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THE INFLUENCE OF SELECTED CLIMATOLOGICAL PARAMETERS ON WATER INTAKE OF CATTLE 1/

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INTRODUCTION

Many factors influence the balance of body water in grazing cattle, and therefore, the total ad libitum intake of water. It would be desirable to know the influence of as many environmental factors as possible for better study of treatment effects, prediction of water intake, or calculation of dry-matter intake.

This symposium paper reports the relationships of some commonly measured meteorological and biological parameters to voluntary ad lib water intake of grazing animals.

THE STUDY AREA

The Squaw Butte Experiment Station is located 65 km west of Burns, Oregon. Elevation of the area is about 1,400 m. The characteristic vegetation of the area is a shrub-steppe with bunchgrass understory and a shrub layer of *Artemisia* spp. This study was conducted on an established crested wheatgrass (*Agropyron desertorum*, [Fisch. ex Link] Schult.) area divided into sixteen 3-ha pastures.

Average annual precipitation for the 20-year period 1938-1957 was 30 cm. About 85-90% of the annual precipitation falls between September and May. The 30-year means (1938-1967) of monthly minimum and maximum temperatures were 49° and 85° F for July and 15° and 32° F for January.

METHODS AND MATERIALS

Animals

In 1969, four yearling heifers averaging 254 kg were place individually in each of four pastures. In 1971, a mature cow and her spring-born calf were placed in each of sixteen pastures. The cows averaged 430 and the calves 85 kg. Calves of one-half of the cow-calf pairs were kept from water by placing the tank on a 12-inch platform; both cows and calves of the other eight pairs had access to water.

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Water was provided in standard 1.2-m-diameter tanks 0.6 m high. Initial water levels were measured with a fishhook gauge, and the amounts consumed were determined by the amount of water required to refill to that level. In 1969, water intake (WI) was measured daily; in 1971, measurements were taken over a four-day period and expressed as average daily intake. Measurements were to the nearest 0.4 liter (l). The amount drunk was corrected for evaporation loss, measured in the same manner from a tank of similar size.

Animals were weighed about every 28 days, after an overnight shrink off feed and water. Daily body weight (BW) of growing animals was interpolated from individual animal-growth curves of growing animals. Average trial weight was used for mature animals.

Meteorological and Biological Parameters

In 1969 ambient mean (T_m), minimum (T_{mi}), and maximum (T_{ma}) air temperatures were recorded at the study site. In 1971, T_m, T_{mi}, and T_{ma} were recorded at the station headquarters, about 3 km from the study site, and also daily integrated solar radiation (SR). Cooling days (CD) were calculated from a 65° F threshold. Percent humidity (H), barometric pressure (BP), wind speed (WS), and sky cover (SC) were taken from Weather Bureau records for Burns, Oregon. Barometric pressure change (BPC) was also calculated from Weather Bureau records. Dry-matter of the grass (DM) was monitored through the grazing trial in 1969.

Study Period

In 1969, water intake was recorded daily between July 13 and September 25. In 1971, four periods were studied: June 7-11, June 21-25, July 5-9, and July 19-23.

Expression and Analysis of the Data

Water intake was expressed as l/day, l/kg BW/day, or l/kg $BW^{0.75}$/day. Treatments were pooled in 1971, based on an analysis of variance of the latter two methods of expressing intake. The relationship of each expression to the parameters previously discussed was determined by simple linear regression and correlation and by multiple stepwise and backstep regression and correlation methods. Comparisons were made from values averaged across animals within a day or a period, that is, 4 animals in 1969 and 16 in 1971.

RESULTS AND DISCUSSION

Water Intake

Animals drank an average of 36 l/day, 0.13 l/kg BW/day, or 0.52 l/kg $BW^{0.75}$/day in 1969, and 56 l/day, 0.11 l/kg BW/day, or 0.52 l/kg $BW^{0.75}$/day in 1971. Cow-calf pairs, in which calves were restricted from water, drank 4.4 liters less total water than cow-calf pairs having access to water, but slightly more per unit of $BW^{0.75}$ (0.54 vs 0.50 l; $P > 0.05$). The *ad lib* water intake recorded in these studies is about the same as that reported by Hyder, Bement, Norris, and Morris (1966) and Stanley (1945), when expressed as a function of $BW^{0.75}$.

Water intake expressed as a function of either BW or $BW^{0.75}$ gave higher correlation coefficients with all parameters studied than water intake per se (Tables 1 and 2). The small difference between expressing WI as a function of BW or of $BW^{0.75}$ was a result of the small range in weight of animals within groups.

Variations among animals and days or animals and periods were significant ($P < 0.01$) in both 1969 and 1971. In 1969, the magnitudes of the animal- and day-variance components were nearly equal (0.00573 and 0.00596, respectively). Based on 1969 data, the following number of animals and/or days are necessary to estimate water drunk within ± 10% of the mean at the 0.05 level of probability, using the same method as Hyder, Bement, and Norris (1968).

Number of animals	Number of days
2	16
3	15
4	14

In 1971, the period component of variance was 2.05 times larger than the animal component of variance. Using 1971 data (based on 4-day periods), the following would be necessary to meet the above statistical criteria:

Number of animals	Number of periods	(days)
2	12	48
4	8	32
6	4	16
8	1	4
10	1	4
16	1	4

Meteorological and Biological Effects

The relationship between daily water intake and the parameters studied in 1969 was low ($r < 0.32$ for WI/BW, and $r < 0.28$ for $WI/BW^{0.75}$) (Table 1). However, grouping consecutive days' water intake into units of 3, 4, · · · 7 days improved the relationship (Table 3). Considering Tm alone, grouping 6 consecutive days resulted in the highest r^2 values. Little was gained by grouping 7 days, and in general, the r^2 value was lower than for 6 days.

Caution should be taken in grouping consecutive days' water intake. Preliminary investigations indicate that various groupings of days might result in different expressions of the relationship between WI and meteorological or biological parameters. For example, grouping of days 1-6, 7-12 · · · p vs 2-7, 8-13 · · · p, gave r^2 values for WI vs mean daily temperature of 0.63 and 0.53, respectively. This is, however, further evidence that WI should be averaged over several days vs measuring daily. Hyder, Bement, and Norris (1968) reported a relationship between temperature and WI on the previous day of the same magnitude as the same day the water was drunk that is, $r = 0.64$ vs 0.59, respectively.

Simple correlation coefficients indicate that parameters other than temperature might influence water intake, although only differences in DM and CD in 1969 and BP in 1971 were statistically significant ($P < 0.05$).

Dry-matter content of the forage has been shown to be closely related to water intake (Hyder et al., 1968; Davies, 1972; Forbes, 1968; Winchester and Morris, 1956; Utley, Bradley, and Boling, 1970). In the 1969 study, DM ranged from 59 to 80%, and the relationship of DM with WI was significant ($r = -0.28$). The slope of the regression line was significantly different from zero ($P < 0.05$). Apparently, the actual influence of DM on WI was confounded with that of temperature and declining forage quality and digestibility with advance in season. Dry-matter percentage and T_m were significantly related ($r = -0.26$).

Winchester and Morris (1956) reported that water intake per unit of dry-matter intake remained relatively constant at ambient air temperatures between 10° and 40° F, but increased at an accelerating rate above 40° F. Although CD vs WI was significant only in 1969 (Table 1), the correlation coefficients computed for 1971 (Table 2) were of the same magnitude as temperature parameters. Because the threshold parameter is easily calculated, standard Weather Bureau records of CD may be of little additional value.

In 1971, only BP vs WI was significant because of the low degrees of freedom, but several other parameters had correlation coefficients above 0.80, namely, in descending order, T_{ma}, BPC, WS, CD, T_m, and T_{mi} (Table 2). Such factors as SC appeared to be important, but were obviously affected by other parameters, which resulted in low correlation coefficients.

The relative importance of these parameters was further investigated by regression analysis.

Table 1. Simple correlation coefficients of the parameters studied, computed from three methods of expressing water intake, 1969

Parameter		Correlation of parameters with daily water intake		
		liters	1/kg BW	$1/kg\ BW^{0.75}$
Mean temperature	(T_m)	0.20	0.26*	0.26*
Minimum temperature	(T_{mi})	0.19	0.24*	0.24*
Maximum temperature	(T_{ma})	0.20	0.25*	0.25*
Cooling days	(CD)	0.21	0.26*	0.24*
Humidity	(H)	0.01	-0.06	-0.05
Barometric pressure	(BP)	o.12	0.18	0.18
Barometric pressure change	(BPC)	0.14	0.15	0.13
Wind speed	(WS)	-0.02	0.06	0.04
Sky cover	(SC)	-0.04	-0.13	-0.12
Dry-matter	(DM)	-0.14	-0.32*	-0.28*

* Significant at 0.05 level.

Table 2. Simple correlation coefficients of the parameters studied, computed from three methods of expressing water intake, 1971

Parameter		Correlation of parameters with daily water intake		
		Liters	L/kg BW	L/kg $BW^{0.75}$
Mean temperature	(T_m)	0.77	0.78	0.78
Minimum temperature	(T_{mi})	0.65	0.66	0.66
Maximum temperature	(T_{ma})	0.88	0.89	0.88
Cooling days	(CD)	0.79	0.80	0.80
Humidity	(H)	0.02	0.02	0.02
Barometric pressure	(BP)	0.98*	0.98*	0.98*
Barometric pressure change	(BPC)	0.87	0.88	0.87
Sky cover	(SC)	-0.47	-0.46	-0.47
Wind speed	(WS)	-0.81	-0.81	-0.81
Solar radiation	(SR)	-0.27	-0.28	-0.28

* Significant at 0.05 level.

Stepwise regression analysis of 1969 data ranked the first three variables in the following order for water intake, WI/BW, and WI/$BW^{0.75}$, respectively: CD, BPC, and H; DM, CD, and BPC; DM, CD, and BPC. However, backstep analysis of the same data showed that T_{ma}, T_{mi}, and T_m (in that order) accounted for the most variability, regardless of the method of expressing water intake. The temperature parameters were followed by BPC, H, and CD; DM, BPC, and DC; DM, WS, and BPC, respectively, for WI, WI/BW, and WI/$BW^{0.75}$.

As with daily observations, the ranked stepwise analysis of grouped observations resulted in different rankings of the importance of various parameters for each method of expressing water intake and also the number of days grouped (Table 3).

Because of the shift in importance of parameters, depending on how the data were analyzed, caution should be exercised in developing prediction or adjustment equations based on a single statistic, such as R^2. Other factors to be considered would include the magnitude of the "t" and "b" values, as well as biological soundness.

Based on 1969 data, the best models for adjusting and predicting WI/kg $BW^{0.75}$, based on daily observation, were, respectively:

$$WI = 0.279 - 0.0782\ T_m + 0.0404\ T_{mi} + 0.0412\ T_{ma}; \text{ and}$$

$$WI\ (adj) = WI + 0.0782\ (T_{ma} - 64.4) - 0.0404\ (T_{mi} - 46.8) - 0.0412\ (T_{ma} - 74.8$$

The R^2 value for this equation was 0.145. The coefficient of variation was 18%.

An example of measured vs predicted values is as follows:

Date	Measured	Predicted
7/15	0.57	0.55
7/20	0.71	0.58
8/5	0.48	0.49
8/15	0.61	0.50
8/20	0.49	0.51
9/7	0.60	0.55
9/20	0.42	0.46

In 1971, the close relationship between BP and WI among periods overwhelmed subsequent statistical analyses using stepwise or backstep analyses (Table 2). It should be noted that BPC was also closely related to WI ($r^2 = 0.76$, $P > 0.05$, Table 2). Because of the limited number of periods involved, no suitable adjustment or prediction equation was developed from the 1971 data.

Table 3. The effect of grouping consecutive days on the ordered best F parameter, and corresponding R^2 value of the prediction equations, for three methods of expressing water intake[a]

	WI		WI/BW		$WI/BW^{0.75}$	
Number of days grouped	Ordered best F parameter[b]	R^2	Ordered best F parameter[b]	R^2	Ordered best F parameter[b]	R^2
3	T_m	0.20	T_m	0.29	T_m	0.28
	H	0.39	H	0.43	H	0.42
	BPC	0.46	DM	0.53	DM	0.48
4	T_m	0.24	T_m	0.32	T_m	0.33
	WS	0.58	DM	0.45	WS	0.48
	DM	0.72	WS	0.78	DM	0.80
5	T_m	0.58	T_m	0.45	T_m	0.49
	H	0.76	DM	0.76	DM	0.77
	SC	0.90	H	0.89	H	0.89
6	T_m	0.51	T_m	0.64	T_m	0.63
	T_{mi}	0.69	DM	0.78	BP	0.78
	WS	0.81	WS	0.95	H	0.86
7	T_m	0.39	T_m	0.48	T_m	0.52
	H	0.89	T_{ma}	0.68	T_{ma}	0.75
	CD	0.92	DM	0.78	SC	0.80

a. Symbols are same as those in Table 1.

b. T_m was forced into model first.

CONCLUSIONS

The amount of water a cow drinks is influenced by various meteorological and biological factors. The influence these factors have on ad lib intake of water varies according to their interactions. Parameters that are expressed as a function of temperature appear to be the most suitable for predicting water intake. However, other factors merit further study. Barometric pressure, temperature thresholds, sky cover, solar radiation, wind speed, and humidity could influence the desire of a cow to drink water. Factors such as temperature and forage quality and digestibility masked the influence of dry-matter percentage on WI.

Water intake should be evaluated across several consecutive days. The relationship of WI to the parameters studied was always highest when six days were grouped. Although some parameters were relatively unimportant when considered on a daily basis, when averaged over days they became more important, and, therefore, merit further study.

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