Animal Science 2002, **75:** 469-476 1357-7298 / 02 / 11450469$20·00

Comparison of lactational responses of dairy cows in Georgia and Israel to heat load and photoperiod

Y. Aharoni[1†], O. Ravagnolo[2] and I. Misztal[2]

[1]*Department of Beef Cattle, Agricultural Research Organization, Newe Yaar Research Center, PO Box 1021, Ramat Yishay 30095, Israel*
[2]*Animal and Dairy Science Department, University of Georgia, Athens, GA 30605, USA*

† E-mail : yoavah@netvision.net.il

Abstract

The seasonal effects of heat load and photoperiod on yield and composition of milk from primiparous cows in the course of lactation were studied using test day records from 8968 primiparous cows on 76 farms in Georgia, collected from 1990 through 1997. The effect of prepartum photoperiod on milk production in the subsequent lactation of these cows was also evaluated. These estimated seasonal effects were compared with those estimated for 4728 primiparous cows on 13 farms, and for 1538 multiparous cows on three farms during consecutive lactations in Israel from 1994 through 1996. During lactation, the day length had a positive effect on milk yield and negative effects on fat and protein concentrations in the milk, but the daily change in day length had positive effects on milk yield and fat concentration, and a smaller positive effect on protein concentration. The day length during the pre-partum *period had negative effects on milk yield and fat and protein concentrations. The heat load during lactation had negative effects on milk yield and fat and protein concentrations. Most of the effects were highly* ($P < 0{\cdot}001$) *significant. There was a very good match between the results obtained for primiparous cows in Georgia and Israel, for the combined effects of heat load and photoperiod during lactation on milk yield and protein and fat concentrations. The match between primiparous and multiparous cows in Israel was better for milk yield and protein concentration than for fat concentration. The estimated effects of* pre-partum *photoperiod were higher for multiparous cows in Israel than for primiparous cows in either country.*

Keywords: *dairy cows, heat adaptation, milk composition, milk yield, photoperiod.*

Introduction

The detrimental effect of heat load on the milk yield (Moody *et al.*, 1968; Her *et al.*, 1988; Ryan *et al.*, 1992) and milk fat concentration (Moody *et al.*, 1968) of dairy cows is well established. However, the decline in protein concentration in the summer, and the relatively low milk yield in autumn cannot be fully attributed to the heat load effect. Photoperiod (PP) is another environmental factor which has been shown to affect milk production (Peters *et al.*, 1981; Stanisiewski *et al.*, 1985; Bilodeau *et al.*, 1989; Phillips and Schofield, 1989; Piva *et al.*, 1992; Guertin *et al.*, 1995; Dahl *et al.*, 1997), and a correlation of the seasonality of milk production in dairy cattle with photoperiod has been suggested (Kashiwamura *et al.*, 1991; Barash *et al.*, 1996). The photoperiod has been shown to affect growth (Dijkstra and Bergström, 1989; Guertin *et al.*, 1995; Mossberg and Jönsson, 1996; Aharoni *et al.*, 1997) and reproduction (Schillo *et al.*, 1992) traits in cattle, in addition to milk production. Mossberg and Jönsson (1996) have suggested that both the day length and the daily change in day length affect appetite and rate of weight gain of growing calves in Sweden, and the effects of both factors on the rate of gain of bull calves has been confirmed in Israel (Aharoni *et al.*, 1997), where the amplitude of the photoperiod change is much smaller than in Sweden. The effects of both photoperiod and heat load on milk yield and composition were also confirmed for cows in Israel (Aharoni *et al.*, 1999) by analysis of test day records of three dairy herds over a 3-year period.

A positive effect of short days during the *pre-partum* period on the milk yield in the subsequent lactation was suggested first by Petitclerc *et al.* (1998), and confirmed recently (Dahl *et al.*, 2000; Miller *et al.*, 2000). Aharoni *et al.* (2000) tested this effect by examining the three-herd data set from their previous study (Aharoni *et al.*, 1999), and found a positive effect of pre-partum short days on milk fat and protein concentrations, in addition to their positive effect on milk yield. Recently, the effect of heat load on the milk yield of primiparous cows in Georgia was studied (Ravagnolo and Misztal, 2000; Ravagnolo *et al.*, 2000) on the basis of a data set of test day records of many herds collected over an 8-year period. Because Georgia and Israel lie on approximately the same latitude but use differing herd management practices, it was of interest to use similar analysis models to compare the same seasonal effects between the two countries. The goal of the present study was to estimate the effects of heat load and photoperiod on milk production of primiparous cows in Georgia, and to compare the estimates of these effects in Georgia with those estimated for Israeli primiparous and multiparous cows.

Material and methods

Data

The data for Georgia were obtained from the Animal Improvement Programs Laboratory of the USDA (Ravagnolo and Misztal, 2000; Ravagnolo *et al.*, 2000) and comprised 64 533 first parity, test day records of milk, fat and protein yields collected from 1990 through 1997 from 8968 Holsteins on 76 farms. Each record included herd and cow identification numbers, date of birth, date of calving, date of test, milk yield, and fat and protein percentages in the milk. From these data, age at parturition and days in milk (DIM) were calculated for each record. Data were discarded for DIM > 270 days. Weather data came from the Georgia Automated Environmental Monitoring Network, and the temperature-humidity index (THI) was calculated from these data and was assigned to each test day record as described by Ravagnolo and Misztal (2000). It was assumed that a THI below 72 does not subject cows to heat load (HL), therefore, the effective THI (ETHI) was calculated as THI-72, for THI > 72 (otherwise ETHI = 0), and was assigned to each record. Of the 76 farms in the data set, 57 milked twice daily (2 ×) and four three times daily (3 ×) throughout the whole 8-year period, 1990 to 1997. The other 15 farms changed from 2 × to 3 × during this period, so, for the whole data set, 85% of the cows were milked 2 × , and 15% were milked 3 × .

The first data set from Israel was based on that used by Aharoni *et al.* (1999 and 2000), from which, all the first-lactation records were discarded, and comprised 18761 test day records of milk yield and milk fat and protein concentrations, for 1538 cows of second or higher lactation, in three Holstein dairy herds. The second data set comprised 33645 records from 4728 primiparous cows in 13 herds in the Western Jazreel Valley in Israel. Records of both data sets were obtained from the central laboratory of the Israel Cattle Breeders Association for the 3-year period from January 1994 through December 1996. All animals were housed in open sheds and were offered a total mixed ration (TMR) consisting of wheat and maize silages as the main forage throughout the year, and were milked three times daily in a milking parlour. All herds were equipped with cooling systems consisting of a water spray and fans in the milking parlour yard, in the sheds, or both. Each record included herd and cow identification numbers, date of calving, date of test, milk yield, and fat and protein percentages in the milk. From these data, the DIM was calculated for each record. Data were discarded for DIM > 270 days and for cows that had less than two consecutive monthly records during the entire 3-year period. The heat load index (HLI) was calculated as described by Aharoni *et al.* (1999) and was assigned to each record.

Photoperiod

Photoperiod was regarded as consisting of two factors : the day length (DL, h) and the daily change in day length (DC, min/day). The day length was calculated for latitude 32ºN for Israel and for mean latitude of 33ºN for Georgia, according to the equation of Mossberg and Jönsson (1996):

$$DL = 7{\cdot}6394 \times \arccos(-\tan(a) \times \tan(b))$$

where a = latitude (radians); and $b = 0{\cdot}4102 \times \cos(6{\cdot}283 \times (c-172)/365)$ (where c is the day of the year).

The DC (min/day) from day to day was calculated as the difference in length, either positive or negative, between each day and the preceding one. The variables DL and DC for the photoperiod conditions of the test day, and pDL and pDC for the photoperiod conditions 3 weeks before the calving date preceding the current lactation, were assigned to each record in all data sets.

Statistical analyses

All the analyses used the FIT procedure of Genstat 5 release 3·2 (Lawes Agricultural Trust, 1995).

The regression model for the analyses of the Georgia data set was:

$$Y_{ijk} = H_i + YR_j + F_k + b_{1k} \times \text{DIM} + b_{2k} \times \text{DIM}^2 + b_{3k} \times \text{DIM}^3 + b_{4k} \times \text{DIM}^4 + c_1 \times \text{DL} + c_2 \times \text{DC} + c_3 \times \text{ETHI} + c_4 \times \text{pDL} + c_5 \times \text{pDC} \{ + d \times \text{MY}\} + e$$

where : Y = daily milk yield or percentage of fat or protein, of a cow in herd i that calved in the year j and was milked at frequency k; H = absorbing effect of herd i; YR = effect of year j; F = effect of milking frequency k (2 × or 3 × ; DIM = days in milk; DL = day length (h); DC = daily change of day length (min/day); pDL = day length (h) at 21 days *pre-partum*; pDC = daily change in day length (min/day) at 21 days *pre-partum*; ETHI = effective heat load index; MY = milk yield, when Y is fat or protein concentration in milk; $b_{1,\ 2,\ 3,\ 4(k)}$ = regression coefficients for milking frequency k; $c_{1,\ 2,\ 3,\ 4,\ 5}$ = regression coefficients for seasonal effects; d = regression coefficient for milk yield; e = random residual effect.

From this full model (M1), the ETHI was omitted in a partial model M2, to evaluate the photoperiod coefficients without accounting for HL. Similarly, the photoperiod (PP) effects (DL, DC, pDL and pDC) were omitted in a partial model M3, to evaluate the HL coefficient without accounting for photoperiod. The estimates obtained with these partial models were compared with those obtained with the full model.

The Israeli primiparous and multiparous cows' data sets were analysed by the same model as the Georgia data, with necessary modifications. For both data sets the ETHI was substituted for by HLI. No account was given to milking frequency for the primiparous cows' data set, whereas milking frequency was substituted for by lactation grade for the multiparous cows' data set, to account for variations of milk yield and concentration curves with increasing lactation number.

Results

Lactation characteristics

The dependence of milk yield and composition on DIM was described in all the model versions in this study as a fourth order polynomial of DIM. Because the seasonal effects were accounted for by the equation, the lactation curve describing this dependence was corrected for these effects, i.e. it described the dependence of yield or composition of the milk from an average cow, in an average year, with a steady 12-h day length, and with no HL. Fat and protein concentrations were corrected for milk yield, because they are negatively related to it. The yield and composition of milk obtained by milking such a cow are depicted in Figure 1, separately for a primiparous cow in Georgia milked twice and three times daily, and for an Israeli primiparous cow.

In Georgia the milk yield of 3 × cows was on average 3·7 kg/day higher than that of 2 × cows, but the fat and protein concentrations in the milk were lower by 0·8 and 0·6 g/kg milk, respectively. The milk curve of primiparous cows in Israel was on average 1·1 kg/day higher than that of 3 × cows in Georgia. The fat concentration in Israel was lower than that in Georgia during most of the lactation (on average –0·7 g/kg milk in comparison), and the protein concentration was lower during the entire lactation (on average –1·1 g/kg milk in comparison).

Evaluation of confounding between heat load and photoperiod effects

It is possible to estimate the influence of such a confounding by comparing estimates made by the

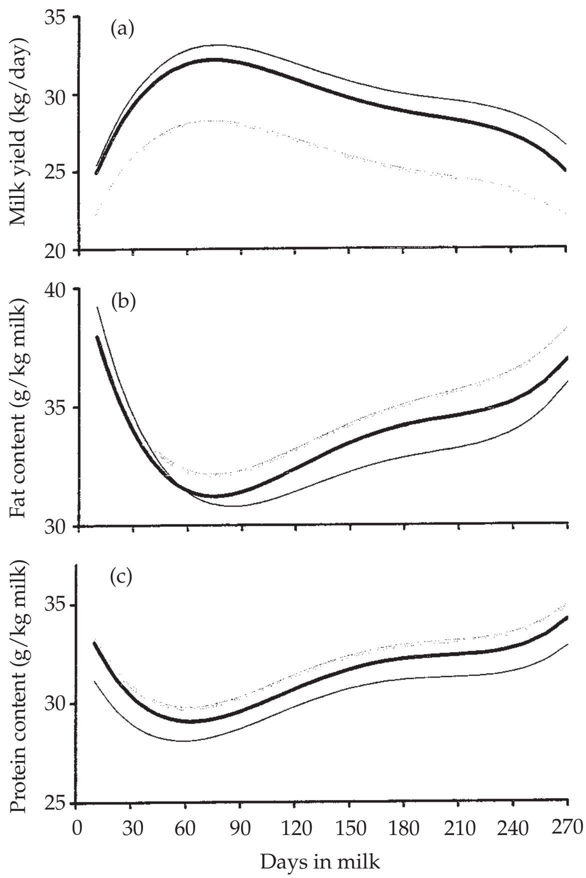

Figure 1 Lactation curves of (a) milk yield and (b) fat and (c) protein contents in milk for primiparous cows in Georgia, milked either two (——) or three (▬▬) times daily, and primiparous cows in Israel milked three times daily (——).

Table 1 *Georgia data: full model (M1) compared with models that do not include either effective THI (ETHI, M2) or photoperiod effects (M3)*

	Milk yield			Fat content			Protein content		
	M1	M2	M3	M1	M2	M3	M1	M2	M3
% of variance accounted for (R^2)	19·0	18·9	16·0	13·3	13·3	12·4	29·7	29·5	27·5
Coefficients:									
ETHI†	–0·053	–	–0·077	–0·039	–	–0·212	–0·050	–	–0·147
s.e.	0·006		0·005	0·011		0·006	0·003		0·002
Significance	***		***	***		***	***		***
DL†	0·335	0·249	–	–0·556	–0·621	–	–0·400	–0·482	–
s.e.	0·018	0·014		0·023	0·018		0·009	0·007	
Significance	***	***		***	***		***	***	
DC†	0·496	0·588	–	0·476	0·545	–	0·177	0·265	–
s.e.	0·019	0·001		0·024	0·018		0·009	0·007	
Significance	***	***		***	***		***	***	
pDL†	–0·150	–0·146	–	–0·060	–0·057	–	–0·008	–0·045	–
s.e.	0·015	0·015		0·020	0·020		0·007	0·075	
Significance	***	***		**	**				
pDC†	0·049	0·045	–	0·158	0·155	–	0·094	0·090	–
s.e.	0·014	0·015		0·019	0·019		0·007	0·007	
Significance	***	**		***	***		***	***	

† Effects: ETHI, effective temperature-humidity index; DL, day length (h) on the test day; DC, daily change in day length (min/day) on the test day; pDL, day length 3 weeks before parturition; pDC, daily change in day length 3 weeks before parturition.

full model (M1) with those yielded by partial models from which either the HL effect (M2) or the PP effects (M3) had been omitted. This comparison is presented in Table 1.

The partial models estimated all the coefficients in the same direction, positive or negative, as estimated by the full model. The ratio of the PP coefficient (DL, DC, pDL and pDC) estimations by M2 to those estimated by M1 was on average 1·06±0·20, when pDL for protein, which was not significant, was excluded from the calculation. Exclusion of the photoperiod variables from the model resulted in a ratio of M3- to M1-estimated HL effects of 1·4 to 5·4.

Table 2 *Estimated coefficients for seasonal effects on milk yield and milk concentrations of fat and protein in Georgian primiparous cows (GEP), and Israeli primiparous (ISP) and multiparous (ISM) cows*

Component	Data set	R^2	ETHI or HLI†	DL‡	DC‡	pDL§	pDC§
Milk (kg/day)	GEP	19·0	–0·053±0·007	0·335±0·019	0·496±0·019	–0·150±0·015	0·049±0·015
	Significance		***	***	***	***	**
	ISP	19·3	–0·037±0·003	0·370±0·027	0·201±0·030	0·017±0·019	–0·182±0·019
	Significance		***	***	***		***
	ISM	40·4	–0·042±0·006	0·412±0·049	0·520±0·057	–0·489±0·038	–0·183±0·035
	Significance		***	***	***	***	***
Fat (g/kg)	GEP	13·3	–0·039±0·010	–0·556±0·024	0·476±0·025	–0·060±0·020	0·158±0·019
	Significance		***	***	***	**	***
	ISP	16·2	–0·050±0·003	–0·363±0·030	0·070±0·034	–0·349±0·021	0·034±0·021
	Significance		***	***	*	***	
	ISM	14·0	–0·096±0·006	–0·169±0·049	–0·543±0·057	–0·552±0·038	0·177±0·036
	Significance		***	***	***	***	***
Protein (g/kg)	GEP	29·7	–0·050±0·004	–0·400±0·009	0·177±0·010	–0·008±0·008	0·094±0·007
	Significance		***	***	***		***
	ISP	33·8	–0·024±0·002	–0·182±0·013	–0·083±0·014	–0·052±0·009	–0·052±0·009
	Significance		***	***	***	***	***
	ISM	35·3	–0·013±0·002	–0·350±0·018	0·057±0·021	–0·162±0·014	0·135±0·013
	Significance		***	***	**	***	***

† ETHI: effective temperature-humidity index (Georgia); HLI: heat load index (Israel).
‡ Photoperiod effects during lactation: DL, day length (h); DC, daily change in day length (min/day).
§ Photoperiod effects 21 days before parturition: pDL, day length (h); pDC, daily change in day length (min/day).

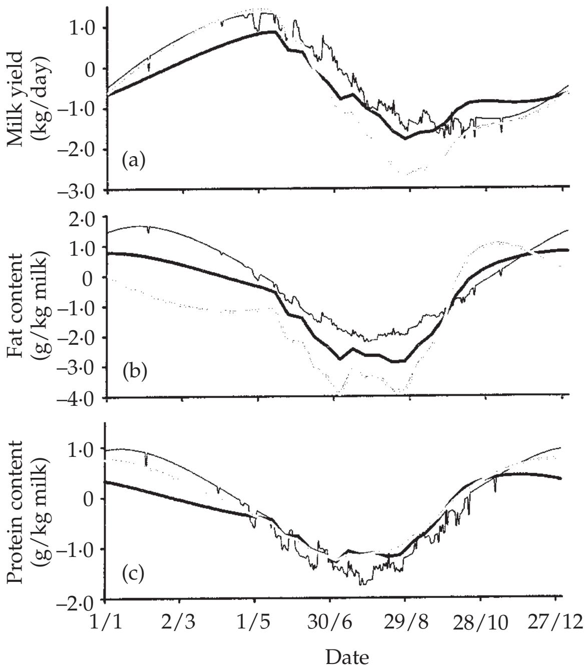

Figure 2 The combined in-lactation effect of photoperiod and heat load on (a) milk yield and (b) fat and (c) protein contents in milk for primiparous cows in Georgia (——) and Israel (▬▬), and multiparous in Israel (——).

The proportion of the variance accounted for by the model was almost unchanged, compared with the full model, when ETHI was excluded; it was considerably reduced when the photoperiod variables were excluded from the model.

Comparison between seasonal effects in Georgia and Israel
Comparison of the estimated coefficients for the seasonal effects on yield and composition of milk from primiparous cows in Georgia and Israel, and from multiparous cows in Israel, is presented in Table 2.

Heat load had a negative effect on both milk yield and composition for all data sets. The day length during the lactation had a positive effect on milk yield and a negative effect on fat and protein concentrations, also with good agreement among the three data sets. The daily change in day length had a positive effect on milk yield in all the data sets, but there was disagreement between data sets as to its effect on fat and protein concentration. Pre-partum day length had a negative effect on both milk yield and composition in most of the cases, with the exception of effects on milk yield of Israeli primiparous cows and protein concentration of Georgian cows, which were estimated not significant. There was some disagreement among data sets as to the effects of pre-partum daily change in day length on milk yield and composition.

The combined in-lactation seasonal effect of PP and HL on milk yield and composition of cows in Georgia and Israel during the year is depicted in Figure 2.

The phase and magnitude of the seasonal fluctuation were similar among data sets for the effects on milk yield and composition. The linear regression coefficients for the match between primiparous cows in Georgia and Israel, and between Israeli primiparous and multiparous cows, are presented in Table 3.

In these regressions, the R^2 values point out the goodness of the phase match, whereas the slope coefficient a indicates the relative magnitude of the effect. All R^2 values in both comparisons were higher than 0·8, but those for the comparison between Georgian and Israeli primiparous cows tended to be lower than those for the comparison within Israel. All the slope coefficients in the first comparison were lower than 1, indicating larger seasonal effects on Georgian than on Israeli primiparous cows. All the slope coefficients in comparison 2 were higher than 1, indicating larger seasonal effects on multiparous than on primiparous cows in Israel.

The combination of day length and its daily change creates an annual PP sinusoid, based on the 3-month difference between the maximal positive change in day length (21 March), and the maximal day length (21 June), when the change in day length is zero. Peak and trough dates of this combined PP effect, as well as its magnitude, could be identified on this sinusoid. The peak dates and maximal positive PP effects on milk yield and composition, estimated for

Table 3 *Linear regression* (Y = aX + b) *coefficients for the match of the combined seasonal effects on milk yield and milk fat and protein contents, between primiparous cows in Georgia* (X) *and Israel* (Y), *and between primiparous* (X) *and multiparous* (Y) *cows in Israel*

Coefficient	Milk yield	Fat content	Protein content
Primiparous cows in Georgia and Israel			
a	0·720±0·014	0·951±0·017	0·603±0·013
b	−0·308±0·014	−0·526±0·023	−0·196±0·011
R^2	0·88	0·89	0·87
Primiparous and multiparous cows in Israel			
a	1·682±0·013	1·065±0·025	1·182±0·014
b	0·207±0·012	−0·589±0·036	0·205±0·009
R^2	0·98	0·83	0·95

Table 4 *Comparison between peak dates (day/month) and maximal positive photoperiod effects in Georgian primiparous (GEP), Israeli primiparous (ISP) and Israeli multiparous (ISM) cows (effect on milk yield (kg/day); effects on fat and protein concentrations (g/kg))*

	Peak dates			Difference†		Peak positive effect			Ratio‡	
	GEP	ISP	ISM	1	2	GEP	ISP	ISM	1	2
In lactation										
Milk	1/5	24/5	8/5	23	16	1·31	0·90	1·42	0·69	1·58
Fat	27/1	31/12	13/10	27	79	1·66	0·78	1·19	0·47	1·53
Protein	13/1	26/11	30/12	48	34	0·98	0·43	0·75	0·44	1·76
Pre-partum										
Milk	8/1	13/9	30/11	117	78	0·35	0·37	1·12	1·06	3·03
Fat	22/2	15/12	7/1	69	23	0·36	0·74	1·20	2·06	1·61
Protein	14/3	8/2	27/1	34	12	0·20	0·20	0·45	1·00	2·30

† Difference, number of days: 1 between GEP and ISP, 2 between ISP and ISM.
‡ The ratio of peak positive effect: 1 ISP to GEP, 2 ISM to ISP.

the three data sets, for the effect during lactation and the pre-partum effect, are presented in Table 4.

There was a good agreement among the three data sets as to the peak dates of the in-lactation PP effect on milk yield and composition, with peak dates of milk yield occurring in spring, and those of fat and protein occurring in winter. All the positive effects on Georgian primiparous cows were estimated to be larger than those on Israeli primiparous cows, and similar to those on Israeli multiparous cows. There was much less agreement among the data sets as to the peak dates of pre-partum PP effects.

Discussion

Milk yield of 3 × cows in Georgia was higher by more than 10% than that of 2 × cows. This increase of milk yield was expected to be associated with a decrease in component concentrations, due to the negative relation of concentration to yield. However, such a concentration decrease was evident even though the concentrations in the analysis model were corrected to milk yield. This finding suggests that other factors, perhaps nutritional ones, differed between 2 × and 3 × cows in Georgia. It is possible that owners of 2 × cows, aiming at lower milk yield than that of 3 × cows, design lower energy-content diets, resulting in higher fat content. This possibility, however, does not explain the higher protein content in milk of 2 × cows. Israeli 3 × primiparous cows yielded more milk than Georgian 3 × cows, with reduced yield-corrected fat and protein concentrations. These differences could be explained by the different dietary and management routines. Because diet composition was not recorded in this study, and factors that affect milk production other than seasonal ones were beyond its scope, they are not discussed further.

The curve of heat load with time differs from that of PP in several traits : (a) the peak of heat load occurs approximately 2 months after the peak of day length; (b) ETHI values are close to zero for more than half a year in both Georgia and Israel, in contrast to the smooth sinusoidal shape of the day length curve; (c) PP is identical in all the years, whereas HL differs among years. Despite these differences, there is some similarity between the annual curves of these variables and therefore, some degree of confounding between their effects should be expected when they are analysed together in the same model. Direct indication of such a confounding is provided by the correlation between the two independent variables in question, i.e. ETHI and DL or ETHI and DC. None of these correlations was higher than 0·7 in the Georgia data set. These relatively low correlations resulted in a very high resolution between the HL and the PP effects as indicated by the low standard errors in the estimation of the effects of each one of the independent variables, and the high significance of these estimations (Table 1, model M1). An indirect way to estimate the confounding effect is to compare the estimates of a full model with the estimates of partial models from which either the HL or the PP effects have been excluded. This comparison (Table 1) indicated only small changes in the PP estimates when ETHI was excluded from the model, and much larger changes in the ETHI estimates when the PP variables were excluded. This suggests that photoperiod effects could be estimated with a reasonable accuracy even when heat load effect is not considered. On the other hand, heat load effect estimates are susceptible to a large bias if photoperiod effects are not considered. The same data set from Georgia was used to derive a genetic component of heat stress in dairy cows, with no account to photoperiod (Ravagnolo and Misztal, 2000). It is possible, therefore, that the estimation of this component was biased.

The effect of ETHI on heat load of dairy cows is expected to vary not only between countries, but also among herds in the same country and with similar management, due to differences in local conditions such as wind, area of shade, area of open yards that help cows to dissipate heat at night, height of the roof in the shade, the existence and efficiency of cooling systems, etc. On the other hand, the photoperiod is identical for a certain latitude all over the globe, and it would be reasonable to assume that its effects on a certain breed of animals will also be identical, regardless of site, on the same latitude. This assumption provides a powerful tool to estimate the magnitude of interference of unidentified factors in the estimation of the PP effect.

In the current study we compared the estimates of PP effects on Israeli and Georgian cows, both residing on the same latitude. In all the inspected herds in Israel, cows were given TMR throughout the year. Because no fresh forages were offered, and most of the forages were conserved and stored once a year, the diet composition and quality did not change during the year (Aharoni *et al.,* 1999). Therefore, estimated PP effects in this database can serve as reference estimates in which dietary interferences are minimal. Cows in Georgia, on the other hand, went on pasture for several months each year. Therefore, and under the assumption of equal PP effect, any difference in the PP estimates between the countries should be regarded as the confounding by factors that were not accounted for by the model. Table 4 summarizes the peak dates and the magnitude of the effects of PP in lactation and prepartum on milk yield and composition. For effect of PP in lactation, peak dates for milk yield were almost identical in the three data sets, all occurring in the same month. Peak dates for effect on milk composition differed among data sets by 1 to 1·5 months, with the exception of fat concentration between Israeli primiparous and multiparous cows. Therefore, it is suggested that the interference of dietary factors in the estimation of PP effects in Georgia was relatively small. The magnitude of these effects on primiparous cows in Georgia was similar to the magnitude on multiparous cows in Israel, and larger than on primiparous cows in Israel. Heifers in Israel calved at a mean age of 24 months, compared with 32 months in Georgia, and it is possible that the weaker effect on primiparous Israeli cows was associated with their younger age during their first lactation. Fat and protein concentrations in milk of primiparous cows in Israel were found to be much lower than those of higher-lactation cows (Aharoni *et al.,* 1999) and it was suggested there that this was the result of a severe energy shortage of the young cows in their first lactation, due to their limited intake capacity. It is possible that this energy shortage depressed or masked their response to the PP effect.

Much less agreement was evident among the peak date estimations of the pre-partum PP effect. It could be concluded that dietary or other seasonal factors, which were not accounted for by these analyses, interfered with the PP effects and modified them to a large extent. It should be noticed that all the differences in peak dates of the pre-partum PP effect were larger between Georgian and Israeli primiparous cows than between primiparous and multiparous cows in Israel. This finding could be related to the introduction of heifers in Georgia from pasture to trough-feeding management after calving, or a short time before it. On the other hand, the estimated magnitude of the effect was similar between Georgian and Israeli primiparous cows, and smaller than that for Israeli multiparous cows. The magnitude of the pre-partum PP effect on Israeli multiparous cows is in agreement with the studies by Petitclerc *et al.* (1998) and Miller *et al.* (2000) but its magnitude on both Georgian and Israeli primiparous cows is much smaller. Although the differences in peak dates among the datasets indicate large interference of other factors in the estimation, we think that such a difference in the magnitude of the pre-partum effect is real, and could be explained by the difference in body condition and energy balance between a cow in a short dry-off period and a heifer before its first calving. There are no published data on comparison between pre-partum PP effects on heifers and those on mature cows. The one study that estimated this effect on both heifers and cows was that of Petitclerc *et al.* (1998), but their abstract did not include any differentiation between cows and heifers, and a full report of that study has not yet been published.

In conclusion, the analysis model should account for heat load and photoperiod effects simultaneously when test day records are used to estimate seasonal effects on milk yield and composition. Exclusion of the photoperiod effects from the model will bias considerably the estimation of the heat load effect, whereas exclusion of the heat load effect from the model will bias the estimation of the photoperiod effects to a lesser extent. The estimation of photoperiod effects on the lactating cow could be biased by seasonal changes that are not accounted for by the model, such as dietary and management changes during the year. In this study, however, the interference by such factors did not change the direction, positive or negative, of any of the estimated PP effects, and resulted in relatively small modifications to their magnitude. It appears that the estimations of effects of photoperiod of the pre-partum cow on milk yield and composition during the subsequent lactation were more susceptible to interference by these unaccounted factors. Even so, the direction of such effects in Georgia was similar to that found in Israel, under different feeding and management routines, and agrees quite well with the that reported by Petitclerc *et al.* (1998) and Miller *et al.* (2000), which were obtained in designed experiments. The use of very large-scale data sets of test day records enabled detection of photoperiod effects on milk composition, in addition to its effects on milk yield. It is suggested that it is more difficult to obtain such detection when data from small-scale experiments are used.

Acknowledgements
This paper forms contribution no. 381/01 from the Agricultural Research Organization, The Volcani Center, Bet Dagan 50250, Israel.

References
Aharoni, Y., Brosh, A. and Ezra, E. 1999. Effects of heat load and photoperiod on milk yield and composition in three dairy herds in Israel. *Animal Science* **69:** 37-47.

Aharoni, Y., Brosh, A. and Ezra, E. 2000. Short communication: prepartum photoperiod effect on milk yield and composition in dairy cows. *Journal of Dairy Science* **83:** 2779-2781.

Aharoni, Y., Brosh, A. and Holzer, Z. 1997. Photoperiodic effect on live-weight gain of bull calves. *Animal Science* **65:** 165-171.

Barash, H., Silanikove, N. and Weller, J. I. 1996. Effect of season of birth on milk, fat, and protein production of Israeli Holsteins. *Journal of Dairy Science* **79:** 1016-1020.

Bilodeau, P. P., Petitclerc, D., St-Pierre, N., Pelletier, G. and St-Laurent, G. J. 1989. Effects of photoperiod and pair-feeding on lactation of cows fed corn or barley grain in total mixed rations. *Journal of Dairy Science* **72:** 2999-3005.

Dahl, G. E., Buchanan, B. A. and Tucker, H. A. 2000. Photoperiodic effects on dairy cattle: a review. *Journal of Dairy Science* **83:** 885-893.

Dahl, G. E., Elsasser, T. H., Capuco, A. V., Erdman, R. E. and Peters, R. R. 1997. Effects of a long daily photoperiod on milk yield and circulating concentrations of insulin-like growth factor-I. *Journal of Dairy Science* **80:** 2784-2789.

Dijkstra, M. and Bergström, P. L. 1989. [The effect of increased day length in winter on the growth of beef bulls.] *Report no. B-337: 34. Instituut-voor-Veeteeltkundig -Onderzoek-Schoonoord.*

Guertin, G., Lachance, B., Pelletier, G., St-Laurent, G. J., Roy, D. L. and Petitclerc, D. 1995. Effects of photoperiod and feeding whole maize, whole barley, or rolled barley on growth performance and diet digestibility in veal calves. *Livestock Production Science* **44:** 27-36.

Her, E., Wolfenson, D., Flemenbaum, I., Folman, Y., Kaim, M. and Berman, A. 1988. Thermal, productive, and reproductive responses of high yielding cows exposed to short-term cooling in summer. *Journal of Dairy Science* **71:** 1085-1092.

Kashiwamura, F., Furumura, K., Iketaki, T., Shinde, Y., Aotani, H., Suda, T. and Sato, F. 1991. Relationship between photoperiod and seasonality of milk production in dairy cattle. *Animal Feed Science and Technology* **62:** 1156-1158.

Lawes Agricultural Trust. 1995. *Genstat 5 release 3·2.* Rothamsted Experimental Station, Harpenden.

Miller, A. R. E., Erdman, R. A., Douglass, L. E. and Dahl, G. E. 2000. Effects of photoperiod manipulation during the dry period on dairy cows. *Journal of Dairy Science* **83:** 962-967.

Moody, E.G., Van Soest, P. J., McDowell, R. E. and Ford, G. L. 1968. Effects of high temperature and dietary fat on performance of lactating cows. *Journal of Dairy Science* **50:** 1909-1916.

Mossberg, I. and Jönsson, H. 1996. The influence of day length and temperature on food intake and growth rate of bulls given concentrate or grass silage *ad libitum* in two housing systems. *Animal Science* **62:** 233-240.

Peters, R. R., Chapin, L. T., Emery, R. S. and Tucker, H. A. 1981. Milk yield, feed intake, prolactin, growth hormone and glucocorticoid response of cows to supplemented light. *Journal of Dairy Science* **64:** 1671-1678.

Petitclerc, D., Vinet, C. M., Roy, G. and Lacasse, P. 1998. Prepartum photoperiod and melatonin feeding on milk production and prolactin concentrations of dairy heifers and cows. *Journal of Dairy Science* **81:** (suppl. 1) 251. (abstr.).

Phillips, C. J. C. and Schofield, S. A. 1989. The effect of supplementary light on the production and behaviour of dairy cows. *Animal Production* **48:** 293-303.

Piva, G., Navarotto, P., Repetti, S. and Fusconi, G. 1992. Effect of photoperiod on the performance of dairy cows. *Atti della Societa Italiana di Buiatria* **24:** 114-119.

Ravagnolo, O. and Misztal, I. 2000. Genetic component of heat stress in dairy cattle, parameter estimation. *Journal of Dairy Science* **83:** 2126-2130.

Ravagnolo, O., Misztal, I. and Hoogenboom, G. 2000. Genetic component of heat stress in dairy cattle, development of heat index function. *Journal of Dairy Science* **83:** 2120-2125.

Ryan, D. P., Boland, M. P., Kopel, E., Armstrong, D., Munyakazi, L., Godke, R. A. and Ingraham, R. H. 1992. Evaluating two different evaporative cooling management systems for dairy cows in a hot, dry climate. *Journal of Dairy Science* **75:** 1052-1059.

Schillo, K. K., Hall, J. B. and Hileman, S. M. 1992. Effects of nutrition and season on the onset of puberty in the beef heifer. *Journal of Animal Science* **70:** 3994-4005.

Stanisiewski, E. P., Mellenberger, R. W., Anderson, C. R. and Tucker, H. A. 1985. Effect of photoperiod on milk yield and milk fat in commercial dairy herds. *Journal of Animal Science* **68:** 1134-1140.

(*Received* 12 *November* 2001—*Accepted* 31 *July* 2002)