LACTATION PERSISTENCY AND PREDICTION OF TOTAL MILK YIELD FROM MONTHLY YIELDS IN EGYPTIAN BUFFALOES

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Abstract

Factors affecting lactation persistency (LP) were studied using 525 lactations of 175 buffalo cows. LP was expressed as: LP1, average of proportions of each month's milk yield (MY) to preceding month's MY after peak yield is reached; LP2, ratio of 305−day MY (M305) to peak weekly yield; LP3, ratio of 2nd 14 weeks MY to 1st 14 weeks MY; LP4, ratio of descending MY to ascending MY; LP5, rate of decrease in weekly MY from peak week yield to last week yield, and LP6, the coefficient of variation (%) among successive weekly yields. Period of calving affected significantly LP2 and LP3. Summer and spring calvings were associated with high LP (LP2, LP3, LP6). Unexpectedly, first parity cows had the least LP, and those in their 4th lactation were the most persistent. LP deteriorated with shorter days open indicating negative effect of early pregnancy. Heritability ranged from 0.02 (LP6) to 0.33 (LP2). Except LP4 and LP6, LP had moderate to high correlation with M305 and days in milk. Maximum R^2 improvement procedure was used to predict M305 from monthly MY (n, 294). First, 3rd and 6th monthly MY can be pooled to precisely predict M305 (R^2, 0.76). Inclusion of more variables in the model caused little improvement in predictability. In conclusion, LP of the study herd was low. It is likely that avoiding short days open, and improving heifer raising program and 1st lactation management, in addition to genetic selection, particularly for LP2, would improve LP.

Key words: Buffalo, lactation persistency, prediction of total milk yield

Abbreviation key: **LP**= lactation persistency, **MY**= milk yield, **M305**= standardized 305–day milk yield, **DIM**= days in milk, **DO**= days open.

INTRODUCTION

Lactation persistency is the ability of the cow to maintain milk production at a high level after the peak yield, i.e. a persistent animal has a flatter milk curve [5]. High persistency is associated with more resistance to disease, better utilization of feed, reduced stress from high peak milk yield, and low reproductive costs [6], [15], [31], [32]. Persistent animals generate more return [8]; therefore, enhancing persistency could promote efficient and economical milk production. Several approaches are used to measure lactation persistency. Gengler [14] and Cobuci et al. [5] grouped persistency measures as being based on (a) differences, ratios, or rates involving peak, partial and total milk yield, (b) variation of test–day yield, (c) parameter estimates from mathematical models of lactation curves, and (d) breeding values from the random regression models. It has been advised to use a persistency measure that is not genetically correlated with 305–day milk yield [15]. Then, selection for total milk and persistency concurrently would decrease the stressful high peak yield, and minimize reproductive failure and disease occurrence, while maintaining a high total milk yield.

Buffaloes contribute 50.08% of Egyptian total milk production [10]. Systematic improvements were not considered for decades since most Egyptian buffaloes are kept under poor socio–economic rural conditions besides few small herds. Several lactations are terminated earlier than desired because of low persistency [24]. Buffalo's contribution towards the country total milk would be higher and more efficient if they were more persistent in lactation.

Aggregated lactation milk yield is the criterion traditionally used for management decisions and genetic evaluation. For Egyptian buffaloes, this information is usually lacking because these animals are owned primarily by small holders where recording facilities are little, and federal organizations are absent. An acceptable approach is to use partial production, e.g. weekly or monthly partial yields, peak yield, or test–day yield as predictors of total lactation milk yield with satisfactory accuracy [20], [30].

The main objective of this study was to evaluate the persistency of milk production in a herd of Egyptian buffaloes, to determine the influence of environmental and genetic factors affecting it, and to find out how persistency is correlated with production and reproduction traits. A second objective was to find the best monthly yields, singly or in combination, as predictors of 305–day milk yield.

MATERIALS AND METHODS

Data, herd and management

The dataset used is a sample of lactation records initiated between 1991 and 2004 in a governmental farm located at Kafrelsheikh province, Egypt. Buffaloes were naturally mated, and hand milked twice a day. Milk was weighed daily, summed and recorded weekly. In the current study, monthly milk yields were the sums of 4–week periods. Lactation means of fat and protein percentages were calculated from monthly fat and protein tests, which were available for 162 lactations. Lactations shorter than 60 days were deleted. Also, records without two successive calving dates for determination of calving interval were excluded. Days open was estimated as calving interval minus the average gestation length (316 days). Final datasheet comprised of 525 lactations of 175 Egyptian buffalo cows descendant of 17 sires.

Calculation of persistency

Lactation persistency (LP) was calculated using six methods [2], [11], [23], [28], [34] as follows:

- LP1, average of proportions of each month’s milk yield (MY) to preceding month’s MY after peak yield is reached.
- LP2, ratio of 305−day MY (M305) to peak weekly yield.
- LP3, ratio of 2nd 14 weeks MY to 1st 14 weeks MY.
- LP4, ratio of descending MY to ascending MY.
- LP5 (kg/week), rate of decrease in weekly MY from peak week yield to last week yield.
- LP6 (%), the coefficient of variation (%) among successive weekly yields.

Classifications and analyses

Lactations were grouped according to calving period (4 levels; 1991–1998; 1999–2000; 2001–2002; 2003–2004), calving season (4 levels; autumn= September, October, November; winter= December, January, February; spring= March, April, May; summer= June, July, August), parity order (6 levels; 1 through 6, the sixth class included lactation $\geq$ 6), and days open (6 levels; <91, 91–120, 121–150, 151–180, 181–210, >210 days). Data were analyzed according to the following linear model using the GLM procedure of the Statistical Analysis System software [29]. Means were compared using the least squares means (LSM/PDIFF) option of the same procedure.

$$Y_{ijklm} = \mu + P_i + S_j + L_k + D_l + e_{ijklm}$$

where Y_{ijklm} = m^{th} observation of the dependent variable, μ = the overall mean, P_i = the effect of i^{th} period of calving, S_j = the effect of j^{th} season of calving, L_k = the effect of k^{th} parity, D_l = effect of l^{th} days open class, and, e_{ijklm} = the random error. Most 2–way interactions, and regression on age at calving were not significant, hence they were removed from the final model.

Heritabilities and genetic correlations were estimated through paternal halfsib correlations by the mixed–models least squares and maximum likelihood software [18]. Equations for predicting 305–day milk yield were derived by (1) simple linear equations using individual monthly milk yield (M), and (2) multiple linear regression equations using the maximum R^2 improvement regression procedure to deduce the best n–variable model (n = M1 through M6). Because of the short lactation length in this population, using all months in multiple regression analysis would eliminate most of records. Therefore, only records with at least 6 monthly milk yields (n= 294) were included in the regression analyses. All equations were derived using SAS [29].

RESULTS AND DISCUSSION

To date, there is no agreement on the best measure of LP. The difficulty is that we aim to wrap up the shape of the lactation curve into one single parameter. LP can be expressed in several ways. In the present work, measures based ratios of partial, total, or peak production (LP1 through LP5), and variation among successive yields (LP6) were used. They have the advantages of being simple in computation, and easy to understand as well as involving the majority of the lactation curve. These methods are still in use to express LP by several authors in buffaloes, e.g. [3], [34], and cattle, e.g. [17], [22].

Overall means and factors affecting LP, M305 and DIM are presented in Table (1). Least squares means of peak week, peak weekly MY, fat%, protein% and days open were 7.38±0.17 weeks, 63.8±0.54 kg, 5.95±0.09%, 3.52±0.02% and 138±4.15 days, respectively (not presented in tables). Higher LP1, LP2, LP3 and LP4, and lower LP5 and LP6 indicate better persistency. On the average, MY of the second 100 d (14 weeks) was 71% of the yield of the preceding 100 d (LP3), and MY during the descending stage of the lactation curve was approximately four times the ascending yield (LP4). Metry et al. [24] reported a mean of 0.46 for LP3 of first lactation Egyptian buffaloes. In Murrah buffaloes, a similar LP4 of 4.00 was calculated [13], but a higher LP3 (0.87) was reported in Nili-Ravi buffaloes [3]. Pathodiya et al. [25] reported similar values (0.69 for LP3, and 4.06 for LP4) in Surti buffaloes. Dhaka et al. [9] obtained a higher LP2 (26.73) in Murrah buffaloes. In Anatolian buffaloes, LP2 (17.22) was lower, possibly because of a much lower M305 (894 kg); however, the variation among successive yield (LP6) was similar (34.99%) to the current study [34].

After peak yield is attained, a given monthly MY was only two–thirds that in the previous month (LP1). This value is much lower than that (0.85) reported by Tekerli et al. [34]. Buffaloes in the current study showed a post–peak weekly reduction rate (LP5) of 2.4 to 3.5 times higher than the rate (0.73 – 1.07 kg/week) calculated elsewhere [11], [13], [25]. Such a poor LP may be explained by the relatively high peak yield and the short lactation length in the study herd. Generally, LP values reported herein were either similar or lower, particularly LP1 and LP5, than those in previous reports on buffaloes indicating a weak LP of the analyzed herd. Another evidence of poor persistency in the current herd was that only 56% of cows (294 of 525, Table 3) could remain in milk for 6 months compared to 96.6% [16].

The effect of calving period was significant for LP2 (P<0.001), LP3 (P<0.01), M305 (P<0.001) and DIM (P<0.01). The four traits showed similar trend and were better in recent years. Several previous researchers have also shown significant year/period effects on production and persistency traits in buffaloes and cattle [19], [25], [26]. However, Tekerli et al. [34] reported significant period effects on production traits but not persistency. Three (including LP3 and LP6) out of 10 LP measures differed among years [36]. Period trends in the present study indicate appreciable changes in management and/or genetics in recent years.

Season did not significantly affect LP1, LP4, and LP5. Other traits were significantly affected by the calving season (P<0.05 to P<0.001). In general, lactations initiated in summer, after that spring, were associated with the highest yield, DIM and LP. On average, buffaloes in the current herd attained peak milk yield during the 8th week post–calving, therefore, the descending phase of the lactation curve of summer calvers would commence in late summer or during autumn, where ambient temperature is less stressful to buffaloes. This is consistent with previous observations on Murrah buffaloes [11], [13], and Nili–Ravi buffaloes [3]. Opposite to these results, no seasonal variations in milk yield and most of persistency measures were reported in Anatolian buffaloes [34].

Table 1 Least squares means and standard errors for persistency, 305-day milk yield and days in milk in Egyptian buffaloes

Effect	n	LP1	LP2	LP3	LP4	LP5 (kg/wk)	LP6 (%)	M305 (kg)	DIM (day)
Overall mean	525	0.67	21.2	0.71	4.05	2.56	32.7	1382	213
SE		0.01	0.29	0.01	0.14	0.08	0.32	21.9	2.91
Period									
1991-1998	89	0.67	19.7^{b}	0.66^{b}	4.18	2.67	34.3	1275^{b}	203^{b}
1999-2000	89	0.66	20.3^{b}	0.70^{b}	4.49	2.81	32.8	1345^{b}	205^{b}
2001-2002	207	0.68	20.9^{b}	0.67^{b}	4.05	2.32	32.2	1289^{b}	212^{b}
2003-2004	140	0.69	23.8^{a}	0.79^{a}	3.50	2.46	31.5	1620^{a}	233^{a}
	SE	0.02	0.73	0.04	0.38	0.20	0.87	50.6	7.51
	Sig.	ns	***	**	ns	ns	ns	***	**
Season									
Autumn	183	0.65	20.5^{b}	0.67^{bc}	4.05	2.76	32.8^{b}	1346^{b}	204^{b}
Winter	119	0.66	19.7^{b}	0.64^{c}	4.17	2.73	34.9^{a}	1315^{b}	208^{ab}
Spring	103	0.69	21.4^{b}	0.74^{ab}	3.93	2.38	32.2^{bc}	1387^{ab}	218^{ab}
Summer	120	0.69	23.1^{a}	0.77^{a}	4.07	2.39	30.9^{c}	1480^{a}	224^{a}
	SE	0.02	0.69	0.03	0.35	0.19	0.81	47.3	7.02
	Sig.	ns	***	*	ns	ns	**	*	*
Parity									
1	130	0.60^{b}	18.3^{c}	0.57^{c}	3.70^{b}	2.85	34.1	1056^{d}	184^{b}
2	126	0.67^{a}	20.2^{b}	0.66^{b}	4.16^{ab}	2.42	33.4	1231^{c}	206^{a}
3	92	0.70^{a}	21.8^{ab}	0.73^{ab}	4.60^{ab}	2.30	31.8	1408^{b}	219^{a}
4	83	0.71^{a}	22.5^{a}	0.78^{a}	4.93^{a}	2.40	31.4	1561^{a}	221^{a}
5	30	0.67^{a}	22.4^{ab}	0.74^{ab}	3.25^{b}	2.77	33.2	1565^{a}	230^{a}
≥ 6	64	0.69^{a}	21.8^{ab}	0.76^{ab}	3.70^{b}	2.64	32.4	1472^{ab}	218^{a}
	SE	0.04	1.21	0.06	0.63	0.34	1.43	83.4	12.4
	Sig.	***	***	***	*	ns	ns	***	***
Days Open									
< 91	191	0.67	19.2^{d}	0.65	3.68^{b}	2.72	33.7	1307^{b}	196^{b}
91-120	78	0.63	20.3^{cd}	0.67	3.50^{b}	2.88	33.3	1341^{b}	201^{b}
121-150	58	0.66	20.7^{bcd}	0.69	3.52^{b}	2.60	33.1	1389^{b}	211^{b}
151-180	58	0.68	21.5^{abc}	0.70	3.78^{b}	2.42	32.3	1373^{b}	210^{b}
181-210	45	0.68	21.8^{ab}	0.75	5.73^{a}	2.38	32.3	1338^{b}	214^{b}
> 210	95	0.71	23.5^{a}	0.78	4.13^{b}	2.38	31.5	1545^{a}	248^{a}
	SE	0.03	1.00	0.05	0.51	0.28	1.17	68.6	10.2
	Sig.	ns	***	ns	**	ns	ns	**	***

LP1 to LP6, different measures of lactation persistency; for definition, refer to the methods section
M305, standardized 305-day milk yield
DIM, days in milk
SE, standard error
Sig., significance levels; ns, not significant (P>0.05); * P<0.05, ** P<0.01; *** P< 0.001
^{a,b,c} Within a column and an effect, least squares means without a common superscript letter differ, P<0.05.

Considerable variation due to parity was evident. M305 and DIM increased steadily toward the 5th lactation. First lactation heifers had the shortest lactation and the least lactation yield. LP1 through LP4 differed among parities (P<0.05 to P<0.001). Unpredictably, first lactation heifers were the least persistent; whereas cows in their 4th lactation were consistently the most persistent (LP1 to LP4). Persistency during first lactation accounted for only 73 (LP3) and 75% (LP4) of those during the 4th one. This is contradictory to the common finding that persistency is highest during the first lactation [3], [19]. In partial agreement, the 3rd lactation cows were the most persistent in [26]. The connection of low persistency and short lactation after first calving is supported by studies that have shown an increase in LP with the increase of lactation length [3], [13], [24]. Persistency did not differ among parities in other reports [34], [37].

Calving–to–conception interval affected LP4 and M305 (P<0.01), and its influence was more pronounced ($P<0.001$) on LP2 and DIM. There was a clear adverse effect of early breeding (short days open) on LP and performance of buffalo cows. Those getting pregnant within the first three months of lactation had 82 to 95% of LP2 estimated for cows becoming pregnant later than 90 DIM. Perhaps, cows with longer DO were more persistent because they had suffered less energy deficit than cows that were concurrently lactating and pregnant during early lactation. Previous researchers reported similar findings [22], [34]. Moreover, it was found that delayed breeding postpartum generally supports lactation performance in buffaloes [21].

Heritability (h^2) and correlation estimates are presented in Table 2. Heritability, particularly of LP2 (0.33), point to a possibility for effective genetic selection through sire evaluation. They are within the range (0.03 – 0.40) of heritabilities estimated by various methodologies for several measures of LP in buffaloes and cattle [4], [6], [12]. Heritability estimates of production traits are generally higher than those (0.055 and 0.132) reported by Ayyat et al. [1] for Egyptian buffaloes, and M305 (0.244) in Nili-Ravi buffalo [20].

Except for the low genetic correlation coefficients (r_G) of LP2 and LP3 with LP6, and the phenotypic correlation (r_P) for LP4 with LP2, LP3 and LP6, other estimable coefficients among the six LP measures were moderate to high (r_G –0.35 to 1.00, r_P –0.33 to 0.85; $P<0.05$ to $P<0.001$). Consequently, a correlated response in one measure would occur as a result of a change in another. Similarly, highly significant r_P (0.31 to –0.619) among different LP measures has been reported in buffaloes [34].

Correlations between LP and other performance traits were very dependant on the method LP was estimated. M305 and DIM had nearly similar correlations, both in magnitude and direction, with LP measures. Most of these coefficients were moderate to high. A correlation of 0.33 between LP and actual DIM has been calculated in buffaloes [3], and moderate r_P (0.30 and 0.36) for first lactation MY with LP have been estimated in Murrah [35] and Swamp buffaloes [7]. Cobuci et al. [4] reported r_G of 0.00 to 0.38 between M305 and nine measures of LP in Holsteins.

PW showed high positive r_G and r_P with LP2 and LP3. It signifies that persistent cows reach maximum production later in their lactations than less persistent ones. In connection, LP has been shown to increase with the increase of days to peak (r_P, 0.234 to 0.244) in Anatolian buffaloes [34]. This is important in the choice of the appropriate LP measure since delayed peak is a characteristic of lactation curves of persistent cows [5].

PWY had low r_G with LP2, so selection for high LP2 would be associated with only a slight increase in peak yield. Persistent cows are often described as those producing less milk at the beginning of lactation with low peak and higher than expected at the end of lactation. Relatively low peak yield (less negative energy balance) has been postulated as being beneficial to cow health (disease occurrence and reproduction efficiency) and economy of production [15], [27].

Milk fat percentage had low negative r_P with LP1, LP2 and LP3, and a low positive r_P with LP6. Genetically, fat% was not related to LP2, negatively associated with LP3 and LP5, and showed a positive r_G with LP1. No conclusions could be drawn about the relationship of milk protein percentage and persistency because of non–estimable heritability and r_G, and the generally non–significant low r_P.

Days open revealed low positive r_P and moderate positive r_G with LP2 and LP3. However, LP5 and LP6 had low to moderate negative r_G and very low negative r_P with days open. As a whole, correlations involving days open with measures of LP support the trend observed in the analysis of variance (Table 1). That is, better LP (high LP1, LP2 and LP3; low LP5, LP6) is associated with delayed breeding after calving in buffaloes. This is in accordance with the positive r_P (0.279 to 0.429) reported previously in Anatolian buffaloes [34]. However, very weak r_P (–0.054 to –0.065) for LP with fertility measures have been estimated during first lactation of Swamp buffaloes [7].

Table 2 Heritability and correlation coefficients among different traits

	LP1	LP2	LP3	LP4	LP5	LP6	M305	DIM	PW^a	PWY	$F\%^a$	$P\%^a$	DO
LP1	0.16±0.10	0.87±0.15	0.79±0.20	NE	-0.92±0.59	0.53±1.45	0.76±0.20	0.95±0.12	-0.39±0.68	0.14±0.53	0.59±0.73	NE	0.11±0.51
LP2	0.64^{***}	0.33±0.15	1.00±0.04	NE	-0.85±0.42	-0.17±1.04	0.95±0.05	0.99±0.02	0.80±0.43	0.17±0.46	0.01±0.63	NE	0.54±0.35
LP3	0.62^{***}	0.85^{***}	0.19±0.11	NE	-0.62±0.51	-0.17±1.12	1.02±0.05	1.01±0.05	0.80±0.39	0.43±0.48	-0.36±0.65	NE	0.56±0.40
LP4	0.40^{***}	0.21^{***}	0.17^{***}	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
LP5	-0.72^{***}	-0.65^{***}	-0.57^{***}	-0.43^{***}	0.15±0.09	-0.35±0.93	-0.62±0.42	-0.88±0.38	0.54±0.39	0.37±0.48	-0.60±0.46	NE	-0.22±0.50
LP6	-0.33^{***}	-0.50^{***}	-0.40^{***}	-0.11^{*}	0.37^{***}	0.02±0.06	-0.27±1.08	0.05±0.88	NE	-0.56±1.21	NE	NE	-0.34±1.16
M305	0.58^{***}	0.86^{***}	0.76^{***}	0.17^{***}	-0.45^{***}	-0.39^{***}	0.31±0.14	0.92±0.07	0.74±0.64	0.47±0.37	-0.83±1.13	NE	0.40±0.39
DIM	0.64^{***}	0.88^{***}	0.77^{***}	0.20^{***}	-0.62^{***}	-0.29^{***}	0.81^{***}	0.44±0.17	0.63±0.44	0.11±0.44	0.15±0.60	NE	0.46±0.36
PW^a	-0.20^{*}	0.25^{**}	0.28^{***}	-0.71^{***}	0.27^{***}	-0.10	0.20^{*}	0.25^{**}	0.40±0.27	-0.52±1.24	-0.59±0.52	NE	0.03±0.72
PWY	0.07	-0.03	0.04	-0.01	0.27^{***}	0.15^{***}	0.46^{***}	0.09^{*}	-0.01	0.10±0.08	-1.84±3.11	NE	-0.29±0.54
$F\%^a$	-0.17^{*}	-0.25^{**}	-0.28^{***}	-0.05	0.03	0.18^{*}	-0.45^{***}	-0.19^{*}	0.02	-0.44^{***}	0.34±0.26	NE	0.73±0.80
$P\%^a$	-0.23^{**}	-0.13	-0.15	-0.05	0.13	0.07	-0.18^{*}	-0.12	0.04	-0.18^{*}	0.24^{*}	NE	NE
DO	0.03	0.18^{***}	0.12^{**}	0.02	-0.06	-0.09^{*}	0.15^{***}	0.21^{***}	0.15	-0.06	-0.05	-0.05	0.13±0.09

LP1 to LP6, different measures of lactation persistency; for definition, refer to the methods section

M305, standardized 305-day milk yield; DIM, days in milk, PW, week of peak yield; PWY, peak weekly yield; F%, fat%, P%, protein%

[a] Heritabilities and correlations were estimated from a subset of data, n = 162; otherwise, n = 525

Diagonal values are the heritabilities and their standard errors

Values above the diagonal are the genetic correlations and their standard errors

Values below the diagonal are the phenotypic correlations

NE, non-estimable

Significance level, * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

Equations of simple linear regression predicting M305 from individual monthly milk yield (M) are Table 3. Generally, prediction of M305 from a single month milk production did show high accuracy. The best single–month prediction model was for M3 (R^2=0.49). Predictability declined afterwards with advancing month of lactation. Contradictory trend was reported in Surti buffaloes where the best prediction was for M6 (R^2=0.684), and the least for M1 (R^2=0.245) [33]. Also, high r_G (0.52 to 0.99) for monthly test day MY with M305 during first lactation of Murrah buffaloes has been reported [16].

Table 4 provides results of prediction using the maximum R^2 improvement regression technique. A combination of M1, M3 and M6 predicted M305 with practically the same accuracy (R^2=0.76) as did the best 5–variable or the best 6–variable models (R^2=0.78). The results imply that lactation milk yield of a buffalo cow can be assessed satisfactorily using early and mid lactation months providing an opportunity for early culling of low producers as well as predicting M305 whenever complete records are not available. In Indian Murrah buffaloes, the 3rd, 6th and 9th test-day monthly MY predicted M305 with accuracy of 91% [30].

In conclusion, buffaloes in the current study have shown low persistency. Avoiding short days open and re–evaluation of heifer raising program would improve lactation persistency. LP2 (ratio of M305 to peak weekly yield) is recommended as a better definition of LP since it had the highest genetic variation, and covers the whole lactation. Selection for high LP2 would have positive effects on persistency and M305 with little effect on peak yield. First, 3rd and 6th monthly milk yields can be pooled to precisely predict M305.

Table 3 Simple linear regression equations for prediction of 305-day milk (M305) from individual monthly yield (M) and their correlation coefficients[a]

Equation, M305=	n	R^2	Equation, M305=	n	R^2
$470.27^{**} + 5.166^{**}$ (M1)	294	0.41	$1035.56^{**} + 4.211^{**}$ (M6)	294	0.44
$456.05^{**} + 5.611^{**}$ (M2)	294	0.47	$1316.95^{**} + 3.078^{**}$ (M7)	191	0.25
$490.14^{**} + 5.647^{**}$ (M3)	294	0.49	$1339.63^{**} + 3.636^{**}$ (M8)	119	0.30
$608.34^{**} + 5.270^{**}$ (M4)	294	0.43	$1410.63^{**} + 3.803^{**}$ (M9)	71	0.21
$714.71^{**} + 5.117^{**}$ (M5)	294	0.43	$1662.68^{**} + 2.130^{*}$ (M10)	40	0.11

[a] Only lactations completed to at least 6 months were used, n = 294.
M1 to M10, 1st through 10th monthly milk yield
R^2, coefficient of determination
Significance levels, * P<0.05, ** P<0.001

Table 4 Prediction of 305-day milk (M305) from monthly yield (M) up to the 6th month using the maximum R^2 improvement regression procedure[a]

n[b]	Best equation, M305 =	R^2	P
1	$490.14^{***} + 5.647^{***}$(M3)	0.49	***
2	$222.29^{***} + 4.566^{***}$(M2) + 3.362^{***}(M6)	0.73	***
3	86.31 + 2.989^{***}(M1) + 2.219^{***}(M3) + 3.196^{***}(M6)	0.76	***
4	54.63 + 2.970^{***}(M1) + 1.765^{***}(M3) + 0.970^{**}(M5) + 2.880^{***}(M6)	0.77	***
5	54.07 + 2.251^{***}(M1) + 1.378^{**}(M2) + $0.820^{\dagger}$(M3) + 1.070^{**}(M4) + 3.095^{***}(M6)	0.78	***
6	45.73 + 2.295^{***}(M1) + 1.323^{*}(M2) + $0.852^{\dagger}$(M3) + 0.699(M4) + 0.567(M5) + 2.95^{***}(M6)	0.78	***

[a] Only lactations completed to at least 6 months were used, n = 294.
[b] Number of independent variables included in the best model
M1 through M6 are the 1st through the 6th monthly milk yield
R^2, coefficient of determination
P, significance of the model
Significance level, †P<0.10, *P<0.05, **P<0.01, ***P<0.001.

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