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677 South Segoe Road, Madison, Wisconsin 53711 USA

Effect of Surface-Applied Wheat Straw on Soil Water Losses by Solar Distillation[1]

B. W. GREB[2]

ABSTRACT

Soil surface application of 1,120, 2,240, and 3,360 kg/ha of wheat straw (*Triticum aestivium* L,), equivalent to 30, 60, and 90% soil surface coverage, reduced water losses from a wet soil surface by solar distillation 16, 33, and 49%, respectively, for a 20-day period compared with no straw. A surface application of 6,720 kg/ha, or 180% soil coverage, reduced soil water loss only slightly more than did the 3,360 kg/ha application. Water losses and effectiveness of straw tended to diminish with time as soil water was depleted. The presence of clear plastic canopy increased daily soil temperature maximums at 2.5-cm depth by approximately 11.5F. Maximum daily soil temperatures, both with and without plastic, were reduced nearly 3 F/1,120 kg per ha of added straw. The results suggest part of the mechanism by which more soil water is conserved under stubble mulch summer fallow than with clean fallow.

THE EXACT ROLE of straw mulches in water conservation is not yet completely understood. Previous work has indicated that significant increases in water conservation from mulches are obtained only at high rates of straw application (4). Both Hanks (2) and Russel (4) suggested that mulches conserve water during frequent rainy periods but mulches decrease in value during prolonged dry periods. It has been found that surface mulches may have little long-range benefit over a bare soil unless low evaporation rates permit a time lag for deeper percolation of water (1).

Russel (4), working with 4,480 to 35,000 kg/ha rates of straw mulch, found that evaporation control was only slightly enhanced by quantities of mulch beyond 4,480 kg/ha. This seemed to indicate that the protection of the wet soil surface from solar insolation was much more important than the interruption of heat flow or obstruction of vapor diffusion. He (4) obtained about a 55% decrease in evaporation the first day after soil wetting, about 20 to 25% decrease in evaporation the second day, and very little thereafter. Application rates of less than 4,480 kg/ha straw were not tested (4).

Two experiments were conducted at Akron, Colorado to study the effect of low application rates of wheat straw (*Triticum aestivium* L.) on soil water evaporation losses. A solar distillation technique modified from Jackson and Van Bavel (3) was used to condense water vapor from specific soil surface mulch treatments for subsequent measurement.

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[2] Research Soil Scientist, USDA, Akron, Colorado.

MATERIALS AND METHOD

A series of solar stills were constructed to enclose a given area of treated soil surface. An individual still consisted of a box frame made of 1.6-cm thickness of plywood, 100 cm², and 38 cm high. Then a 142-cm square of clear 1-mil plastic was taped to the outside box frame and folded toward the open center in such a manner that a 1.36-kg lead weight was held 7.6 cm above a water catchment pan. This provided an angle greater than the 25° necessary to assure that migrating water droplets forming on the underside of the plastic would reach the focal point for release into a catchment pan as shown in Fig 1. The area occupied by the pan (0.1 m²) was subtracted from the 1-m² area as noncontributing to the treatment surface. The bottom outside edges of each solar still were banked with dry soil to provide a windless system. The boxes were opened for about 0.5 min each day to obtain water yield measurements.

In the first experiment conducted from Sept. 10 to 24, 1965, wheat straw at rates of 0, 3,360, and 6,720 kg/ha was applied to a prewetted Weld silt loam soil. Straw at 0, 1,120, 2,240, 3,360 kg/ha for soil surface treatments was used for the second experiment on the same soil type. Calculations derived from the measurement of length, width, and weight of clean oven-dried wheat straw particles used in both experiments showed that it would take about 3,600 kg/ha of straw to achieve 100% soil cover assuming perfect distribution. On this basis, and allowing for some cross lapping of straw particles, the application rates of 1,120, 2,240, and 3,360, kg/ha of straw were equivalent to about 30, 60, and 90% soil surface cover.

A soil thermograph sensor for the second experiment was installed at 2.5-cm depth oriented east to west and half way between the water catchment pan and the north side of each box. The solar stills and soil thermograph shelters were oriented to reduce and equalize shadows as much as possible. The soil itself

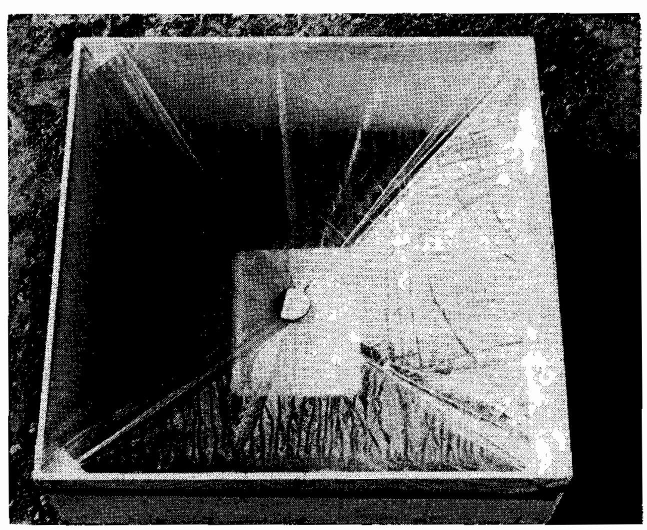

Fig. 1—The solar still in operation showing water droplets forming on underside of plastic and migrating to lead ball focal point for release into pan.

Table 1—Mean daily soil water loss by solar distillation as affected by application rates of wheat straw

Measurement period	Max. air temp.*	Water loss† at straw rates, Kg/ha		
		0	3,360	6,720
	F	ml/0.9 m²		
Sept. 10–14	82.2	970 ± 105	340 ± 45	250 ± 65
Sept. 15–19	61.4	770 ± 50	230 ± 35	200 ± 15
Sept. 20–24	49.2	755 ± 135	260 ± 35	290 ± 25
Fifteen-day means	64.3	830	275	245

* Mean daily.
† Five-day means with standard error.

Table 2—Mean daily soil water loss by solar distillation as affected by application rates of wheat straw

Measurement period	Water loss* at straw rates kg/ha			
	0	1,120	2,240	3,360
	ml/0.9 m²			
Oct. 7–11	690 ± 65	525 ± 45	370 ± 40	265 ± 35
Oct. 12–16	650 ± 70	565 ± 50	430 ± 50	320 ± 35
Oct. 26–30	525 ± 35	455 ± 30	365 ± 20	315 ± 20
Oct. 31–Nov. 4	415 ± 20	390 ± 20	345 ± 15	295 ± 10
Twenty-day means	570	485	380	300

* Five-day means with standard error.

contained 22 cm water above the wilting point within 180 cm of soil depth. A total of 2.54 cm of additional water was then applied to the soil surface in each box immediately before covering with a plastic canopy. The addition of 2.54 cm water wetted the soil to 15 cm and the average water content of this wetted zone was 24% on an oven-dry basis. Two replications of each treatment were placed under plastic. Single treatments of 0 and 3,360 kg/ha of straw were handled as above but without plastic to serve as a check on soil temperature changes.

The complete battery of solar stills, soil surface treatments, installation of soil thermographs, and wetting of soil for the second experiment was completed on October 5, 1965. Water losses and soil temperatures were recorded daily from October 7 to 16 and again from October 26 to November 4, 1965. No recordings were made from October 17 to 25 because of rain and cold temperatures. The solar stills remained unopened during this period but required constant removal of rainwater on the outside of the inverted plastic to prevent breakage. The recordings were taken on clear days with daily air temperature maximums averaging 71.5F for the 20-day period of testing. Near the end of the second experiment, minimum daily temperatures were approaching the freezing point in response to the advanced autumn season.

RESULTS AND DISCUSSION

A sharp reduction in soil water loss was recorded for both the 3,360 and 6,720 kg/ha (90 and 180% soil cover) application of straw throughout most of the 15 days of the first experiment, as shown in Table 1. During the first 5 days, the higher application of straw was more efficient in evaporation control than the lower rate. By the end of the last 5 days, however, this was no longer true. For the entire 15-day test, there was little difference in the capacity of the 3,360 and 6,720 kg/ha straw application to reduce soil water loss. For the particular air temperature conditions prevailing, a 67% reduction in soil water loss was achieved by the 3,360 kg/ha straw application and a 70% reduction by the 6,720 kg/ha rate during the

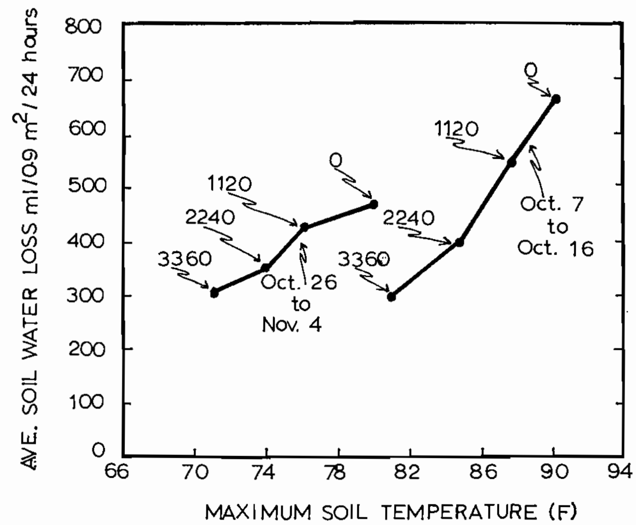

Fig. 2—Effect of surface application of wheat straw on soil water evaporation loss and maximum daily soil temperatures at the 2.5-cm depth under plastic solar still. (Figures along curves are straw application rates in kg/ha.)

15-day test. In terms of water loss, 1.37, 0.46, and 0.41 cm was evaporated for the test period using the 0, 3,360, and 6,720 kg/ha straw treatments, respectively. Large air temperature changes during the September test period caused high variation in daily water losses, particularly on bare soil, as shown by the standard error of means in Table 1.

Throughout most of the second experiment, presence of wheat straw reduced soil moisture evaporation losses in almost linear proportion to the amount of surface straw applied, up to 90% soil cover tested, as shown in Table 2. Reduction of water loss by straw was greatest immediately after initial wetting and tended to diminish with time (Table 2). For the entire 20 days, straw reduced water losses by 16, 33, and 49% for the increasing rates tested compared with no straw. Of the 2.54 cm of water added at the beginning of the experiment, a total of 1.14, 0.96, 0.76, and 0.58 cm were recovered as evaporative losses from the 0, 1,120, 2,240, and 3,360 kg/ha straw treatments, respectively, within the closed systems.

The reduction of soil water evaporation by increased application of wheat straw as shown here may help explain some of the net water gains in summer fallow at Akron, Colo. Results of a 3-year study at Akron, Colo. showed that 2.1 and 4.3 cm more soil water was stored from rainfall during fallow with initial rates of 3,360 and 6,720 kg/ha of straw compared with 1,680 kg/ha. Most of this net gain credited to straw mulches occurred during the spring season when the interval between rainstorms was short and overall quantities of straw had been reduced about 40% by tillage. (Unpublished data recorded from 1963 to 1965 is being prepared for publication as "Effect of straw mulch on soil water storage during summer fallow in the Great Plains" by B. W. Greb, D. E. Smika, and A. L. Black, Research Soil Scientists, U S D A, at Akron, Colo., North Platte, Nebr., and Sidney, Mont., respectively.)

Data in Table 3 show the effect of plastic and various application rates of wheat straw on daily soil temperature maximums compared with no plastic soil treatments. Maximum daily soil temperatures at the 2.5-cm depth under plastic averaged about 11.5F higher than without plastic at

Table 3—Maximum daily soil temperature at 2.5-cm depth as affected by the solar still and application rates of wheat straw

Measurement period	Max. air temp.*	Straw rates under plastic, kg/ha				No plastic, kg/ha	
		0	1,120	2,240	3,360	0	3,360
1965	F	Max. soil temp.*, F					
Oct. 7–11	77.0	90.6	88.9	85.7	81.5	75.8	67.2
Oct. 12–16	75.0	89.7	86.2	84.3	80.3	78.4	68.4
Oct. 26–30	67.0	80.5	76.6	74.8	71.3	70.0	61.8
Oct. 31–Nov. 4	66.8	78.9	75.4	73.4	70.4	68.6	60.6

* Five-day means.

both the 0 and 3,360 kg/ha rates of straw. Maximum daily soil temperatures were reduced approximately 3F/1,120 kg per ha of straw with or without plastic. Thus, it appears that placing plastic over the straw did not impose an additional temperature interaction.

Examination of Fig. 2 indicates that a relation does exist between evaporation losses and maximum soil temperatures as influenced by straw. However, graphing means of temperature vs. water loss for two 10-day periods produces widely separated curves, indicating that such factors as diminishing daylight hours and diminishing available water supply are involved.

Results presented do not imply that evaporation losses under the solar still are comparable to losses to be expected from uncovered fields. The results of evaporation control with straw mulches in these experiments and in conjunction with the results of Russel (4), does suggest, however, that evaporation control by straw is a straight line function up to 100% soil cover. Thereafter, there appears to be little advantage in mulches of > 100% soil cover, at least within the 6 days tested by Russel (4) with an open evaporation system or within 15 days by the solar distillation technique used here. Smaller quantities of mulch may be more important in the overall conservation of soil water than has been suspected.

Mulches should influence both the percolation and the evaporation of soil water. In terms of evaporation, mulches could theoretically reduce soil water losses by reducing soil temperatures, impeding vapor diffusion, acting as periodic focal points for temporary vapor condensation and absorption into mulch tissue, and by reducing wind velocity at the soil interface. Evidence presented here indicates that reduction of soil temperature by mulches is involved with the evaporation reduction process.

From the operational standpoint, the solar still technique is vulnerable to physical damage from cold temperatures, high wind velocity and hail. With an exposed cavity of plastic, rainfall weight may produce breakage. Use of the solar still for soil water evaporation studies would best be suited to semiarid and arid areas where daily minimum temperatures are > 40F. Improvements in strength of plastic and automation of water yield measurements would help.

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