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Soil Moisture Depletion by Irrigated Crops Grown in South Dakota

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soil moisture depletion

BY IRRIGATED CROPS GROWN IN SOUTH DAKOTA

AGRICULTURAL ENGINEERING DEPARTMENT
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SOUTH DAKOTA STATE COLLEGE

Foreword

It is true that we have a fairly abundant yearly rainfall in this state, but almost every year we have hot, dry periods during the summer and fall which seriously injure and curtail the growth of one or more of our crops. A dependable supply of water through some form of irrigation would often mean the difference between success and failure for the farmer.

Dry-land practices and crop varieties, over a long period of time, have been modified and adapted to combat better the periods of drouth. These practices and varieties may not necessarily be best adapted to the area if irrigation water were used to supplement the natural rainfall. By utilizing irrigation water, fertilizers, high seeding rates, and crop varieties adapted to irrigation, more stabilized farming could be achieved.

A successful irrigation enterprise depends in part upon the irrigation management which includes a knowledge of: the amount of water required by a particular crop, where in the soil profile water is used by specific plants, and the time this water should be supplied to the plants for the most economical and abundant production. It is with these thoughts in mind that this circular was prepared. It represents the best information we have found up to the present time. The information included will acquaint the reader with the responsibilities of the irrigator and technician in promoting better irrigation management practices.

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Acknowledgement

This publication summarizes, in part, studies being conducted at the Redfield Development Farm, Redfield, South Dakota, in cooperation with the Bureau of Reclamation and the South Dakota Agricultural Experiment Station. The project was inaugurated with the Division of Irrigation and Water Conservation, Soil Conservation Service, USDA, and is now with the Soil and Water Conservation Research Branch, Agricultural Research Service, USDA. Special acknowledgment is made to Director I. B. Johnson, of the South Dakota Agricultural Experiment Station, for his support of this endeavor, Dr. Lawrence O. Fine, Agronomy Department, to members of the Agricultural Engineering Department, and to other Federal and State personnel for their critical review and comments.

Definitions

Consumptive Use: The sum of the volumes of water used by the vegetative growth in transpiration and building of plant tissue and that evaporated from adjacent soil.

Profile Consumptive Use: The percentages of the total water consumptively used which are derived from specific segments of the soil profile during the growing season by the various crops. One foot intervals are used for this circular.

Peak Period: That part of the growing season in which the maximum daily consumptive use occurs.

Transpiration: The water absorbed by the crop and evaporated from leaf and stem surfaces.

Field Irrigation Efficiency: The percentage of irrigation water delivered to the field that is stored in the soil for consumptive use by the crops.

Leaching: The process of removal of soluble material from soil by the passage of water through the soil. This is a primary step in the improvement of saline soils.

Soil Moisture Depletion

By Irrigated Crops Grown in South Dakota

Leonard J. Erie and Niel A. Dimick[1]

Introduction

Many of the failures and disappointing results in some of the new irrigation enterprises are a direct result of not meeting the moisture needs of the growing crop. Frequently the failure can be traced back to the under-designing of the distribution system. However, the main causes for failure are insufficient amounts of irrigation water, poor distribution, and applying the water too late to prevent a few days of high moisture stress in the plant, which results in an inevitable loss in yield.

If irrigation systems are designed to cover too many acres, the crops cannot be supplied with adequate water during periods of drouth. Oftentimes too much faith is placed in the probability of rain, and irrigation water is not applied in time to prevent serious effects of dry weather on the crop.

The four potential sources of water the plants can use are: precipitation, stored soil moisture, ground water and irrigation water. The availability of water from any or all of these sources is the key to the prevention of drouth periods which may curtail yields and materially lower the quality of the produce.

If, for instance, rainfall is inadequate to maintain the supply of stored moisture, then irrigation water must be supplied.

For best irrigation results, it is not only important to know how much water to apply and when to apply it, but also where in the soil the plant obtains the moisture. Excessive quantities of irrigation water will cause moisture to pass below the root zone where it can not be used by plants. Furthermore, it will carry plant nutrients downward and out of reach of the plant, cause additional erosion and aggravate drainage problems.

Successful irrigation farming includes good water management, high fertility, adapted crops and proper seeding for maximum production. Omitting any one of the essential practices will result in disappointing crop yields.

This report presents some estimates of the amounts of water that the more common crops will use; shows where in the soil profile this moisture is obtained, and gives the periods of maximum or most critical moisture needs of the crops.

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Moisture Used by Growing Crops

At times, an excellent small grain crop may be achieved in a low rainfall year, or a poor corn crop in a high rainfall year, or a short soybean crop under high moisture conditions. This may happen because of the timeliness of rains, the amount of stored moisture in the soil at various times and the quantity of effective rainfall. The corn may have been slightly dry at the beginning of its critical period of growth and a few days of dry weather at this time will drastically cut down the yield. The same condition might have occurred for soybeans, while the small grain crop may have utilized a bountiful supply of stored water and then received a rain just at its critical stage, thus accounting for a satisfactory small grain crop.

The fact remains that crops do need a fairly *definite* amount of moisture during the growing season. They use it at rates which are not constant over any extended period of time. Some crops have a gradually increasing rate from planting time until the peak use period is reached, then a gradual decrease until harvest, while others use moisture more uniformly all year. Different crops require water in varying amounts, from different soil depths, and may have different peak use periods.

Many natural factors influence the amount of water consumed by plants, such as climate, water supply and daytime hours. The climatic factors that particularly affect consumptive use are temperature, humidity, wind movement and length of growing season. Irrigation practices and the intensity and frequency of rains also influence the amount of water consumed. Recent investigations show that differences in consumptive use between any two locations are due mainly to length of growing season, temperature and daytime hours. These factors are taken into consideration in the consumptive use determinations that follow.

Previous Estimates of Consumptive Use

A publication[2] prepared in 1952 provided an estimate of the consumptive use requirements of crops for the various areas of South Dakota, using a method developed by Blaney and Criddle[3]. Through the use of a formula the results of experimental studies throughout the western United States were utilized in showing the relationship between temperature, length of growing season, monthly percent of annual daytime hours and consumptive use. By using this formula, consumptive use and irrigation water requirements of crops can be quickly estimated for any area where the necessary climatological data are available.

With monthly temperature records and latitude data, the consumptive use can be computed from the formula U equals KF; where U equals consumptive use of water in inches for any period, K equals empirical

[2]Leonard J. Erie, "Consumptive Use and Irrigation Water Requirements of Crops in South Dakota," USDA, SCS, Research, Div. of Irrigation and Water Conservation, 1952.

[3]Harry F. Blaney and Wayne D. Criddle, "Determining Water Requirements in Irrigated Areas from Climotological and Irrigation Data," USDA, SCS, Research Div. of Irrigation and Water Conservation, 1950.

consumptive-use coefficient (determined by experimental or actual quantitative measurements), and *F* equals sum of the monthly consumptive-use factors for the period (sum of the products of mean monthly temperature and monthly percent of annual daytime hours.)

The net amount of irrigation water necessary to satisfy consumptive use is found by subtracting the growing season rainfall from the consumtive-use requirements for the growing season. This assumes that precipitation occurring during the growing season is used by the crops and decreases the irrigation requirements by the same amount. This is not always true. Precipitation may be of such intensity that surface runoff occurs, or may come in such small amounts that it does not effectively reduce the irrigation requirement. Also stored soil moisture may contribute to plant growth. It is assumed, in this report, that runoff, deep percolation and excessive evaporation of growing season rainfall is compensated for by the stored moisture that is in the soil at planting time and is available for plant growth.

Actual Measurements on Various Crops

Research was conducted at the Redfield Development Farm to gather information on consumptive use of water by crops and to test the validity of the original estimates made in the bulletin on consumptive use for South Dakota. The procedure followed was to actually measure the water used by the various crops, and then correlate it with the temperature and latitude data. Through substituting in the formula *U* equals *KF*, the measured values of *U* and *F*, "*K*" values were determined. These values were then compared with the original assumed "*K*" values used in the previous mentioned bulletin (Table 1).

From an analysis of these results and previous records "*K*" values were determined and summarized in Table 2 which are believed to be most representative of South Dakota conditions. These values were used in computing the consumptive use data in Table 3.

An inspection of the data in Tables 1 and 2 will show the flax and corn coefficients to be the only ones changed from the original estimates. The "*K*" values for flax and corn were changed from 0.80 to 0.70.

The length of growing season directly affects the total or seasonal consumptive use estimates. It would be impossible to state the exact number of days required for a particular crop to mature, as this varies from year to year as well as among localities. The research at Redfield showed that during the period of study, dry beans required 3½ months to mature instead of 3, as assumed in Table 2, flax 3½ instead of 4, and potatoes 3½ instead of 4. A slight adjustment might have been in order for the Redfield area; however, no adjustments were made in this circular because of the growing season variability. The actual consumptive use corrections, if made, would have been about 2 inches of water for each above named crop per growing season.

Determining Consumptive Use Rates

South Dakota was divided into 32 separate areas as shown in Fig. 1. These are the same as in the original bulletin. In each of the areas the pertinent climatic characteristics are generally uniform and climatological data are available.

Table 3 shows the normal consumptive use of water by crops in the various areas during their respective growing seasons. It also shows the es-

Table 1. Seasonal Consumptive Use of Water by Crops at the Redfield Development Farm, Redfield, South Dakota

Crop and Year	Measured Consumptive Use		"K" Values		Yield Per Acre§
	Seasonal*	Av. Daily	Determined†	Assumed‡	
	Inches	Inches			
Alfalfa‖				0.85	
1950	21.8	0.20	0.88	—	5.88 T.
1951	20.5	0.19	0.88	—	4.93 T.
1952	23.1	0.20	0.91	—	6.74 T.
1953	23.6	0.17	0.82	—	5.40 T.
Dry beans				0.65	
1952	15.8	0.15	0.64	—	
1953	17.0	0.17	0.75	—	1354 Lbs.
Corn				0.80	
1951	16.7	0.15	•.73	—	
1952	16.8	0.13	0.68	—	85 Bu.
1953	16.4	0.14	0.64	—	92 Bu.
Flax				0.80	
1952	16.0	0.15	0.67	—	24.9 Bu.
1953	14.0	0.16	0.73	—	21.4 Bu.
Potatoes				0.70	
1950	15.3	0.15	0.69	—	506 Bu.
1951	15.7	0.14	0.67	—	273 Bu.
1952	15.1	0.13	0.66	—	450 Bu.
1953	16.8	0.15	0.67	—	297 Bu.
Soybeans				0.65	
1952	15.3	—	—	—	37.7 Bu.
1953	16.0	0.14	0.63	—	31.7 Bu.
Sugar beets				0.70	
1951	24.7	0.18	0.91	—	24.7 T
1952	23.3	0.15	0.71	—	19.6 T.
1953	24.0	0.15	0.73	—	15.4 T.
Wheat				0.75	
1953	16.3	0.18	0.84	—	31.3 Bu.

*Seasonal use divided by daily use equals the number of days used in determining the consumptive use figure (usually planting date to harvest date).

†Computed from measured values of consumptive use and climatic factors.

‡Assumed for use in bulletin on consumptive use in South Dakota but largely determined in other areas of the West.

§Inspection of the yield values show considerable variability, however, it should be observed, though the yields vary, the consumptive use values are nearly constant from year to year. The inference would be that specific plants use a certain quantity of water regardless of other variables affecting yield. These yield differences were due to fertility differences, weather and disease infestation.

‖Consumptive use figures for alfalfa represent that moisture used during the growth of three hay crops, and not that used for the entire growing season.

timated consumptive irrigation water requirement of crops in years of average rainfall. It should be kept in mind that these figures represent only the water required for consumption by the plants and not the quantity required to be pumped or supplied to the farm headgate. The pumping or headgate requirement is determined by considering the efficiency with which the water can be applied to the soil and made available for plant use.

Table 2. Recommended "K" Values for South Dakota

Crop	Growing Season or Period	Consumptive Use Coefficient for Growing Period "K"
Alfalfa	Frost-free period	0.85
Grass pastures	Frost-free period	0.75
Small grain	3 months	0.75
Corn	4 months	0.70
Beans	3 months	0.65
Potatoes	4 months	0.70
Flax	4 months	0.70
Sugar beets	Frost-free period	0.70

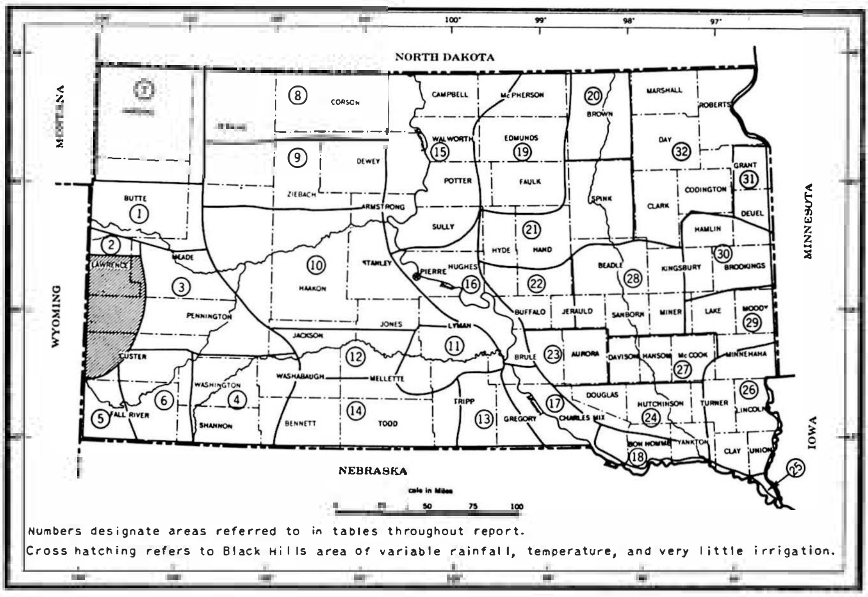
Table 3. Summary of Estimates of Normal Consumptive Use of Irrigation Water and Total Consumptive Use by the Crops Grown in Various Areas of South Dakota

Unit No.	Unit Area	Consumptive Use of Irrigation Water*—Total Consumptive Use in Parentheses† Alfalfa	Grass Hay and Pasture	Grain (Small)	Corn and Flax	Sugar Beets	Potatoes	Dry Beans
		Inches	Inches	Inches	Inches	Inches	Inches	Inches
1.	Belle Fourche	16 (25)	13 (22)	8 (16)	10 (19)	11 (20)	10 (19)	6 (14)
2.	Spearfish and Redwater Creek	15 (26)	12 (23)	7 (15)	9 (19)	10 (21)	9 (19)	5 (13)
3.	East Black Hills Streams	16 (27)	13 (24)	7 (15)	9 (18)	11 (22)	9 (18)	5 (13)
4.	Washington and Shannon	15 (24)	12 (21)	8 (16)	10 (19)	10 (20)	10 (19)	6 (14)
5.	Edgemont Unit	16 (26)	13 (22)	8 (16)	10 (19)	11 (21)	10 (19)	6 (14)
6.	Angostura Unit	15 (25)	12 (22)	8 (16)	10 (19)	11 (20)	10 (19)	6 (14)
7.	Northwest South Dakota	15 (23)	12 (20)	8 (15)	10 (18)	11 (19)	10 (18)	6 (13)
8.	Grand River Unit	14 (24)	12 (21)	8 (16)	10 (19)	10 (20)	10 (19)	6 (14)
9.	Moreau River Unit	15 (25)	12 (22)	8 (16)	10 (19)	11 (20)	10 (19)	6 (14)
10.	Cheyenne Bad River	17 (26)	14 (23)	9 (16)	10 (19)	12 (22)	10 (19)	6 (14)
11.	East White River	16 (27)	13 (23)	8 (16)	10 (20)	12 (22)	10 (20)	6 (14)
12.	West White River	18 (29)	15 (25)	9 (16)	11 (20)	13 (24)	11 (20)	6 (14)
13.	Winner-Gregory	17 (29)	13 (26)	7 (16)	9 (20)	12 (24)	9 (20)	5 (14)
14.	Rosebud	18 (28)	15 (25)	8 (16)	10 (20)	13 (23)	10 (20)	6 (14)
15.	Upper Missouri	16 (26)	13 (23)	9 (16)	10 (19)	12 (21)	10 (19)	6 (14)
16.	Pierre-Chamberlain	18 (29)	15 (26)	9 (16)	11 (20)	13 (24)	11 (20)	6 (14)
17.	Chamberlain-Fort Randall	14 (28)	11 (24)	6 (16)	7 (19)	9 (23)	7 (20)	4 (14)
18.	Fort Randall-Yankton	13 (29)	10 (25)	6 (16)	6 (19)	8 (24)	6 (20)	4 (14)
19.	Northwest Oahe	13 (25)	10 (22)	7 (16)	8 (19)	9 (20)	8 (19)	5 (14)
20.	Aberdeen	12 (26)	9 (22)	6 (16)	7 (20)	7 (21)	7 (19)	4 (14)
21.	West Oahe	14 (26)	11 (22)	7 (16)	9 (19)	10 (21)	9 (19)	5 (14)
22.	Gann Valley	14 (26)	11 (23)	7 (16)	8 (20)	9 (21)	8 (20)	4 (14)
23.	White Lake	17 (28)	14 (25)	8)16)	10 (20)	12 (23)	10 (20)	6 (14)
24.	Lower James River	14 (28)	11 (25)	6 (16)	7 (19)	9 (23)	7 (20)	4 (14)
25.	Elk Point	9 (29)	6 (25)	5 (16)	5 (20)	4 (24)	5 (20)	3 (14)
26.	Southeastern South Dakota	11 (28)	8 (25)	5 (16)	5 (19)	6 (23)	5 (20)	3 (14)
27.	Mitchell	13 (28)	10 (24)	6 (16)	7 (20)	8 (23)	7 (20)	4 (14)
28.	Southeast Huron	13 (26)	10 (23)	6 (16)	7 (19)	8 (21)	7 (19)	4 (13)
29.	Madison-Flandreau	11 (25)	8 (22)	5 (15)	6 (19)	6 (21)	6 (19)	3 (13)
30.	Brookings, Arlington, Castlewood	12 (24)	9 (22)	6 (15)	7 (19)	8 (20)	7 (19)	4 (13)
31.	Milbank	10 (25)	7 (22)	5 (16)	5 (18)	6 (20)	5 (19)	3 (14)
32.	Northeast South Dakota	11 (25)	9 (22)	6 (15)	6 (18)	7 (20)	6 (19)	4 (13)

*Does not include the rainfall occurring during the crop growing period which is assumed to be used by the crops. The total crop application may be determined by dividing the consumptive use of irrigation water by the irrigation efficiency.

†The difference between consumptive use of irrigation water and total consumptive use represents the expected rainfall for the growing season for each crop, in its area.

Fig. 1. Consumptive use areas of South Dakota



Irrigation Efficiency and Headgate Water Needs

Since all of the irrigation water delivered to the farm headgate cannot be fully utilized, and since the crop requires a rather definite amount of water available in the soil, it is necessary to divide the net consumptive water requirements by an efficiency figure in order to obtain the gross or actual irrigation water requirement at the farm headgate. Field irrigation efficiency is defined as the percentage of irrigation water delivered to the field, that is, stored in the soil and thus made available for consumptive use by the crop. Irrigation efficiencies are affected by length of run, size of irrigation streams, slope, soils, skill of the irrigator and many other factors. Efficiencies of 65 to 70 percent can be expected.

As an example, the Grand River Unit, area No. 8, may be used with an assumed 70 percent field irrigation efficiency. From Table 3, it is observed that potatoes consume a total of 19 inches of water during the growing season. Normally, rainfall will furnish 9 inches and the consumptive use of irrigation water is 10 inches. The 10 inches must be supplied through irrigation to satisfy plant growth. If the 10 inches of water are divided by the assumed efficiency of 70 percent, the gross or headgate water requirement will be established.

10 inches ÷ .70 equals 14.3 inches

Thus 14.3 acre-inches per acre is the amount of water required at the headgate to supply 10 inches for crop growth.

To determine the quantity of water needed for a particular acreage, multiply the number of acres by the headgate water requirement in acre-inches per acre. Assuming the potato acreage was 30, then:

30 acres x 14.3 acre-inches per acre equals 429.0 acre-inches.

To estimate how many hours of irrigation are necessary, the following equation can be used:

1 cubic foot per second (1 CFS) equals 450 gallons per minute (approximately)

1 cubic foot per second (1 CFS) equals approximately 1 acre- inch per hour

Assuming a well produces 2 CFS, which is equal to 2 acre-inches per hour, it would require about 215 hours (429 ÷ 2) to apply the total seasonal requirement. If this water were applied in three equal applications, it would require about 72 hours operation for each irrigation, assuming the water was uniformly distributed over the field.

In this way the number of hours necessary per set, to apply a certain quantity of water can be determined. For instance, a 6-inch application with a sprinkler system that covers 1½ acres per set would require 9 acre-inches of water. If the well produces 2 CFS, or 2 acre-inches per hour, the total time required for the set would be 9 divided by 2, or 4½ hours. The amount of water required to irrigate an entire farm can also be estimated, provided the kind and acreage of each crop grown, the consumptive water requirement, and the irrigation efficiency are known.

It is often desirable to design an irrigation system on the basis of the peak irrigation water requirement period. This period would extend from about July 15 to August 15 in South Dakota. The irrigation time interval or the time between irrigations, would depend upon the available moisture for plant growth in a particular soil, divided by the peak consumptive use per day. For additional information on designing with peak consumptive use rates, the reader is referred to Hanson and Meyer[4] and Criddle.[5]

[4]R. E. Hanson, and W. R. Meyer, "Irrigation Requirements, (Estimates for Kansas)," Manhattan, Kansas, Bulletin 69, 1953.

[5]Wayne D. Criddle, "Computing Use and Irrigation Water Requirements, Logan, Utah," *Journal of Soil and Water Conservation*, Vol. 8, No. 5, September 1953.

Soil Moisture Taken From Different Depths

Soils are capable of holding only specific amounts of moisture that are available to plants. This moisture may range from as low as one-half inch of water or less per foot of soil in sands, to nearly 2½ inches per foot in clays. The moisture in the soil at planting time which is in the root zone of the crop is referred to as stored moisture. This moisture is usually used early in the growing season.

It is not only important to know how much water the plant uses, but where in the soil the plant obtains this moisture. Many researchers feel that under optimum growing conditions there is a direct relationship between distribution of the plant root system and the quantity of water used from the respective soil depths. When irrigation water is applied it is essential, for maximum water use and economy, to place this water where the plant can use it. Exceptions to this practice would be warranted under certain saline conditions, when excessive water is required for leaching.

In the process of obtaining consumptive use data, profile use data were also obtained and are summarized in Table 4.

Profile distribution of water used can, for all practical purposes, be expected to be fairly constant for a certain crop, on a given soil. Frequent rains and/or irrigations will slightly increase the moisture used from the top foot of soil as well as tend to increase the over-all consumptive use.

From Table 4 it can be seen that, on the average for all crops studied, nearly 90 percent of the moisture used was consumed from the top 3 feet; of this approximately 75 percent was from the first 2 feet and over half

Table 4. Soil Profile Distribution of Consumptive Use by Various Crops at Redfield Development Farm

Crop	Depth-Feet	Water Extracted from Each Foot of Soil Profile 0-1	1-2	2-3	3-4	4-5
		%	%	%	%	%
Alfalfa						
1951		54	23	16	7	–
1952		42	25	22	11	–
1953		47	23	18	9	3
	Average	48	24	19	9	–
Dry Beans						
1952		53	23	15	9	–
1953		57	22	13	8	0
	Average	55	22	14	8	–
Corn						
1951		49	19	19	13	–
1952		44	25	20	11	–
1953		58	23	12	5	2
	Average	50	22	17	10	–
Flax						
1952		52	21	17	10	–
1953		68	20	12	0	0
	Average	60	20	14	5	–
Potatoes						
1951		69	13	11	7	–
1952		54	21	18	7	–
1953		52	20	15	9	4
	Average	58	18	15	8	–
Sugar beets						
1951		54	22	15	9	–
1952		52	25	15	8	–
1953		52	24	12	9	3
	Average	53	24	14	9	–
Wheat						
1953		56	21	13	9	1
Over-all average		**54**	**22**	**15**	**8**	

NOTE: Average percentages were rounded and consequently do not all total exactly 100 percent.

These data were determined only from those periods of the growing season where it was reasonable to assume the precipitation that fell penetrated no further than the upper foot and thus was consumed from this layer.

from the top foot. All plants do not react the same under different soil conditions. Alfalfa, under dry-land conditions, is known to extract moisture from 20-foot depths in some soils, while corn may use moisture from a depth of 7 feet. The top 3 feet can be expected to contain the majority of plant roots in South Dakota soils.

Unless leaching is necessary, no more water than would bring the top 3 feet up to field capacity should be applied in most areas in South Dakota. Crops produced on a sandy loam or an unusually deep soil high in organic matter may be expected to have deeper rooting systems than the soils at Redfield. Deeper rooting systems will justify larger, less frequent applications of irrigation water, with resultant deeper penetration. Soils may also influence the moisture withdrawal pattern. The soil at Redfield is classified as a silt loam, however a laminated silt is encountered at about 3 feet.

Peak Rates for Specific Crops

As previously mentioned, the consumptive use rate is not constant. Most crops will reach a peak rate sometime during the growing season. Little basic research has been accomplished to determine when this peak period occurs for the various crops. There is also a need for additional research to define the optimum moisture conditions for maximum yields.

During the past three years, while collecting data on consumptive use of water at Redfield, many observations have been made on crop growing habits. Consumptive use rates were plotted against time, and from this, good indications of peak rate periods were obtained. This information was then correlated with the planting dates for the different crops.

Flax seems to begin its peak consumptive use rate period about two months after the planting date. It usually starts blossoming about 10 days before this period. The daily consumptive use rate during this peak period is considerably higher than at any other time during the growing season.

Sugar beets appear to require considerable moisture during the first three weeks of August, which is normally about three months after the planting date. Beets show a gradual increase in use of water. Thus the peak use rate is not a great deal higher than at other times during the middle of the growing season.

Potatoes use a large quantity of water about six weeks after the planting date, or about the time tubers are beginning to set. They continue this high use rate for one month.

Alfalfa seems to have no unusually high consumptive use rate periods other than would be expected because of temperature conditions. Practically no water is used for about a week following the cuttings of the crop. Immediately after this period the consumptive use rate jumps to about 0.20 of an inch of water per day and stays there until the crop is mature. The alfalfa crop produced the latter part of June and the first part of July uses more water than the crops produced before or after this period. It is essential that alfalfa has abundant moisture during the early part of its growing period.

Corn studies indicate that a peak rate period occurs shortly after the silking stage, which is about nine weeks after the planting date. This period lasts about a month.

Dry beans appear to have a high consumptive use rate period of one month starting about seven weeks after the planting date. This high rate starts when the beans begin to blossom.

Wheat begins a high rate period about seven weeks after the planting date when it is in the early boot stage.

If the critical moisture period can be assumed to coincide with the peak consumptive use rate periods, which in turn coincide with the seed and tuber forming period, it would seem that the observations and data on the above mentioned crops could be used as a guide for irrigating. The best recommendation on time of irrigation would be to never let the crop wilt seriously and to make sure the crop has ample moisture, just before, and during these peak periods. It is expected that greater refinement and adjustments will be made as additional information is obtained.

Conclusions and Recommendations

1. A specific crop uses moisture at a definite, but not necessarily constant, rate over any extended period of time. It does use a fairly definite volume of water during its growing season, at a particular location, irrespective of the water source.

2. Nearly 90 percent of the moisture used by crops grown under irrigation at Redfield, South Dakota, is extracted from the top 3 feet of the soil; approximately 75 percent from the first 2 feet and over 50 percent from the top foot. Since 90 percent of the moisture is used from the top 3 feet, the aim of the irrigator should be to apply only enough water to bring the top 3 feet to field capacity. (Exception to this would be under certain saline conditions when excessive water is required for leaching.)

3. Crops should never be allowed to suffer from lack of moisture. Each crop has a definite period—usually at blossoming time—that might be called a critical period. At this time, abundant moisture must be available to the plant for high production. A few days drouth during this period will drastically cut yields. If only one irrigation were to be applied, it would probably bring the largest return if applied at or shortly before this critical period.

4. It should be kept in mind that the consumptive use figures given in this circular are water requirements of the plant, and that efficiency figures must be applied to obtain the total water requirements at the field. Careful water spreading; adequate, but not over, irrigation; maintenance of structures and irrigation equipment; and knowledge of soil and its reaction to water are important items to consider for more efficient irrigation and more profitable irrigation farming.