EVAPORATIVE COOLING OF SOWS FOR THE FIRST FIVE TO SEVEN DAYS POST BREEDING

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF SOILS, WATER, AND ENGINEERING

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN AGRICULTURAL ENGINEERING

In the Graduate College

THE UNIVERSITY OF ARIZONA

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ACKNOWLEDGMENTS

The author wishes to express sincere thanks to the Arizona Hog Company in cooperation with The University of Arizona for the opportunity to conduct this study.

Special thanks is given to Bob Hanneman, Manager of the Arizona Hog Company, for his time and help in conducting the tests. Special thanks is also given to Professor Frank Wiersma, the author's advisor, for his guidance in research and preparation of the thesis. Sincere appreciation is given to my wife, Jan, whose help and encouragement will never be forgotten.

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ABSTRACT

Studies have shown heat stress soon after breeding will lower the farrowing capabilities of swine. The purpose of this study was to evaluate three evaporative cooling treatments applied for a brief period at breeding time as compared to conventional practices of shades and sprinklers to relieve heat stress and improve first service farrowing rates.

Research was done in cooperation with a swine producer in Southern Arizona operating under normal swine production. Their breeding and farrowing records showed that high ambient temperatures decreased farrowing from first service. The control, treatment I, and treatment II breeding pens were dirt with slatted shades and sprinklers. Treatment I involved the use of a fan discharging air into the breeding pen. Treatment II had an evaporative cooler discharging cooled air into the breeding pen. An enclosed brick structure cooled only by an evaporative cooler was used in treatment III.

Comparison of the farrowing of sows in the treatments with the control did not show any significant increase in farrowing from first service. The cooling methods used were not sufficient to relieve heat stress.

INTRODUCTION

A consistently high level of efficiency in reproduction of swine is important for a profitable farrow to finish operation. For an efficient operation, a constant supply of piglets is necessary so the facilities can be used to maximum capacity. The number of pigs available for feeding is dependent upon the number of sows which farrowed and upon the size of their litters. With good breeding and environmental conditions, a farrowing rate of 90 to 95 per cent from service at the first estrus after farrowing can be expected. In Southern Arizona farrowing rates from breeding during the hot summer months may be lowered to 60 or 70 per cent. A means to improve the climatic environment might effectively increase the farrowing rate from summer breeding.

Evaporative cooling can be used to improve the climatic environment. The summer ambient climatic conditions in Southern Arizona are usually hot and dry. These conditions are suitable for use of evaporative cooling to produce a more comfortable climate by lowering the air temperature. The use of an evaporative cooler discharging cooled air in the area of breeding swine may increase the reproductive efficiency of the swine.

The object of this study was to determine the effects of short term evaporative cooling on breeding swine. This objective was achieved by:

1. Identifying the relationship between reproductive performance in swine and the seasonal temperature pattern.
2. Evaluating the effectiveness of evaporative cooling during the first five to seven days post breeding on the farrowing capabilities of breeding swine.

LITERATURE REVIEW

Research has been done by agriculture engineers and animal scientists to determine the effects of high temperatures on gilts and sows during breeding and gestation. Under controlled environmental studies, reproduction of swine has been shown to be lowered in a hot environment. At the Ohio Agricultural Research and Development Center, researchers observed data from 240 gilts at three different wet-bulb temperatures (Roller, Teague, and Grifo 1967). They found that the per cent pregnant at 25 days was reduced with the higher dry-bulb temperatures, but an increase in the relative humidity had no effect. The bred gilts in the higher temperatures showed a lower feed consumption and lower average daily gain.

Researchers in California exposed sows after 85 days of pregnancy to 105 F temperatures (Hughes, Heitman, and Kelly 1951). The high temperatures caused increased respiration rates, lowered feed consumption, and elevated body temperatures. During the heat exposure, one sow died due to the high temperatures. They concluded that although the sows showed obvious symptoms of stress, after 85 days of pregnancy the reproductive capacity of the sows was not greatly affected by the high temperatures.

In Florida, embryo survival up to 25 days of pregnancy was compared in gilts in environments with temperatures maintained at 60 F and 90 F in shaded pens during late summer (Warnick et al. 1965). After two years and three different trials, they concluded that there were 1.9 more embryos (13.2 - 11.3) at 25 days post breeding in gilts maintained at 60 F than in gilts maintained at 90 F. Cooling sows during periods of high temperatures, especially immediately after breeding, may increase embryo survival and subsequent litter size.

The effect on conception rate of high ambient temperatures prior to breeding and in early gestation was investigated in Oklahoma (Edwards et al. 1968). Two environmental chambers were used. In one chamber the temperature was kept at 102 F for seventeen hours and 90 F for the remaining seven hours of the day. The second chamber was controlled not to exceed 74 F. No attempt was made to regulate humidity. In all trials, gilts were housed in outside lots prior to entering the chambers and returned to the outside lots after being released from the chambers. In Trial I, conducted from February to April, 17 gilts were placed in the hot chamber for one estrous cycle before breeding. After breeding, they were moved to the outside lots. In the hot chamber, five gilts died and another did not conceive. The gilts in the cool chamber had an average of 12.3 viable embryos as compared to an average of 11.6 per surviving gilts in the hot chamber. This difference was not significant.

In Trial II, conducted during June and July, 11 gilts were placed in each of the chambers five days prior to breeding. After breeding, they were returned to the outside lots. The results were similar to those in Trial I, except no gilts died.

In Trial III, three replications of four different treatments were conducted during March and April, November and December, and January and February. In treatment 1, the gilts were confined in the hot chamber for the first 15 days after breeding and then moved to the outside lots until slaughter. In treatment 2, gilts were kept in the outside lots for the first 15 days after breeding and then placed in the hot chamber for 15 days. In treatment 3, gilts were confined to the cool chamber from breeding until slaughter. In treatment 4, gilts were maintained in the outside lots until slaughter. Gilts were slaughtered between the 30th and 35th day of gestation and the reproductive tracts were recovered.

The reproductive performance of the gilts in Trial III is summarized in Table I. The gilts exposed to heat stress for the first 15 days post breeding had the lowest conception rates and significantly fewer viable embryos.

From these trials, the researchers concluded that heat stress during early gestation is more critical than

Table I. Performance of Gilts Following Post Breeding Exposure to Environmental Chambers (Edwards et al., 1968)

	Treatments			
	1 Stressed 15 Days Post Breeding	2 Stressed 15-30 Days Post Breeding	3 Cooled 1-30 Days Post Breeding	4 Control
Per cent pregnant at slaughter	62.0	90.0	94.0	91.0
Viable embryos per gilt	8.7	12.5	12.2	11.6
Per cent viable of ovulated	59.7	83.2	81.6	83.4

heat stress prior to breeding. Gilts were more susceptible to high ambient temperatures the first few days after breeding than after implantation had occurred.

In a Purdue study, post breeding heat stress consistently decreased embryonic survival if begun the first day after breeding (Heidenreich, Tompkins, and Stob 1967). Heat stress beginning 20 days after breeding did not cause any significant loss of embryos when compared with animals without heat stress. It was also observed that increased levels of stress 29 days after breeding resulted in death of the sows before death of the embryo.

The results of these studies show heat stress of breeding swine will lower the reproductive capabilities. Heat stress right after breeding is the time most detrimental to pregnancy. A means to relieve heat stress during and following breeding may improve the swine's breeding efficiency.

Evaporative Cooling as a Means of Reducing Heat Stress

The simplicity of equipment and low operating costs of evaporative cooling enhance the practicality of its use for improving agricultural production where climatic conditions are favorable. An understanding of the basic theory involved in the cooling process is helpful in using it to its greatest potential.

Evaporative cooling (Watt 1963) occurs when a free water surface and a nonsaturated air-vapor mixture are in contact. Heat and water transfer occurs because the air-vapor mixture seeks an equilibrium of temperature and vapor pressure. Heat flows from the warmer to the colder medium and water vapor flows from the higher vapor pressure to the lower vapor pressure.

Evaporative cooling is an adiabatic process, involving an exchange of sensible heat for latent heat. The initial air-vapor mixture, usually at a higher temperature than the water, releases sensible heat, heat that is associated with a change in temperature, to the water. This heat evaporates the water and is retained as latent heat, heat associated with a change in the physical state of the substance. The end result is an air-vapor mixture with a lower sensible heat and temperature and a higher latent heat and relative humidity. The total heat content remains the same.

With no heat gained or lost, evaporative cooling is limited in cooling capacity. The cooling capacity is directly related to a value equivalent to one minus the degree of saturation of the initial air condition. At a given temperature, dry air can absorb more water vapor than moist air before it becomes saturated, so the air-vapor mixture at lower relative humidity has the potential to exchange more heat and provide a greater decrease in the dry-bulb temperature of the air.

The evaporative cooling process can be illustrated by the use of a psychrometric chart (Figure 1). When an unsaturated air-vapor mixture with dry-bulb and wet-bulb temperatures of state point A enters an evaporative cooler and comes in contact with a free water surface, the cooling of air takes place by the adiabatic process. The mixture will follow the constant wet bulb line towards state point B. In an evaporative cooler, complete saturation does not occur. The final condition of the air would fall between points A and B. The exact location of point C is dependent upon the evaporating efficiency of the cooler.

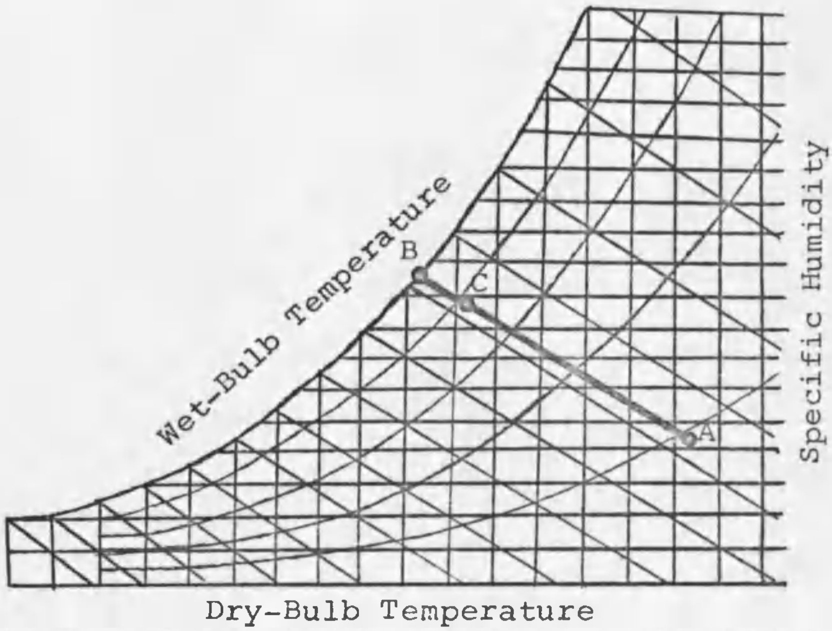

Figure 1. Psychrometric Chart Illustrating Adiabatic Cooling

When cooling large quantities of air, a large wetted surface area is needed to provide the opportunity for vaporization. This is usually accomplished by forcing air through a one- to two-inch thick layer of wet porous material, such as aspen excelsior. The sheet, or pad as it is more commonly called, is kept wet either by dripping water on the upper edge when oriented vertically or by spraying the entire surface. Air is forced through the pad by a fan, usually pulling from the downwind side, and discharged into the area to be cooled. The reduced temperature and constant movement of the air enhances the convective cooling of any object or occupant in the area.

The principle of cooling by evaporation can be applied more directly to enhance conduction cooling by wetting a surface. Removal of heat by evaporation of water from the swine's skin surface can be described by the evaporative heat transfer equation (Esmay 1969):

$$Q_e = k_e A_e V^n (p_s - p_a) \tag{1}$$

where: Q_e is the evaporative heat transfer,

k_e is the evaporative constant,

A_e is the effective evaporative (wet) area,

V^n is the air velocity to some power n,

p_s is the vapor pressure of water on animal's surface, and

p_a is the vapor pressure of water in the air.

As seen by equation (1), air velocity is an important factor in evaporation of water in evaporative heat-transfer. Using a fan to increase the air velocity near the skin's surface will enhance the amount of heat removed by evaporation from the swine's body.

EXPERIMENTAL PROCEDURE

This study was made in cooperation with the Arizona Hog Company and the manager of their swine production facility at Sahuarita in Southern Arizona. The tests were made during normal operation of the facility and integrated into the system to minimize changes in the management program.

Sows were bred the year around to keep their farrowing house and other equipment fully utilized. The sow cycle included consecutive periods in the breeding pen, gestation pen, farrowing house, and the holding pen or pre-breeding conditioning pen.

After five to seven days in the breeding pen, the sows were transferred to the gestation or range pens (Figure 2). These pens were fenced areas provided with slatted shades. Fifty sows and one boar were kept in each pen. The boar in the gestation pen was used to breed any sow that failed to conceive on the first estrus after farrowing. Sprinklers were used in the pens to provide partial relief from the heat.

From the gestation pens, the sows were moved to the pre-farrowing preparation pens one to four days prior to farrowing and prepared for the farrowing house. In the farrowing house, the sows were kept in crates (Figure 3)

Figure 2. Gestation Pen

Figure 3. Farrowing Crate in Farrowing House

with snout evaporative coolers to reduce the effects of high ambient temperatures.

The piglets were weaned at four weeks of age, and the sows were transferred to the conditioning pen located adjacent to the breeding pens. After two or three days, two or three sows were put in a breeding pen for five to seven days and serviced by one boar.

The breeding pens were 20- by 30-foot dirt pens with slatted shades eight feet wide and extending over the 20-foot dimension of the pen. Sprinklers were used to provide relief from the high ambient temperatures. Two manually controlled sprinklers were placed at the edge of the shaded area. The rate of sprinkling was set to provide wetting of the breeding swine. If the weather conditions were such that the rate of application from the sprinklers was too great and excess water accumulated on the ground, the sprinklers were turned off. The sprinklers were off until the excess water had seeped or evaporated away. The management preferred a relatively dry ground to provide sure footing for the breeding swine.

Management records for previous years were analyzed to identify reproduction performance in the existing facilities and conditions. This analysis revealed that the combination of shades and sprinklers had not provided a climatic environment sufficient for good summer breeding efficiency. The percentage of sows farrowing from first service when bred at different months of the year (Figure 4) is based on data from records of the Arizona Hog Company, Sahuarita, Arizona (Hanneman 1969). During 1969, there were 1476 matings of which 20 per cent were gilts. The sows that failed to produce a litter after several services or culled for other reasons are not included in these data. First service pregnancies included any sows that farrowed between four days prior to due date and eight days after due date.

The monthly average maximum temperatures as recorded at Sahuarita Arizona Climatological Observation Station during the same period are also shown on Figure 4 (U. S. Weather Bureau 1969). The general relationship between the temperature and the percentage of sows farrowing during the year is obvious. During the months of highest temperatures the breeding efficiencies are the lowest. This relationship also reflects the near ideal climatic conditions during the winter. That is, except for January, there appears to be no detrimental effects from cold weather stress. At temperatures lower than those recorded here, the influence on breeding efficiency would likely be detrimental.

The monthly average maximum temperatures are plotted against the per cent of sows farrowing from service during their first estrus period in Figure 5. The linear correlation coefficient for these points is -.79 and is significant at the 5 per cent level. The correlation would have been higher if data were limited to temperatures above 65 F or

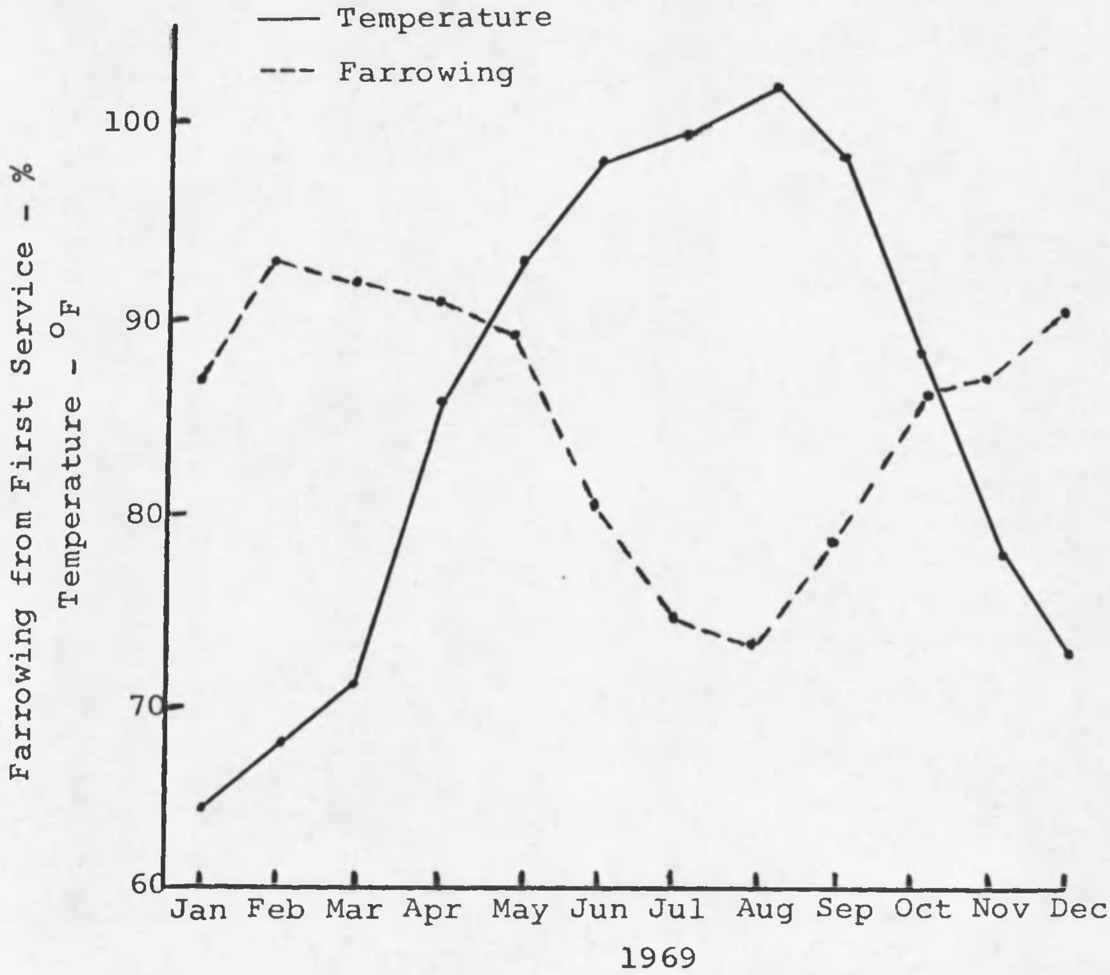

Figure 4. Monthly Average Maximum Temperature Recorded at Sahuarita, Arizona and Percentage of Sows Farrowing from First Service Each Month

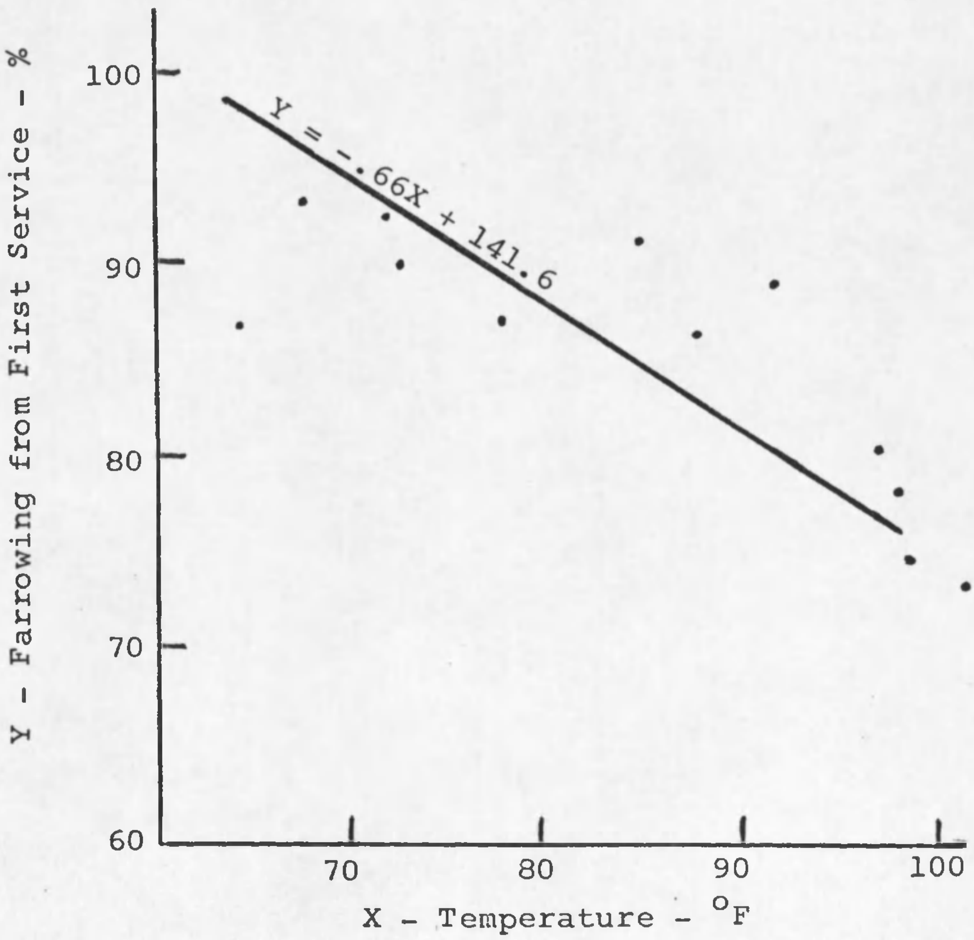

Figure 5. Percentage of Sows Farrowed on First Service Versus Monthly Average Maximum Temperatures

70 F. This shows there is an inverse relationship between farrowing from first service and the monthly maximum temperatures, clearly substantiating the detrimental effects of heat stress on swine reproduction in a commercial herd under production management conditions.

Three different evaporative cooling treatments for improving the climatic environment were included in this study. In treatment I, a fan was mounted to provide untreated air movement under the shaded part of an open pen (Figure 6). The fan was eight feet above the ground and positioned with the fan axis at a 45^{o} angle to the ground. The fan delivered 5,500 cfm of air under the shaded area. The fan was turned on at 11:00 a.m. and turned off at 8:00 p.m. each day. Sprinklers identical to those in the breeding pens were operated on a similar schedule. The moving air enhanced evaporation from the wet surface of the sow's body, providing direct surface cooling.

Treatment II had a conventional package evaporative cooler in place of the fan (Figure 7). It was placed and positioned to blow air within the shaded area of the pen. The evaporative cooler was turned off and on at the same time as the fan. The pen included sprinklers with a design and schedule of operation similar to treatment I and other breeding pens. The cooling method was similar to that in treatment I, but possessed the potential for cooling whether the body surface was wet or dry.

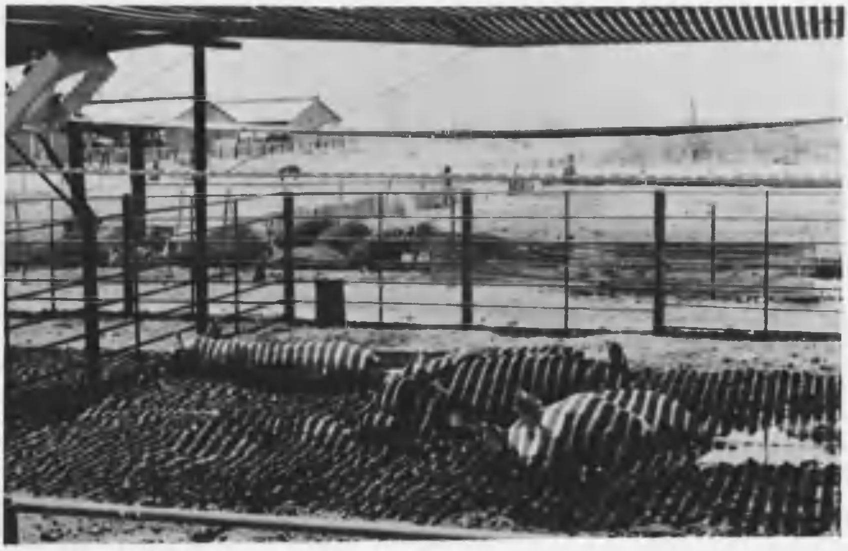

Figure 6. Fan Cooled Pen (Treatment I)

Figure 7. Open Pen with Evaporative Cooler (Treatment II) -- Duct in photograph receives air from cooler on roof and directs it in same direction as in fan cooled pen.

In treatment III, sows were housed in a 28- by 14-foot enclosed, evaporatively cooled brick structure (Figure 8). The walls were six and one-half inches thick with three windows and two wood doors. The overall heat transfer U-value for the walls, including doors and windows was 0.64 BTU/hr ft^2 F. The ceiling was constructed of corrugated steel roofing with three inches of glass wool for insulation. The heat transfer U-value for the ceiling was 0.078 BTU/hr ft^2 F. The gabled roof consisted of corrugated steel with open air space above the ceiling. There were no sprinklers. The conventional package cooler was controlled by a thermostat set at 80 F. It provided approximately one air change within the structure per minute.

The breeding pens used for control treatment were the same size and design as the open experimental pens (Figure 9). Sprinklers were used, but there was no forced movement of air. As in all pens, sprinklers were turned off and on by hand.

The sows, boars, and physical equipment were all handled and operated by employees of the Arizona Hog Company under the supervision of the farm manager. The cooling equipment was added to the existing facilities and all treatments were integrated into their system of management.

Figure 8. Enclosed Evaporative Cooled Structure (Treatment III)

Figure 9. Control Pen

DATA AND RESULTS

The cooling tests were conducted during the period of July 1 through September 28, 1971. Hygrothermographs were installed to record temperature and relative humidity. The hygrothermograph in the control pen was located five feet above the ground in the shaded area. The hygrothermograph in the enclosed structure of treatment III was located four and one-half feet above the floor and near the center of the pen. Figure 10 shows the weekly high temperatures and relative humidities recorded by the hygrothermographs. The average daily high temperature and corresponding relative humidity for the control pen were 92.3 F and 24.2 per cent. The temperatures recorded for the month of August are lower than the normal temperatures for that month. The enclosed structure had an average daily high temperature of 80.4 F and a relative humidity of 62.8 per cent. There were no temperature or relative humidity recording devices within the other treatment areas because of the variability of the air conditions at different locations within the pen and the limited number of hygrothermographs available.

Each week respiration rates of the sows were counted at a time corresponding to the daily high temperature. At the time of measurement, there were no other visible signs of heat stress or discomfort. A non-stressed sow will

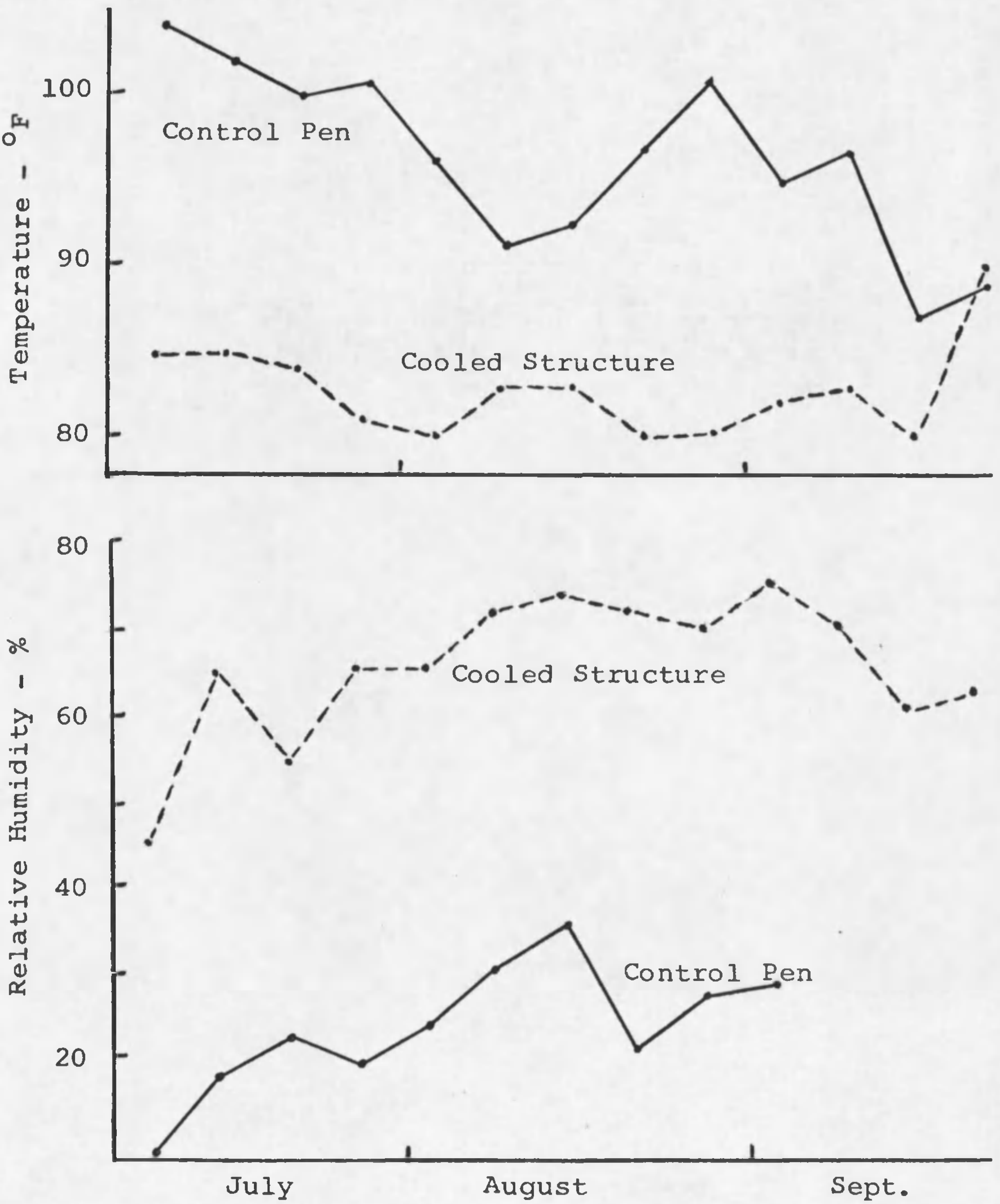

Figure 10. Weekly High Temperatures and Corresponding Relative Humidities in the Control Pen and Cooled Structure

normally have a respiration rate of 8 to 18 breaths per minute with an average of 13 (Ensminger 1961). The average respiration rates for treatment I, treatment II, treatment III, and control are 28, 23, 33, and 26, respectively. The sows were apparently under stress and there were differences in average respiration rates of sows in different treatments, but the variability between individual sows was so great that the difference between treatments was not significant.

Since the tests were conducted under production conditions in a cooperating producer's herd, internal body temperatures were not taken. Any measurement or activity that might contribute to stress was purposely avoided.

The breeding swine's skin surface temperature was measured at mid-day. With the slatted shading, there were differences in temperatures between points in a shaded strip and points in an immediately adjacent strip exposed to direct sunlight. For example, using a small thermocouple to measure surface temperature of dry skin, areas exposed to the sun read 100 F as compared to 91 F in the shaded area. Consequently, the temperatures recorded did not give a good representation of the surface temperature.

Table II shows a comparison of performance associated with the evaporative cooling treatments used in this study. Treatment II is the only treatment that showed any improvement over the control in farrowing percentage from

Table II. Comparison of Reproductive Performance

	Treatment I	Treatment II	Treatment III	Control	1971 Totals
Sows serviced	29	29	99	224	1530
Sows farrowing from first service	6	22	59	139	1050
Per cent of sows farrowing from first service	20.6	75.9	59.5	62.1	68.6
Total per cent of sows farrowed	79.4	93.1	88.7	91.1	95.0
Per cent of sows culled					
Non breeding	17.0	6.9	6.7	5.9	3.0
Health reasons	3.6	0.0	6.6	3.0	2.0
Litter size (first service)					
Born	11.0	10.6	11.3	11.3	10.8
Alive at birth	10.6	9.6	10.1	9.9	9.8

first service. Statistically, using the multiple range test on proportions with the Student-Newman Kuel's procedure (Steel and Torrie 1960), there are no significant differences at the 5 per cent level in the farrowing of sows in control and treatment II or treatment III. Treatment I was significantly lower than control at the 1 per cent level.

The low reproduction performance of the sows in treatment I may have been caused by one or two factors. First, examination of records revealed differences in previous performance between sows of different treatments. The percentage of sows in treatment I failing to farrow from first service during previous pregnancies was higher than in other treatments. Sows in treatment I previously had first service farrowing rates of 67 per cent as compared to 97 per cent in sows of treatment II, and 83 per cent among those in treatment III. In this study, the sows for each treatment were selected at random, dividing them among various pens as they became available from the farrowing house and conditioning pen to minimize the possible differences from changes in weather.

Second, the breeding pen of treatment I was higher in elevation than the other breeding pens. Therefore, when the sprinklers were turned off, any excess water drained away faster than in the other pens and the sows did not have sufficient residual water to relieve the high temperatures. On one occasion, water was standing in the other breeding pens, so the sprinklers were left off to prevent further development of wallows. The sows in treatment I were dry, had no wet ground, and were hot. This may have happened at other times during the summer, inflicting periods of heat stress on the sows.

There was no significant difference in average litter size between sows that farrowed with different cooling treatments. Comparing the average litter size for the year with the average litter size for the summer also showed no significant difference.

CONCLUSION

The results of this study show there is a detrimental effect of seasonal high temperatures on breeding swine. Use of evaporative cooling to relieve heat stress may be helpful, but the degree of climate modification necessary to maintain normal reproductive performance must be greater than any provided in this test. Neither first service farrowing percentage nor litter size were improved by environmental change.

Recommendations for Future Study

Future studies in evaporative cooling for swine should include solid shades rather than the slatted type used in this study. The cooling potential of snow fencing is only about 60 per cent that of solid shades (Welchert 1960). It is quite possible that replacing the existing slatted shades with solid ones would do more to improve the climatic environment than any of the evaporative cooling treatments in this study. The variation in skin temperatures between shaded and unshaded portions of a sow demonstrate the incomplete utilization of shade potential.

The tests would also be improved by providing individual control of sprinkling systems for each pen. Thus, when one pen is getting muddy, the flow need be adjusted for that pen only. Automated controls to totally wet the sows every few minutes might improve both cooling effectiveness and control of excess water.

Improved cooling might be achieved in treatment II with the conventional cooler by partially enclosing the pen. Three sides of a rectangular area might be enclosed with the evaporative cooler discharging air into the enclosure from the open side. The open end would provide free movement of the swine to minimize changes from current practices in handling. Enclosing the sides only part way down might cool with equal effectiveness and further minimize restriction of animal movement.

The experimental design should include selection of sows to reduce differences in previous performances. Sows for each treatment could be randomly selected from groups with comparable breeding and gestation history.

The boars used in this study were assigned to the breeding pens by the farm manager and replaced or rotated on a regular but infrequent interval. This practice, though customary in production management, may inflict boar fertility differences in the treatments. For a more nearly ideal experiment, the boars should be rotated more frequently, perhaps on a daily basis.

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