A Report on Field Research in Soils

(A compilation of recent experimental results by personnel of the Department of Soil Science, Extension Specialists and Agronomists at the Branch Stations at Crookston, Duluth, Grand Rapids, Lamberton, Morris, Rosemount, and Waseca).

Department of Soil Science
University of Minnesota

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Some of the results herein reported are from experiments carried on during 1963 only, and should not be regarded as the results obtained over a number of years. The investigations are those of a more practical nature, and do not include some of the more theoretical problems presently under study in greenhouse and in the laboratory. Because these are largely one year results they should not be considered as conclusive and the results are not for publication.

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Soil Surveys

H. F. Arneman, R. S. Farnham and R. H. Rust

The soil survey project is a project of long standing which deals with the mapping, correlation and classification of the soils of the state. Soil surveys are thought of as an inventory of this important resource.

The soil survey in Minnesota is a cooperative effort between the Department of Soil Science, Minnesota Agricultural Experiment Station, and the U.S.D.A. Soil Conservation Service. In recent years the Soil Conservation Service has had some 30 soil scientists mapping soils in Minnesota. With the sizeable group of men mapping soils many problems in classification and laboratory characterization of the soils have come about. With this in mind and because of our fine physical facilities, we in the Department of Soil Science have strengthened our survey effort in the field of laboratory characterization of the soils and in the field of soil correlation.

Soil correlation is a necessary step in the publication of the soil survey in any county. This past year we took part in final field reviews in Stevens and Steele Counties and the Lamberton Experimental Station. Reports are in progress for the counties.

Other activities of the soil survey group this past year included:

1) Publication of the revised generalized soils map and report on "The Soils of Minnesota".

2) Soil survey progress reviews in 6 counties.

3) Began making a systematic soil inventory on areas of possible plot area expansion at the Rosemount Station.

4) Gave assistance to county assessors where they are planning to use soil survey information as a real estate tax base.

5) Laboratory characterization of soil profiles was carried out to aid in soil correlation procedures.

This next year we plan to participate in final soil survey reviews in Goodhue and Swift Counties and progress reviews in Benton, Carlton, and Houston Counties; soils in the Chippewa National Forest will be studied broadly in the field; and an effort will be made to inform certain agencies and individuals such as the metropolitan planners, highway engineers and residential developers of the use and value of soil surveys in multiple land use planning.

Soil Productivity Study

R. H. Rust

The soil productivity study which began in 1956 is an attempt to gain reliable estimates of the productivity of major soil types in Minnesota. This productivity is estimated for the major crops under several generally specified soil management programs. The estimates are incorporated in the soil survey reports published for the individual counties by the Soil Conservation Service, USDA, and the Experiment Station, cooperatively.

Since the project began 491 farm cooperators have furnished crop and soil management data on some 92 extensive soil types in the state. Currently 327 cooperators are enrolled in the project. The following kinds of data are recorded: date and rate of seeding; stand estimate; kind and amount of soil amendments used; moisture and temperature conditions during the growing season; weed and insect control measures; yields and losses of yield from harvesting or abnormal conditions; soil tests of pH, available P and K, organic matter.

Since it is planned that productivity estimates be based on multiple regression analysis and since there are a number of factors to be studied, a relatively large number of observations (generally more than 30) of each crop on each soil is necessary in order to establish reliability. In addition, the evaluation of yield variation associated with weather observations (chiefly rainfall and temperature) necessitates collection of data over several years.

In the following table the various soils included in the study are listed together with (1) number of fields, and (2) number of yields. Where 2 or more yields of a crop have been recorded, the crops, number of fields, and the average yields are given. The reader may establish the location of the listed soils by reference to Soils of Minnesota, Ext. Bul. 278 (1963), or to the appropriate county soil report.

It should be noted that the average yields listed do not necessarily reflect the relative productivity of the soils listed. They serve only to indicate the nature of yield levels attained in the last one to seven years by farmers who are in general using above average management. Many of the yields also reflect very favorable weather patterns as well as very unfavorable seasons. For those personnel concerned the data may serve to indicate where additional effort is needed.

Table 1. Soil series, number of fields, and number of yields included in soil productivity study to date. Average yields of selected crops given where two or more yields received. Yields of grain crops in bushels; hay, silage, and sugar beets, in tons; pasture, in cow-acre days.

* Number of fields on this series
** Number of yields on all crops

Aastad	(11)*	(39)**
Corn	11	48
Flax	6	12
Oats	5	53
Spring wheat	3	32
Barley	3	49
Alfalfa-brome-past.	3	136
Soybeans	2	22
Hay (other)	2	4.6
Anoka	(1)*	(1)**
Arlington	(1)	(4)
Oats	2	64
Barnes	(15)	(74)
Corn	25	56
Oats	11	61
Flax	7	8
Soybeans	6	23
Alfalfa-brome	6	1.6
Barley	5	42
Alfalfa	5	1.9
Spring wheat	4	31
Corn silage	2	6.0
Bearden	(7)	(15)
Corn	4	56
Barley	3	56
Spring wheat	3	37
Sugar beets	3	11.6
Beltrami	(4)	(11)
Oats	3	66
Alfalfa	3	3.4
Alfalfa-brome-past.	2	76
Corn	2	66
Blue Earth	(3)	(11)
Corn silage	4	8.9
Corn	3	48
Soybeans	3	18
Oats	2	25
Alfalfa-brome	2	3.0
Borup	(1)	(1)
Braham	(2)	(2)
Brainerd	(5)	(11)
Oats	4	32
Corn	2	52
Corn silage	2	13.0
Brickton	(4)	(4)
Buse-Barnes	(2)	(10)
Alfalfa-brome	3	1.6
Flax	2	9
Soybeans	2	13
Central	(4)	(5)
Chilgren	(5)	(22)
Oats	5	36
Barley	3	47
Flax	2	10
Spring wheat	2	25
Alfalfa	2	2.3
Alfalfa-tim.	3	2.4
Hay (other)	3	2.4
Corn silage	2	13.0
Clarion	(34)	(223)
Corn	44	75
Oats	24	67
Soybeans	10	29
Spring wheat	8	31
Alfalfa-brome	12	2.9
Alfalfa	9	2.6
Mix. Leg. grass	3	5.0
Corn silage	3	14.5
Alfalfa-brome-past.	3	228
Colvin	(5)	(14)
Alfalfa	4	3.6
Corn	5	61
Comfrey	(1)	(7)
Sorghum	3	8.0
Corn	2	60
Cormant	(4)	(12)
Oats	6	33
Alfalfa-brome	3	4.0

Downs	(3)	(12)
Corn	6	105
Oats	2	72
Alfalfa	3	3.4
Dubuque	(4)	(4)
Dundas	(4)	(12)
Alfalfa-brome	3	4.5
Alfalfa	2	1.7
Enstrom	(1)	(4)
Alfalfa-brome-past.	2	222
Estelline	(1)	(2)
Esterville	(14)	(49)
Corn	16	59
Oats	10	42
Alfalfa-brome	9	2.2
Alfalfa	6	3.3
Corn silage	6	7.8
Fairhaven	(4)	(12)
Corn	6	62
Oats	4	63
Fargo	(19)	(60)
Spring wheat	13	36
Oats	8	41
Soybeans	3	23
Flax	6	12
Barley	6	29
Alfalfa-brome	5	1.6
Alfalfa	2	3.1
Sugar beets	7	12.5
Fayette	(7)	(34)
Corn	14	92
Oats	6	50
Alfalfa-brome	6	6.0
Alfalfa	3	3.0
Flom	(8)	(27)
Corn	8	68
Oats	6	56
Soybeans	3	17
Flax	3	19
Corn silage	3	15.0
Floyd	(5)	(18)
Corn	9	81
Soybeans	4	26
Oats	3	87
Fossum	(2)	(4)
Foxhome	(1)	(3)
Freer	(3)	(15)
Oats	5	66
Hay (other)	3	2.3
Corn silage	2	6.7
Freon	(6)	(8)
Oats	5	56
Glencoe	(1)	(1)
Greenbush	(3)	(7)
Corn silage	2	12.5
Hay (other)	2	1.5
Grimstad	(6)	(21)
Barley	4	44
Flax	3	10
Soybeans	3	15
Spring wheat	3	27
Oats	3	75
Grygla	(3)	(9)
Oats	3	35
Hamerly	(1)	(3)
Flax	2	15
Hantho	(1)	(1)
Harpster	(1)	(2)
Oats	2	34
Hayden	(22)	(79)
Corn	24	76
Oats	15	55
Alfalfa	15	3.6
Alfalfa-brome	15	3.8
Alfalfa-brome-past.	6	267
Hegne	(6)	(14)
Spring wheat	4	35
Barley	3	47
Alfalfa	2	1.2
Potatoes	2	251
Hibbing	(4)	(4)
Hubbard	(14)	(59)
Corn	24	63
Soybeans	11	21
Oats	6	43
Potatoes	5	425
Alfalfa	6	2.4
Alfalfa-brome	3	2.3
Corn silage	3	15.5

Kasson	(2)	(7)
Oats	2	65
Kato	(1)	(5)
Kenyon	(2)	(9)
Corn	4	86
Hay (other)	3	3.7
Kingston	(3)	(13)
Corn	9	80
Soybeans	3	18
Kittson	(2)	(9)
Corn silage	2	4.9
Kranzberg	(2)	(7)
Alfalfa-brome	3	2.3
Alfalfa	2	2.3
Lamoure	(2)	(12)
Corn	4	56
Soybeans	3	32
Sweet corn	3	7.0
Lerdal	(1)	(6)
Corn	3	82
Lester	(10)	(36)
Alfalfa	13	3.8
Corn	9	69
Oats	6	58
Alfalfa-brome	5	3.2
LeSueur	(9)	(33)
Corn	20	76
Soybeans	5	22
Oats	3	53
Barley	2	49
Litchfield	(2)	(9)
Corn	2	83
Soybeans	2	23
Oats	2	86
Potatoes	2	455
Marcus	(1)	(1)
Marna	(5)	(16)
Corn	8	95
Soybeans	3	38
Alfalfa	2	5.1
Mavie	(1)	(2)
McDonaldsville	(1)	(2)
McIntosh	(3)	(16)
Oats	4	66
Spring wheat	4	35
Barley	3	64
Corn	2	70
Alfalfa	2	3.0
Menahga	(6)	(12)
Oats	2	31
Alfalfa-brome	4	2.5
Corn silage	4	9.4
Milaca	(8)	(25)
Oats	4	41
Corn	3	54
Hay (other)	5	2.2
Mix leg.-grass	4	2.0
Corn silage	4	12.1
Moody	(2)	(6)
Corn	4	70
Mora	(4)	(12)
Corn	4	55
Oats	2	75
Mixed leg.-grass	3	3.1
Nebish	(7)	(28)
Oats	9	48
Alfalfa	5	1.4
Alfalfa-brome	5	1.9
Alfalfa-brome-past.	5	80
Nicollet	(19)	(89)
Corn	37	75
Oats	13	58
Soybeans	12	29
Spring wheat	3	32
Barley	2	94
Alfalfa	11	3.8
Alfalfa-brome	4	4.0
Corn silage	4	7.9
Nokay	(5)	(10)
Corn	5	64
Oats	2	55
Nymore	(1)	(1)
Onamia	(5)	(19)
Oats	5	63
Corn	4	68
Alfalfa	4	3.5
Alfalfa-brome	2	1.8

Ostrander	(7)	(18)
Corn	6	86
Soybeans	2	26
Alfalfa	2	4.8
Parnell	(1)	(7)
Corn	4	38
Oats	2	75
Deep Peat	(6)	(19)
Corn	3	77
Soybeans	2	24
Timothy (seed)	2	330
Corn silage	2	6.5
Hay (other) past.	2	100
Leg.-grass past.	2	242
Shallow Peat	(5)	(7)
Soybeans	3	24
Barley	2	56
Pierce	(1)	(1)
Racine	(1)	(1)
Redby	(3)	(9)
Leg.-grass hay	3	1.5
Leg.-grass past.	3	63
Rocksbury	(12)	(32)
Oats	9	62
Flax	4	8
Alfalfa	2	2.3
Hay (other)	5	1.5
Sweet corn-brome	2	1.7
Hay (other) past.	3	117
Rockwell	(5)	(13)
Oats	3	52
Barley	3	23
Alfalfa	2	1.7
Corn silage	2	12.9
Rothsay	(1)	(1)
Sioux	(3)	(8)
Oats	4	31
Soybeans	2	12
Alfalfa	2	0.8
Shooks	(2)	(6)
Oats	2	38
Alfalfa	2	2.0
Skyberg	(3)	(10)
Corn	4	81
Oats	2	83
Leg.-grass past.	2	154
Sletton	(1)	(3)
Soybeans	2	30
Storden-Clarion	(1)	(6)
Oats	2	80
Alfalfa	4	2.6
Tama	(8)	(33)
Oats	10	64
Corn	6	94
Corn silage	3	14.2
Alfalfa	3	4.1
Alfalfa-brome	3	4.6
Leg.-grass hay	3	3.0
Alfalfa-brome past.	3	178
Taylor	(1)	(3)
Terrill	(1)	(2)
Todd	(2)	(6)
Alfalfa-brome	4	2.2
Truman	(3)	(9)
Corn	4	90
Ulen	(4)	(21)
Oats	6	43
Corn	5	56
Corn silage	2	15.5
Alfalfa	2	2.6
Vallers	(3)	(16)
Corn	4	55
Oats	2	63
Soybean	5	20
Varco	(1)	(5)
Corn	3	88
Alfalfa-brome	2	2.8
Vienna	(2)	(6)
Corn	3	63
Oats	2	60
Wabash	(1)	(4)
Corn	3	109
Wadena	(4)	(15)
Corn	6	81
Soybean	3	19
Oats	3	80

Waukegan	(9)	(33)
Corn	14	80
Oats	8	81
Alfalfa-brome	3	3.1
Alfalfa	2	2.5
Waukon	(9)	(32)
Corn	8	59
Oats	6	54
Barley	4	36
Spring wheat	2	30
Alfalfa	9	2.1
Mix. leg.-grass	2	3.2
Webster	(36)	(132)
Corn	62	88
Oats	22	61
Soybeans	14	19
Alfalfa	14	4.2
Alfalfa-brome	8	2.9
Corn silage	5	10.1
Alfalfa-brome past.	2	75
Webster Calc. Var.	(8)	(34)
Corn	12	89
Oats	3	85
Soybeans	10	34
Alfalfa	4	3.2
Wildwood	(2)	(6)
Oats	2	33
Winger	(4)	(18)
Oats	7	75
Barley	3	46
Spring wheat	3	34
Alfalfa	3	1.6
Zimmerman	(3)	(13)
Corn	2	71
Oats	2	57
Corn silage	3	11.0
Hay (other)	2	10.9

	No. Fields	No. Yields
Grand total as of December 1963	508	1844

Water Infiltration Studies on Some Minnesota Soils

R. H. Rust

During the past year a portable sprinkling infiltrometer (developed in a North Central States project) has been used to measure infiltration on the Port Byron soils (at Rosemount) and the Kenyon soils (in southeastern Minnesota).

Infiltration was measured on soils under bromegrass and on soils under corn for 2 or more years. The average intake rate on the Port Byron soils under corn was 0.8 in/hr; under bromegrass, 1.9 in/hr. On the Kenyon soils under bromegrass, 1.1 in/hr. (Corn plot measurements not completed). Water is applied at the rate of 4-5 inches per hour. As compared to other soils in the region, these rates are indicative of rather permeable soils.

The depth of wetting after 24 hours and after applying a total of about 6 inches of water was about 30 inches on the corn plots and about 48 inches under the bromegrass. Corn and bromegrass roots extend to at least 5 feet on the Port Byron and Kenyon soils.

The Probable Occurrence and Significance of Fragipan Soils in Minnesota

R. H. Rust

During the course of soil survey mapping in several areas in central and east-central Minnesota counties, a number of soils have been found to have horizons of a compacted, or somewhat cemented, character. To a considerable extent these soils seem to be associated with the occurrence of drumlin fields (the Wadena, Pierz-Brainerd, possibly the Toimi in parts of Ottertail east), Wadena, Todd, Morrison, Crow Wing, Benton, and St. Louis Counties. In addition, the soils in east-central Minnesota on the red to brown sandy loam tills often exhibit a compacted horizon in the lower part of the rooting zone.

One of the principal effects of this "fragi-zone" is to produce perched water tables which are most evident in late spring and result in delayed field operations often on the crests of drumlin ridges. The perched water table apparently also inhibits good root penetration by corn and legumes and probably increases the damage from frost-heaving on legumes. Whether the "fragi-zone" is compacted or cemented to the extent that roots cannot penetrate has not been fully established although preliminary observations suggest this is the case.

The occurrence of the "fragi-zones" is generally below 24 inches and commonly observed below 30 inches. This reduces the possibility of mechanical or chemical treatment of the zone as such although at the present no research has been done on this aspect.

Commonly a fertility problem also exists on these soils. Lime and potash are generally needed. Where these needs are met, the adverse effect of the fragipan seems to be somewhat reduced.

The Soil Conservation Service and the Experiment Station are currently studying the duration and effect of the perched water table as well as certain other physical and chemical properties of the soils.

Subsoil Fertility Study[1]

John Grava

Soil testing, in most cases, means analyses of samples collected from the top six inches, or plow layer. Since a great majority of recommendations are made for fields going into corn, a crop with comparatively shallow fibrous root system, sampling the topsoil alone seems to be sufficient. However, the subsoil largely determines the amount of moisture available to plants and often may be an important source of plant nutrients. Subsoil fertility may be especially important to deep rooted plants, such as alfalfa.

Since subsoil sampling is both time consuming and inconvenient, it is doubtful that farmers will adopt the practice as an integral part of a soil testing program. However, if information were available on subsoil fertility of major soil series, sampling the plow layer alone would be sufficient. With this in mind a subsoil fertility study was initiated in 1956. Profile samples were obtained by S.C.S. area soil scientists in connection with their regular soil survey work. Some profile samples are taken from fields included in the "Soil Productivity Study". It is expected that 20 or 30 profiles of each major soil series will be collected.

The samples are analyzed by routine testing methods and the results made available to S.C.S. soil scientists and staff members of the Soil Science Department. Information provided by this study has been used by staff members in selecting soils for a number of specific research projects. A portion of each sample is stored in a sample library for future use.

During the eight years of this study 4225 horizon samples from 840 soil profiles have been collected. General information on the soil profiles obtained for this study are given in tables 1 and 2. A list is also included to indicate the number of profiles collected for each soil series.

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[1]Department of Soil Science and Soil Conservation Service cooperating.

Table 1. Number of soil profiles received for the subsoil fertility study, 1956 to 1963.

Year	Number of Profiles	Number of Samples
1956	55	333
1957	185	984
1958	162	804
1959	101	487
1960	89	426
1961	60	307
1962	112	531
1963	76	353
Eight Year Total	840	4225

Table 2. Number of soil profiles obtained for Minnesota's subsoil fertility study by counties and SCS areas, 1956 to 1963

Area I. Scilley, Ravenholt, Barron Jacobson		Area II. Tordsen, Erickson, Lewis Friedrich, DeMartelaere, Miller		Area III. Grimes, Ziebell, Chamberlain		Area IV. Edwards, Diedrick, Sutton, Lueth, Munter Nyberg		Area V. Hokanson, Lorenzen, Paulson, Murray		Area VI. Cummins, Carlson		Area VII. Harms, Poch	
Beltrami	10	Becker	2	Aitkin	4	Big Stone	16	Jackson	1	Blue Earth	3	Dodge	3
Clearwater	3	Douglas	11	Benton	15	Carver	42	Lincoln	16	Brown	21	Fillmore	8
Kittson	7	Grant	7	Chisago	3	Chippewa	23	Lyon	10	Freeborn	21	Goodhue	9
Koochiching	4	Ottertail	19	Kanabec	4	Hennepin	6	Murray	13	LeSueur	15	Houston	6
Lake of the Woods	8	Stevens	24	Mille Lacs	6	Kandiyohi	20	Nobles	20	Martin	6	Mower	6
Mahnomen	6	Traverse	11	Morrison	12	Meeker	28	Pipestone	36	Rice	38	Olmsted	8
Marshall	3	Wadena	14	Sherburne	21	Pope	18	Redwood	4	Steele	42	Wabasha	19
Norman	14	Wilkin	10	Stearns	4	Renville	26	Rock	1	Waseca	20		
Pennington	5					Sibley	38	Yellow Medicine	6	Watonwan	10		
Polk	6					Swift	33						
Red Lake	4					Wright	6						
Area Total	70		101		69		256		109		176		59

List of profiles obtained from major soil series for Minnesota's subsoil fertility study, 1956-63.

FD Fayette - Dubuque	
Fayette	15
Dubuque	5
Whalan	1
Bertrand	3
TD Tama - Downs	
Tama	8
Muscatine	1
Downs	6
Watopa	2
Cashton	1
LH Lester - Hayden	
Dundas	9
Hayden	32
Erin	2
CL Clarion - Lester	
Lester	36
LeSueur	19
Cordova	20
Lerdal	4
HB Hayden - Bluffton	
Bluffton	2
Nessel	1
Ames	1
OFK Ostrander - Kenyon - Floyd	
Ostrander	3
Kenyon	5
Floyd	2
Racine	1
Taopi	3
Varco	1
SK Skyberg - Kasson	
Skyberg	2
Kasson	4
CNW Clarion - Nicollet - Webster	
Storden	6
Lakeville	1
CNW (Continued)	
Clarion	24
Nicollet	29
Webster	17
Webster, Calc. Var. (Canisteo)	21
Harpster	7
Terril	1
Comfrey	1
Fieldon	1
Rolfe	1
Thurman	1
Glencoe	9
Blue Earth	1
Truman	2
Kingston	4
Madelia	5
Marna	12
Lura	6
Guckeen	5
Beauford	9
MKV Moody - Kranzburg - Vienna	
Kranzburg	14
Brookings	3
Hidwood	2
Moody	2
Primghar	2
Marcus	2
Afton	1
Vienna	4
Lismore	4
Leota	2
Lamoure	3
Ihlen	1
BA Barnes - Aastad	
Buse	9
Barnes	28
Arco	3
Aastad	22
Hendricks	1
Flom	10
Parnell	7

BA (Continued)

Hamerly	13
Vallers	10
Alcester	2
Sverdrup	5
Tetonka	1
Pierce	1
Rothsay	2
Hantho	2

WB Waukon - Barnes

Waukon	4
Gonvick	2

FB Fargo - Bearden

Hegne	1
Fargo	5
Glyndon	1
Bearden	12
Colvin	9
Sletten	2
Borup	2

UST Ulen - Sioux - Tanberg

Ulen	9
Sioux	8
Fossum	2
Grimstad	3
Rockwell	4
Mavie	2

MW McIntosh - Winger

McIntosh	3
Winger	2
McDonaldsville	1

NR Nebish - Rockwood

Nebish	6
Beltrami	2
Shooks	2
Rockwood	3
Blowers	3
Paddock	2
Brickton	2
Todd	1

RKP Rocksbury - Kittson - Peat

Kittson	1
Rocksbury	3

TGP Taylor - Grygla - Peat

Baudette	2
Hiwood	2
Redby	1
Potamo	1
Chilgren	4
Grygla	1
Wildwood	1
Indus	1

MBH Milaca - Brainerd - Hibbing

Freon	7
Freer	2
Parent	2
Milaca	3
Mora	6
Bock	3
Langola	1
Pomroy	2
Watab	1
Flak	2
Brainerd	3
Barrows	1

ZIP Zimmerman - Isanti - Peat

Zimmerman	7
Nymore	8
Lino	2
Isanti	2

M Menahga

Menahga	5

WH Wadena - Hubbard & Terrace Soils

Hubbard	16
Wadena	6
Dickinson (CNW Group)	1
Estherville (BA group)	11
Fairhaven (CNW group)	6
Litchfield	2
Biscay	4
Kasota	5
Kato	1
Bixby	2
Waukegan	3
Estelline	5
Central	4
Renshaw	2
Fordville	1

Summary of Climatological Investigations 1963

by Donald G. Baker

Dept. of Soil Science

University of Minnesota

Soil Moisture

In table 1 are shown the fall, 1963, soil moisture results at various sites within the state. Almost all sites are lower in moisture than they were in fall, 1962. It is not apparent from these data, since only a limited part of the state is sampled, but from precipitation data and river flow it is known that except for the Southwest, south-central and a part of the southeast the state is in a very dry condition. Unless conditions change drastically it would appear that the soil moisture status is indeed low and in a precarious position for the 1964 season in all but the southwest, south-central and a small part of the southeast.

For all sites except Crookston, Polk County, the approximate amount of water used during the season by the crop (see last column in table 1) is almost certainly too high. It would appear that either runoff or drainage, or both, were excessive at these stations this year. Values of 18-22 inches are more nearly what is to be expected. The low values at Crookston, 12.72-16.09 inches, are some lower than usual largely due to the low precipitation that fell during the sampling period, 9.88 inches.

Tables 2 and 3 show water use by period and the average amount consumer per day for several crops. Perhaps the most outstanding feature in these tables is the fact that water use per day is very nearly the same regardless of the crop. The total amount of water consumed during a season may vary between crops but this difference is essentially due to a longer or shorter growing period and in periods of moisture stress to one crop being able to exploit a greater volume of soil.

Based upon the data from Lamberton and Crookston (tables 2 and 3) the average amount of moisture used per day is the following:

April - 0.03 in./day	August - 0.14 in./day
May - 0.09 "	September - 0.09 "
June - 0.15 "	October - 0.05 "
July - 0.17 "	

Table 1. Summary of fall, 1963, soil moisture measurements.[1]

County	Nearby Town	Farm Operator	Soil Type	Date Sampled	Crop	Tot. available water present[2]	% Poss. Water	Diff. Fall'63-Fall'62	Approx. Am't[3] water used in season
Chippewa	Milan	H.S.Olson	Rothsay silt loam	11/5/63		8.12 in.	59%	-0.12 in.	
Dodge	Dodge Center	Sutherland	Kasson silt loam	11/12/63	Corn	6.45 in.	61%	+1.41 in.	
Kandiyohi		E. Nordstrom	Clarion silt loam	11/5/63	Alfalfa			Not sampled '62	
Kandiyohi		H. Arvidson	Nicollet	11/5/63		7.80 in.	54%	Not sampled '62	
Lac Qui Parle		Thompson	Aastad	11/5/63		9.64 in.	61%	-1.85 in.	
Lac Qui Parle	Marietta	I. Aebli	Rothsay silt loam	11/5/63		4.16 in.	32%	-4.14 in.	
Lac Qui Parle		M. Nelson	Barnes	11/5/63					
Lincoln	Arco	C. Madsen	Barnes clay loam	11/5/63					
Lincoln	Porter	B. Boulton	Barnes silty clay loam	11/5/63	Flax				
Lyon	Minneota	N. Orsen	Barnes clay loam	11/5/63		6.15 in.	53%	Not sampled '62	

Table 1. (Cont.)

County	Nearby Town	Farm Operator	Soil Type	Date Sampled	Crop	Tot. available water present[2]	% Poss. Water	Diff. Fall'63-Fall'62	Approx. Am't[3] water used in season
Lyon	Cottonwood	R. Olson	Aastad silty clay loam	11/5/63		8.37 in.	63%	Not sampled'62	
Lyon	Cottonwood	R. Olson	Barnes clay loam	11/11/63	Corn	6.68 in.	66%	Not sampled'62	
Lyon	Marshall	C. Boerboom	Vallers clay loam	11/11/63	Alfalfa	6.32 in.	51%	Not Sampled'62	
Mille Lacs	Milaca	T. Nichols	Mora silt loam	11/6/63	Hay	6.32 in.	65%	-1.99 in.	27.66 in.
Polk	Crookston	U. Minn.	Hegne silty clay	11/1/63	Alfalfa	0.07 in.	0%	-5.06 in.	16.09 in.
Polk	Crookston	U. Minn.	Fargo silty clay loam	11/1/63	Wheat	4.30 in.	25%	-3.82 in.	12.72 in.
Polk	Crookston	U. Minn.	Fargo silty clay loam	11/1/63	Sugarbeets	1.69 in.	10%	-4.92 in.	15.43 in.
Ramsey	St. Paul	U. Minn.	Waukegan silt loam	9/8/63	Soybeans	1.80 in.	21%	-6.30 in.	10.36 in.

Table 1. (Cont.)

County	Nearby Town	Farm Operator	Soil Type	Date Sampled	Crop	Tot. Available water present[2]	% Poss. water	Diff. Fall'63-Fall'62	Approx. Am't[3] water used in season
Redwood	Wabasso	D. Kuehn	Clarion silty clay loam	11/5/63	Corn	5.41 in.	42%	Not sampled'62	
Redwood	Belview	V. Anderson	Nicollet clay loam	11/5/63		7.09 in.	61%	-2.61 in.	
Redwood	Wabasso	D. Kuehn	Nicollet clay loam	11/6/63		7.18 in.	55%	Not sampled'62	
Redwood	Lamberton	U. Minn.	Webster silty clay loam	11/4/63	Corn	6.21 in.	63%	-1.12 in.	22.49 in.
Sibley	Gaylord	D. Woods	Nicollet clay loam	11/8/63	Corn	8.63 in.	73%	-0.47 in.	26.64 in.
Swift		C. Stobbs	Barnes	11/5/63				Not sampled'62	
Swift		J. Koosman	Pierce	11/5/63				Not sampled'62	
Swift		R. Tucker	Vallers	11/5/63		6.99 in.	48%	Not sampled'62	
Wabasha	Kellogg	K. Zickerick	Fayette silt loam	11/6/63	Oats	8.26 in.	53%	-3.33 in.	26.04 in.
Watonwan	Butterfield	E. Hansen	Nicollet clay loam	11/4/63	Alfalfa	5.19 in.	37%	-3.52 in.	27.77 in.

Table 1. (Cont.)

County	Nearby Town	Farm Operator	Soil Type	Date Sampled	Crop	Tot. Available water present[2]	% Poss. water	Diff. Fall'63-Fall'62	Approx. Am't[3] water used in season
Watonwan	Butterfield	Tilney	Kingston silt loam	11/15/63	Corn	5.61 in.	47%	+1.41 in.	24.14 in.
Yellow Medicine	Granite Falls	K. Velde	Aastad silty clay loam	11/5/63	Corn	10.24 in.	68%	Not sampled'62	

1. For the soil moisture samples we are indebted to many individuals of the Soil Conservation Service, U.S.D.A., the Agricultural Extension Service and the University of Minnesota Experiment Stations.

2. Within a 5 foot column of soil.

3. In all calculations it was assumed that all measured precipitation was used by the crop and that there was neither runoff nor drainage losses, which of course, is incorrect.

Table 2. Water consumption by corn, Lamberton, Minnesota - 1961, 1962 and 1963. [1]

1961			1962			1963		
Period	Water Use*	Water Use/ Day	Period	Water Use*	Water Use/ Day	Period	Water Use*	Water Use/ Day
4/12-5/1	3.14 in.	0.16 in.	5/1-5/28	2.22 in.	0.08 in.	4/3-5/1	1.28 in.	0.05 in.
5/1-6/28	6.89	0.12	5/28-6/27	7.31	0.24	5/1-6/13	6.07	0.14
6/28-7/28	3.01	0.10	6/27-7/31	6.86	0.20	6/13-6/27	2.15	0.15
7/28-8/30	5.11	0.15	7/31-8/31	4.61	0.15	6/27-7/29	5.92	0.19
8/30-10/2	4.01	0.12	8/31-9/26	2.03	0.08	7/29-8/29	4.65	0.15
Total = 22.16			9/26-10/31	0.02	0.00	8/29-10/19	2.42	0.05
			Total = 23.05			Total = 22.49		

* As determined in a 5 foot column of soil.

1. In all calculations it was assumed that all measured precipitation was used by the crop and that there was neither runoff nor drainage losses, which, of course, is incorrect; soil moisture determined gravimetrically; field soil moisture samples and precipitation data obtained through the courtesy of Dr. W. W. Nelson, Southwest Experiment Station, Lamberton.

Table 3. Water consumption of three crops, Crookston, Minnesota, 1962 and 1963. [1]

Alfalfa			Soybeans			Sugarbeets		
Period 1962	Water Use*	Water Use/ Day	Period 1962	Water Use*	Water Use/ Day	Period 1962	Water Use*	Water Use/ Day
4/17-5/7	0.13 in.	0.01 in.						
5/7-6/1	2.68	0.11	4/25-6/1	2.04 in.	0.05 in.			
6/1-6/30	4.65	0.16	6/1-7/2	4.51	0.15	5/31-6/30	4.55 in.	0.15 in.
6/30-7/31	5.46	0.18	7/2-7/31	5.58	0.19	6/30-7/31	6.05	0.19
7/31-8/30	4.55	0.15	7/31-8/30	3.58	0.12	7/31-8/30	2.98	0.10
8/30-10/1	2.85	0.09	8/30-10/1	2.39	0.07	8/30-10/1	2.84	0.09
10/1-11/1	2.59	0.08	10/1-11/1	1.60	0.05	10/1-11/2	2.82	0.09
Total = 22.91			Total = 19.70			Total = 19.24		

Alfalfa			Wheat			Sugarbeets		
Period 1963	Water Use*	Water Use/ Day	Period 1963	Water Use*	Water Use/ Day	Period 1963	Water Use*	Water Use/ Day
6/3-7/1	1.64 in.	0.06 in.	6/3-7/1	5.99 in.	0.21 in.	6/3-7/1	2.71 in.	0.10 in.
7/1-8/1	9.09	0.29	7/1-8/1	1.68	0.05	7/1-8/1	5.15	0.17
8/1-9/3	2.10	0.06	8/1-9/3	4.83	0.15	8/1-9/3	6.48	0.20
9/3-11/1	3.26	0.12	9/3-11/1	0.22	0.01	9/3-11/1	1.09	0.04
Total = 16.09			Total = 12.72			Total = 15.43		

* As determined in a 5 foot column of soil.

1. In all calculations it was assumed that all measured precipitation was used by the crop and that there was neither runoff nor drainage losses, which, of course, is incorrect; soil moisture determined gravimetrically; field soil moisture and precipitation data obtained through the courtesy of Dr. Olaf Soine, Northwest Experiment Station, Crookston.

Soil Temperatures

Average monthly soil temperatures under three different covers, sod, soybeans, and bare soil, are shown in Table 4. The great insulating value of sod is apparent for soil temperatures under the sod are cooler in summer and warmer in winter than in the other two plots.

Possibly the most interesting feature is the lag of both the average monthly maximum and minimum temperatures with depth. From about 960 cm. on the maxima and minima are about six months out of phase. This is apparent in Table 4 and particularly so in figure 1, in which is also presented a representation of the amount of heat gained and lost from the soil on an annual basis. This was calculated to be 3198 calories which is a bit less than 2½% of the annual incoming solar radiation as measured by an Eppley pyrheliometer. Most of the incoming solar energy is expended in evaporation rather than heating the earth.

Figures 2 and 3 show the sod plot soil temperatures at two different times of the year, one of which, figure 2, shows the "heating cycle" and the other is the "cooling cycle", figure 3.

As indicated in both figures 1 and 2 there is apparently still a 1° F. change at the 1280 cm. depth. It is not known for certain if this is real. Hopefully, with improved instrumentation this can be resolved in the coming year. If this temperature difference is real, then the fact that the annual heat wave is still apparent at 1280 cm. becomes rather surprising.

Table 4. Average Monthly soil temperatures, °F., St. Paul Campus, October, 1962, through September, 1963.

Depth	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Ave.
						Sod Covered Soil							
1	55	40	32	25	22	32	45	59	73	81	78	68	51
5	55	40	32	25	22	31	44	58	73	79	77	68	50
10	55	40	33	26	22	30	42	56	71	77	75	67	49
20	55	41	34	27	22	29	38	53	67	73	72	65	48
40	55	43	36	30	24	29	35	50	62	68	69	64	47
80	56	46	40	34	27	29	32	46	57	64	66	63	47
120	57	49	43	37	33	31	33	43	53	60	63	62	47
160	57	51	44	39	35	33	33	41	51	58	61	61	47
320	56	54	50	45	42	39	38	40	45	50	54	56	47
480	53	53	51	49	47	45	43	42	44	46	49	51	48
640	50	51	51	50	49	48	47	46	45	45	47	48	48
800	--	49	50	50	49	49	49	48	47	47	47	49	49
960	--	48	49	49	49	49	49	48	48	47	47	47	48
1120	--	48	48	48	48	49	49	48	48	48	47	47	48
1280	--	48	48	48	48	49	49	49	48	48	48	48	48
						Bare Soil							
1	56	37	23	10	20	39	57	69	89	95	89	74	55
5	57	37	26	11	21	37	55	67	87	93	87	75	54
10	56	38	27	12	20	33	51	62	81	88	83	72	52
20	54	37	28	12	18	30	46	57	74	82	78	68	49
40	54	39	32	15	17	28	40	52	69	77	75	67	47
80	56	44	37	23	20	27	35	48	62	71	72	66	47
						Soybean Soil							
1	54	37	26	18	20	37	53	65	89	85	74	68	52
5	56	37	28	19	19	35	52	63	83	80	72	67	51
10	55	38	29	19	19	33	50	61	79	79	71	67	50
20	54	38	30	21	19	31	45	56	73	76	70	65	48
40	53	40	33	24	20	28	38	51	66	72	68	64	46
80	55	44	38	31	24	28	33	47	60	67	66	63	46

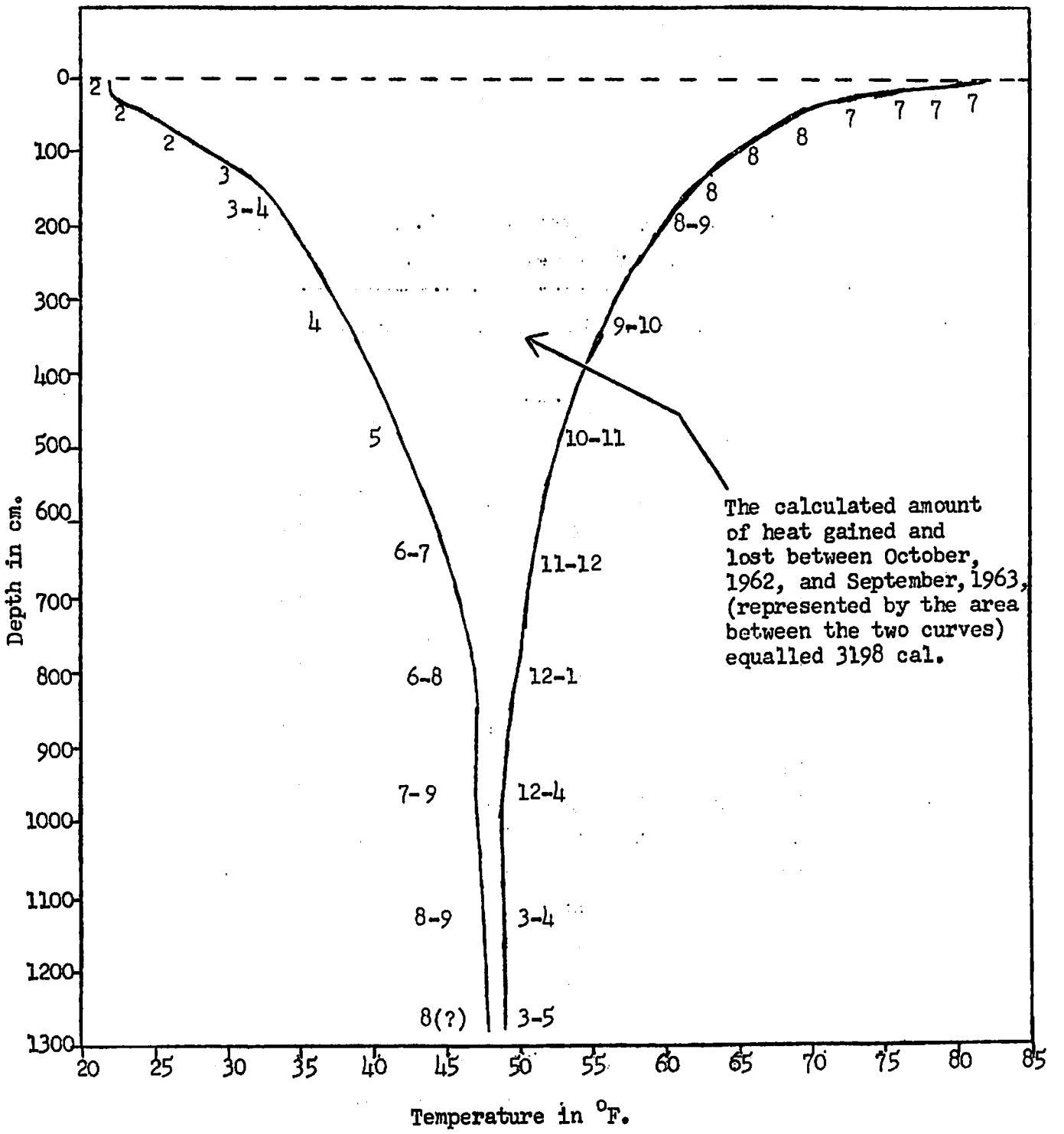

Fig. 1. Maximum and minimum average monthly soil temperatures under sod during the period October, 1962, to September, 1963. The numbers at each depth represent the month or months when the maximum or minimum average monthly temperature occurred (1 = January, 2 = February, etc.).

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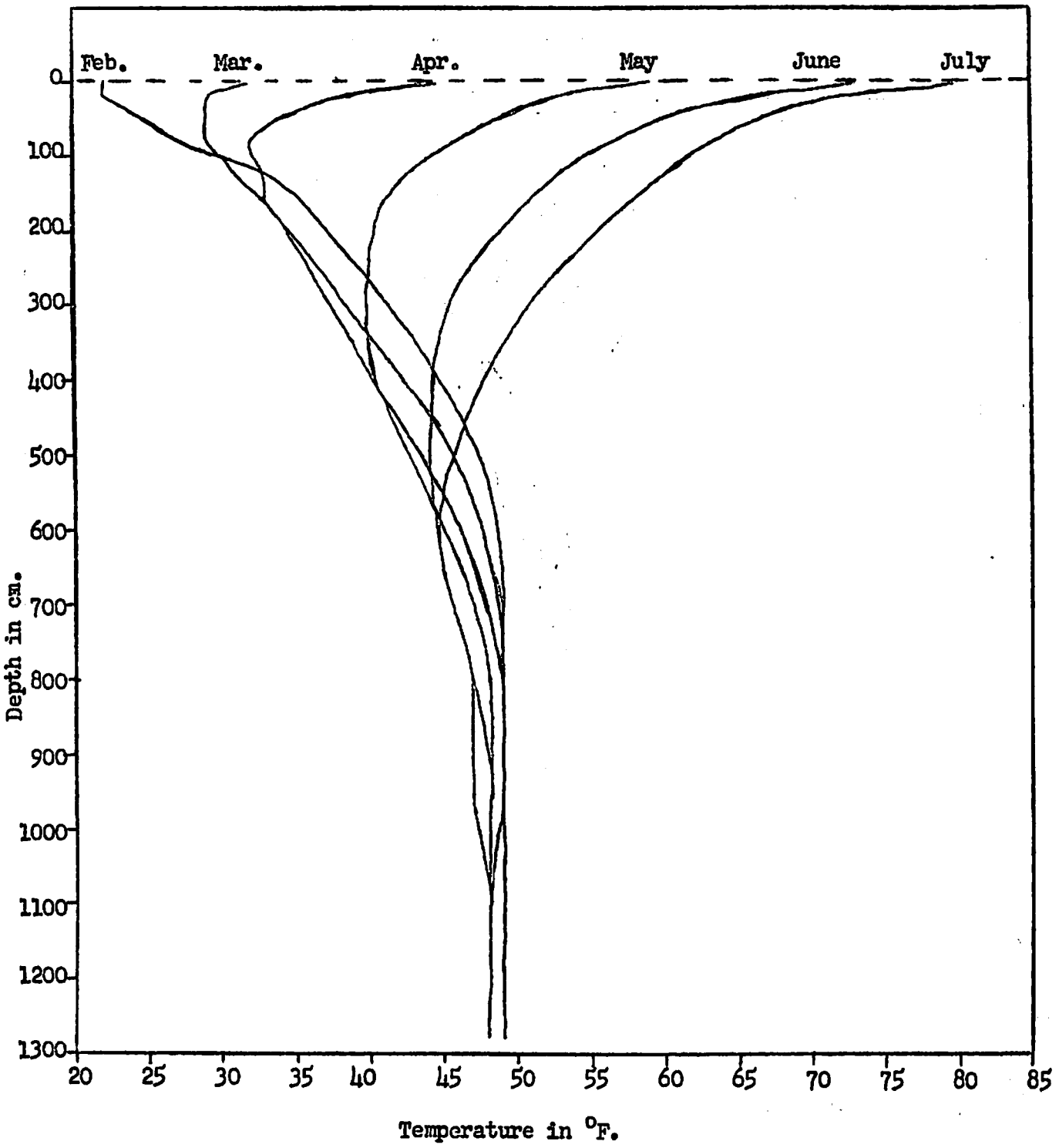

Figure 2. Average monthly soil temperatures under sod, February - July (from Oct., 1962 - Sept., 1963, data).

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1/64

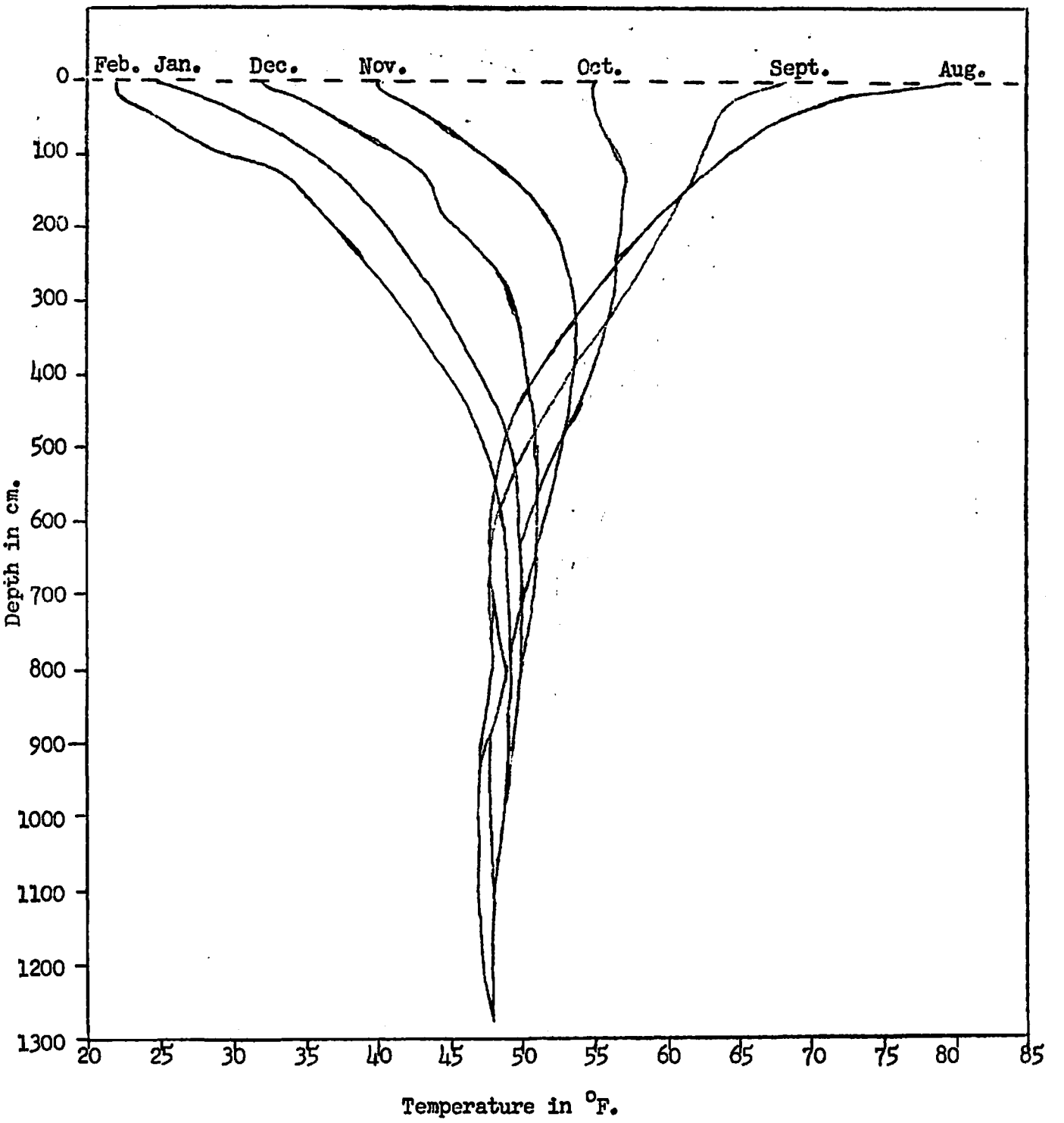

Figure 3. Average monthly soil temperatures under sod, August - February. (from Oct., 1962 - Sept., 1963, data).

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1/64

Air Temperatures in the Microclimate

For several years a daily record has been maintained of the minimum air temperature close to the earth's surface. The major objective was to determine how well the minimum temperatures as measured in the standard Weather Bureau shelter, which stands 5½ feet above the surface, agreed with minimum temperatures in the microclimate. As might be suspected the shelter temperatures are quite a bit higher as shown in Table 5. In December through February differences are not as great between the three microclimates and between them and the shelter due to snow cover. The minimum over a sod averages 5° F. lower and the bare soil only 3° F. lower than the shelter temperature. This is because when free of snow the bare soil loses more heat at night and thus prevents lower microclimatic temperatures from developing. The minimum temperatures in the soybean plot are not as low as over the sod because of protection offered by the soybean vegetative canopy.

Table 5. Comparison of average monthly minimum air temperatures, °F., October, 1962, through September, 1963, at St. Paul.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Ave.
Shelter[1]	43	29	12	-3	6	26	38	45	59	63	59	53	36
Sod Soil[2]	36	25	11	-5	1	21	32	40	52	56	54	49	31
Soybean Soil[3]	38	26	11	-6	0	23	32	42	54	59	---	---	---
Bare Soil[4]	39	26	11	-4	3	22	33	42	55	60	56	50	33

1. Temperature measured within standard Weather Bureau shelter about 5½ feet above ground.

2. Temperature measured at top of grass blades during growing season or at 2 cm. above snow surface when snow present.

3. Temperature measured at 2 cm. above soil in soybean field during growing season or at 2 cm. above snow surface when snow present.

4. Temperature measured at 2 cm. above soil surface or at 2 cm. above snow surface when snow present.

General Climatology

Based upon Weather Bureau records the probability of occurrence in the spring and fall of certain low temperatures have been determined. Figures 4 and 5 illustrate some of the information obtained in that study.

A second study of similar nature was made with respect to defining agricultural seasons, determining when they began and ended and their average duration. Figures 6 and 7 are taken from that study.

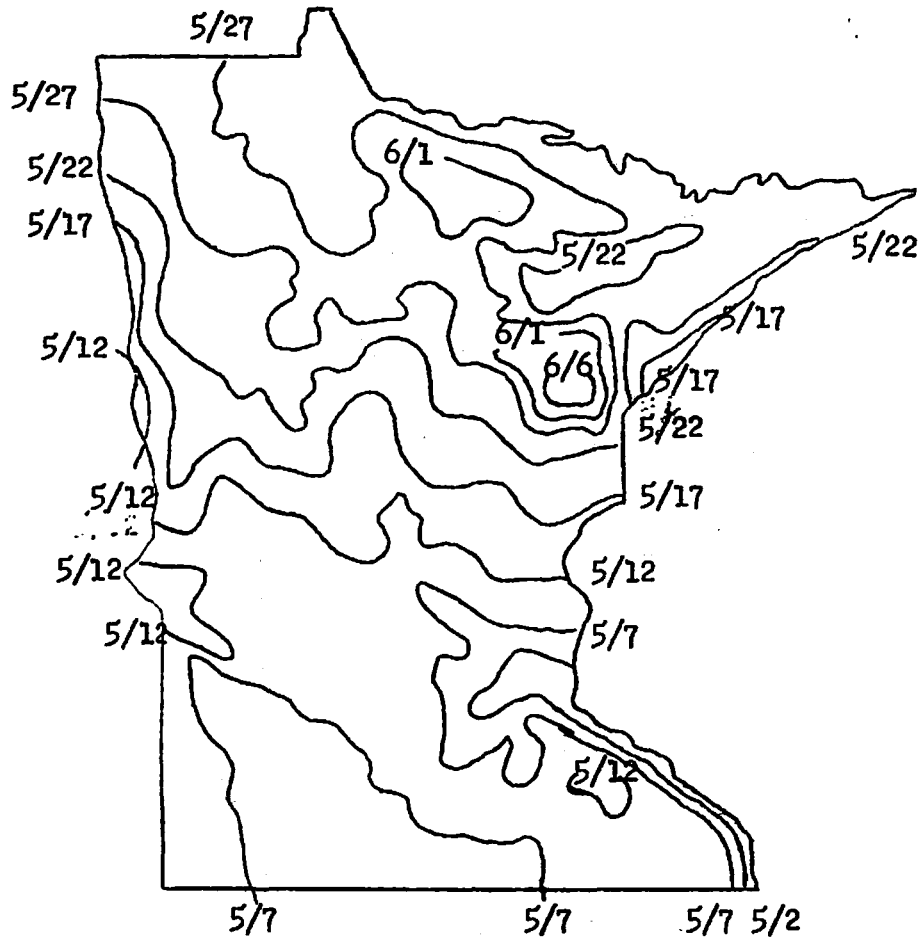

Fig. 4. Average date of last occurrence of 32° F. or lower in the spring.

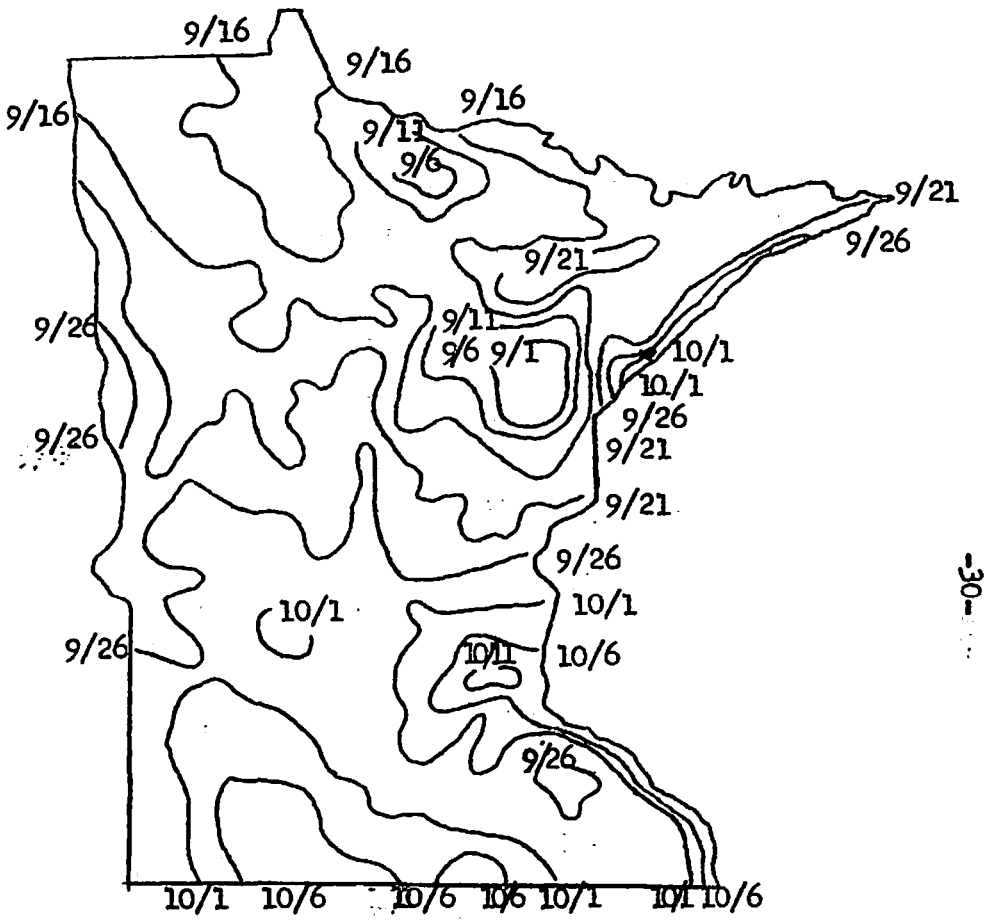

Fig. 5. Average date of first occurrence of 32° F. or lower in the fall.

(Both figures from: Baker, D. G., and Strub, J. H., Jr. 1963. Climate of Minnesota. Part I. Probability of occurrence in the spring and fall of selected low temperatures. Minn. Agric. Expt. Sta. Tech. Bull. 243.)

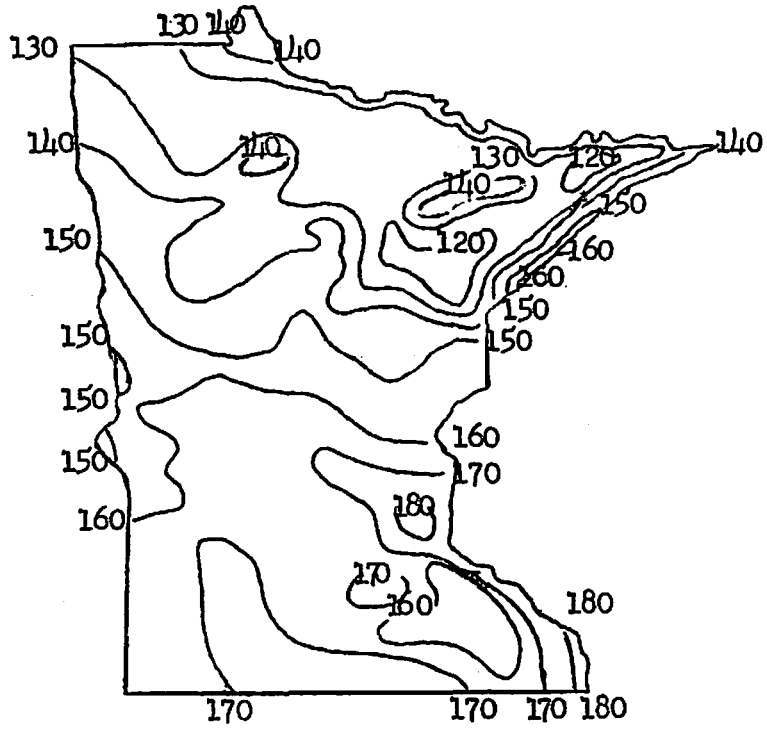

Figure 6. Average duration in days of the warm season crop (corn, soybeans) period -- late spring through late fall.

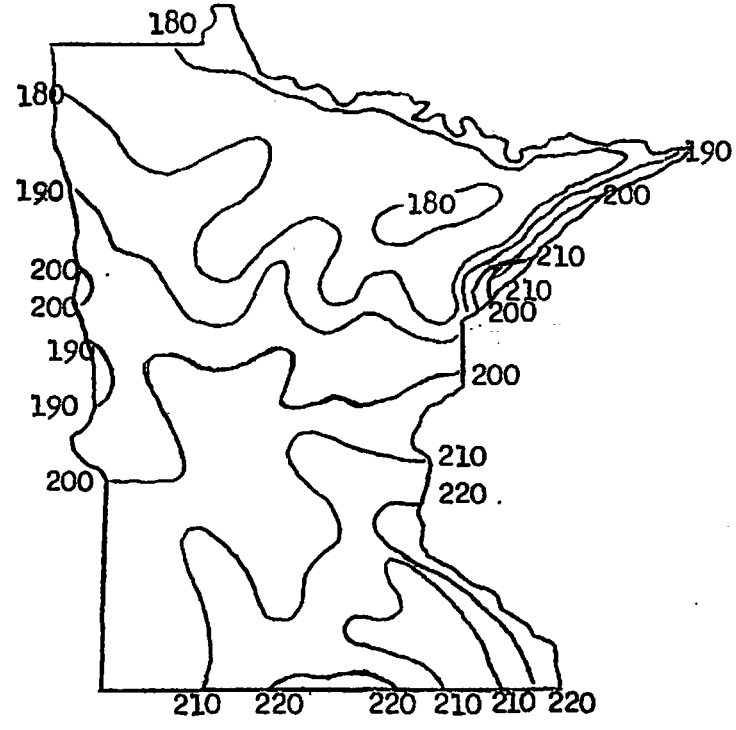

Figure 7. Average duration in days of the total crop season -- early spring through late fall.

(Both figures from: Baker, D. G., and Strub, J. H., Jr. 1963. Climate of Minnesota. Part II. The agricultural and minimum - temperature - free seasons. Minn. Agric. Expt. Sta. Tech. Bull. 245.)