The Effect of Evaporative Cooling in Alleviating Seasonal Differences in Milk Production of Almarai Dairy Farms in the Kingdom of Saudi Arabia

A. K. A. Ali, A. A. AL-Haidary*, M. A. Alshaikh and E. Hayes[1]

Department of Animal Production, College of Agriculture, King Saud University
P.O. Box 2460, Riyadh 11451, Kingdom of Saudi Arabia

ABSTRACT : The effect of evaporative cooling in alleviating seasonal variations of dairy cows raised in AlMarai Dairy Farms in the Kingdom of Saudi Arabia were studied using milking record collected during the period of 1991 to 1996. The data included 13303 and 8137 records represented winter and summer calving seasons. Evaporative cooling system improved production for cows calved in summer. The least square means of milk yield were 9631 and 9556 liter for cows calved in winter and summer seasons but no significant differences (p<0.05) were observed between the yield of two seasons. No significant effect of season on calving under evaporative cooling on most of the biweekly points of the lactation curve. The farm, parity and milk level showed a significant effect on the shape of the curve. Functions of the lactation curve like initial yield, 305 MY, peak yield, time of peak and duration were estimated for each phase of the lactation curve. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 590-596*)

Key Words : Evaporative Cooling, Lactation Curve, Seasonal Variations

INTRODUCTION

Season of calving is one of the main source of environmental variation in the lactation curve. It affects the shape of the lactation inclusively in two ways: first; through the influence of the prevailing environmental conditions such as air temperature, humidity, wind speed and solar radiation. Second; the quality of feed stuff available for feeding in different seasons of the year. The effects of season of calving on the shape of lactation curve were reported by several researches, Wood (1968, 1969 and 1972), Goodall (1986), Grossman et al. (1986) and Stranberg and Lundberg (1991).

It is generally known, that summer heat stress affect the productivity of dairy cows, Fuquay (1981), reported that to reduce that stress and to decrease the reduction in milk yield, cooling dairy cows was used as a managerial practice in hot season. Schneider et al. (1984) reported a 20% reduction in milk yield for cows raised under non-cooling system. Walfenson et al. (1988) used water spray and fan as a cooling methods and found that milk production increased by 3.6kg/day during the 150-day postpartum period. Evaporative cooling have been used extensively in almost all the dairy farms in the Kingdom of Saudi Arabia. El-Nouty et al. (1990) reported that 26% increased in milk production when cows were sprayed with water during hot summer months compare to the non-sprayed cows. The purpose of this study was to investigate the effect of season of calving on the lactation curve of AlMarai Holstein Friesian cows "one of the largest specialized dairy farm in the Kingdom of Saudi Arabia" raised under Koral evaporative cooling system.

MATERIALS AND METHODS

The data used in this study included biweekly test-day milk records of six specialized dairy farms in Al-Marai company in the central region of the Kingdom of Saudi Arabia. Data were collected during the period of 1991 to 1996 and included two seasons; 1-winter (S1); for cows calved during October to March and 2-Summer (S2); for cows calved in April until September. The number of records were 13303 and 8137 for winter and summer calving seasons, respectively. These records represent five parities and two milk levels, records with 9500 liter or less were assigned to milk level 1, while records with level greater than 9500 considered of milk level 2. Records with a lactation period less than 100 days or greater than 360 days were excluded from the analysis. The effect of season of calving on the points of the lactation curve was examined by analyzing the data according to the following model:

$$Y_{ijklm} = \mu + F_i + P_j + L_k + S_l + \text{two-way interactions} + E_{ijklm}$$

Where: Y_{ijklm} = Total milk yield and biweekly yield.
μ = Overall mean
F_i = Farm effect (i=1,.....6)
P_j = Parity effect (J=1,...5)
L_k = Milk level effect (k=1,2)
S_l = Season of calving effect (l=1,2)
E_{ijklm} = Error effect ~ n(0, δ^2).

The parameters of the lactation curve were computed using the multiphasic function of Grossman and Koops (1988).

$$Y_t = \sum_{i=1}^{n} \{a_i \ b_i [1 - \tanh^2 (b_i(t - c_i))]\}$$

Where: Y_t is milk yield at time t (t=days in milk);
n is number of lactation phases.

tanh is the hyperbolic tangent
a_i is asymptotic total yield (Liter);
b_i is rate of yield relative to a_i (days^{-1})
c_i is time of peak yield (days).

Functions of three phases were: 1) Initial yield was computed when t=0 in the multiphasic function. 2) peak yield was represented by a_ib_i. 3) Duration defined as the period in days required to attain about 75% of symptotic total yield during that phase was computed as $2b^{-1}$.

Marquardt's method of nonlinear regression [proc Nlin using Marquardt; SAS (1985)] was used to estimate the parameters because Marquardt is equivalent to performing a series of ridge regression which correct for colinearity or near singularity problems that arise from the correlation between the parameters of lactation curve as given by Bates and Watts (1988).

RESULTS AND DISCUSSION

Climatic condition in Saudi Arabia during six months of summer (from April to September) are characterized by dry and hot weather. Figure 1 shows that the average daily temperature (T_a) remains above 33°C and reached maximum (43°C) during July and August. Moreover, the relative humidity (RH) was at low level during summer and reached the trough during July (less than 10%). Ryan et al., (1992) reported that daily peak temperature in Saudi Arabia during hot summer months ranged from 37 to 55°C and daily average relative humidity ranged from 5 to 19%.
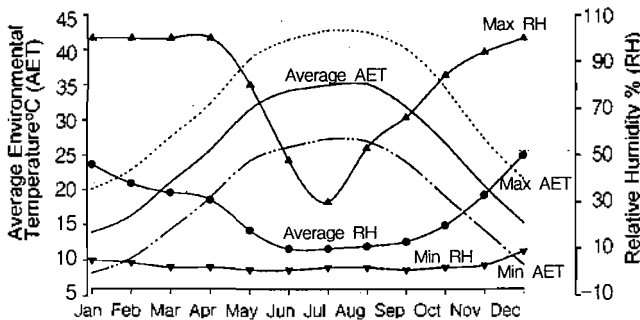

Figure 1. Average environmental temperature and relative humidity in the central region of Kingdom of Saudi Aribia

Milk production of exotic temperate-evolved Holstein cows transferred to hot region is known to decline. The decline has been ascribed to heat-induced suppression of thyroid activity along with many other physiological changes (including alteration of thermal and other hormonal energy and water balance) these physiological changes are necessary to minimize the rise in body temperature (Colleir et al., 1981; Johnson, 1965).

Evaporative cooling system used in Al-Maraie dairy herd improved milk production (figure 3) for cows calved in summer. The least square means of milk yield

were 9631 and 9556 liter for cows calved in winter and summer seasons but no significant differences (p<0.05) were observed between the yield of the two seasons. In three farms in the Kingdom of Saudi Arabia, Wiersma and Armstrong (1989) found that average milk production was higher on each farm for cows cooled prepartum than for control groups of cows not cooled, but the differences were not significant (p<0.05).
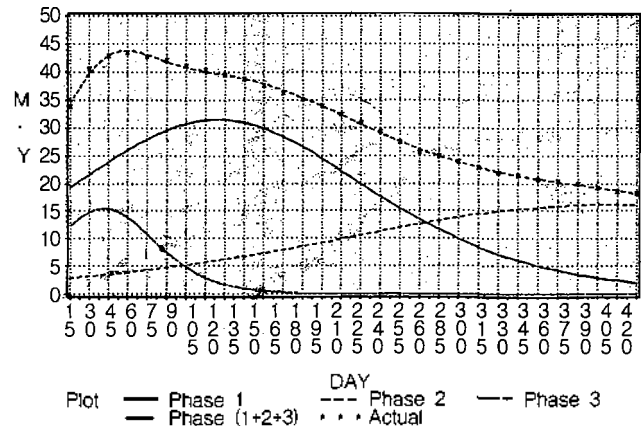

Figure 2. Triphasic lactation curve for overall and actual data
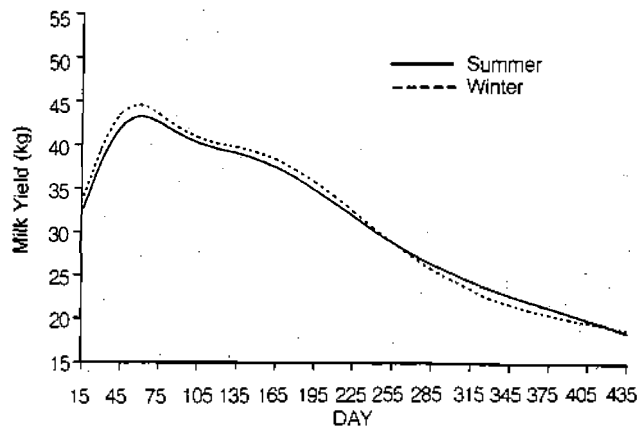
Figure 3. Lactation curves of two calving season for the overal data

Many investigators have reported that milk production of cows raised under evaporative cooling system was significantly higher than the non-cooled cows. The improvement in milk production was mainly due to the increased in dry matter intake, lower rectal temperature and respiratory rate (Armstrong et al., 1988; Ryan et al., 1992; Chen et al., 1993). On the other hand, Her et al. (1988) showed that different cooling methods decreased body temperature, partially improved milk production but did not totally eliminated seasonal variations.

The effect of seasonality on milk production can take two forms; first: the effect of season of calving on milk yield which is associated with the period of the year in

Table 1. The effect of non-genetic factors (farm (FN), parity (P), milk level (L), season of calving (S), and the interactions) on biweekly milk yield

	FN	L	P	S	FN*L	FN*P	FN*S	S*P	L*S	P*S
1	**	**	**	NS	NS	NS	**	NS	**	NS
2	**	**	**	**	**	NS	**	NS	**	NS
3	**	**	**	*	**	*	NS	NS	**	*
4	**	**	**	*	**	NS	NS	*	**	**
5	**	**	**	NS	**	**	**	NS	**	NS
6	**	**	**	NS	**	**	NS	NS	**	*
7	**	**	**	NS	**	**	**	NS	**	NS
8	**	**	**	NS	**	**	**	**	**	NS
9	**	**	**	NS	**	**	**	NS	**	NS
10	**	**	**	NS	**	**	NS	**	**	NS
11	**	**	**	NS	**	**	**	*	**	**
12	**	NS	**	NS	NS	**	**	**	**	NS
13	**	NS	**	**	**	**	**	**	**	NS
14	**	NS	**	NS	NS	**	*	**	*	NS
15	**	**	**	*	NS	**	NS	**	**	NS
16	**	**	**	**	NS	*	*	**	*	NS
17	**	**	**	NS	**	**	NS	**	**	NS
18	**	**	**	NS	**	*	NS	**	*	NS
19	**	**	**	NS	**	**	*	**	*	NS
20	**	**	**	NS	**	*	NS	**	**	NS
21	**	**	**	NS	**	**	NS	**	**	**
22	**	**	**	NS	**	NS	NS	**	**	NS
23	**	**	**	NS	**	**	NS	NS	NS	**
24	**	**	**	NS	**	*	**	NS	*	*
45	**	**	**	NS	**	NS	NS	NS	NS	*
26	**	**	**	NS	**	NS	NS	NS	NS	NS
27	**	**	*	NS	NS	NS	NS	NS	NS	NS
28	**	**	**	NS	NS	NS	NS	NS	NS	NS
29	*	*	NS	NS	NS	NS	*	NS	NS	NS
30	**	**	**	NS	NS	NS	NS	NS	*	NS

* p<0.05; ** p<0.001; NS: Non-significant.

which lactation was initiated, second: the stimulus to milk production associated with season of production, Wood (1969) refer to as the spring hump seasonality. Thus, month of calving in which the cow was producing affected the lactation curve. Wood (1969 and 1980) corrected the incomplete gamma function to adjust for spring hump. Furthermore, Grossman et al. (1986) modified Wood's equation to account for seasonal variation other than season of calving.

The cow that freshens in summer would be affected more than the one calves in winter because the first, face the heat stress of summer when the cow has the urge to produce milk and the lactation curve is in the ascending phase. Likewise, cows freshening late in winter will have an effect due to summer heat different from those freshening early in winter. Table 1 shows no significant effect of calving season on most of the biweekly points of lactation calve. The difference between winter and summer calving were more obvious along the lactation curve of high producers than the low producers, because high producing cows have a higher metabolic rate than the average producers, and consequently, lower resistant to the effect of heat stress. The interaction of season of calving and milk level had

a significant or highly significant on the biweekly yield at twenty two points of the lactation curve.

The significant effect of farm has been excreted on biweekly milk yield as shown on table 1. Farm effect reflects the effect of all managerial conditions prevailed in the farm during the lactation period. Age or the parity effect is the second important managerial factor affect the curve through the development of the secretary tissue of the mammary gland. The average milk yield for the first five lactation were 9231, 9612, 9678, 9672 and 9773 liter, respectively. Wood (1969, 1976); Papajcsik (1988), Kellogg et al. (1977) and Grossman and Koops (1988) showed changes in the shape of the curve with age. The effect of milk level showed a highly significant effect along all the lactation curve. The discrepancy between the lactation curves of high and average or low producing cows (figure 4-8) is mainly due to the differences in genetic structure of high and low producing cows.

Applying Grossman and Koops (1988) equation resulted in estimating nine parameters which were used to draw the three phases of the lactation curve and computing the functions (initial yield, peak yield, time of peak, 305-yield and duration) of each phase as well.
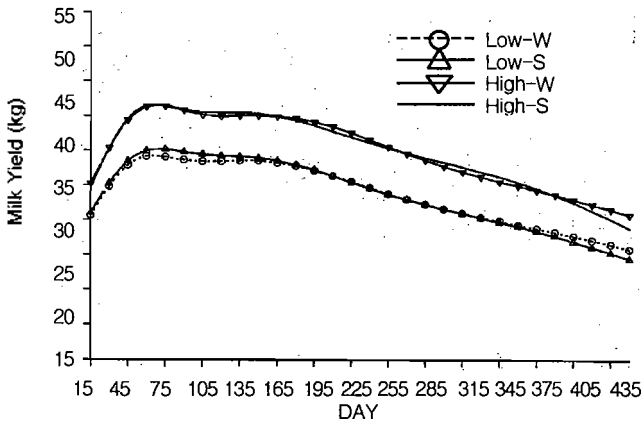
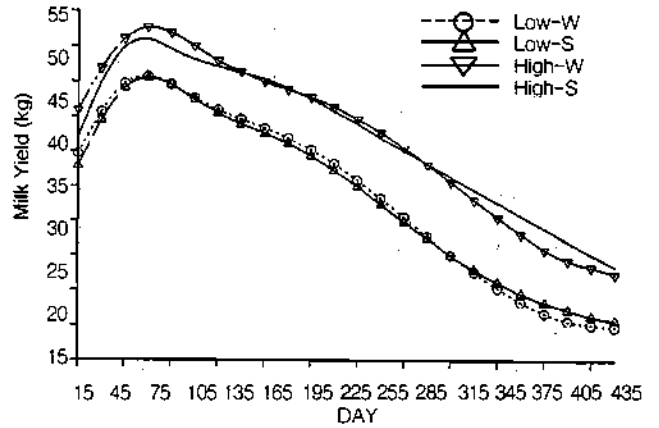**Figure 4.** Lactation curves of the 1st parity with two milking levels and two seasons of calving

Figure 7. Lactation curves of the 4th parity with two milking levels and two seasons of calving

Figure 5. Lactation curves of the 2nd parity with two milking levels and two seasons of calving

Figure 8. Lactation curves of the 5th parity with two milking levels and two seasons of calving
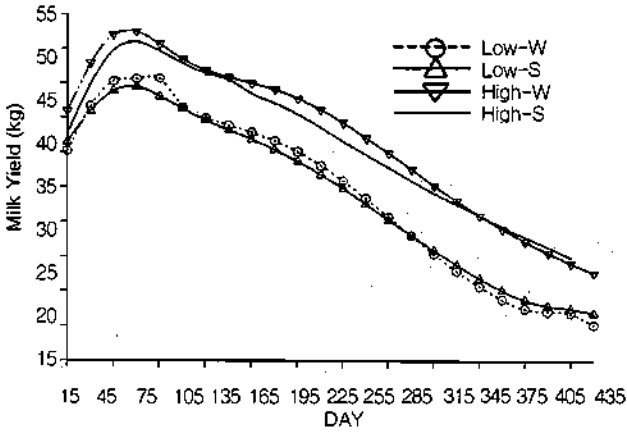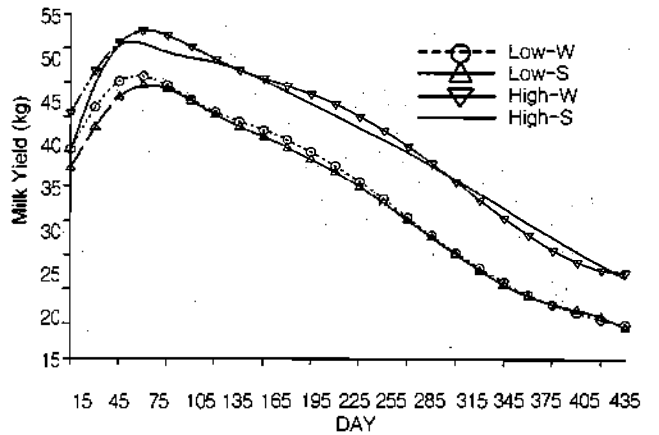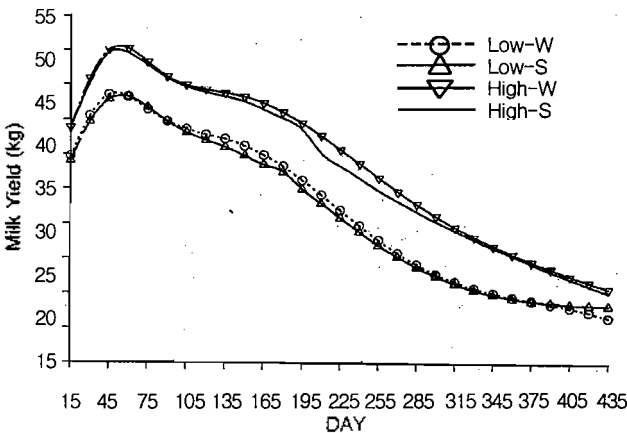
The curve points of the overall dam (figure 2) are the sum of the three phases. The functions of the parameters of different phases of the lactation curve were computed for overall data and for different parities and across different milk levels season of calving combinations. The curves of the multiphasic function of the overall data (figure 2) shows that phase 1 occupied the most area of the curve. Moreover, for the three phases, initial yields were 17.1, 2.7 and 9.0 liter, respectively; peak yields were 31.5, 16.3 and 15.5 liter, respectively and 305-yields were 7345.3, 2232.6 and 1373.9 liter, respectively. Times of peak of the three phases were 129.6, 425.7 and 41.5 day and duration were 314.8, 547.9 and 107.6 day respectively. Comparison among phases of different lactations (tables 2, 3 and 4) show that phase I and phase II of first lactation had the least yield for initial, peak and 305-days. However, phase III contributed more to the

Figure 6. Lactation curves of the 3rd parity with two milking levels and two seasons of calving

three functions than both phases I and II. The initial milk yield averaged 7.81, 16.3 and 3.2.1 liter for the three phases, respectively.

Table 2. Initial yield (L) of different lactations by four milk levels and season of calving combinations

Lactation#	MY1S1	MY1S2	MY2S1	MY2S2
		Phase I		
1	4.3	5.1	6.2	5.8
2	7.9	9.7	6.3	8.3
3	7.4	3.4	10.5	9.4
4	8.5	9.1	12.0	6.9
5	8.7	9.4	11.7	4.8
Average	7.4	7.3	9.3	7.0
		Phase II		
1	10.4	10.0	12.8	9.8
2	20.1	16.7	19.9	16.5
3	21.0	28.7	19.7	13.2
4	19.8	16.4	18.6	10.5
5	19.3	17.0	22.3	2.9
Average	18.1	17.8	18.7	10.6
		Phase III		
1	6.6	6.4	6.1	8.5
2	0.08	1.1	3.3	6.8
3	0.0	0.0	3.0	7.3
4	0.0	0.6	0.4	11.9
5	0.0	0.0	0.5	1.6
Average	1.3	1.6	2.6	7.2

MY1S1: High producing cow calved in winter.
MY1S2: High producing cow calved in summer.
MY2S1: Low producing cow calved in winter.
MY2S2: Low producing cow calved in summer.

Table 3. Peak yield (L) of different lactations of four milk levels and season of calving combinations

Lactation#	MY1S1	MY1S2	MY2S1	MY2S2
		Phase I		
1	9.5	10.2	13.2	12.9
2	15.8	17.6	18.2	17.3
3	16.4	9.5	20.2	19.4
4	16.8	18.7	23.7	16.7
5	17.9	18.5	20.6	14.2
Average	15.3	14.9	19.2	16.1
		Phase II		
1	20.2	20.0	25.8	21.5
2	35.9	31.7	35.7	29.5
3	36.9	37.4	36.5	27.7
4	36.7	33.9	40.4	22.0
5	36.3	33.9	42.0	12.6
Average	33.2	31.4	36.1	22.7
		Phase III		
1	21.3	21.8	24.8	29.0
2	9.0	12.2	13.9	18.3
3	3.7	3.2	11.6	21.3
4	4.8	8.5	8.2	27.9
5	30.9	2.9	35.1	36.0
Average	13.9	9.7	18.7	26.7

MY1S1: High producing cow calved in winter.
MY1S2: High producing cow calved in summer.
MY2S1: Low producing cow calved in winter.
MY2S2: Low producing cow calved in summer.

Peak yield averaged 16.4, 30.9 and 17.3 liter for the three phases and 305-day averaged 1433.1, 6920.7 and 3336.0, for the three phases respectively. The duration of phase, defined as days required to attain about 75% of asymptotic total yield during the phase, as indicated by Grossman and Koops (1988), can be interpreted as being associated with persistency. So a cow with short duration could be considered as a low persistent cow. Moreover, the authors stated that the duration of the second phase of lactation was a possible measure of

persistency. Present study third phase shows that cows in first lactation and winter calving have high duration and consequently have high persistency.

Table 4. Milk yield (L) of different lactations of four milk levels and season of calving combinations

Lactation#	MY1S1	MY1S2	MY2S1	MY2S2
		Phase I		
1	787.1	895.6	1,183.3	1,088.5
2	1,207.1	1,490.2	1,404.8	1,365.6
3	1,284.3	790.5	1,672.5	1,594.3
4	1,441.4	1,646.7	2,271.1	1,242.4
5	1,739.3	1,758.3	2,030.8	1,181.0
Average	1,291.9	1,304.3	1,707.7	1,434.4
		Phase II		
1	4,546.1	4,356.5	6,041.5	4,469.8
2	8,402.9	7,205.2	8,341.5	6,603.5
3	8,651.7	9,119.9	8,404.4	5,686.0
4	8,490.0	7,508.3	9,595.4	4,016.7
5	7,911.1	7,921.3	10,429.8	712.2
Average	7,600.4	7,222.2	8,562.5	4,292.6
		Phase III		
1	4,148.2	4,340.5	4,249.6	5,903.7
2	396.9	1,085.3	2,476.6	4,134.3
3	9,946.5	6.5	2,283.1	4,883.9
4	9.9	642.2	527.1	6,978.9
5	350.9	23.5	16.7	9,568.8
Average	2,970.5	1,219.6	2,860.0	6,293.9

MY1S1: High producing cow calved in winter.
MY1S2: High producing cow calved in summer.
MY2S1: Low producing cow calved in winter.
MY2S2: Low producing cow calved in summer.

Tables 5 and 6 show that time of peak and duration were lower for phase I than phases II and III for all lactations across milk level and season of calving combination. Median time of peak yield averaged over lactation and across milk level and season of calving, were 47,120 and 359 day for the three phases, respectively. Median duration of phase averaged about 101 day for phase I, about 298 day for phase II and about 387 day for phase III. No relationship was found between duration of any phase and the advanced in age or parity increase. However, Grossman and Koops (1988) found that duration of second phase decreased as parity number increased. Phase I and phase II of low producing cows calved in winter gave more initial yield (9.3 and 18.7 liter); more peak yield (19.2 and 36.1 liter) and more 305-day yield (1701.7 and 8562 liter) than other groups. Phase III of low producing cows calved in summer gave the highest initial, peak, and 305-day (9.3, 26.7 and 6293.9 liter, respectively).

The curves of different lactations have a long descending after peak, figures (3-8) which is mainly due to a long lactation period since dairy farms in the kingdom of Saudi Arabia do not dry their cows on 305 day of milk, rather, they let the cows to milk for a period grater than 305 day. Long lactation period (>305day) in Holstein cows raised in the Kingdom Saudi Arabia is mainly due to: 1-low conception rate, Salah and Mogawer (1990a) found the conception rate to be 45% in two herds of Holstein cows in the

Kingdom. 2-Long day open, in another study, Salah and Mogawer (1990b) estimated the average length of day open to be as long as 140 days. Lower values for the different functions (initial yield, peak yield, and 305-day, time of peak and duration) were observed by De Boer et al. (1989). Discrepancy between the present result and their Finding can be attributed to difference in data which represented Israeli Holstein that were raised under different climatic condition.

Table 5. Time of peak yield (day) of different lactations of four milk levels and season of calving combinations

Lactation#	MY1S1	MY1S2	MY2S1	MY2S2
		Phase I		
1	45.1	45.3	48.1	46.1
2	19.6	41.0	42.2	41.6
3	42.6	46.9	41.6	43.3
4	44.2	46.1	47.8	42.4
5	44.6	48.6	46.8	83.3
		Phase II		
1	126.1	122.0	138.7	120.5
2	118.2	126.1	127.5	118.1
3	125.6	101.1	126.9	114.9
4	128.1	127.8	150.5	99.6
5	106.6	136.6	150.5	41.2
		Phase III		
1	367.1	340.1	393.9	325.4
2	270.1	504.2	364.9	301.6
3	349.1	105.8	322.8	626.2
4	389.6	522.6	1,061.3	211.2
5	129.9	346.3	448.4	162.7

MY1S1: High producing cow calved in winter.
MY1S2: High producing cow calved in summer.
MY2S1: Low producing cow calved in winter.
MY2S2: Low producing cow calved in summer.

Table 6. Duration of peak yield (day) of different lactations of four milk levels and season of calving combinations

Lactation#	MY1S1	MY1S2	MY2S1	MY2S2
		Phase I		
1	95.2	102.7	103.8	96.1
2	89.4	101.6	88.8	91.8
3	8.8	85.3	88.8	91.8
4	100.8	102.4	110.1	84.4
5	98.8	112.1	118.9	146.3
		Phase II		
1	292.4	277.1	312.9	255.2
2	226.9	299.4	317.9	294.7
3	319.8	303.0	306.6	251.2
4	310.1	383.0	320.8	217.2
5	310.6	311.0	358.9	603.0
		Phase III		
1	614.7	558.6	592.1	532.2
2	414.6	544.0	541.2	557.7
3	52.7	66.9	501.0	161.1
4	90.3	529.5	502.0	426.9
5	144.8	76.5	112.1	416.2

MY1S1: High producing cow calved in winter.
MY1S2: High producing cow calved in summer.
MY2S1: Low producing cow calved in winter.
MY2S2: Low producing cow calved in summer.

Further studies are needed to examine 1)The stage of lactation during which cooling is the most effective. 2)The variability in heat tolerance of high producing cows and what possibility may exist for intensive selection programs with these cows. 3) Possibly improved herds could be developed when an index would include as well milk yield and heat tolerance under local conditions. Finally, proper selection and management of high producers and their progeny are the keys to improve the animal production and health and to maximizing profitability of dairy enterprise regardless of physical location and degree of heat stress.

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