SNOW CONSERVATION POTENTIAL

in the

WEST CENTRAL GREAT PLAINS

B. W. Greb and A. L. Black

SNOW CONSERVATION POTENTIAL in the WEST CENTRAL GREAT PLAINS[1]

B. W. Greb and A. L. Black[2]

ABSTRACT

Variables affecting snow control and utilization include: quantity of snowfall, density of snow, placement and depth of drift by control mechanisms, runoff and evaporation losses.

Mean annual snowfall varies from 15 to 46 inches within the West Central Great Plains as a function of mean annual temperature and not of mean annual precipitation. Quantity of snow per year and density per storm vary greatly at any specific location.

---

1 Contribution from Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture, Colorado Agricultural Experiment Station cooperating, Scientific Journal Series ________.

2 Soil Scientists, Northern Great Plains Branch, Soil and Water Conservation Research Division, Agricultural Research Service Central Great Plains Field Station, U. S. Department of Agriculture, Akron, Colorado and Eastern Montana Branch Station, Sidney, Montana.

Mean densities of .125 in ten storms and .095 for nine storms were obtained at Akron, Colorado in 1960 and 1961 respectively. Snow density results indicate rain gauge measurements of winter precipitation may be low by .5 to 2.5 inches for a particular season.

Evaporation losses from snow were relatively low when measured in absence of wind at subfreezing temperatures.

Crop residues offer two systems for snow retention (a) snow deposition within crop residue strips of calculated width (b) leeward of very narrow residue barriers. Artificial fences of various design may be used to modify the size and shape of snow drifts for specific conservation purposes.

# # #

Investigations regarding snow control usually involves two broad purposes; first, deposition and intake of snow moisture as a water resource on forestry and agricultural lands; second, protection of highway and railroads from drifting snow and elimination of avalanche hazards.

Although more snow research is being conducted on forested land than on agricultural land, in neither case do investigations appear to be sufficient in relation to the importance of snow as a water resource potential. Basic research on snow in the United States is nearly non-existant and applied research is hardly past the trial and error stages of measurement.

This report represents an outline summary to classify snow research information and to present observed and measured snow phenomena at the U.S.D.A. Central Great Plains Field Station.

NATURE OF SNOW

Quantity of Snowfall

Moisture in the form of snow contributes 8 to 33 percent of the total precipitation in the West Central Great Plains with highest quantities received in extreme western Nebraska and northeastern Colorado. Snowfall means shown on figure 1 include records generally in excess of forty years duration (7). Mean quantities vary within the region from 15 inches in southwest Kansas to 46 inches in Banner County, Nebraska. Snowfall quantities were found to be highly correlated with cooler annual temperatures (r = -.86) and not correlated with mean annual precipitation (7). An arbitrary lower limit of 25 inches mean annual snowfall would seem necessary for snow conservation work to be considered feasible.

Snow expectancy in any specific location within the Central Plains is highly variable. Data shown on table 1 for the Central Great Plains Field Station at Akron, Colorado shows a variation of 15 to 67 inches snow in succeeding years. Holyoke, Colorado reported 146 inches of snowfall during 1946.

Nearly half of the snowstorms occuring at Akron, Colorado (table 1) are accompanied by relatively high wind velocity. Storms deposit 1 to 4 inches of snow during the drier months of December, January, and February. Higher quantities per storm can be expected to occur in October and November and again in March and early April.

Severe blizzards have occurred periodically on the Central Plains. One of the most notable began January 2, 1949 which continued for 72 hours and deposited 24 to 50 inches.

Figure 1.--Mean Annual Snowfall

West Central Great Plains

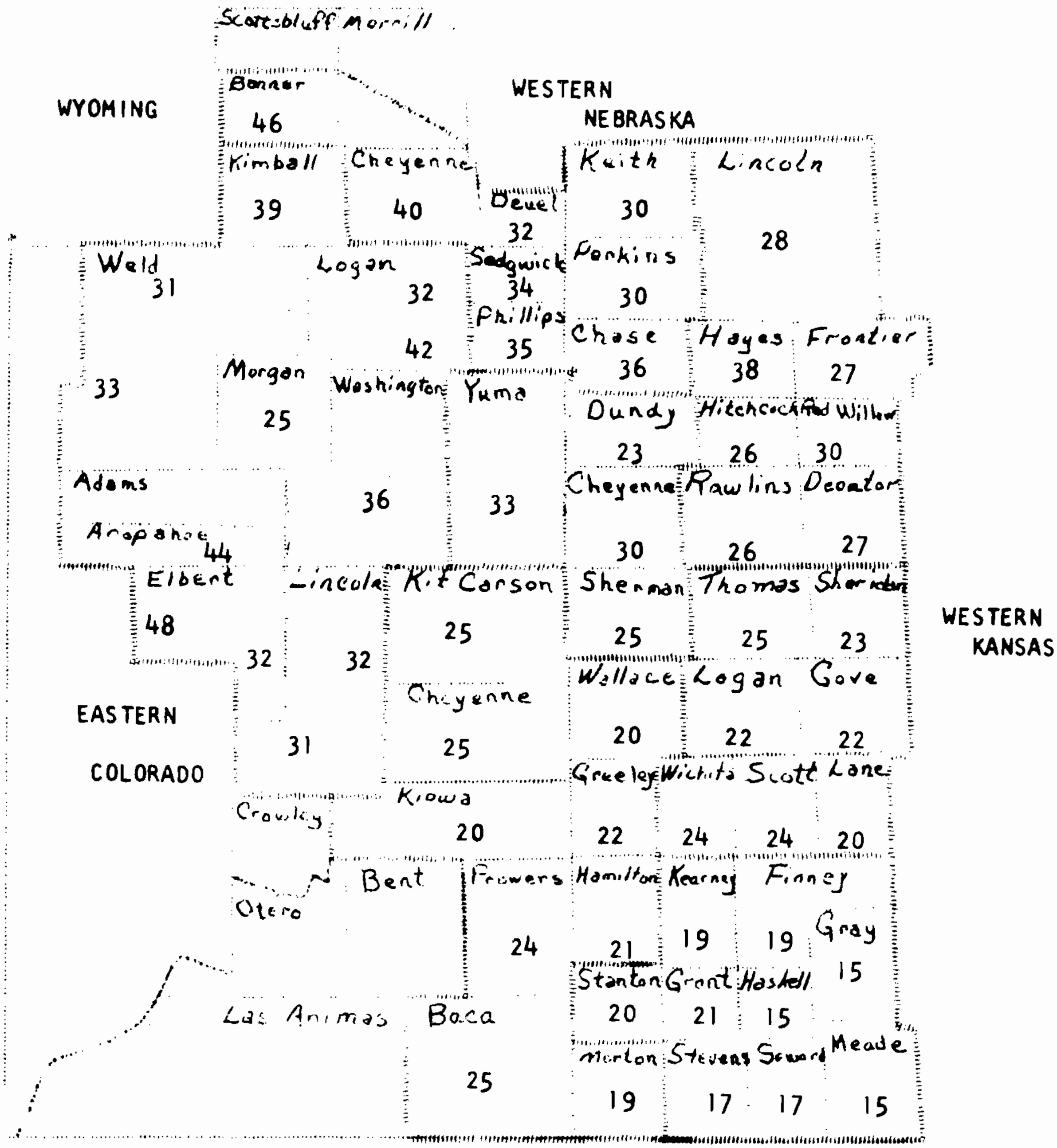


Table 1.--Snowfall and Estimated Winter Precipitation at the U.S.D.A. Central Great Plains Field Station 1955-1962

Winter Season	Snowfall, Inches	Precipitation by Rain Gauge	Precipitation by Density Meas.	Drift Producing storms
1908-1954	32	2.7	3.5*	
1954-1955	19	1.7	2.1*	N.R.**
1955-1956	15	1.3	1.7*	N.R.
1956-1957	67	5.2	7.2*	N.R.
1957-1958	29	2.3	3.2*	N.R.
1958-1959	22	2.0	2.4*	3
1959-1960	39	2.0	4.3*	8
1960-1961	28	2.7	3.8	5
1961-1962	19	1.2	1.8	3
Means	30	2.3	3.3	4 to 5

*Estimated from density measurements of 1960-1961 and 1961-1962 snowstorms. See table 3.

**N.R. = Not Recorded

Snowstorms of low quantity and high wind velocity are sometimes responsible for soil blowing. Snow crystals undergo saltation and sifting processes as do soil particles.

Wet level snows of high quantity are rare. Storms of this type are most likely to occur in mid-spring or mid-fall.

Snow Crystals

Fundamental research regarding snow crystal formation and crystal shapes has been reported by Mason (10). Crystals are formed around very small nuclei particles. These nuclei particles can be natural substances such as volcanic ash, koalinite, magnetite, and other natural dusts. Crystal symmetry is governed by the particular dust particle and crystallization proceeds only after temperatures drop to critical levels. Various natural and artificial nuclei which have been tested for snow crystal symmetry and threshold temperatures are shown on table 2. Temperatures as low as -15^{o}C are required for snow crystallization with certain nuclei materials (10). Mason (10) reported a number of interesting phenomena involved with natural production of snowfall.

1. Snow crystals fall at the rate of about one foot per second in the atmosphere.
2. Drop size is logarithmically related to temperature. Small crystals being produced at lower temperatures.

    10 mm at -18^{o}C

    1 mm at -24^{o}C

    1 mm at -31^{o}C

Table 2.--Crystal Forms of Snow Induced by Various Nuclei[1]

Natural Nuclei			Artificial Nuclei		
Substance	Crystal Symmetry	Threshold Temp. °C	Substance	Crystal Symmetry	Threshold Temp. °C
Ice crystal	Hexagonal	0	Silver iodide	Hexagonal	- 4
Covellite	Hexagonal	- 5	Lead iodide	Hexagonal	- 6
Beta Tridymite	Hexagonal	- 7	Cupric sulfide	Hexagonal	- 6
Magnetite	Cubic	- 8	Mercuric iodide	Tetragonal	- 8
Kaolinite	Triclinic	- 9	Silver sulfide	Monoclinic	- 8
Glacial debris		-10	Ammonium floride	Hexagonal	- 9
Hematite	Hexagonal	-10	Silver oxide	Cubic	-11
Gibbsite	Monoclinic	-11	Cadmium iodide	Hexagonal	-12
Volcanic ash		-13	Vanadium pentoxide	Orthorhombic	-14
Vermiculite	Monoclinic	-15	Iodine	Orthorhombic	-14

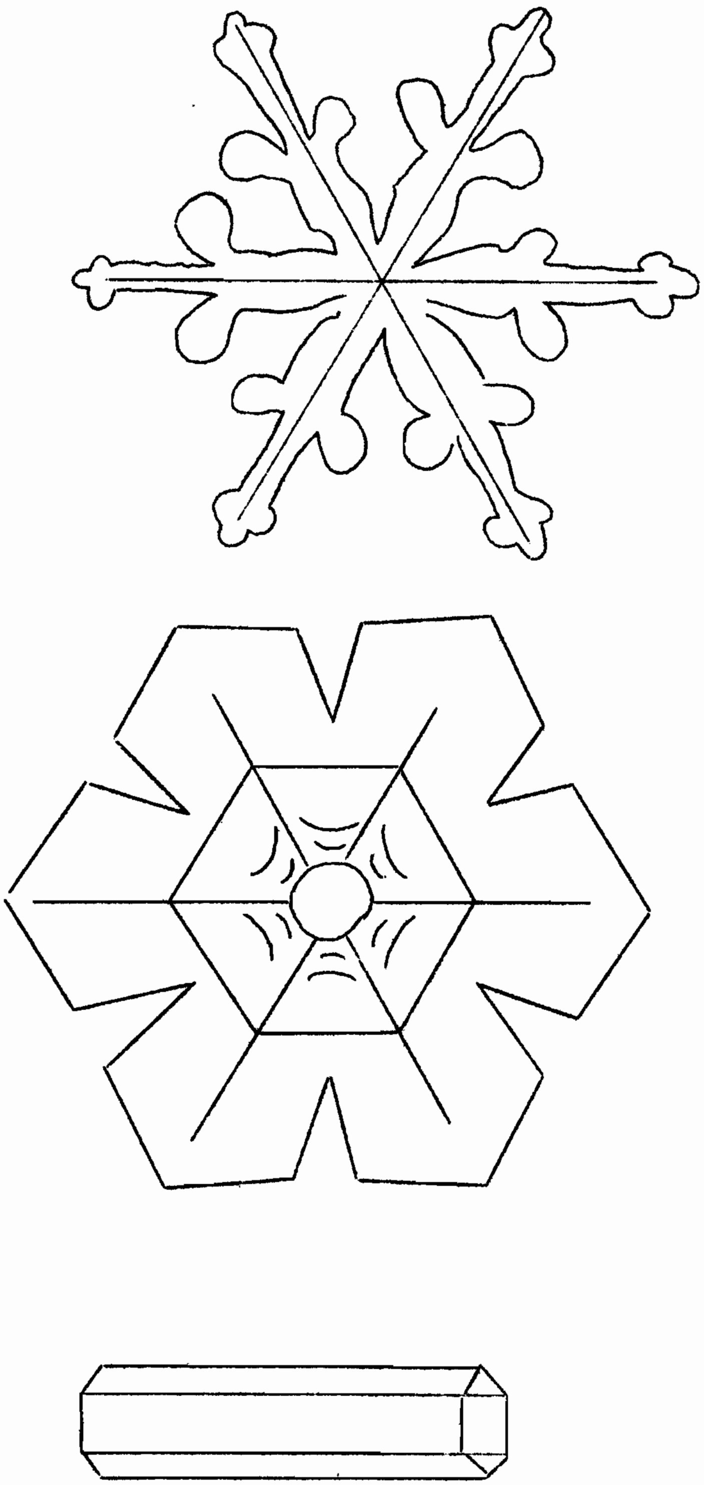
1 Data from Mason (10)

3. Decreasing temperatures logarithmically increase number of atmospheric particles capable of acting as nuclei.
4. Nuclei particles can be pre-activated to initiate crystallization at higher temperature.
5. Koalinite is the most abundant and active of natural atmospheric nuclei.
6. Soil particles make up 75% of source material for nuclei.
7. Montmorillonite is relatively poor as nuclei material and needs extremely low temperatures to be active. Usually found in high cirrus clouds.

Snow crystals are generally hexagonal and classified into three categories; star, leaf, and columnar, as shown on figure 2.

The transition of moisture in the form of snow to hail is difficult to define. Very small, dry, porous particles of hail take on the appearance of fused snow crystals. Hail stones reported by Schleusener (13) as damaging to crops are usually round ice particles exhibiting concentric rings.

Figure 2.--Forms of Snow Crystals[1]



Star Shaped Crystal

Hexagonal Plate (Leaf)

Hexagonal Tube or solid

[1] Drawn from Mason (10)

Snow Density

Moisture from snow has often been estimated by using a density value of .100. This value appears to be reasonable for calculating precipitation from all storms for a given year, but not for individual storms within a given winter season. Densities of level snow, measured by core sampling at Akron of 19 storms, varied from .060 to .166 (table 3). The mean density of ten storms during the 1960-1961 winter season was .125 and .095 for nine storms in 1961-1962. The mean density for the 19 storms of .115 is somewhat higher than the assumed .100 value used.

Core sampling of level snow accounts for significantly more winter precipitation than has been recorded by standard rain gauges. Comparisons shown on table 3 show 1.1 and .6 inches more winter precipitation during 1960-1961 and 1961-1962 when measured by core sampling. Using a mean density value of .110 for snow density for back calculation of winter precipitation at Akron for the previous six years, mean winter precipitation was 1.0 inch higher than rain gauge recordings (table 1). The primary differences in a core sample measurement versus rain gauge have occurred in snow storms with higher wind velocities.

Snow density increases greatly in newly formed drifts. Drift density varies with depth, place within this drift, and age of drift (see table 4). Core samples of new drifts were found to show highest density in the surface crust, next highest in the softer middle, and lowest on the drift bottoms. With drift aging the reverse situation with respect to density is found. Old drifts show greatest density (approaching pack ice) on the bottom, granular ice middle, and softer surface.

Table 4.--Snow Densities in New Drifts Compared with Level Snow

Storm Date	Density Level Snow	Depth Drift	Density in Drift		
			Surface	Middle	Bottom
1960-1961		Inches	4 inches	4 inches	2 inches
Mar. 7, 1961	.166 (3.5)*	8 12 16	.211 .189 .172	.198 .177 .162	.160 .145 .155
April 10, 1961	.085 (4.0)	4 6	.110 .105		 .081
Jan. 12, 1962 36" drift aged to Jan. 24	.077 (8.0)	20 36 24	.321 .285 .272	.278 .283 .318	.257 .228 .368
Feb. 25, 1962	.111 (1.5)	4 6	.120 .149		
March 11, 1962	.060 (2.0)	6 12	.238 .293		

*( ) Inches level snow

New drifts may be 2 to 4 times more dense than nearby level snow and reaching densities of .250 to .350.

Surface crust formation in new drifts is an interesting phenomena. Crust formation may be the result of cross lamination of reworked crystals. Another hypothesis involves the movement of water vapor from the drift bottom (warmer temperature) toward the surface with a consequent refreezing of the vapor near the surface thereby acting as a cementing agent for crystal particles.

Gerdel (4) reporting work in the Sierra Nevada mountains on the ripening process of drifts stated:

> "The structure of the surface of a ripe snow-pack varies with changes in climatic and meteorological conditions. During periods of high temperatures a loose, coarsely crystalline condition prevails. When temperatures drop below freezing these crystals are consolidated into crusts from a fraction to several inches in thickness. Below the surface few inches the matrix of a ripe pack appears to consist of relatively uniform oriented crystals with considerable interfacial contact. Occasional thin, discontinuous ice-planes may be present, probable remnants of old snow-surfaces."

Snow Evaporation

Some moisture from snow is lost by sublimation at subfreezing temperatures. Ackermann et al. (1) states that whenever vapor pressure of the air above snow is less than at the snow surface, water evaporates from snow. Snow can also receive heat from the soil below causing a temperature gradient and eventual evaporation. Moisture losses by sublimation measured in Colorado and California mountains were reported to be quite low however (1). The values for evaporation losses are shown below:

	Winter Sublimation Inches	Spring Evaporation Inches
Rocky Mountain (Colorado)	.24	1.99
Sierra Nevada Mountains	.75 (4 months)	.69 (1 month)

Goodell and Wilm have pointed out high losses of snow in forested areas can result from tree canopy effect (5). Snow suspended by limbs is subject to accelerated evaporation losses because of greater exposure to air movement.

Evaporation estimates at subfreezing temperatures at Akron,Colorado are shown on table 5. These estimates were made by placing snow on flat half-inch deep pans for 16 hours on a relatively wind protected bench. Temperatures were recorded at the initial and final weighing of snow. Water loss data for 24 hour periods were calculated on both a percent sample loss and by an area loss (size of pans). Evaporation losses in 24 hours were quite low, 1200 to 1400 pounds water per acre, but showed tendencies to increase somewhat with temperature and especially with air movement. Evaporation losses decreased with higher humidity. Although these results are preliminary, the trends recorded follow logical expectancy.

SNOW CONTROL MECHANISMS

Artificial and Mechanical Control

Snowfences have been investigated for drift control purposes on highway and forest lands in various parts of the United States (3, 8, 9, 11, 12, 13). The primary objective of drift control for right-of-ways is one of protection and not of water resource manipulation. Induced snow drifting for water storage on forested lands have been reported by Lull (8) and Martinelli (9). Snow control investigations locally in progress on forest lands are being conducted by the Rocky Mountain Forest and Range Experiment Station. One test, using four patterns of modified standard fencing is being carried out at Pole Mountain between Laramie and Cheyenne, Wyoming. Additional testing by the Rocky Mountain station includes a project to increase the size of drifts at alpine elevations. The primary objective of these experiments is to increase the amount of snow retained on a particular watershed to increase water yield to streams (9). Snow control in mountain regions have also been conducted in Scotland, Germany, Japan, and Russia (9).

Research by Theakston and Underwood (14) is primarily concerned with snow and wind control around farmsteads of the Canadian provinces. They are using scale model buildings and windbreaks, sand, aluminum dusts, and dyes to study air flow and drift deposits. Fencing placed around experimental buildings and yards included the standard fences recommended for Scottish conditions which consists of approximately 40 percent wood slats placed either vertical or horizontal (14). This same wood to air ratio is commonly used in the United States with slats wire woven vertically, made 48 inches in height and 50 feet long.

Mechanical treatment of snow by heavy plows and rollers is being tested in the Soviet Union (2). In this case packing or stock piling delays snow melt and reduces surface evaporation.

Snow Fence Experiment at Akron, Colorado

Early in January 1962 various snowfences were installed on pasture-land to study snow drift characteristics which might offer possibilities for specific water conservation purposes (windbreak establishment, water yield to stock ponds, etc.). Using the standard 42% wood slat, 48 inch height-50 foot length fence as a basis for comparison; fences of 62%, 31%, 21% and 15% wood to air ratios were constructed and placed end to end to the standard fence in decending order of wood-air ratio.

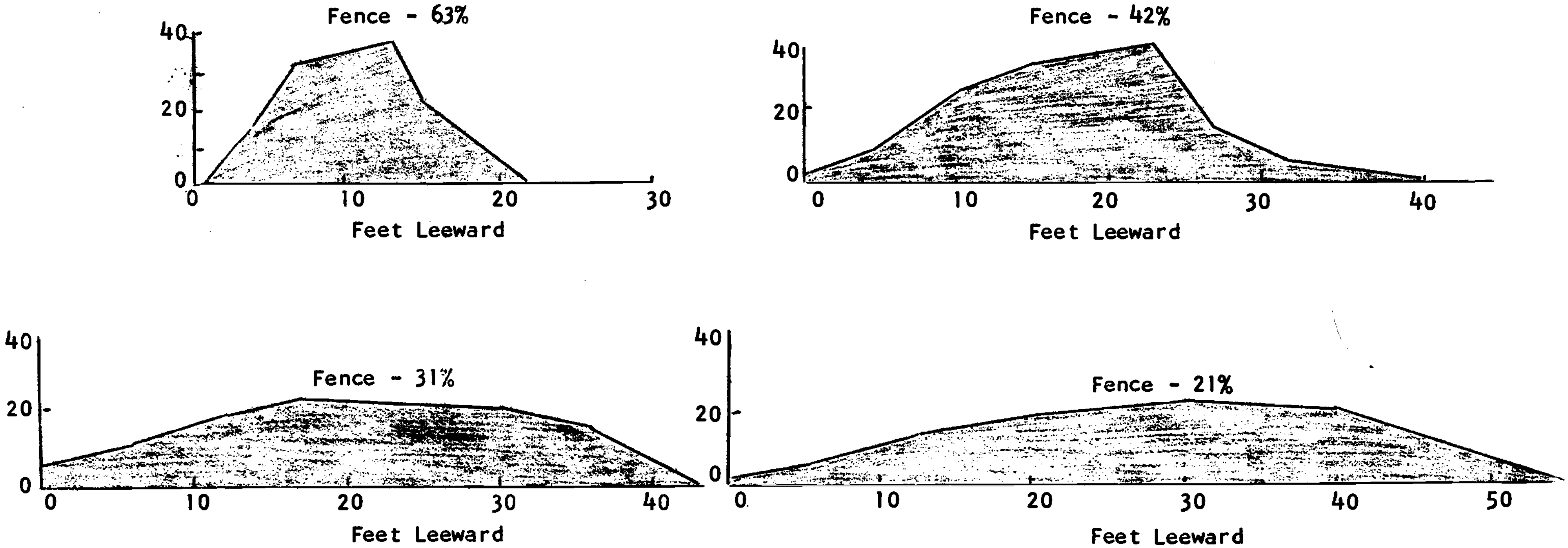
On January 8, 1962, 8 inches of level snow of .077 density (see table 3) was received. The next day a strong northwest wind (30-40 mph) blew the loose snow for several hours. The greatest volume of snow accumulated leeward of the fence containing only 21% wood or half of the standard snow fence (see figure 3).

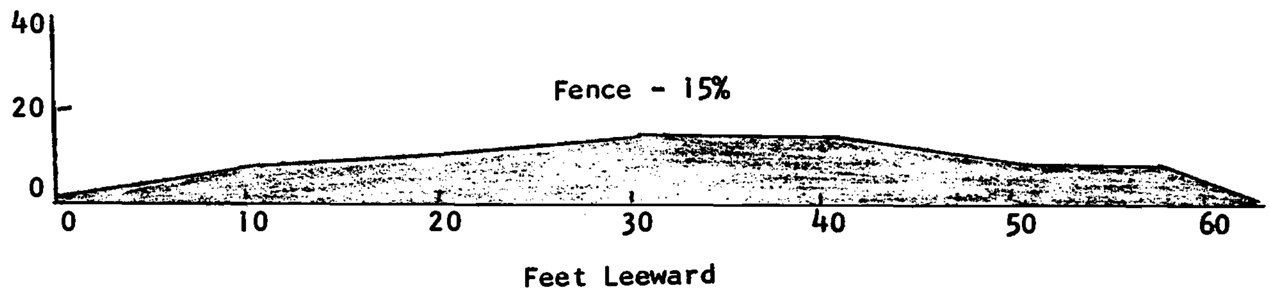
Calculations, based on volume and density, of another drift in the field produced leeward of a 250 foot standard 42% wood fence showed 40,000 gallons of water deposited, equivalent to 1.45 acre inches.

Drift size and shape produced in 1 and 2 inch snowstorms of February 25 and March 11 are shown on figures 3b and 3c. In both cases, the greatest volume of snow was obtained leeward of the 31% wood slat fence.

After three storms, one of high volume and two of much lower volume, it appears that snow drift shapes are formed very early and of a predictable pattern. The final volume appears to be a function of

Figure 3.--Profile of Snow Drift* Leeward of Snow Fences Containing Various Percent Saturation of Air by Wooden Pickets.



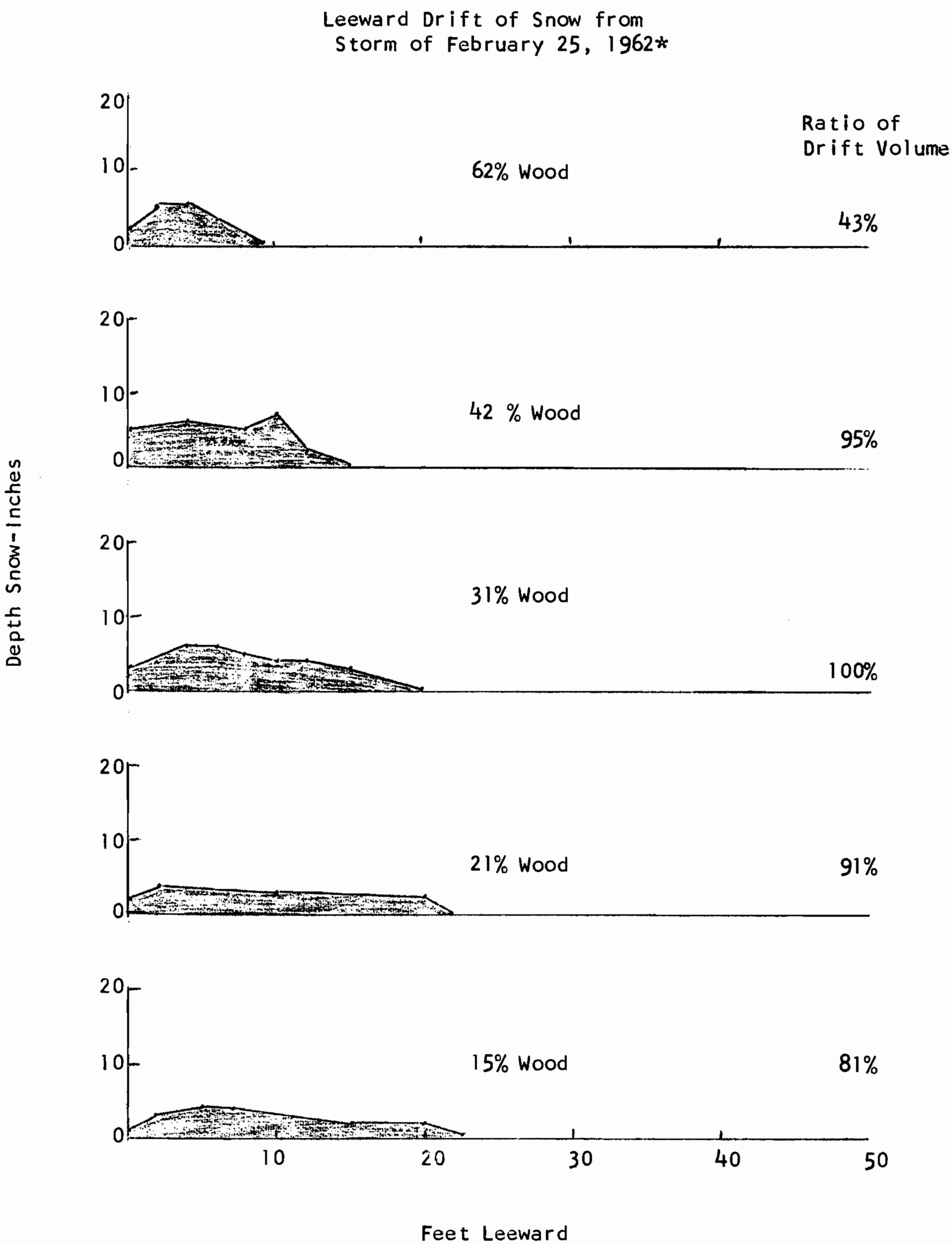


Wood in Fence %	% Vol. Snow Ratio
63	59
42	89
31	96
21	100
15	74

*Storm Jan. 8, 1962

B. W. Greb
Akron, Colorado

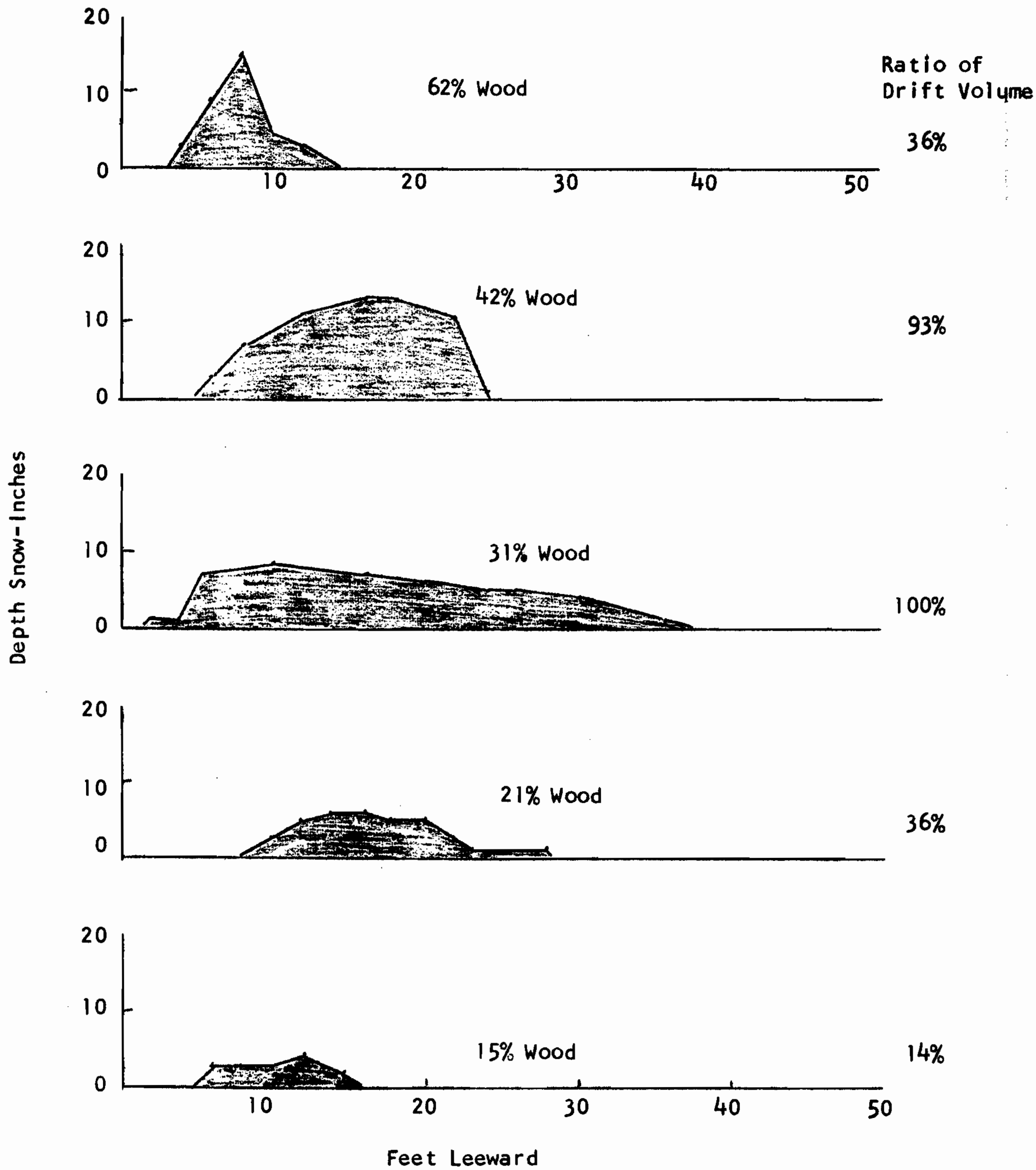
Figure 3b



*See storm characteristics

Figure 3c

Leeward Drift of Snow from
Storm of March 11, 1962*



*See storm characteristics

duration and volume of storm, and wind currents flowing over the growing drift. In no case however, has the standard 42% fence produced the greatest volume of snow.

Preliminary core samplings of drifts show snow densities of the 42% and 21% fence to be nearly the same. Higher densities were obtained for the 21% fence snow drift in the January 9 storm but slightly lower for the February 25 and March 11 storms compared with the 42% wood fence.

Crop Residues

Crop residues may be used to control blowing snow under semi-arid conditions by two systems: (a) Deposition of snow within crop residue strips of widths considered necessary for the particular field, crop, and climatic region involved. (b) Use of very narrow parallel crop residue barriers to deposit snow leeward of the barrier.

Bolyshev and Solov'yev (2) mentioned the use of snow retention strips in the Kazakhstan virgin lands project of the Soviet Union. Corn, sunflower, sorghum, mustard, safflower, and sudangrass were considered the best plants for snow-retaining strips, although sunflower and Indian mustard proved best (2). No details of strip widths nor cultural practices were reported.

Greb and Black (6) have experimented with the use of narrow parallel sorghum stubble barriers for depositing snow onto adjacent plantings by summer fallowed winter wheat. Wheat plantings were made between 25 to 50 ft. intervals of barriers.

Crop Residue Snow Retention Strips (Snow Trapping)

In 1958 strip cropping patterns were initiated at Akron, Colorado to determine feasible ratios of contributing area to receiving area for snow retention. Original designs included 4:1 and 2:1 ratios of planted wheat to sorghum stubble (south position receiving strip). Because of field space limitations for replication purposes, the designs included only 4 row strips of sorghum stubble. These strips proved to be too narrow for snow trapping and too wide to act as barriers for leeward drifts. Highway construction adjacent to the field in 1960 necessitated abandonment of the strips when 50 feet of the south side was included for right-of-way.

The strips were redesigned in 1961 and are composed of a 2:1 and 1:1 ratio of contributing snow blowing area to sorghum stubble receiving area. The sorghum stubble strips are 8 and 10 rows wide (28 and 35 ft. wide) respectively for the above two patterns. No data will be collected until the 1962-1963 winter season at which time the various fallow-crop sequences will have been established.

Photographs and observations have been made on snow trapping by sorghum stubble on a rotation x row spacing experiment (Colo. A-3) at Akron. Some of the drift phenomena observed are sketched on figure 4 for storms of various types. In all cases, 8 rows of stubble (28 to 42 inches in width per row) appears to be the minimum for the average 1 to 4 inch snowstorm accompanied by moderate wind velocity. Snow generally sifts past the north row of stubble, begins to accumulate in rows 2 and 3 and reaches maximum height somewhere between rows 4, 5, and 6. High wind velocity, low snow volume storms naturally tend to sift snow toward the south side of a strip and lower velocity storms drop snow closer to the north 4 or 5 stubble rows.

Experience has indicated a minimum sorghum population of 18,000 stalks per acre and 12 inch height of stubble is required for snow trapping to be effective for most storms.

Snow Spreading with Residue Barriers

Snow spreading with narrow two row crop barriers spaced at regular intervals across a fallow field represents an attempt to create a series of parallel fences to contain snow within the field. In this manner snow is deposited onto wheat plantings between the barriers. Sketches on figure 5 show drift deposits produced by various storm types typical of the West Central Great Plains.

A two row (14 inches apart) barrier was chosen in experiment Colo. A-7a for reasons given below:

a. Single rows easily develop wind gaps which would destroy succeeding barriers across the field (avalanche effect). These wind gaps can be the result of natural stubble lodging or by poor crop stand.

b. Three row plantings at narrow width spacing tends to destroy the middle row because of water competition.

c. Two rows appears ideal because healthy sorghum plants can be produced by root extension for water to each side of the barrier. Moderate weed infestation is an asset rather than a liability. Weeds lend support to lodging stalks.

d. Two row plantings are easily installed with standard wheat drilling equipment at convenient intervals for tillage equipment and multiples of drill machines.

e. Moderate cultivation (only one usually necessary) is handled by spacing cultivator blades 25 to 26 inches apart.

Barrier material may include crops besides sorghum. However, for the conditions at Akron, corn proved inadequate and other crops offer little in the way of harvestable return to compensate for the space occupied by the barrier planting. Corn plantings at Akron needed to be spaced too wide apart for normal growth with resultant insufficient stubble density to reduce wind velocities for snow deposition.

One of the objectives of experiment Colo. A-7a includes selection of the best sorghum materials. At the present time two adapted forage sorghums, two early grain varieties, and two later maturing, shorter growing grain varieties are being grown. The varieties used are given below:

FS-1A	Reliance	Midland
Coes	RS-501	RS-608

Preliminary evidence from the standpoint of stand, lodging, height, density, (leaf + stalk) and yield of harvestable grain indicates Reliance to be the poorest. Coes and RS-501 were next poorest, being too tall - spindly- and easily lodged. Forage variety FS-1A had oustanding barrier characteristics but grain production was seasonally too late for harvest.

Midland and RS-608 proved to be excellent in barrier characteristic and high yielding. In all varieties, sorghum has been combine harvested at 22-26 inch height. Stubble taller than 26 inches tends to increase lodging (top heavy), and stubble shorter than 18 inches would lose barrier effectiveness.

Barriers grown for the 1959-1960 season consisted of RS-501 variety and in 1960-1961 the data was obtained leeward of Fremont, FS-22, RS-608 and RS-610 sorghum varieties. Drift deposits have been similar for most varieties if adequate stands, good growing conditions, and reduced stubble lodging is obtained.

The graph curve for snow accumulation shown on figure 6 is typical of each winter season as well as for the three season average. With greater quantities of snow deposited 5 to 15 feet leeward of a barrier, it is only natural that soil moisture and wheat growth would reflect a similar pattern as shown on figures 7 and 8.

Net gains in soil moisture during two winters averaged 1.8 inches between 5 and 30 feet leeward of barriers. The net gain is reduced with distance as shown below:

Feet Leeward	Soil Moisture Gain (Inches)
5	2.8
10	2.5
15	1.8
20	1.7
25	1.3
30	.8

[redacted] Snow Drift Accumulation Leeward of Sorghum Barrier; Mean Three Winters*

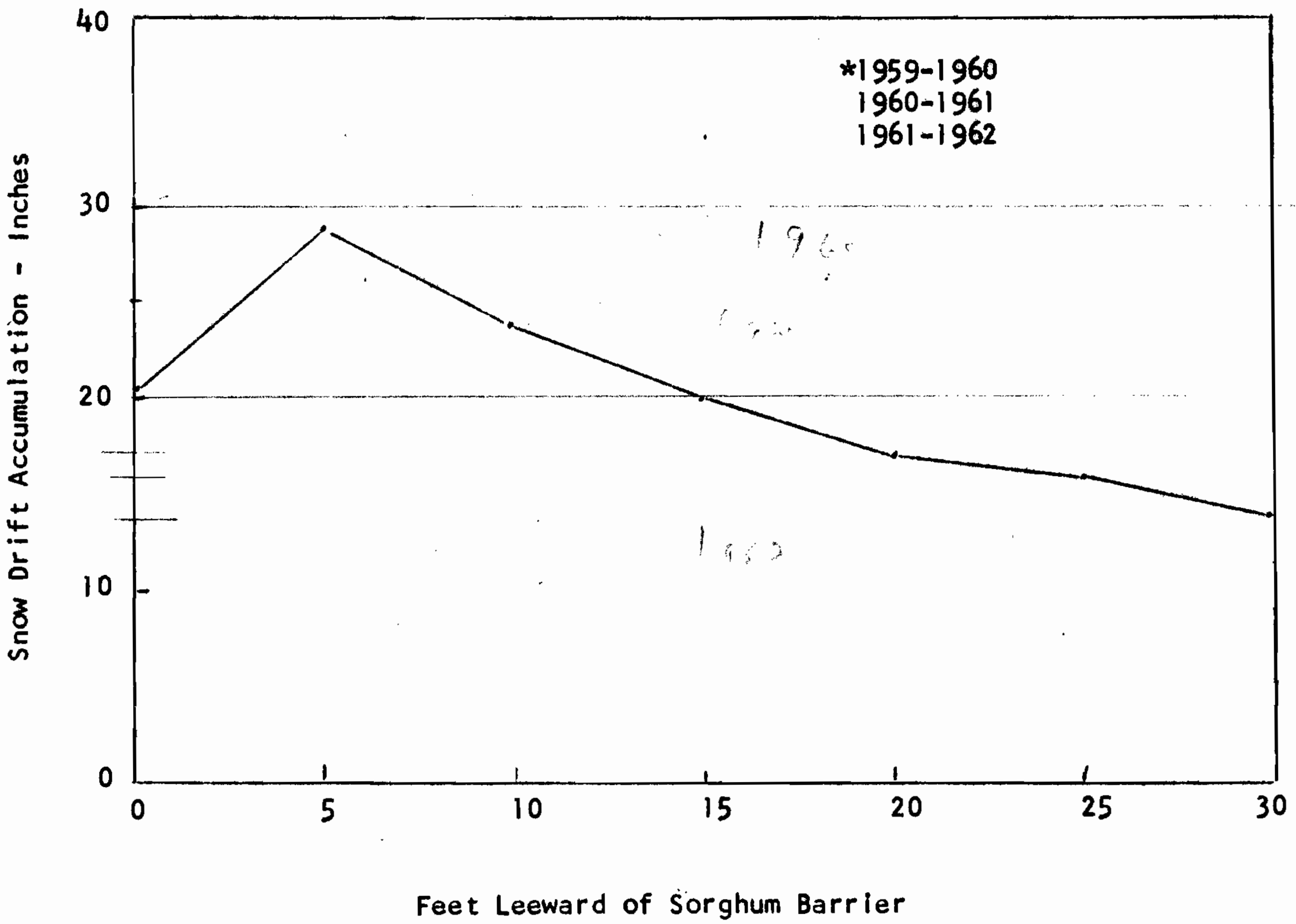
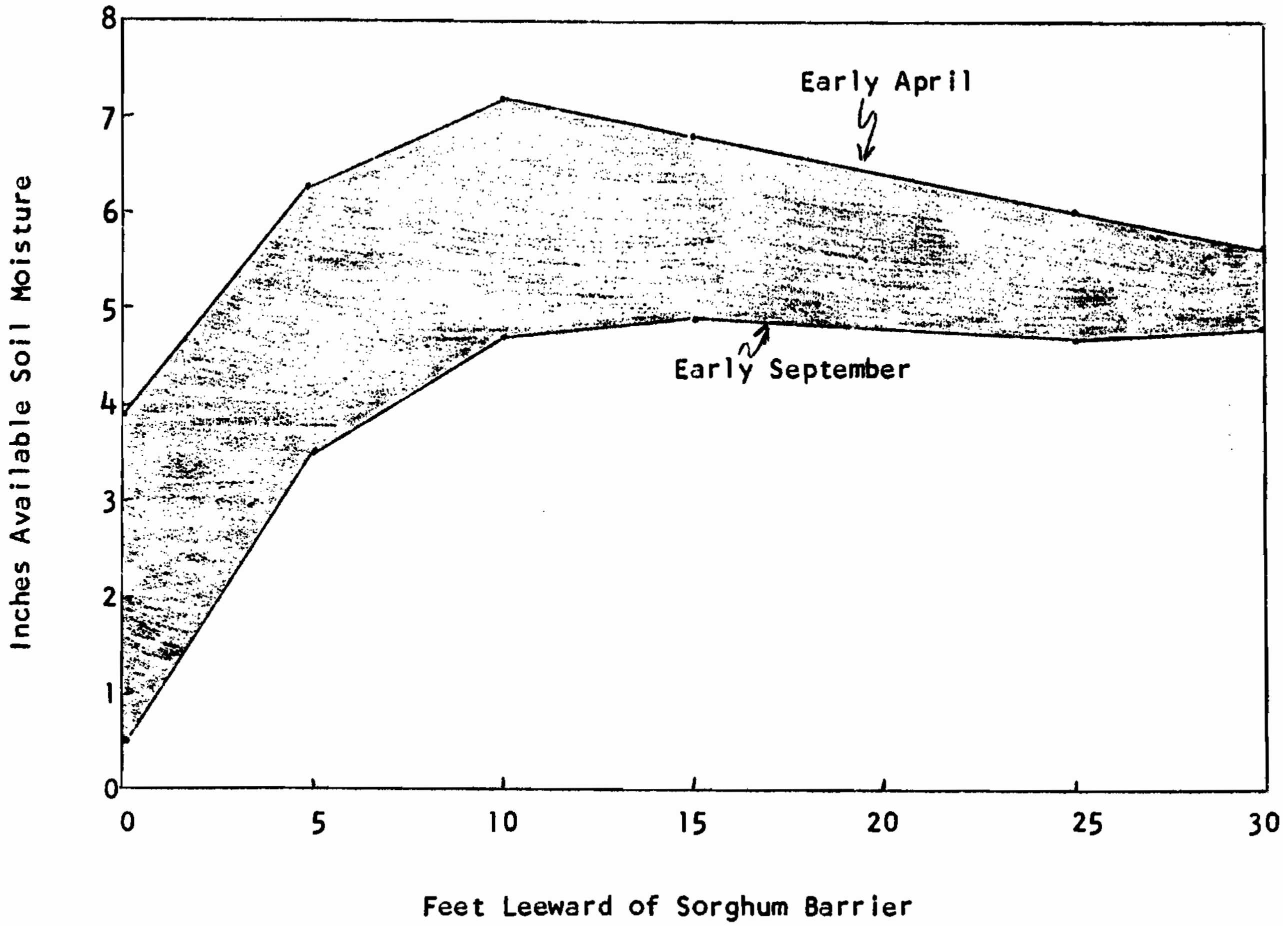


Figure 7.--Soil Moisture Accumulation Leeward of Sorghum Barrier. Mean of 1959-1960 and 1960-1961



It was interesting to note in the fall of 1961 that soil moisture had declined 1.0 to 1.5 inches from August 29 to January 23 leeward of dwarf corn which had not produced snow drifts from four snow storms (.96 inches water) and 2.08 inches rain; while leeward of FS-22 and RS-608 soil moisture was maintained. The data was surprising. Not only for the above reasons but also in the capacity of wheat to consume 3 to 4 inches moisture during the fall and early winter season. This indicates that replacement of soil moisture by snow could have very important consequences in marginal moisture seasons when winter wheat would be in danger of winter kill.

Wheat growth characteristics reflecting snow deposition appears to be more magnified in straw growth than grain production as seen on figure 8. Yield advantages for wheat grown in these strips compared with adjacent wheat grown without snow spreading barriers has been estimated at 3.1 bushels per acre for three field locations. The unofficial (lack of statistical verification) gains were 4.6, 1.0, and 3.6 bushels per acre.

There should be no advantage to barrier stripping for nearly half of the snow storms which occur because of level deposit. However, snow movement by wind can occur after snow has fallen in addition to those several snow storms which do occur annually accompanied by moderate to high wind velocities.

SUMMARY

1. Analysis of snow phenomena under semi-arid climatic environment is a relatively unexplored field of investigation which would readily adapt itself to controlled laboratory conditions; particularly in regards to physical properties and drift studies.

2. About 60% of the West Central Great Plains receives a mean annual snowfall of over 25 inches, sufficient for snow conservation consideration purposes.

3. Snowfall expectancy and density of snow is highly variable.

4. Crystallization of snow is largely governed by nuclei particles and threshold temperatures.

5. New snow drifts are much higher in density than adjacent level loose snow. Most drifts exceed .200 density upon formation.

6. Evaporation of snow at subfreezing temperatures in absence of wind is low, generally less than 1-ton of water per acre per 24 hour period.

7. Artificial fences containing various wood:air ratios greatly modified the shape and volume of snow drifts. Maximum volumes were obtained leeward of fences constructed of 21% and 31% wood:air ratio fence. Of three storms tested, one of high volume and two of low volume, the fences containing 31% wood:air ratio appeared to have the superior attributes for shape and volume characteristics. However placement of snow could be varied according to a particular objective.

9. Crop residue strips for snow retention should be at least 28 to 42 feet wide with stubble height exceeding 12 inches.

10. Crop residue barriers for leeward drift deposition of snow should be at least 18 inches tall containing a stalk:air density over 20-25% for effectiveness. Rigidity of stalk is necessary to withstand winter conditions.

LITERATURE CITED

1. Ackermann, William C., Coleman, E. A. and Ogrosky, Harold O. 1955. From Ocean to Sky to Land to Ocean. U.S.D.A. Yearbook of Agr. pp. 44-46.

2. Bolyshev, N. N. and Solov'yev, M. V. 1958. Soil Investigation Methods on State Farms Organized on Virgin Soil. Soviet Soil Science. No. 4 pp. 388-396.

3. Finney, E. A. 1934. Snow Control on the Highways. Michigan Eng. Exp. Sta. Bull. No. 57. 62 pp. Illus.

4. Gerdel, R. W. 1945. The Dynamics of Liquid Water in Deep Snow-Packs. Transactions, Amer. Geophysical Union. Vol. 26, Part 1.

5. Goodell, B. C. and Wilm, H. G. 1955. How to Get More Snow from Forest Lands. U.S.D.A. Yearbook of Agr. pp. 228-234.

6. Greb, B. W. and Black, A. L. 1961. Strip Cropping for Extra Moisture. U.S.D.A. Agr. Res. Vol. 9, No. 7 p. 7.

7. Greb, B. W. 1962. Soil Resources, Climate, and Cultural Practices Affecting Winter Wheat Production in the West Central Great Plains (Unpublished).

8. Lull, Howard, W. and Orr, H. K. 1950. Induced Snow Drifting for Water Storage. Jour. Forestry. Vol. 48 pp. 179-181.

9. Martinelli, M. Jr. 1962. Snow Research in the Rocky Mountain Forest and on Pole Mountain. Personal Communication.

10. Mason, B. J. 1961. The Growth of Snow Crystal. Sci. Amer. Vol. 204, No. 1 pp. 120-131.

11. Pugh, H. L. D. Snowfences. 1950 Dept. Sci. and Ind. Res. Road Res. Tech. Paper No. 19.

12. Pugh, H. L. D., and Price, W. I. J. 1954. Snowdrifting and the Use of Snowfences. Polar Record. 7:47.

13. Schleusener, R. A. 1960. A Review of Research on Hail. Colo. Home and Farm Res. Vol. 10, No. 2.

14. Theakston, F. A. and Underwood, John A. Draft and Drift Control. The Farm Quarterly. Winter 1961-1962 Ed. Vol. 16. No. 4 pp. 68-69.