1.4 g/cm^3. Available moisture per two feet of soil = $(.10-.04) \times 1.4\ g/cm^3 \times 24$ inches = 2.02 inches. Irrigations are designed to take place when a pre-determined percent depletion level is reached.

With this example a 45 percent depletion level is used as follows: 2.02 inches x 0.45 = 0.91 inches of water that can be depleted before the next irrigation.

The soil water budget equation was used to determine Et_A. The equation is:

$$Et_A = I + Re + D - Wd,$$

where I = irrigation, Re = rainfall, D = soil water depletion in inches of available water, and Wd = drainage. Since irrigation and rain and depletion were measured in the field and drainage was estimated, Et_A could be determined. Water applications in excess of estimated soil moisture depletion is assumed lost to drainage.

The number of days before the next irrigation for the gravimetric and E-pan methods was estimated from the remaining soil moisture (depending on the time period from the previous irrigation) that could safely be depleted for each field and the expected average Et. The equation for this (from Jensen et al., 1971) is:

$$N = \frac{Do-D}{\overline{Et}}$$

where N = the estimated number of days until the next irrigation is needed; Do = the maximum depletion of soil moisture allowed for the present stage of growth; D is the estimated/measured depletion of the soil moisture from application of E-pan prediction or actual gravimetric measurements; and $\overline{Et}$ = the expected average Et figured from past E-pan values.

Evaporation pan method of irrigation scheduling

Much work with evaporation pans has been carried out at many places in the world for the purpose of scheduling irrigations (Linacre and Till, 1969). Since 1952 investigations have been conducted by Washington State University to correlate pan evaporation to actual evapotranspiration. Since the Washington growing and climatic conditions are generally similar with those of Idaho, many of the concepts employed in Washington are used in this study. For various crops, ratios of pan evaporation to Et_A were determined by gravimetric and lysimeter measurements (Hagood, 1971). The investigations on potatoes indicate a near constant relationship (95 percent of E-pan = Et_A) after the crop has developed 80 percent effective canopy cover and continues until the crop matures at about lodging time.

This relationship permits estimation of soil water depletion if the amount of evaporation is known (Jensen, Middleton, 1970). The equation relating pan evaporation to predicted Et_A is:

$$Et_A = \text{E-pan} \times K_c$$

where Et_A and E-pan are expressed in cm or inches per day and K_c is the appropriate crop coefficient for the stage of growth of the crop.

Rewriting the soil water budget equation, the equation for soil water depletion is:

$$D = Et - Re - I + Wd.$$

Considering the time period after an irrigation or rain, Et and D are the only factors involved if drainage can be assumed zero, so

D = Et. Thus when E-pan has reached a predetermined level (relating to a predetermined allowable soil depletion level) irrigation can be applied in an amount equal to E-pan loss times K_c to refill the soil water reservoir. In this case measured evaporation will relate to scheduling irrigations by time and amount (Hagood, 1971). An example utilizing the same soil characteristics as the example in the previous section is given. In this case the crop has 80 percent effective cover so a K_c of 0.95 is assumed. Allowable pan evaporation before the next irrigation equals

$$\frac{2.02 \text{ inches} \times 0.45}{0.95} = 0.96 \text{ inches}$$

Thus when 0.96 inches of water has been evaporated from the pan an irrigation in the amount of 0.91 inches should be applied to refill the soil water reservoir.

The E-pan method for scheduling irrigations has taken on wide use in the U.S. especially in Washington, Oregon and Hawaii. Other parts of the world notably Africa, Australia, Israel, Cyprus and Israel have used this method with success (Hagood, 1971; Linacre and Till, 1969; Doorenboos and Pruitt, 1975). The method was judged a most practical method by the Congress of the International Commission on Irrigation and Drainage in Mexico City in 1969 (Hagood, 1971).

Pruitt (1960) compared Penman's equation, Blaney-Criddle, Thornthwaite, Jensen-Haise and two different size E-pans to actual Et and found the E-pans had excellent correlation with Et_A.

Field studies utilizing E-pans have been carried out by the state of California since 1954. They compared net atmometer evaporation, solar radiation, the Blaney-Criddle "f" factor and the evaporation pan method from eight different locations in the state. These studies found the best correlation (± 10 percent) between E-pan and Et_A (California, State of, 1975).

Doorenboos and Pruitt (1975) compared the Blaney-Criddle "f" method, radiation, modified Penman and pan evaporation to Et_A data from lysimeter and gravimetric measurements. They concluded that the E-pan could be superior to any of the other methods and could be used with a high degree of accuracy for scheduling irrigations if proper pan siting took place.

The principle advantage of the in-field evaporation pan as an irrigation scheduling device is freedom from labor. After the K_c has been applied, the in-field pan indicates when to irrigate, how much water to apply and when to terminate the irrigation (Haise and Hagen, 1967). The chief advantage of the E-pan is that it is a simple, direct method (Hanks and Ashcroft, 1976). The chief disadvantage is that the E-pan is very sensitive to site location. This method is based on the assumption that Et_A and E-pan are influenced similarly by the same climatic variables. These local variations include advection, wind, soil water availability, irrigation methods, practices and frequency, length of growing season and stage of crop development (Doorenboos and Pruitt, 1975).

All these factors may influence plant growth and, thereby Et and E-pan. Thus Et may vary from farm to farm, season to season and day to day (Jensen and Erie, 1971).

Pruitt (1960) concluded that environmental variables are very important when relating E-pan values to Et_A. Pruitt found a difference in coefficients from 30-35 percent for like pans located in different environments. The reliability of using E-pans depends on the immediate environment (Tanner, 1967; Wright, 1967; Pair, 1975; Burman et al., 1975).

Climatic Method of Irrigation Scheduling

Part of this study utilized climatic calculations of Et_p. This method includes use of meteorological data to estimate daily Et_p. Hanks and Ashcroft (1976) site three reasons for the increasing use of these methods:

1. The climatic variables apply on a broader scale than spot soil sampling.

2. The methods provide for estimation of Et without the problems associated with soil sampling and lysimeters.

3. These methods can be used for predictive purposes when climatological data are available.

Out of the many different equations for computing Et_p the Jensen-Haise and the Modified Penman Combination Equation were chosen for this evaluation. The Jensen-Haise equation was chosen for several reasons:

1. It was developed for use in inland arid regions, specifically the Twin Falls area of Idaho.

2. Climatological data needed for the method was easily obtainable.

3. It was found to be the best method for estimating Et for inland-semi-arid to arid regions (Jensen, 1974).

Jensen and Haise (1963) evaluated 3000 observations of Et as determined by soil sampling procedures over a 35 year period from the western U.S. to obtain the constants for the equation. This data was correlated with the main components of solar radiation and mean air temperature to come up with the following equation:

$$Et_p = C_T \ (T - T_X) \ R_S$$

where C_T is an air temperature coefficient which is a constant for a given area (0.014 in this case), and is derived from long term mean maximum and minimum temperatures for the month of highest mean air temperature, T is daily air temperature, (°F) T_X is a constant for a given area (26.4F in this case) and R_S is daily solar radiation expressed as the equivalent depth of irrigation.

The Penman equation was also used to compute Et_p. This method was judged useful since it takes into account the effect of wind on Et_p and has been used widely throughout the world. For areas where measured data on temperature, humidity, wind and radiation are available this method is suggested to provide the best estimate of Et_p (Doorenboos and Pruitt, 1975). Jensen (1974) ranked the modified Penman second under Jensen-Haise for prediction accuracy of Et_p for inland arid regions. Thus the top two methods for computing Et_p are used in this study.

The modified Penman consists of two terms, the energy (radiation) term and the aerodynamic (wind and humidity) term. Under windy, arid conditions the aerodynamic term becomes important. The form of the equation is:

$$Et_p = W \cdot Rn + (1 + W) \cdot f(u) \cdot (ea - ed)$$

where W is a temperature-related weighing factor, Rn is net radiation in equivalent evaporation in inches per day, f(u) is the wind-related function, (ea - ed) is the difference between the saturation vapor pressure at mean air temperature and the mean actual vapor pressure of the air, both in mbars.

For the Et_p values from the various methods to make any sense, a crop coefficient must be applied to relate Et_p to Et_A. K_c values developed by Jensen (1974) were used in this study as shown in Figure 1. Many K_c curves have been developed for potatoes but this K_c curve was used for several reasons: (1) the K_c curve covers an entire growing season, (2) the K_c curve has been published for several years so it serves as a good reference K_c, and (3) it was developed for the arid west, specifically Southern Idaho.

The main crop factors affecting the K_c are (1) the stage of growth, (2) the percent canopy cover, (3) the soil moisture status, and (4) irrigation frequency and amounts.

This method can be used to schedule irrigations in a similar manner with the E-pan method. The predicted Et_A represents the amount of soil water depletion. After a predetermined percent soil depletion level is reached irrigation should be applied in an amount equal to depletion to refill the soil water reservoir.

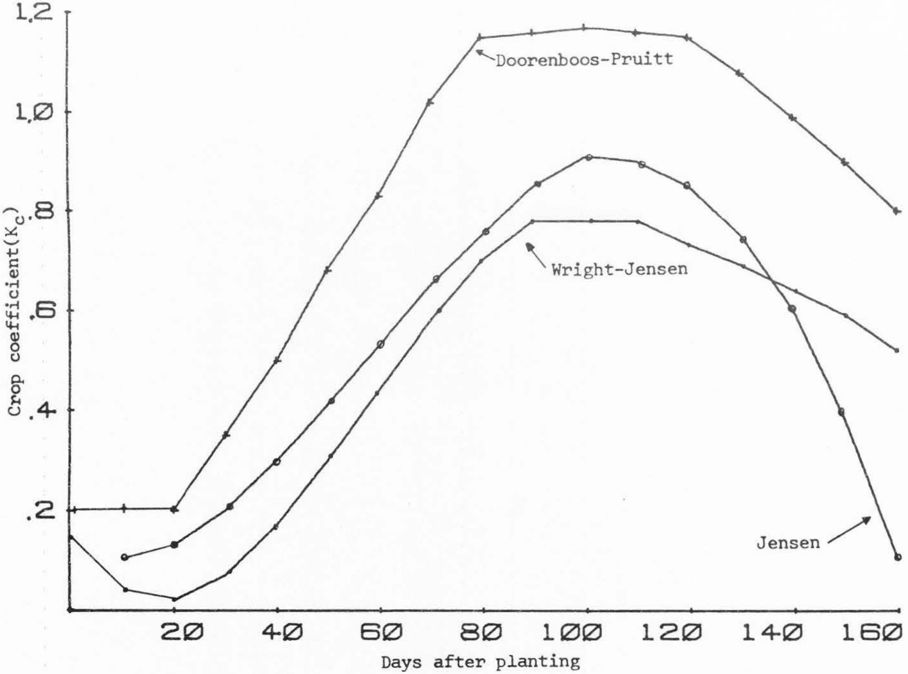

Figure 1. A comparison of three recent K_c curves.

MATERIALS AND METHODS

In this study circular two foot diameter evaporation pans made of 22 gauge galvanized sheet metal or one foot diameter plastic pans were used instead of the standard four foot weather bureau evaporation pan. The reason for this change was so that it would be less bulky to set up and maintain in the field. Pruitt (1960) confirmed that no significant difference in evaporative losses existed for these two pan sizes. Sims and Jackson (1971) worked with small inexpensive pans and found the correlation with the standard four foot pan to be in good agreement ($r = 0.958$).

The plastic E-pan values from two locations under potatoes in 1974 are shown in Table 11 in the appendix as plotted against the values from the two foot metal pan. An R^2 of 0.999 was found when the line was forced through zero as shown in Figure 12 in the appendix. These one foot plastic pans were made at a cost of about $2.50 each. Only about 2.5 gallons of water is needed to fill the plastic pan while about 12 gallons is needed for the two foot pan. The main disadvantage of the plastic pan is that the total water depth is only 6 inches while the U.S. Weather Bureau and the metal in-field pan is 10 inches. The pans were painted with acid-resistant yellow-gold paint instead of the standard aluminum paint. The rationale for this was (1) the paint would not deteriorate in the field because of applied foliar chemical sprays and (2) harmful potato insects, specifically the green peach aphid, would be trapped in the pan. The peach aphid which transmits mosaic, leafroll and spindling tuber diseases is attracted by the yellow color. Thus another advantage of the in-field pan is to indicate the presence of incoming airborn insect attacks.

Jensen and Middleton (1970) use a stilling well which supplies a constant supply of water to the pan to keep the water at a set level. Sims and Jackson (1971) used a meter stick to measure the water height in the pan. The in-field pan used in this study utilized a glass monometer (sight gate) which was calibrated to tenths of an inch. The monometer was connected by rubber tubing to a coupling located on the bottom of the pan. Thus the pan was a complete unit and could be read easily at a glance. Accurate readings of evaporation could be made within 0.025 of an inch. For accuracy, pan readings were taken about the same time of the day as the previous reading.

To set the pan properly in the field, the top of the pan was kept even with the top of the foliage. The pan should not be elevated too high or excess evaporation will occur. Pruitt (1960) found poor correlation when relating pan values from an elevated pan to Et_A when the pan was elevated several feet above the top of the crop. In application of pans to schedule irrigations on sugarcane, the pan was raised to keep level with the top of the foliage (Hagen and Haise, 1967).

In this study care was taken to locate a field site for the pan away from desert areas, roads, bare field spots, rock piles and faulty sprinkler systems so that accurate values could be measured. In the early part of the season, the pan was placed upon a firm, level base of bricks. After the crop was at about the 10 leaf stage, the pan was then placed upon a leveled 30 gallon drum and the top of the pan was kept even with the top of the foliage. The water height was not allowed to drop below about 2.5 to 3.0 inches from the top of the pan. After each visit to the pan accumulated debris was cleaned off the top of the water so as not to interfere with the evaporation.

Field study

In order to evaluate the in-field E-pan method two 132 acre potato fields were selected in the Twin Falls area of Southern Idaho. This region has a low yearly rainfall of about 7 inches with little summer rainfall, low relative humidity and high Et losses.

Field 1 (loamy sand) was irrigated by a Gifford-Hill 360 center pivot irrigation system. The field was located in an advective desert environment between Jerome and Wendell, Idaho, about 15 miles north and 10 miles west of Twin Falls, Idaho. This field was in its second year of potato production which had previously been in sagebrush.

Field 2 was irrigated by a Zinmatic low pressure, mist-type center pivot irrigation system. The field was located about 4.5 miles north of Twin Falls in an irrigated valley environment. Coming out of alfalfa, it had never had potatoes grown on it before. Table 1 summarizes the various characteristics of each field. These two locations were selected because of (1) varying soil types, (2) differing locations and microclimates, (3) uniform soil with good drainage, (4) lack of potato disease factors, (5) adequate soil fertility, and (6) newness of the pivots to ensure against worn nozzles and faulty water application.

Both fields were planted with certified Idaho Russet potato seed at a rate of about 2000 pounds of seed to the acre. Precision cup

Table 1. Important field details.

	Field 1	Field 2
Location	Wendell, Idaho	Jerome, Idaho
Acreage	132	132
Type of center pivot	Gifford-Hill 360	Zinmatic low pressure
Average sprinkler line pressure	85-90 lbs.	45 lbs.
% sand	85.2	50.6
silt	11.5	36.7
clay	3.3	12.7
Soil type	Loamy sand	Loam
Previous crop	Potatoes	Alfalfa
Age of pivot	Second season	First season
Average water application rate	0.8-0.9 inches	0.4-0.8 inches
Average peak season rotation interval	2 1/2-3 1/2 days	1 1/2-2 1/2 days
Date of first irrigation	May 19	May 25
Planting date	April 26	April 26
Emergence date	May 16	May 18
Stolon formation	May 25	May 26
Tuber formation	June 5	June 6
Date of row closure	July 2	July 4
Date of maximum cover	August 3	August 4
Date of lodging	August 21	August 20
Harvest date	October 3	October 8
Field capacity	9.3%	16.5%
Permanent wilting	4%	6.5%
Amount of applied fertilizer	80N-80P_2O_5-100K_2O-8#Zn	250N-235P_2O_5-200K_2O-15#Zn
How applied	Sidedressed	Banded at planting
Total applied uran in irrigation water	180 lbs/acre	60 lbs/acre

type planters placed the seed at an average depth of six inches. Average seed piece size was about 1.75 ounces.

Adequate soil nitrate nitrogen (NO_3-N) is assumed the most important nutrient for maximum yields (Middleton et al., 1975; Painter and Augustin, 1976). On field 1 the carryover from the previous potato crop was about 40 pounds of NO_3-N. For the 1976 season 80 pounds of NO_3-N, 100 pounds of P_2O_5, 100 pounds of K_2O and 8 pounds of zinc was sidedressed on about June 5. Supplemental liquid nitrogen (uran) was pumped through the irrigation lines onto field 1 starting the second week in July. This cultural practice of foliar nitrogen feeding resulted in 25-30 pounds of uran being applied per week for 6 weeks. Field 2 was fertilizer very heavily with 250 pounds of N, 235 pounds of P_2O_5, 200 pounds of K_2O and 15 pounds of zinc being banded prior to planting. Nitrogen carryover from the previous season was about 12 pounds per acre. Sixty pounds of uran was applied to field 2 during the last two weeks in June after an unseasonably late frost damaged the foliage. The late frost occurred twice on the 14th and 26th of June. Field 1 only had the edges of the leaves burned and yield reduction was only slight. Field 2 was hit hard both times and received considerable foliage damage. Plant growth was set back about a week in each case. The June 26 frost caused some of the tuber set to be lost. Numbers of tubers per five feet of row for fields 1 and 2 is shown in Table 2.

Cultivation was carried out once on each field then a herbicide (Sencor) was applied for weed control 1.5 weeks prior to canopy closure. Each field was sprayed for potato blight every 10 days after canopy closure. Generally, for both fields the nutrient status was maintained at an adequate level and, with the use of foliar sprays, weeds were kept to a minimum. These factors resulted in a healthy potato crop for both fields.

In order to provide yield values for the different irrigation treatments, field plots were set up so that three distinct moisture levels could be monitored for each field. The last wheel of each pivot inward toward the center was considered the normal moisture regime. Gravimetric soil moisture samples were taken from this area for determination of θ_m, which were used to compute Et_A. The wet moisture regime for field 1 was located on the western perimeter of the pivot where an overlap of water occurred between the field in study and a neighboring pivot. The wet moisture regime for field 2 was located in a 15 foot area completely around the perimeter of the pivot where the end gun applied a higher percentage of water than under the rest of the pivot. The dry moisture regime for both fields was a 15 foot wide area around the perimeter of the pivot where the end gun applied less water then under the main part of the pivot.

Three replications were made for each moisture regime, resulting in a total of nine field sites. Figure 2 shows the two fields and the field sites. Applied water whether from the pivot or from rain was measured in five locations per field site by using plastic bottles with aluminum funnels.

Three evaporation pans (2 metal and 1 plastic) were located in representative areas of each field under the main body of the pivot in the normal moisture regime. The three E-pan values were averaged twice weekly for calculation of Et_p by the in-field E-pan method.

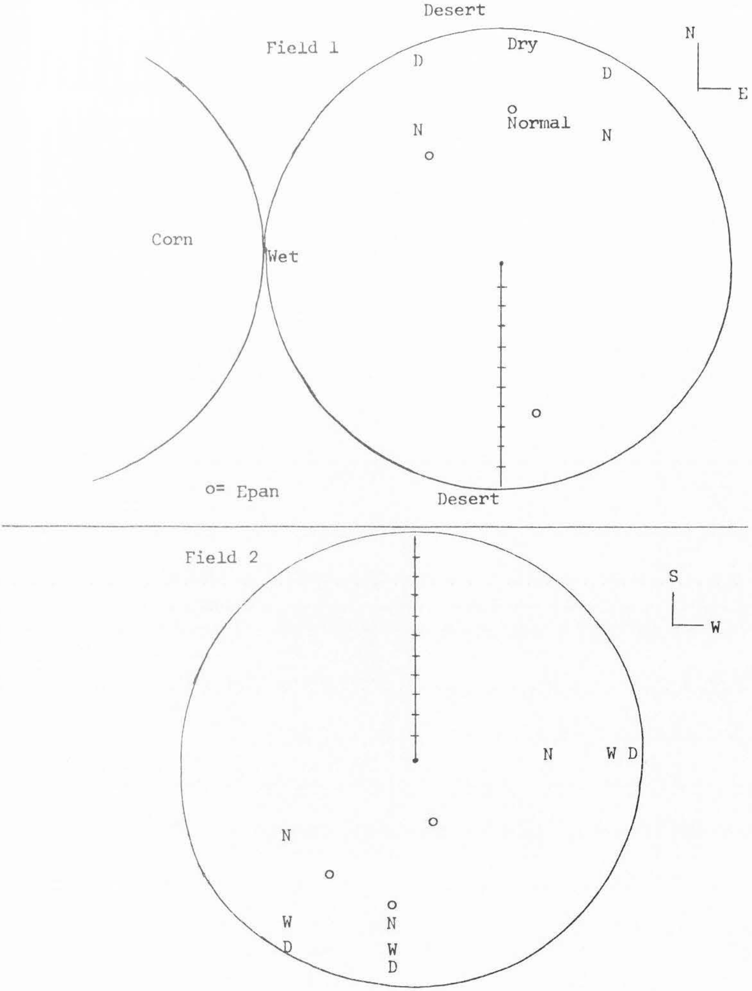

Figure 2. Map of fields 1 and 2 with location of moisture regimes and Epans.

Treatment of the data and irrigation procedure

At each moisture regime soil water content was determined to compute Et_A by gravimetrically sampling the topsoil (0-12 inches) and the subsoil (12-24 inches). Ten to twelve soil moisture samples were collected for each moisture regime twice weekly.

For field 1 the field capacity was 9.3 percent and the permanent wilting percentage was 4.0 percent and the bulk density was 1.40 g/cm^3. Thus there was 1.78 inches of available water per two feet of soil. If a 45 percent available water depletion level is used, irrigation should be applied when 0.80 inches of water has been depleted. For field 2 the field capacity was 16.5 percent, the permanent wilting percentage was 6.5 percent and the bulk density was 1.35 gm/cm^3 which gives 3.17 inches of available water per two feet of soil. If a 40 percent available water depletion level is used, irrigation should occur when 1.27 inches of water has been depleted.

Prior to 80 percent effective canopy closure, irrigations were scheduled by gravimetric measurements of soil water depletion since an appropriate K_c had not yet been correlated with E-pan. Once canopy closure did occur irrigations were scheduled by using E-pan evaporation times the K_c of 0.95 which has been used in Washington State. This practice continued until after maturity (lodging) then gravimetric measurements were again used to schedule irrigations since an appropriate K_c had not yet been determined for this period of the season.

Parts of the field that received a known amount of irrigation water were sampled for yield and quality by taking the tubers from five feet of potato row. Four samples were taken from each moisture regime. This data was run for statistical significance by the t-test method.

RESULTS AND DISCUSSION

The measured bi-weekly Et_A values determined from gravimetric measurements are shown in Tables 3 and 4. Reference climatic potential evapotranspiration (Et_p) was computed by using the modified Jensen-Haise equation and the Penman combination equation as shown in Table 12 in the appendix. The Et_p from Jensen-Haise was calculated from data gathered at the U.S. Weather Bureau station at Kimberly, Idaho. The calculated Et_p from the Penman equation was furnished by the U.S. Bureau of Reclamation at Burley, Idaho.

Two sources of potential Et from evaporation pans were used in this study. Reference daily E-pan values were furnished by the U.S. Weather Bureau at Kimberly as shown in Table 12 in the appendix. The bi-weekly Et_p measure by the in-field E-pan method is shown in Tables 3 and 4. Thus a total of four different methods were used to compute Et_p. The evaluation of Et_p by the in-field E-pan method and Et_A computed by the gravimetric method are also shown in Figures 3 and 4.

The weekly, monthly and seasonal totals for the four methods of determining Et_p, summarized in Table 5, show considerable variation. Considering the three E-pan measurements, E-pan (in-field) was highest for field 1, with the Kimberly E-pan being intermediate and the E-pan (in-field) of field 2 being the lowest. The variation between these three methods appears reasonable since Et_p should have been highest in the most advective area, that of field 1. Comparing the Kimberly E-pan values with those of field 1, they had a good correlation of R^2 =

Table 2. Yield and quality information.

Field	Moisture regime	Rep	Number tubers per 5 feet of row	Total lbs.	lbs. #1	lbs. #2	lbs. culls	I inches	Percent number ones	CWT per acre
1	Dry	1	35	11.1	4.3	6.3	0.5	17.19	38.4	322.0
	"	2	30	10.3	4.0	5.5	1.2	15.8	39	300.5
	"	3	39	11.6	4.5	6.3	0.8	17.7	39	336.8
	"	4	36	11.3	4.3	7.0	0.3	18.0	38	328.0
		Ave	35	11.07	4.3	6.2	0.7	17.17	39	321.8
	Norm	1	39	16.5	13.5	2.8	0.8	27.40	81	485.0
	"	2	31	15.5	13.0	1.5	0.8	25.10	85	444.0
	"	3	41	17.6	13.5	3.1	0.5	28.7	77	511.0
	"	4	48	17.3	14.0	3.0	0.3	28.5	81	502.0
		Ave	39.7	16.7	13.5	2.5	0.6	27.42	81	485.7
	Wet	1	41	16.8	14.4	1.9	0.7	36.3	86	490.0
	"	2	44	17.0	15.0	1.4	0.6	35.4	88	493.0
	"	3	40	17.0	14.4	2.0	0.6	36.0	85	493.0
	"	4	38	16.6	14.0	2.0	0.6	37.2	84	483.0
		Ave	40.7	16.87	14.4	1.8	0.6	36.2	85.7	489.4
2	Dry	1	22	6.0	2.5	3.0	0.5	15.2	42	174.0
	"	2	31	8.0	2.7	4.5	0.8	17.4	16	232.0
	"	3	32	5.5	3.0	1.5	1.0	14.8	54	142.5
	"	4	28	8.2	3.2	3.8	1.2	16.8	39	235.0
		Ave	28.2	6.92	2.85	3.2	0.87	16.05	37.7	195.87
	Norm	1	35	9.7	6.7	2.0	1.0	25.6	69	281.6
	"	2	27	7.5	6.2	1.0	0.3	22.2	83	218.0
	"	3	32	10.0	7.0	2.5	0.5	25.0	70	290.0
	"	4	35	13.7	9.2	3.7	0.8	28.4	67	397.6
		Ave	32	10.2	7.3	2.3	0.65	25.3	72	296.8

Table 2. Yield and quality information (continued).

Field	Moisture regime	Rep	Number tubers per 5 feet of row	Total lbs.	lbs. #1	lbs. #2	lbs. culls	I inches	Percent number ones	CWT per acre
	Wet	1	32	10.0	7.2	1.8	1.0	35.0	72	290.0
	"	2	28	12.4	10.0	1.7	0.5	38.2	81	360.0
	"	3	33	13.8	8.7	4.6	0.5	37.0	63	404.0
	"	4	30	16.0	11.5	4.5	0/.6# rot	40.8	72	464.0
		Ave	31	13.05	9.35	3.2	0.65	37.75	72	379.5

Table 3. Data on the normal moisture regime of field 1.

Date	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	E pan in/day	Et_A in/day	Dr. inches
April 26-30	92	94	93		.22	.040	
May 1-4	84	91	87.5		.26	.025	
5-7	80	88	84		.19	.021	
8-10	70	83	76.5		.29	.050	
11-13	74	78	76	.32	.36	.10	
14-17	51	73	62	.08	.37	.08	
18-21	90	94	92	.96	.37	.101	
22-23	71	82	77.5		.32	.072	
24-26	49	68	58.5		.37	.113	
27-30	70	86	78	.96	.30	.153	.197
May 31-June 2	46	75	60.5		.32	.104	
3-6	75	86	80.5	1.04	.34	.171	
7-9	100	100	100	.83	.37	.161	.374
10-13	91	96	93.5	.25	.25	.092	
14-16	61	77	69		.33	.145	
17-20	68	96	82	1.04	.38	.269	.273
21-23	94	100	97	.96	.40	.231	
24-28	51	75	63	.96	.36	.342	
29-31	78	78	78	.90	.37	.211	
July 1-4	47	62	54	.69	.35	.324	

Table 3. Data on the normal moisture regime on field 1 (continued).

Date	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	E pan in/day	Et$_A$ in/day	Dr. inches
5-7	100	75	87.5	1.95	.37	.351	
8-11	75	87	81	.89	.30	.239	
12-14	62	64	63	.83	.39	.383	
15-18	100	77	88.5	2.10	.26	.247	
19-21	38	57	47.5		.25	.243	
22-25	100	74	87	2.0	.325	.324	
26-28	58	56	57	.94	.348	.364	
July 29-Aug. 1	68	51	60	.80	.24	.213	
2-4	100	77	86.5	.76	.20	.096	
5-8	100	60	80	.99	.32	.276	
9-11	38	32	35		.25	.267	
12-15	89	56	72.5	1.80	.24	.283	
16-18	72	73	72.5	.19	.13	.063	
19-22	92	76	84	1.30	.26	.274	
23-25	38	60	49		.27	.208	
26-29	43	45	44	.97	.33	.265	
Aug. 30-Sept. 1	72	38	55	1.00	.38	.268	
2-7	62	40	51	.83	.30	.18	
8-12	74	36	55	1.06	.28	.165	
13-19	35	25	30		.15	.064	
Season total				27.40	43.37	27.28	.844

Table 4. Data on the normal moisture regime of Field 2.

Date	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I in/day	E pan in/day	Et_A in/day	Dr. inches
April 26-30	80	93	86.5		.19	.040	
May 1-4	68	88	78.0		.23	.135	
5-7	62	83	72.5		.19	.06	
8-10	60	79	69.5		.27	.03	
11-13	56	77	66.5	.32	.33	.03	
14-16	49	73	61.0	.08	.35	.05	
17-21	45	70	57.5		.35	.03	
22-23	42	66	54.0		.30	.055	
24-26	59	74	66.5	.46	.36	.032	
27-31	62	68	65.0	1.05	.25	.174	
June 1-2	46	54	50.0		.31	.238	
3-7	48	79	63.5	1.17	.30	.148	
8-11	51	70	60.5	.40	.29	.124	
12-13	81	66	73.5	.90	.25	.244	
14-15	54	64	59.0		.32	.229	
16-21	85	62	73.5	1.68	.30	.228	
22-23	53	58	55.5	1.15	.40	.29	.10
24	91	69	80.0	.97	.30	.20	
25-28	69	64	66.5	1.02	.36	.362	
29-July 1	74	79	76.5	1.03	.27	.238	
2-5	66	72	69.0	1.49	.25	.239	
6-8	74	79	76.5	.82	.24	.194	
9-13	95	70	82.5	1.75	.31	.312	
14-15	99	97	98.0	.93	.26	.219	
16-19	99	94	96.5	.92	.21	.24	

Table 4. Data on the normal moisture regime of Field 2 (continued).

Date	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I in/day	E pan in/day	Et_A in/day	Dr. inches
20-22	97	88	92.5	1.17	.22	.24	.40
23-27	100	87	93.5	1.20	.28	.246	
28-29	95	91	93.0	.43	.16	.223	
30-Aug. 2	88	83	85.5	1.15	.188	.20	.30
3-5	65	70	67.5		.197	.190	
6-9	60	66	63.0	.60	.23	.186	
10-12	68	70	69.0	.68	.21	.163	
13-16	80	78	79.0	1.23	.16	.18	.50
17-19	74	66	70.0	.10	.14	.098	
20-23	76	62	69.0	.76	.20	.198	
24-26	71	56	63.5	.36	.23	.178	
27-30	61	50	55.5	.31	.19	.141	
31-Sept. 2	48	46	47.0	.41	.25	.226	
3-7	33	29	28.0		.20	.12	
8-9	36	25	30.5	.34	.20	.13	
10-13	70	30	50.0	1.02	.14	.10	
14-19	45	25	35.0		.11	.079	
Season average				25.90	35.54	23.43	1.30

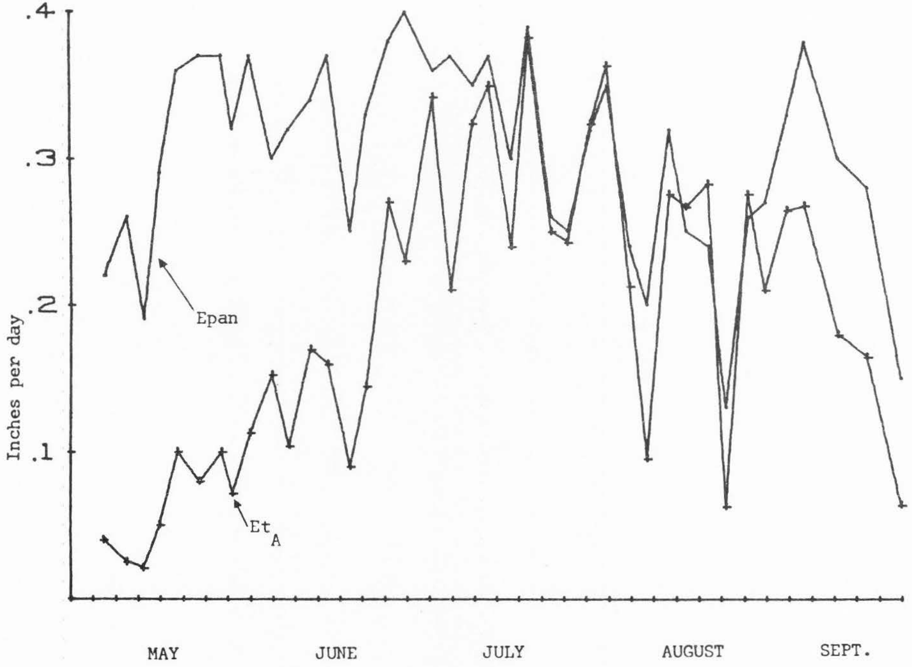

Figure 3. Comparison of Epan and Et_A for field 1.

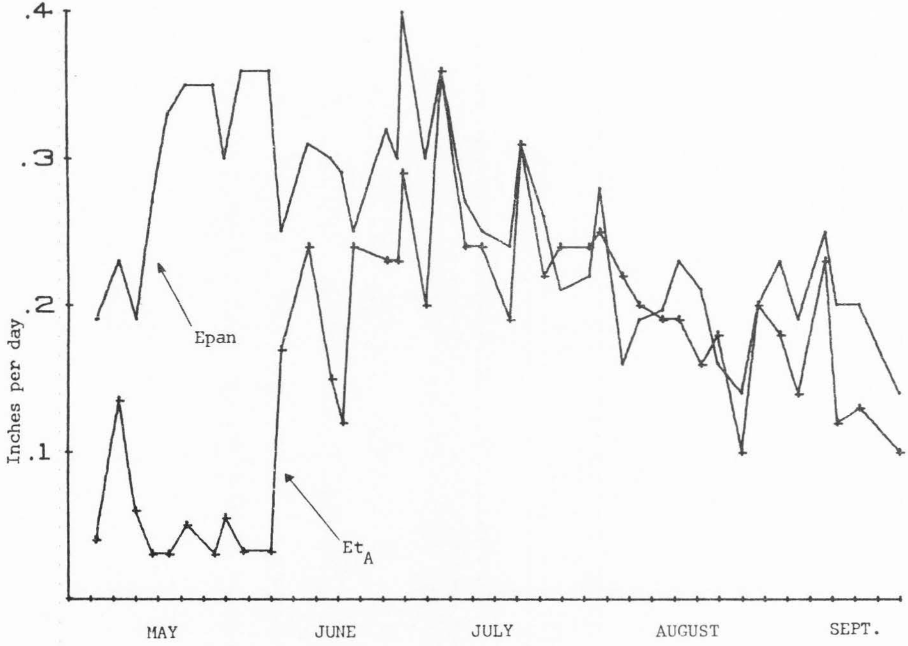

Figure 4. Comparison of Epan and Et_A for field 2.

Table 5. Weekly Et_p totals by the various methods and Et_A.

	Field 1 E pan inches	Field 2 E pan inches	Kimb. E pan inches	Jensen Haise Et_p inches	Penman Et_p inches	**Field** 1 Et_A inches	**Field** 2 Et_A inches
April 26-30	1.1	1.1	1.0	0.87		0.24	0.19
Subt.	1.1	1.1	1.0	0.87		0.24	0.24
May 1-7	1.90	1.54	1.47	0.73		0.16	0.72
8-14	2.15	2.13	2.20	1.29		0.53	0.23
15-21	2.62	2.18	2.37	1.26	2.19	0.64	0.25
22-28	2.03	1.85	2.31	1.32	1.76	0.68	0.50
29-31	.92	.75	.85	0.49	.561	0.41	0.52
Subt.	9.62	8.45	9.20	5.09	4.51	2.38	2.46
June 1-7	2.05	2.14	2.06	1.43	2.00	1.05	1.22
8-14	2.07	1.86	1.96	1.08	1.70	.83	1.21
15-21	2.58	1.83	2.23	1.52	1.91	1.60	1.60
27-28	2.98	2.77	2.81	1.55	2.45	2.19	1.45
29-30	.74	.54	.84	.55	.58	.42	.47
Subt.	10.42	9.14	9.90	6.69	8.44	6.09	5.96
July 1-7	2.51	1.75	2.25	1.71	2.13	2.35	1.58
8-14	2.37	2.05	2.28	1.90	2.04	2.10	1.97
15-21	1.79	1.54	1.93	1.78	1.76	1.72	1.66
22-28	2.34	1.82	2.34	1.83	1.96	2.39	1.69
29-31	.72	.39	.64	.54	.65	.63	.42
Subt.	9.73	7.55	9.44	7.76	8.53	9.20	7.32
Aug. 1-7	1.80	1.36	1.81	1.33	1.70	1.33	1.34
8-14	1.55	1.41	1.86	1.33	1.74	1.64	1.22
15-21	1.41	1.34	1.36	1.01	1.34	1.29	1.05
22-28	2.06	1.46	1.72	1.22	1.72	1.69	1.21
29-31	1.09	.63	.83	.59	.69	.80	.50
Subt.	7.91	6.20	7.58	5.49	7.91	6.75	5.31
Sept. 1-7	2.16	1.50	1.85	1.30	1.75	1.35	1.05
8-14	1.70	1.07	1.32	0.84	1.18	.95	.73
15-19	.72	.52	.61	0.45	.76	.32	.39
Subt.	4.59	3.10	3.78	2.60	3.69	2.62	2.19
Total	43.37	35.54	40.9	28.5	33.08	27.28	23.43

0.99. Comparing field 2 with field 1 and Kimberly, it is obvious that little similarity exists from July through September. Even though the Kimberly E-pan and the field 2 E-pan were only seven miles away from each other and were located in the same irrigated valley, their values were not similar.

Comparing Jensen-Haise and the Penman equation from May 15 to September 19, Et_p was about 7.5 inches greater by the Penman equation than by Jensen-Haise. This large variation is surprising since these methods are supposed to calculate Et_p similarly during the summer months (Jensen, et al., 1969).

Et_p values have been converted to Et predicted by multiplication by K_c values developed by Jensen (1974) as shown in Table 6.

Table 6. K_c values for potatoes after Jensen (1974) relating to stage of growth.

Days after planting	K_c	Days after planting	K_c
10	0.10	90	0.85
20	0.13	100	0.91
30	0.20	110	0.90
40	0.30	120	0.85
50	0.41	130	0.75
60	0.53	140	0.60
70	0.65	150	0.38
80	0.75	160	0.10

Et predicted values from the various methods are shown in Table 7.

It is evident that by comparing these predicted Et values to the measured Et_A values from Table 5 that much discrepancy exists. Et_A was underestimated by all methods from May through July, after which mixed results were obtained. Seasonal predicted crop Et was underestimated by each method when compared with Et_A.

A discrepancy was very evident if the Jensen-Haise equation is used. Using this equation and considering that the K_c values were assumed to predict well for this equation, it is obvious by comparing with Et_A values that Et was greatly underestimated. Et predicted for field 1 was underestimated by 40 percent and underestimated by 29 percent on field 2. Since the dry plots of both fields received 37 percent less water than was applied to the normal plots as shown in Table 2 and yield was cut by 34 percent, then it can be assumed with confidence that yield and quality would have been reduced significantly if Jensen-Haise had been followed to schedule irrigations. Much higher K_c values would need to be applied for Et to be estimated properly by Jensen-Haise.

The predicted Et by the other methods was also underestimated when the Jensen K_c values were applied but not by as much error as Jensen-Haise. Higher K_c values would need to be applied in the May through July period for these methods to properly predict Et_A.

Considering seasonal totals only for the predicted Et on field 1 in relation to Et_A, the in-field pan predicted Et best, the Kimberly E-pan second best, followed by Penman and Jensen-Haise. For field 2 the Kimberly E-pan would have predicted Et best, Penman second best, followed by the in-field pan and Jensen-Haise. Since all the methods predicted Et lower than Et_A, it is evident that the Jensen K_c values did not predict accurately or consistantly in this study.

Part of this study was intended to develop K_c values for the various stages of growth. K_c values have been developed by dividing in-field E-pan values by Et_A as shown in Figure 5. The two K_c curves were very similar for most of the season. In this study both fields were planted on April 26, 1976, so that the time scale is the same for both fields. $\frac{Et_A}{E\text{-pan}}$ increased quickly after plant emergence until the rows close, then $\frac{Et_A}{E\text{-pan}}$ stayed at a constant of about 0.95 for a 45-50 day period until lodging occurred on both fields about August 20. These findings are similar to those of Nelson and Hwang (1975) who found a constant transpiration rate period of 42-48 days during this stage of growth. During this mid-season stage transpiration was accounting for about 90 percent of the total Et loss (Childs and Hanks, 1975). Constant adequate soil moisture during this period after effective canopy closure is crucial for maximum gross yield and quality. This period is when the E-pan predicts Et_A very well. By using Table 5 and comparing E-pan for fields 1 and 2 to the corresponding Et_A, slightly less than a 1:1 relationship between Et_A and E-pan is found. A K_c of 0.95 appears to predict well during this constant relation period. Table 7 includes the predicted Et values for fields 1 and 2 when E-pan is multiplied by a K_c of 0.95 during July and most of August. Thus irrigation could be applied in an amount slightly less than a 1:1 ratio with evaporation loss from the E-pan, ensuring that the goals of crop water requirements and minimum drainage are met. Figures 3 and 4 help to illustrate this point with a comparison of Et_p and Et_A.

After lodging occurred the K_c curves show that Et_A dropped off while Et_p stayed about the same. This Et_A reduction occurred because the plants were maturing and not growing and transpiring as rapidly as they previously had been. Et_A did not drop off as much on field 2

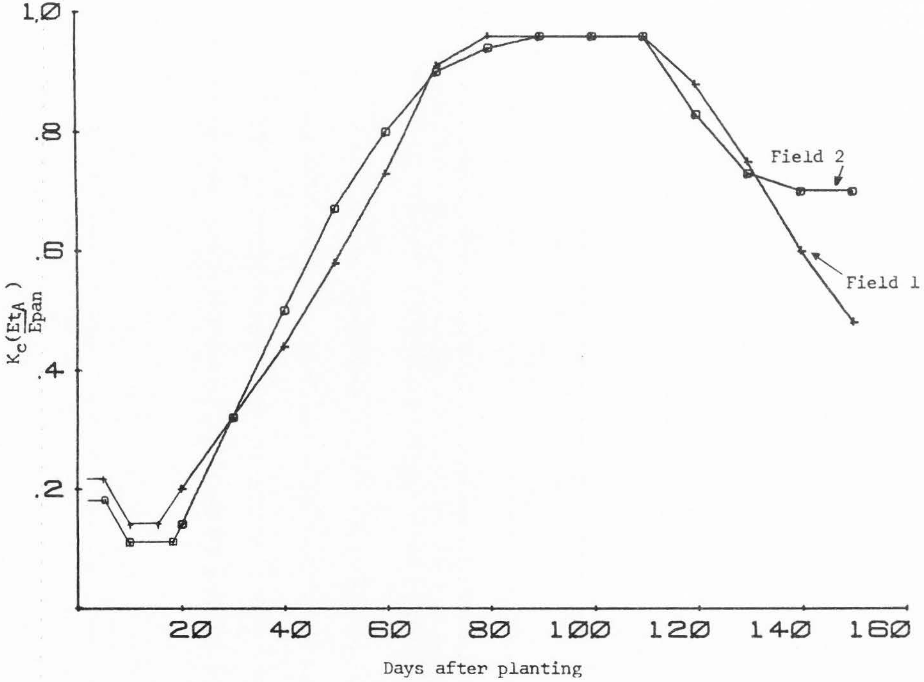

Figure 5. K_c curves for fields 1 and 2 calculated by dividing Et_A by Epan.

Table 7. Weekly Et_p totals of the various methods times K_c (after Jensen); also field 1 and 2 E pan times K_c of 0.95.

	1 E pan inches	2 E pan inches	Kim. E pan inches	Jensen Haise inches	Penman inches	1 E pan x 0.95 inches	2 E pan x 0.95 inches
April 26-30	.11	.11	.10	.087			
Subt.	.11	.11	.10	.087			
May 1-7	.21	.167	.163	.081	.60		
8-14	.258	.256	.264	.155			
15-21	.433	.360	.391	.209	.438		
22-28	.406	.370	.462	.264	.352		
29-31	.23	.187	.212	.123	.140		
Subt.	1.54	1.34	1.49	.831	.93		
June 1-7	.894	.642	.618	.43	.60		
8-14	.745	.67	.706	.389	.612		
15-21	1.06	.75	.914	.623	.783		
22-28	1.58	1.47	1.49	.82	1.30		
29-30	.481	.351	.546	.357	.377		
Subt.	4.76	3.88	4.27	2.62	3.67		
July 1-7	1.91	1.33	1.71	1.30	1.62	2.38	1.66
8-14	1.80	1.56	1.73	1.44	1.34	2.25	1.95
15-21	1.44	1.24	1.55	1.43	1.42	1.70	1.46
22-28	1.99	1.55	1.99	1.56	1.67	2.22	1.73
29-31	.612	.33	.544	.461	.552	.68	.37
Subt.	7.75	6.01	7.52	6.19	6.60	9.23	7.17
Aug. 1-7	1.64	1.24	1.64	1.21	1.55	1.71	1.29
8-14	1.40	1.28	1.78	1.20	1.57	1.47	1.34
15-21	1.27	1.21	1.22	.91	1.21	1.34	1.27
22-28	1.75	1.24	1.46	1.04	1.46		
29-31	.93	.54	.71	.51	.59		
Subt.	6.99	5.51	6.72	4.87	6.38		
Sept. 1-7	1.62	1.12	1.39	.975	1.31		
8-14	1.15	.72	.89	.57	.80		
15-19	.44	.32	.366	.274	.456		
Subt.	3.21	2.16	2.62	1.82	2.57		
Total	24.36	19.01	22.72	16.42	20.75		

as compared with field 1 because of the denser crop canopy and continued higher transpiration rate. It was assumed that the higher soil fertility level of field 2 caused greater vine growth and kept the vines green longer, causing the Et_A to Et_p ratio to level off instead of allowing the continual decline as did field 1 which had less dense vine growth and a lower fertility level as shown in Figures 6 and 7. Field 1 was more normal for potatoes for that time of the growing season.

The problems associated with the climatic equations and which K_c to use is one of the reasons the in-field pan was developed. The specific micro-climate of each field had a definite response to Et. Even though the micro-climate and corresponding Et_p and Et_A are different for different fields as shown for field 1 versus field 2 in Table 5, the in-field E-pan reflected these differences. The climatic methods or the U.S. Weather Bureau pan did not and cannot take these individual field differences into account unless the measurements are made in the field. The question of which is the proper K_c seems to be a constant problem if the climatic methods are to be used to properly schedule irrigations. Figure 1 shows the wide variability of K_c from three recent studies on potatoes. It is obvious that Et predicted would vary considerably depending on the K_c curve that was utilized. Considering only the mid season period, when the actual K_c was shown to be about 0.95, these methods would not have predicted Et accurately. The E-pan method did a good job of predicting Et since the K_c used was reliable.

It is realized that the E-pan overestimates Et prior to effective canopy closure and after maturity; however, with the application of

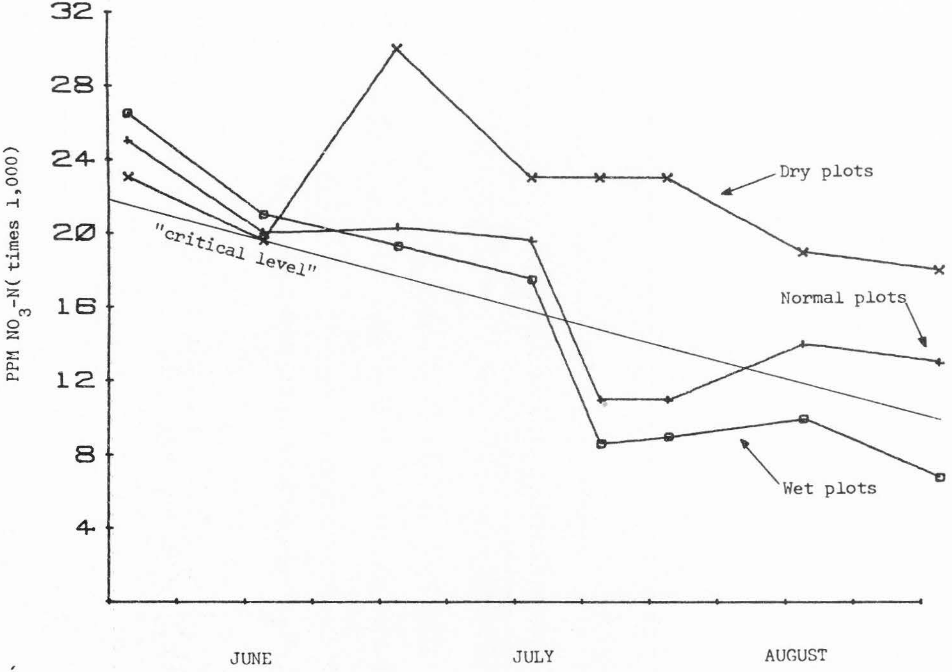

Figure 6. Plant NO_3-N for the three moisture regimes of field 1.

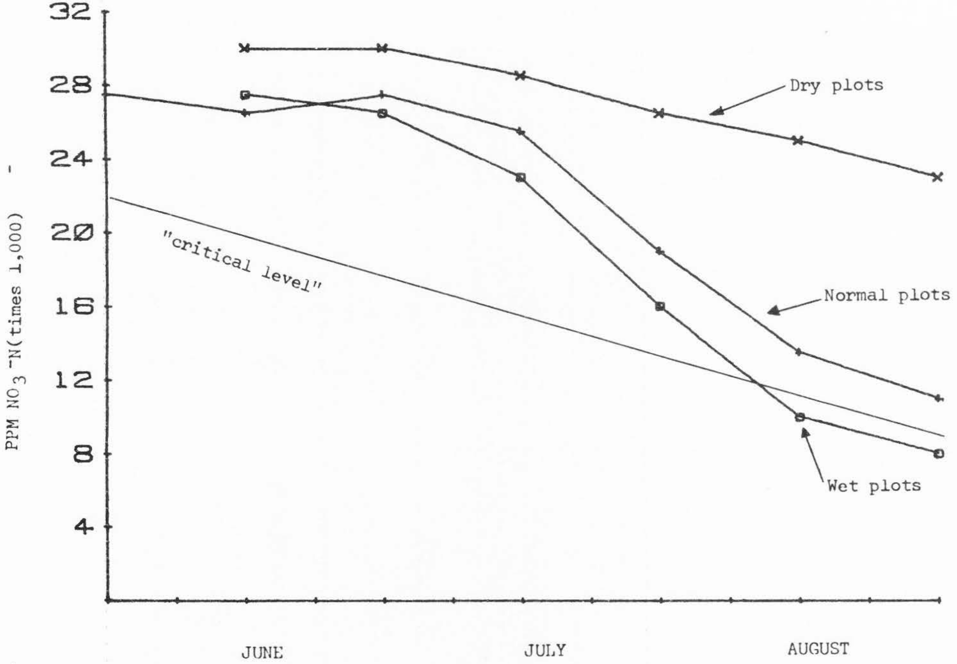

Figure 7. Plant NO_3 -N for the **three** moisture regimes of field 2.

the appropriate K_c, dependant on stage of growth, derived from the generalized K_c curves of field 1 and 2, the E-pans predictive value should still be good. It is assumed that the developed K_c curves will at least be as good as those already developed.

Both fields generally had an adequate supply of soil moisture throughout the growing season as shown in Tables 3 and 4. In this study both fields were considered to be at a transpiration potential (when the plant was continuously well-supplied with water and transpiration not limiting (Hanks and Ashcroft, 1976)) and were considered never to be limited by any type of plant stress for the entire growing season. On field 1 from June 15 to August 15, irrigation was applied at an average rate of 0.90 inches per rotation with a rotation interval of 2.5-3.5 days. A few times during the season available moisture did get below 55 percent as shown in Table 3, but the stress period was so short that yield and quality reduction apparently did not occur. Water application as measured by the irrigation water catch method kept up with Et_A as shown in Table 3. Field 2 was never stressed for moisture during the critical stages of growth as shown in Table 4. In fact during June and July water application exceeded that what was needed to replace soil moisture lost because of soil depletion. The pivot was run almost constantly resulting in a consistantly high available moisture level. Frequent light irrigations ranging from 0.4 to 0.8 inches per rotation were applied every 1.5 to 2.5 days. It was assumed that some deep percolation took place as shown in Table 4.

Since the dry plots of both fields only received 63 percent of the water that the normal plots received, the sub-soil moisture fell below 50 percent available by June 10 and dropped to zero by August 1 as shown in Tables 8 and 9. For most of the critical growth period sub-soil moisture was inadequate or not available so the plant lived on the moisture that was supplied to the top 12 inches of soil. The top moisture was still low when compared with the normal plots. Since water was more than adequate on the wet plots of both fields water application greatly exceeded soil depletion for the entire growing season as shown in Tables 8 and 9.

By comparing Et_A from the dry plots (Tables 8 and 9) with the Et_A from the normal plots (Tables 3 and 4) of both fields, it is evident that Et_A was considerably lower on the dry plots. Also Et_A for the wet plots was somewhat higher. This relationship was similar to Corey and Myers (1955) who found a correlation between amount of applied water and Et_A. Since the foliage was less developed on the dry plots and slightly more developed on the wet plots, Et was influenced by the amount of foliage. This agrees with Nelson and Hwang (1975) who concluded that transpiration on potatoes was significantly correlated with the amount of foliage. Downey (1972) found that as transpiration declines so does photosynthesis and yield. The trend is for yield to be a linear function of Et. Similarly, the present study indicates that yield was highly correlated with water application as shown in Table 2.

Comparing the dry to the normal plots of both fields 63 percent of the "normal" applied water resulted in 66 percent of the maximum yield. For field 1 comparing the dry and normal plots, yields and quality was significantly different at the 95 percent level as shown in Table 13 in the Appendix. Amount of applied water for all the field

Table 8. Data on the dry and wet moisture regimes of field 1.

	Dry Plots					Wet Plots					
Date	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et_A in/day	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et_A in/day	Dr. inches
April 26-31	91	92	91.5		.040	92	94	93		.040	
May 1-4	83	89	86		.024	84	91	87.5		.025	
5-7	79	87	83		.018	80	88	84		.021	
8-10	72	82	77		.036	70	83	76.5		.035	
11-13	72	79	75.5	.32	.115	74	78	76	.32	.107	
14-17	50	74	62	.08	.08	50	73	61.5	.08	.084	
18-21	86	80	83	.53	.04	92	97	94.5	1.42	.12	.40
22-23	60	77	68.5		.129	72	92	82		.11	
24-26	48	66	57		.068	57	88	72.5		.079	
27-30	68	65	66	.55	.106	50	70	60	.72	.115	
May 31-June 2	38	60	49		.101	44	71	57.5		.101	
3-6	59	53	56	.59	.116	77	92	84.5	1.48	.25	.22
7-9	71	50	60.5	.51	.143	100	100	100	1.10	.27	
10-13	48	42	45		.069	80	96	93	.25	.094	
14-16	28	40	34		.065	60	77	68.5		.145	
17-20	48	32	40	.62	.128	68	97	87.5	1.40	.27	
21-23	60	25	42.5	.59	.182	98	100	99	1.29	.33	
24-27	48	21	34.5	.59	.183	52	77	64.5	1.25	.46	
28-31	50	16	33	.55	.192	79	81	80	1.18	.31	
July 1-4	39	11	20.5	.45	.166	47	63	55	.90	.336	
5-7	60	15	31	1.17	.259	100	96	98	2.55	.39	.60
8-11	47	15	31	.56	.191	76	88	82	1.20	.37	
12-14	23	8	15.5	.50	.259	63	66	64.5	1.14	.42	.20
15-18	77	12	44.5	1.22	.158	100	96	98	3.05	.28	.80
19-21	30	12	21		.139	41	71	56		.249	

Table 8. Data on the dry and wet moisture regimes of field 1 (continued).

	Dry Plots					Wet Plots					
Date	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et$_A$ in/day	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et$_A$ in/day	Dr. inches
22-25	75	15	45	1.25	.203	100	90	95	2.60	.34	.40
26-28	58	6	32	.57	.264	60	67	63.5	1.42	.36	.40
July 29-Aug. 1	43	0	21.5	.51	.172	69	51	60	1.14	.30	
2-4	47	0	23.5	.59	.181	100	86	93	.99	.164	
5-8	46	0	23	.63	.157	100	90	95	1.36	.309	
9-11	16	0	8		.089	40	70	55		.237	
12-15	64	0	32	1.14	.176	91	89	90	2.52	.27	.50
16-18	67	0	33.5	.19	.054	73	83	78	.19	.135	
19-22	65	10	37.5	.72	.162	94	94	94	1.70	.20	.45
23-25	20	0	10		.151	40	76	58		.214	
26-19	14	0	7	.55	.151	46	50	63	1.40	.24	.40
Aug. 30-Sept. 1	30	0	5	.68	.147	73	74	75	1.30	.24	.30
2-6	18	0	9	.42	.105	62	85	73.5	1.06	.22	
7-12	64	1	37	1.06	.079	89	90	89.5	1.06	.16	
13-19	24	0	12		.064	70	82	76		.04	
Season total				17.14	18.59				36.07	30.09	4.67

Table 9. Data on the dry and wet moisture regimes of field 2.

	Dry Plots					Wet Plots					
Date	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et_A in/day	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et_A in/day	Dr. inches
April 26-31	80	93	86.5		.035	80	93	86.5		.035	
May 1-4	68	88	78		.135	68	88	78		.135	
5-7	62	83	72.5		.06	61	82	71.5		.069	
8-10	60	79	69.5		.03	59	79	69		.026	
11-13	56	77	66.5	.32	.03	55	79	67	.32	.085	
14-16	49	73	61	.08	.05	47	73	60	.08	.100	
17-20	44	70	57		.032	44	69	56.5		.028	
21-23	41	66	54		.032	40	66	53		.037	
24-26	54	65	60	.27	.027	64	80	74	.76	.053	
27-31	49	56	53	.50	.144	68	92	80	1.55	.27	
June 1-2	33	50	41.5		.182	50	76	63		.27	
3-7	46	43	44.5	.60	.062	69	92	80	1.35	.162	
8-11	48	41	44.5	.40	.10	68	84	76	.40	.176	
12-13	65	33	48	.49	.189	96	98	92	1.23	.26	.20
14-15	43	20	34.5		.214	59	93	76		.25	
16-21	50	30	40	1.11	.156	90	96	93	3.03	.28	1.0
22-23	48	30	39	.45	.241	59	81	7-	1.73	.31	.55
24-28	90	29	60	1.02	.254	72	91	81.5	2.76	.37	.75
29-July 1	65	33	49	.67	.312	86	100	93	1.58	.30	
2-5	56	65	60.5	1.44	.196	70	94	82	2.24	.26	.50
6-8	65	54	59	.92	.177	82	100	91	1.22	.29	
9-13	72	53	62.5	1.25	.226	96	100	98	2.21	.33	1.20
14-15	84	26	55	.20	.223	100	100	100	1.78	.29	
16-19	86	7	52	.51	.15	100	100	100	1.58	.24	.65
20-22	83	18	53	.62	.193	98	100	99	1.58	.24	1.10

Table 9. Data on the dry and wet moisture regimes of field 2 (continued).

Date	Dry Plots					Wet Plots					
	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et_A in/day	Avail. water 1st foot percent	Avail. water 2nd foot percent	Aver. avail. water percent	I inches	Et_A in/day	Dr. inches
23-27	79	10	44.5	.68	.192	86	100	98	1.71	.35	
28-29	88	4	46	.25	.10	94	96	95	.60	.19	.10
30-Aug. 2	84	0	42	.60	.182	88	86	87	1.70	.23	.50
3-5	67	0	33.5		.166	70	75	72.5		.18	
6-9	44	0	22	.38	.131	63	80	71.5	.91	.20	
10-12	49	0	24.5	.42	.114	73	88	80.5	1.05	.25	
13-16	62	0	31	.62	.103	85	96	90.5	1.98	.18	1.15
17-19	54	0	27	.05	.059	76	84	80	.10	.10	
20-23	48	0	24	.38	.119	79	89	84	.92	.20	
24-28	40	0	20	.18	.102	72	85	77	.55	.26	
29-30	30	0	15	.17	.082	63	74	68.5	.42	.17	
31-Sept. 2	25	0	12.5	.24	.106	52	63	57.5	.65	.23	
3-7	10	0	5		.047	36	39	37.5		.127	
8-9	12	0	6	.23	.09	46	36	41	.52	.205	
10-13	56	0	35	1.02	.081	70	52	61	1.02	.096	
14-19	44	0	22		.069	55	40	45		.084	
Season total				16.07	17.48				37.53	27.04	7.70

plots of field 1 and the corresponding yield from each plot were plotted in Figure 8 and resulted in an R^2 of 0.998 if only the dry and normal plots are considered. If the wet plots are also considered in the analysis, the R^2 was 0.80. No significant difference in yield was found between the wet and normal plots, but the quality was significant at the 95 percent level. These findings are similar to those of an extensive study on a similar soil type (Quincy sand) by Middleton et al. (1975). Irrigation was applied in a 1:1 ratio on the normal plots according to E-pan depletion while the other treatments had increasing water application rates. Their findings indicated that all four moisture treatments, ranging from 30 to 49 inches of applied water produced about the same yield with a tendency for higher quality with increased water application.

On field 2 the dry plots and normal plots were significantly different at the 90 percent level. In this case a higher yield was found on the wet plots. The wet and normal plots were significantly different at the 90 percent level. Plotting all the yield values in relation to amount of applied water an R^2 of 0.73 was found for the regression line as shown in Figure 9.

The normal plots of field 1 had higher quality (81 percent number one potatoes) than did field 2 (72 percent number one potatoes) as shown in Table 2. It was assumed that the high NO_3-N concentration depressed the quality of field 2. The dry plots were essentially the same with 39 percent versus 38 percent number one potatoes for field 1 and 2 respectively. Thus gross tonnage, percent number one potatoes and amount of applied water was very similar when the dry plots were compared with their respective normal counterparts.

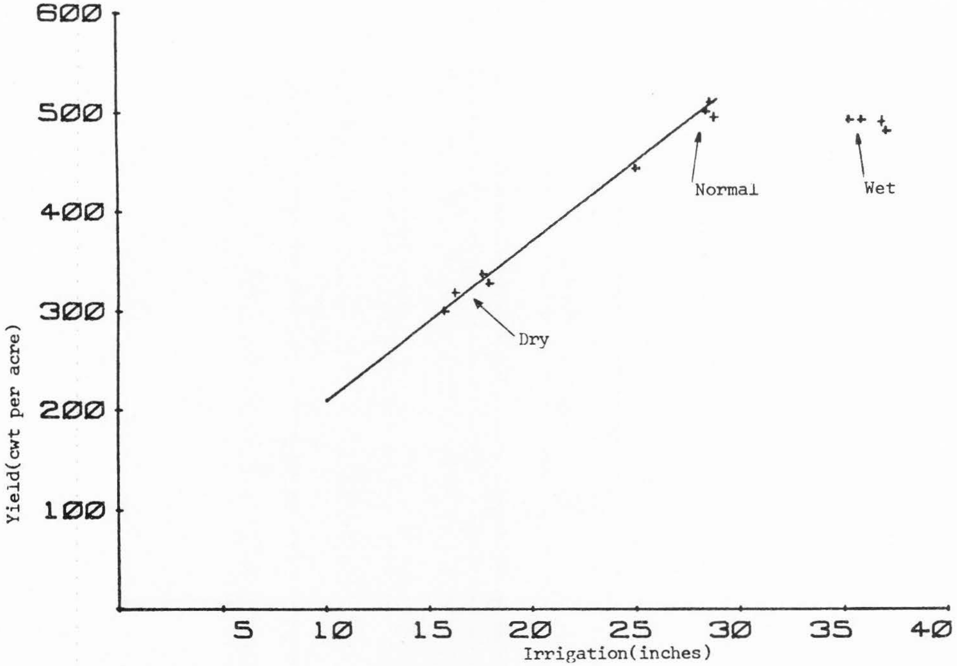

Figure 8. Irrigation treatments versus yield for field 1.

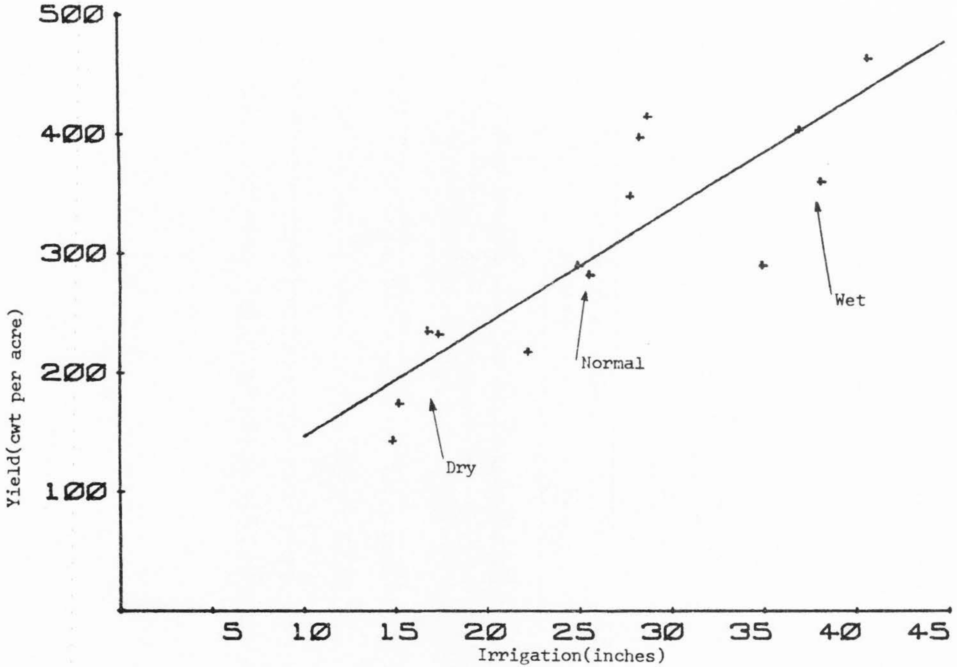

Figure 9. Irrigation treatments versus yield for field 2.

Table 10 shows that the tuber size development was considerably depressed on the dry plots when compared with the normal and wet plots. The main reason the quality was reduced was because of malformed tubers. It was assumed (after Corey and Myers, 1955) that the less dense foliage and the increase in soil temperature caused a depression in the quality causing more malformation than in the normal plots. The wet plots on field 2 showed the same trends as the normal plots with 72 percent number one potatoes; however, when compared with the 86 percent number one potatoes of field 1, quality was considerably less. In figures 10 and 11 the amount of applied water was plotted against percent quality for each respective field. When all the moisture plots are considered, the regression line showed an R^2 of 0.82 for field 1 and an R^2 of 0.42 for field 2. When only the dry and normal plots are considered an R^2 of 0.91 was found for field 1 and an R^2 of 0.42 for field 2. These comparisons show that similar amounts of water did not result in a similar quality.

Since the NO_3-N concentration was very high in the soil and plants for field 2, this factor must have had some bearing on the yield and quality differences. With the increase of water on the wet plots, the plant NO_3-N concentration was decreased sooner than on the normal plots as shown in Figure 7. Plant tissue tests for NO_3-N were running about 6000-7000 ppm lower on the wet plots than on the normal plots during the latter part of the season. This reduction may have been enough to cause some of the difference in yield and quality. The high NO_3-N concentration probably kept field 2 from attaining a higher yield as did field 1 because more growth went into producing vines than did to tuber production. Evidence indicates that plant

Table 10. Tuber sizes for the three moisture regimes of both fields (inches).

	Field 1			Field 2		
Date	Normal	Wet	Dry	Normal	Wet	Dry
June 1	0.12-0.25	0.12-0.25	Stolon	Stolon	Stolon	Stolon
June 15	0.75-1.00	1.00-1.25	0.12-0.50	0.12-0.75	0.50-1.00	0.12-0.50
June 29	1.00-1.50	1.25-1.75	0.50-0.75	1.00-1.25	1.00-1.50	0.50-1.00
July 14	1.50 x 2.50	1.75 x 2.75	1.00 x 1.50	1.50 x 2.00	2.00 x 2.50	1.00 x 1.25
July 21	2 x 3	2.50 x 3.50	1.50 x 2.00	2 x 3	2.50 x 3.50	1.50 x 2.00
July 28	2.50 x 3.50	3.00 x 4.50	1.75 x 2.50	2.50 x 3.50	3 x 4	1.75 x 2.50
Aug. 10	3 x 5	3 x 6	2 x 3	3 x 5	3 x 6	2 x 3
Aug. 24	3 x 6	3.50 x 6.50	2.25 x 4.00	3 x 6	3.50 x 6.50	2.50 x 3.50
Sept. 14	3.50 x 7.00	3.50 x 7.00	2.75 x 5.00	3 x 7	3.50 x 7.00	3.00 x 4.50

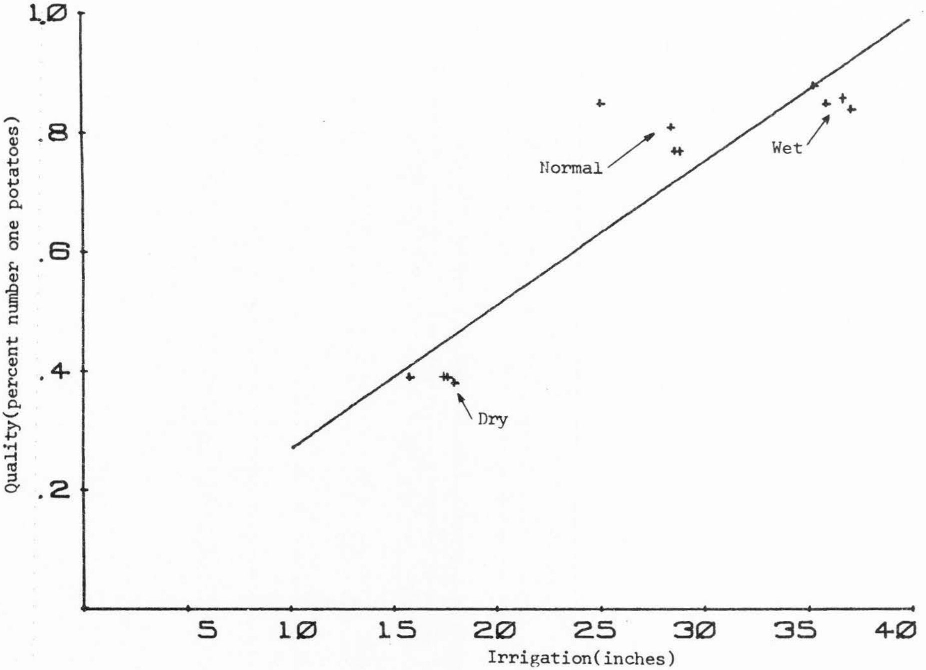

Figure 10. Irrigation treatments versus quality for field 1.

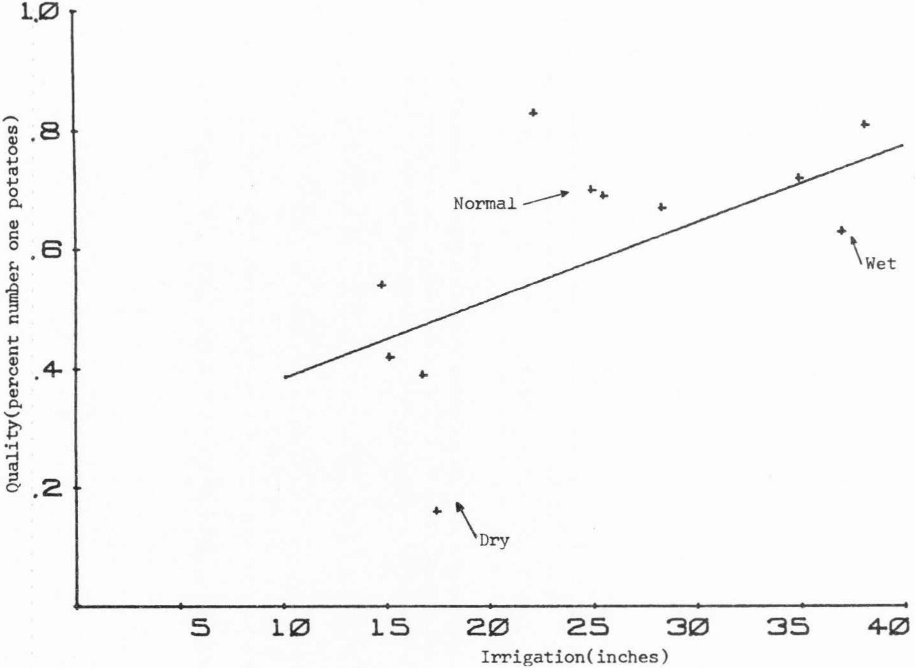

Figure 11. Irrigation treatments versus quality for field 2.

NO_3-N levels need to drop off in August for proper tuber size and quality to develop (Haddock et al., 1974). Ohms (1961) concluded that with increased vine growth there is a corresponding increase in "knobby" tubers. In this particular case it was not known whether the yield increase was due to the higher water application rate or to the leaching of some of the nitrogen below the root zone resulting in the lowering of the plant NO_3-N level and increased tuber weight. Since the average number of tubers per five feet of row for the normal plots and the wet plots were essentially the same, individual tuber weight, not numbers, caused differences in yield. The wet plots did put on size and weight sooner than did the normal plots as shown in Table 10.

On the wet plots of field 1, the plants were turning yellow and the plant NO_3-N level was low at 6250 ppm by August 20 as shown in Figure 6. The plants in the normal plots were at 13,000 ppm NO_3-N and still green. It is not known whether the wet plots would have outyielded the normal plots if higher levels of NO_3-N had been present in the plants. The Middleton et al. (1975) study found no significant difference in yield on the over-irrigated plots even when the plant NO_3-N level was kept at an adequate level. Thus it is assumed in the present study that extra nitrogen would have made no difference in yield.

Considering only field 1 and neglecting field 2 because of the high fertilizer level, it is apparent that a good irrigation schedule had been followed with a minimum amount of leaching. Increased water application, higher than the E-pan or gravimetric methods indicated, made no difference in yield, while reduced water application rate depressed the yield and quality significantly.

SUMMARY AND CONCLUSIONS

The overall objective of this study was to evaluate the in-field E-pan as an irrigation scheduling device. During the mid-season stage of growth, the in-field pan scheduled irrigations well when using the same value of K_c of 0.95 used by Washington State people (Jensen and Middleton). This study has shown that this same K_c can be applied to Southern Idaho with reliability. This K_c can be applied with more accuracy than the three K_c curves discussed in this study. Generalizing, irrigations can be scheduled by time and amount during this 50 day period in nearly a 1:1 relationship with E-pan evaporation loss, since $Et_A = 0.95 \times$ E-pan. The K_c values developed for the early and late season growth stages should hold true from season to season. The early and late portions of the curve are very similar with many of the present K_c curves. It is significant that two different soil types, different irrigation timings and amounts, and different microclimates produced very similar K_c curves for the data for this year particularly.

Another objective of this study was to compare the E-pan irrigation scheduling method with the gravimetric and climatic methods. Assuming that proper sampling and handling of the soil takes place, the gravimetric method was the more precise. The main problem with this method for irrigation scheduling was that of a time-delay (because of time required to dry the sample) in predicting future irrigation dates. The E-pan and climatic methods have an advantage that they can predict irrigation timing and amounts the same day the field is checked. The two climatic methods used in this study showed considerable variation in predicting Et_p. The Penman equation did a much better job than the Jensen-Haise equation. The E-pan method predicted Et much better than the Jensen-Haise equation and equally as well as the Penman equation.

Another objective of this study was to compare the relationship between applied water and crop production. This study verified the results of many other people by definitely correlating amount of applied water with yield. Both fields resulted in 34 percent reduction in yield with 37 percent reduction in water. Quality was reduced by about 50 percent with the reduction of applied water. The wet treatment data on field 1 showed that increased water application, beyond that to maintain transpiration at potential, made no difference in yield. Thus with a combination of two irrigation scheduling methods, proper irrigation scheduling took place. The yield data on field 2 was inconclusive, since a higher water application rate gave higher yield.

FUTURE RESEARCH

This research project has left several areas open for future research. (1) Will the proposed K_c curves hold true from year to year, especially in the early and late parts of the season. (2) Was the increase in yield on field 2 on the wet moisture regime due to increased water application or to the lowering of the soil nitrate level because of leaching or did the E pan underestimate Et. (3) Will the in-field pan method apply to other sprinkler irrigated crops with success.

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APPENDIX II

THE 1:4 MUD-SOIL STUDIES

Table 11. Comparison of two foot metal and one foot plastic in-field E pans conducted in 1974 in Wendell, Idaho

	Field 3		Field 4	
	Metal E pan in/day	Plastic E pan in/day	Metal E pan in/day	Plastic E pan in/day
July 5-9	.270	.257	.21	.21
10-12	.30	.267	.267	.30
13-16	.20	.20	.205	.205
17-19	.353	.353	.30	.32
20-23	.25	.275	.243	.267
24-26	.40	.40	.34	.34
27-30	.26	.31	.20	.20
31-Aug. 2	.356	.32	.237	.237
3-6	.275	.275	.265	.24
7-9	.10	.10	.235	.235
10-13	.325	.325	.25	.225
14-20	.26	.25	.283	.267
21-23	.23	.23	.207	.24
24-31	.286	.203	.244	.231
Average	.276	.275	.249	.251

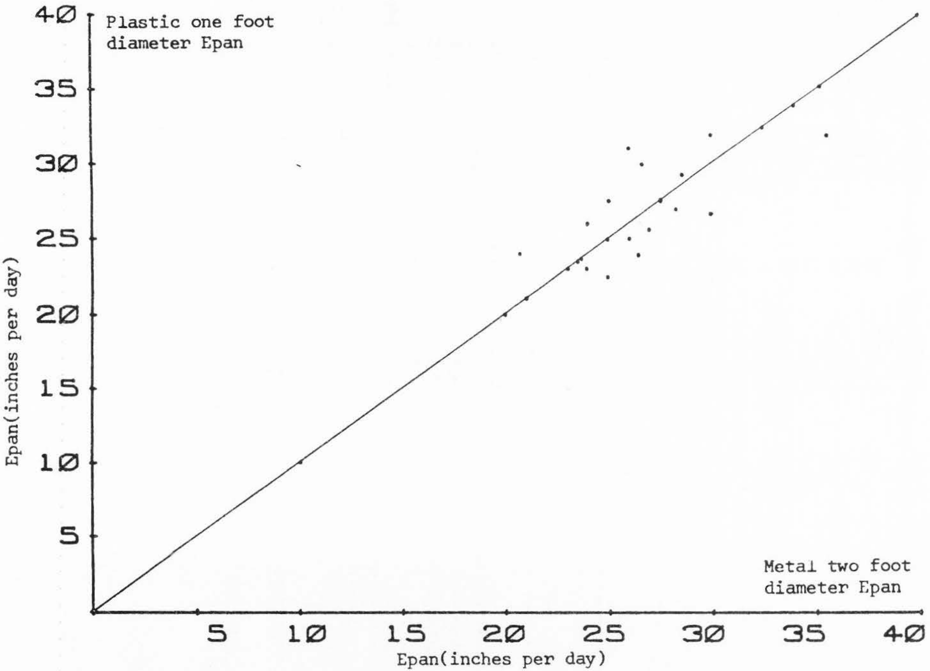

Figure 12. Epan values from two different size Epans for two potato fields at Wendell, Idaho for 1974.

Table 12. Data used for computation of Jensen-Haise Etp; also Penman Etp and Kimberly E pan Etp.

Date	Rs Ly/day	Mean T Deg. F	Jensen Haise Etp In/D	Penman comb. Etp In/D	Kimberly E pan
Apr. 26	378.3	40	0.49		.20
27	535.3	39	.064		.20
28	593.7	44	.144		.20
29	633.7	47	.124		.20
30	663.6	50	.149		.20
Subt. Ave.			.106		.20
May 1	661.4	50	.148		.30
2	384.5	55	.105		.32
3	446.0	58	.134		.15
4	592.5	53	.150		.20
5	412.3	51	.096		.23
6	251.2	52	.061		.22
7	656.4	46	.22		.05
Subt. Ave.			.104		.21
8	629.9	56	.177		.26
9	618.7	59	.192		.27
10	433.5	61	.142		.28
11	705.0	60	.225		.33
12	696.2	50	.156		.40
13	680.6	54	.179		.27
14	577.9	67	.223	.39	.39
Subt. Ave.			.184		.31
15	712.2	51	.166	.34	.39
16	696.3	53	.176	.41	.30
17	684.3	60	.218	.30	.41
18	690.3	59	.214	.32	.36
19	575.3	58	.174	.30	.30
20	720.5	59	.162	.38	.31
21	671.3	50	.150	.24	.30
Subt. Ave.			.180	.313	.34
22	553.8	60	.177	.18	.28
23	504.4	56	.142	.21	.26
24	590.5	60	.188	.25	.26
25	702.3	62	.237	.32	.34
26	720.7	52	.175	.23	.46
27	638.2	56	.179	.35	.27
28	583.9	66	.220	.22	.44
Subt. Ave.			.189	.251	.33

Table 12. Data used for computation of Jensen-Haise Etp; also Penman Etp and Kimberly E pan Etp (continued).

Date	Rs Ly/day	Mean T Deg. F	Jensen Haise Etp In/D	Penman comb. Etp In/D	Kimberly E pan
May 29	722.7	51	.169	.23	.28
30	569.9	54	.149	.18	.31
31	566.2	49	.175	.15	.26
Subt. Ave.			.164	.187	.28
June 1	715.4	56	.201	.28	.24
2	573.1	61	.188	.20	.33
3	670.8	57	.195	.33	.27
4	732.5	54	.192	.35	.34
5	699.3	56	.197	.30	.26
6	665.7	61	.219	.32	.40
7	639.0	65	.234	.22	.22
Subt. Ave.			.204	.286	.294
8	646.4	69	.261	.30	.32
9	570.0	63	.198	.29	.27
10	362.2	67	.139	.26	.31
11	278.0	55	.076	.17	.15
12	513.6	51	.120	.18	.11
13	640.1	54	.168	.28	.29
14	762.6	43	.120	.22	.41
Subt. Ave.			.155	.243	.28
15	677.6	51	.158	.27	.24
16	738.2	64	.264	.25	.32
17	683.1	58	.205	.16	.38
18	742.1	57	.216	.27	.31
19	610.0	60	.195	.31	.29
20	695.2	72	.262	.32	.36
21	596.2	65	.219	.33	.33
Subt. Ave.			.217	.273	.32
22	751.3	63	.261	.37	.37
23	757.1	57	.220	.37	.53
24	747.7	55	.203	.38	.43
25	746.4	61	.245	.29	.41
26	741.0	51	.173	.26	.48
27	738.6	55	.20	.26	.28
28	684.6	65	.25	.32	.31
Subt. Ave.			.221	.321	.40

Table 12. Data used for computation of Jensen-Haise Etp; also Penman Etp and Kimberly E pan Etp (continued).

Date	Rs Ly/day	Mean T Deg. F	Jensen Haise Etp In/D	Penman comb. Etp In/D	Kimberly E pan
29	559.6	73	.248	.28	.51
30	614.3	79	.307	.30	.33
Subt. Ave.			.277	.29	.42
July 1	653.0	68	.258	.27	.33
2	692.4	56	.195	.33	.32
3	687.6	61	.226	.34	.31
4	604.4	71	.256	.34	.24
5	696.0	67	.268	.31	.36
6	599.1	72	.259	.27	.40
7	508.6	77	.245	.22	.29
Subt. Ave.			.244	.304	.32
8	681.4	70	.282	.30	.30
9	694.4	72	.30	.32	.33
10	688.9	71	.292	.30	.35
11	517.3	73	.229	.27	.31
12	692.6	73	.307	.32	.28
13	710.1	60	.227	.30	.41
14	706.1	65	.259	.30	.30
Subt. Ave.			.271	.291	.326
15	620.0	67	.239	.27	.37
16	621.0	72	.269	.28	.30
17	620.0	78	.304	.21	.36
18	620.4	67	.239	.22	.16
19	652.7	67	.252	.23	.23
20	600.4	65	.220	.27	.28
21	642.0	70	.266	.28	.23
Subt. Ave.			.254	.251	.276
22	660.8	70	.276	.29	.28
23	528.0	72	.229	.26	.30
24	489.4	76	.230	.26	.38
25	668.4	68	.264	.27	.29
26	700.0	68	.296	.29	.30
27	682.0	72	.295	.31	.34
28	599.0	69	.242	.28	.45
Subt. Ave.			.261	.28	.334
29	315.9	73	.139	.14	.27
30	371.3	71	.157	.25	.17
31	583.7	71	.247	.26	.20
Subt. Ave.			.181	.217	.213

Table 12. Data used for computation of Jensen-Haise Etp; also Penman Etp and Kimberly E pan Etp (continued).

Date	Rs Ly/day	Mean T Deg. F	Jensen Haise Etp In/D	Penman comb. Etp In/D	Kimberly E pan
Aug. 1	432.2	73	.191	.22	.32
2	329.8	68	.130	.18	.23
3	606.1	63	.211	.20	.25
4	543.7	64	.194	.25	.28
5	617.0	60	.197	.26	.12
6	499.5	66	.188	.31	.33
7	601.7	64	.215	.28	.28
Subt. Ave.			.19	.243	.258
8	594.5	61	.195	.27	.27
9	637.8	61	.210	.29	.29
10	591.5	63	.206	.22	.28
11	477.9	65	.175	.26	.25
12	417.2	67	.161	.21	.25
13	521.3	67	.201	.23	.29
14	472.4	68	.187	.26	.24
Subt. Ave.			.19	.249	.266
15	264.5	63	.092	.12	.13
16	385.3	54	.101	.17	.14
17	435.3	57	.126	.20	.13
18	291.8	62	.099	.16	.20
19	557.9	57	.162	.20	.10
20	592.7	62	.201	.24	.22
21	588.8	67	.227	.25	.26
Subt. Ave.			.144	.191	.194
22	262.8	72	.114	.22	.30
23	528.5	69	.214	.24	.15
24	576.3	61	.189	.21	.19
25	513.9	66	.193	.32	.25
26	561.6	66	.211	.29	.31
27	582.9	52	.142	.23	.28
28	566.0	56	.159	.21	.24
Subt. Ave.			.174	.246	.246
29	462.5	64	.165	.24	.26
30	553.1	68	.129	.23	.28
31	548.3	67	.211	.22	.29
Subt. Ave.			.199	.23	.277

Table 12. Data used for computation of Jensen-Haise Etp; also Penman Etp and Kimberly E pan Etp (continued).

Date	Rs Ly/day	Mean T Deg. F	Jensen Haise Etp In/D	Penman comb. Etp In/D	Kimberly E pan
Sept. 1	546.9	67	.211	.26	.25
2	541.3	70	.224	.29	.25
3	538.2	66	.202	.38	.33
4	520.5	64	.186	.24	.24
5	446.1	69	.181	.27	.26
6	356.5	72	.154	.19	.27
7	552.0	53	.139	.22	.25
Subt. Ave.			.186	.25	.264
8	539.8	48	.111	.20	.25
9	532.3	52	.129	.20	.20
10	491.2	58	.147	.22	.22
11	253.5	65	.093	.11	.23
12	467.2	64	.167	.15	.16
13	319.1	54	.084	.16	.19
14	436.8	54	.115	.14	.07
Subt. Ave.			.121	.169	.189
15	355.6	59	.110	.16	.13
16	343.1	63	.119	.22	.19
17	197.0	61	.065	.14	.14
18	227.0	51	.053	.10	.06
19	455.4	52	.110	.14	.09
20	455.7	59	.141	.15	.16
21	180.6	62	.061	.13	.23
Subt. Ave.			.094	.149	.143
22	448.0	60	.143		.09
23	369.6	60	.118		.17
24	391.9	57	.114		.18
25	429.2	57	.125		.12
26	427.0	58	.128		.20
27	426.6	59	.132		.17
28	423.0	60	.135		.19
Subt. Ave.			.128		.16
29	416.0	59	.129		.20
30	410.5	59	.127		.19
Subt. Ave.			.128		.195

Table 13. Values of t for quality and yield for the three moisture regimes of field 1 and 2.

	Quality percent number one's	Yield (cwt per acre)	Quality percent number one's	Yield (cwt per acre)
Dry	39.0	321.8	37.7	195.87
Normal	81.0	485.7	72.0	296.8
Wet	85.7	489.4	72.0	379.5
t at 95% level--Normal vs. Dry*	25.68	9.77	3.95	N.S.
t at 95% level--Normal vs. Wet	2.58	N.S.	N.S.	N.S.

*t value from table at 95% level for 6 degrees of freedom = 2.447.

VITA

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