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Genetic and permanent environmental variations in daily milk yield and milk flow rates in Hungarian Holstein Friesian

Abstract

Random regression animal model was applied for analyzing the relationships between test-day milk yields (DY), and milk flow rate (FR). The current study involved 169,491 sample test-day records of Hungarian Holstein-Friesian cows. A quadratic random regression was applied for declaring additive genetic variances in all studied traits during biweekly observations across the first three parities. Estimates of heritability for test-day milk yield and udder milk flow rates ranged from 0.09 to 0.58 and from 0.02 to 0.50, respectively through 42 milk-weeks (Wk). The highest heritability estimates occurred during the end of trajectory for both traits. In general DY tended to be more heritable than FR across lactation except during the first few weeks of lactation. Performance of DY was less affected by environmental variation than FR, while both values were moderate to high (0.63 to 0.75). Correlations among measurements showed that additive correlations (Ra) of $^{4\text{Wk}}\text{FR}$ with the reminder part of lactation were high during early and late lactation. Also $^{24\text{Wk}}\text{FR}$ was more genetically correlated with next measures and reached $Ra = 0.94$. Whereas $^{42\text{Wk}}\text{FR}$ was high additively correlated with other biweekly measurements and ranged from 0.53 to 0.99. Performance of early and late DY was negative additively correlated and ranged from -0.03 to -0.53. Heritability of DY within levels of FR ranged from 0.09 to 0.33 within very slow and medium milk flow, respectively. Correlations among both traits increased linearly toward lactation end. DY during $^{24}\text{Week}$ and $^{42}\text{Week}$ of lactation accounted the highest additive correlations with FR across lactation. Estimated breeding values for DY and FR increased in different rates with progressing lactation. These results may indicate that individual selection results would be favorably achieved during the late part of lactation. More details about estimates of breeding values, estimates of permanent environmental and additive genetic correlations for all traits were tabulated.

Key Words: Holstein Friesian, milk yield, milk flow rate, random regression, estimated breeding value, test day

Zusammenfassung

Titel der Arbeit: Testtagmilchertrag und Milchflussrate in Beziehung zur genetischen und Umweltvariation bei ungarischen Holstein Friesian Kühen

Für die Analyse der Beziehungen zwischen dem Testtagmilchertrag (DY) und der Milchflussrate (FR) wurde das zufällige Regressions Tiermodell genutzt. Der Studie liegt eine Stichprobe von 169491 Testtagsabschlüssen zu Grunde. Zur Klärung der additiv genetischen Varianz der zweiwöchentlich erfassten Merkmale aus den ersten drei Laktationen von ungarischen Holstein Friesian Kühen wurde die quadratische Zufallsregression angewandt. Während der 42-wöchigen Laktationsperiode (Wk) lagen die Heritabilitätsschätzwerte für den Testtagmilchertrag im Bereich von 0,09 bis 0,58 und für die Milchflussrate von 0,02 bis 0,50. Die höheren Schätzwerte fanden sich für beide Merkmale zum Ende der Laktationsperiode. Im allgemeinen tendierten in den ersten Laktationswochen die höheren Schätzwerte für DY gegenüber FR. Der DY zeigte eine geringere Umweltvarianz als die FR während sie im allgemeinen für beide Merkmale im mittleren bis hohen Bereich lagen (0,63 bis 0,75). Die Beziehungen zwischen additiver- und Umweltvarianz veränderten sich im Laktationsverlauf, wobei $^{42\text{Wk}}\text{FR}$ höher additiv mit den anderen zweiwöchigen Messungen korreliert war und die Werte zwischen 0,53 bis 0,99 lagen. Die geschätzten Werte für DY am Anfang und Ende der Laktation waren negativ additiv korreliert und lagen bei -0,03 bis -0,53. Die Heritabilitätsschätzwerte für DY innerhalb der niedrigen und mittleren Werte für FR lagen bei 0,09 bis 0,33. Die Korrelationen zwischen beiden Merkmale erhöhten sich linear zum Laktationsende. Die höchsten additiven Korrelationen zwischen DY und FR ergaben sich während der 24. und 42. Laktationswoche. Die geschätzten Zuchtwerte für DY und FR erhöhten sich in unterschiedlicher Weise mit fortschreitender Laktation. Diese Ergebnisse zeigen, dass eine Selektion auf der Grundlage von Ergebnissen aus späteren Laktationsschnitten bessere Ergebnisse erwarten lassen. Detailliertere Ergebnisse über geschätzte Zuchtwerte, Umwelteffekte und additiv genetische Korrelationen sind tabellarisch dargestellt.

Schlüsselwörter: Testtagmilchertrag, Milchflussrate, Zufallsregression, Heritabilität, Zuchtwertschätzung, Holstein Friesian

Introduction

Milk flow rate, milking speed, and milking ease are different expressions used in several publications for demonstrating the magnitude of one of the most important functional traits in dairy cattle. It is well known in practice that slow and long milked cows are not desirable. Therefore genetic selection against these characteristics would be appreciated by farmers. In operating a selection schemes for milking speed and duration a basic moment is the phenotypic measurement. Rates for high-producing herds should be at least 4 kg per cow per minute. Milking time for cows producing 9 to 11 kg of milk should not exceed 4.25 minutes, with an additional $\frac{3}{4}$ minute for each additional 4.5 kg of milk harvested (MATTHEW, 2001). These milking characteristics can be measured as a threshold traits classifying cows in categories, or alternatively recording duration in time quantitatively for each cow during routine test day (NAUMANN et al., 1998). Different approaches are described by BANOS and BURNSIDE (1992). The flowmeter, an instrument widely applied in many fields, can represent a break through in milk recording system: it can easily record the amount of milk produced together with milking speed and parameters describing milk release characteristics for each cow. Flowmeter is not an expensive instrument and can be adapted easily on different old milking machine in our country.

Estimates of heritability for milking speed was approximately 0.25 and its genetic correlation with milk production was on overall 0.40 (NAUMANN et al., 1998; SANTUS and BAGATO, 2000). Milking speed was strong negatively correlated with total milking time either phenotypic (-0.50) or genetic (-0.90) and their heritabilities were less than 0.20 (BOETTCHER et al., 1998). Several reports (e.g. NAUMANN et al., 1998; RUPP and BOICHARD, 1999; NAUMANN and FAHR, 2000; MIJC et al., 2004), concluded that milking ease was found to be low inheritable and unfavorably correlated with udder health. Desirable high milking speed (or milking ease) has been reported to be associated with an undesirable high somatic cell count (SEYKORA and MCDANIEL, 1986; BOETTCHER et al., 1998; MIJC et al., 2004).

A recent approach has been to use covariance functions (CF, KIRKPATRICK and HECKMAN, 1998) and random regression models (RR, HENDERSON, 1982; SCHAEFFER and DEKKERS, 1994). The equivalence of CF and RR has been described by many authors (e.g., MEYER and HILL, 1997; VAN DER WERF et al., 1998). Under this framework, infinite-dimensional stochastic models have been proposed with the phenotype represented as a continuous function of time. Advantages of random regression test-day models over using 305-day lactation yields are now widely acknowledged. The approach of test-day (TD) yields can account more precisely for environmental factors that could affect cows differently during lactation. Random regressions allow for a different shape of lactation curves. The RR model also allows a cow to be evaluated on the basis of any number of TD records during lactation and it can account for different genetic, permanent environmental and residual variances in the course of lactation. Works of SWALVE (1995), JAMROZIK and SCHAEFFER (1997) and SWALVE (1999) were the early published study in using RR for describing genetic effects. Further developments of the variance component estimation by RR model were suggested in several recent studies.

The objectives of the current study were to estimate (co)variance components of the first three parities data with random regression models and to characterize some genetic aspects of some test-day milk yield and milk flow rate across weeks in milk for Hungarian Holstein-Friesian.

Materials and Methods

Data consisted of 169,491 test-day milk yield ($DY_{\text{kg/day}}$), and udder milk flow rate ($FR_{\text{kg/min}}$). Records were for the first three lactations of Hungarian Holstein Friesian. All studied traits were required to be recorded on each test day between 5 and 365 days in milk. The current data were presented in 21 biweekly observations that covered 42 weeks in milk across lactation period. Cows had to have at least the first lactation, while the average was 1.2 lactations with 28.4 test-week records. Data were extracted from cows calving between 1996 and 2000. Biweekly observations were 79,542, 48,647, and 41,302 in the first three parities. Number of cows, sires and dams in the first three parities were 4,173, 453 and 3,967, respectively. Overall mean of DY and FR were 24.7 ± 3.2 kg/day and 4.8 ± 0.40 kg/min, respectively. Estimates of phenotypic ranges were from DY: 4.40 to 43.70 and from FR: 0.50 to 10.30. Genetic and permanent environmental variations in test-day milk yield were studied within five levels of milk flow rate (very fast, fast, medium, slow and very slow).

Statistical analysis

The random regression model used in the current study was

$$Y_{ijklm} = HTD_{il} + \sum_{n=1}^{n_p} \beta_{ilo} X_{klmo} + \sum_{n=1}^{n_p} \alpha_{klo} X_{klmo} + \sum_{n=1}^{n_p} \psi_{klo} X_{klmo} + \varepsilon_{ijklm}$$

Where:-

Y_{ijklm} is the m^{th} test-day observation of the k^{th} cow in the l^{th} lactation, HTD_{il} is the independent fixed effect of j^{th} herd-test-date for l^{th} lactation, n_p is the number of parameters fitted on days in milk function, β_{jlo} is the o^{th} fixed regression coefficient on j^{th} DIM effect in l^{th} lactation, X_{klmo} is the o^{th} dependent trait on DIM, α_{klo} is the O^{th} random regression coefficient of additive genetic effect of k^{th} cow in l^{th} lactation on DIM, ψ_{klo} is the o^{th} random regression coefficient of permanent environmental effect of k^{th} cow in l^{th} lactation on DIM and ε_{ijklm} is the random residual.

The following (co)variance structure was assumed:

$$V \begin{bmatrix} \alpha \\ \psi \\ \varepsilon \end{bmatrix} = \begin{bmatrix} G \otimes A & 0 & 0 \\ 0 & P \otimes I & 0 \\ 0 & 0 & E \otimes I \end{bmatrix}$$

where:- \mathbf{G} = genetic covariance matrix among random regression coefficients and traits, \mathbf{A} = additive numerator relationship matrix, \mathbf{P} = permanent environmental covariance matrix among random regression coefficients and traits, and \mathbf{E} = residual variance for lactation n assumed to be constant throughout the lactation due to program limitations.

Variance-covariance parameters for each of the current longitudinal traits (test-day milk yield and udder milk flow rate) were estimated using the software random regression package, DFREML (MEYER, 1998 Version 3 β). Estimates of additive and permanent environmental co-variances for coefficients of random regression function are provided in the Table.

Table

Estimates of Co-variances for additive and permanent environmental random regression coefficients for test-day milk yield and milk flow rate (Kovarianzschätzung für additiv und umweltbedingte Zufalls-Regressionskoeffizienten der Merkmale Testagsmilchertrag (DY) und Milchflussrate (FR))

Test-day milk yield						Test-day milk flow rate						
Additive			Permanent environmental			Additive			Permanent environmental			
0	1	2	0	1	2	0	1	2	0	1	2	
0	19.46		49.10			0.85			2.33			
1	13.58	17.70	3.33	9.99		0.57	0.45		-0.07	0.74		
2	-2.27	2.30	6.15	-9.36	1.42	10.31	0.30	0.13	0.19	-0.40	0.21	0.46

0: Intercept, 1: Linear, 2: Quadratic

Estimates using fixed multivariate animal model									
	h^2	C^2	σ_A^2	σ_C^2	σ_P^2		R_A	R_C	R_P
DY	0.21 \pm .07	0.48 \pm .13	12.38	27.63	57.97	DY*FR	0.95 \pm .19	.75 \pm .18	0.57 \pm .18
FR	0.19 \pm .11	0.52 \pm .12	00.50	1.34	2.59				

σ_P^2 , σ_A^2 , σ_C^2 : Phenotypic, additive and permanent environmental variances,
 C^2 , h^2 : Permanent environmental effect and heritability.

R_p , R_A , R_{pe} : Phenotypic, additive and permanent environmental correlations

Results

Multi-lactations estimates of heritability (h^2) and permanent environmental effect (C^2) for test-day milk yield and milk flow rate are illustrated in Figure 1. Estimates of h_{DY}^2 ranged from 0.09 to 0.58 (\bar{X} : 0.28 \pm 0.04) and h_{FR}^2 ranged from 0.02 to 0.50 (\bar{X} : 0.20 \pm 0.04) across 42 weeks in milk using multi-lactations.

The highest differences among curves of h_{DY}^2 and h_{FR}^2 ranging from 0.13 to 0.15 were occurred during 16 Wk to 22 Wk across lactation.

While the corresponding estimates for permanent environmental effects were C_{DY}^2 (\bar{X} : 0.60 \pm 0.13, ranging form 0.40 to 0.75) and C_{FR}^2 (\bar{X} : 0.51 \pm 0.13, ranging from 0.30 to 0.63). In addition C_{DY}^2 and C_{FR}^2 starting increasing at 6 Wk to 14 Wk (0.63), reached a pack at 16 Wk (0.75) and then decreased gradually till trajectory end. Differences among curves of C_{DY}^2 and C_{FR}^2 across 42 weeks in milk were 0.085 \pm 0.05 on average.

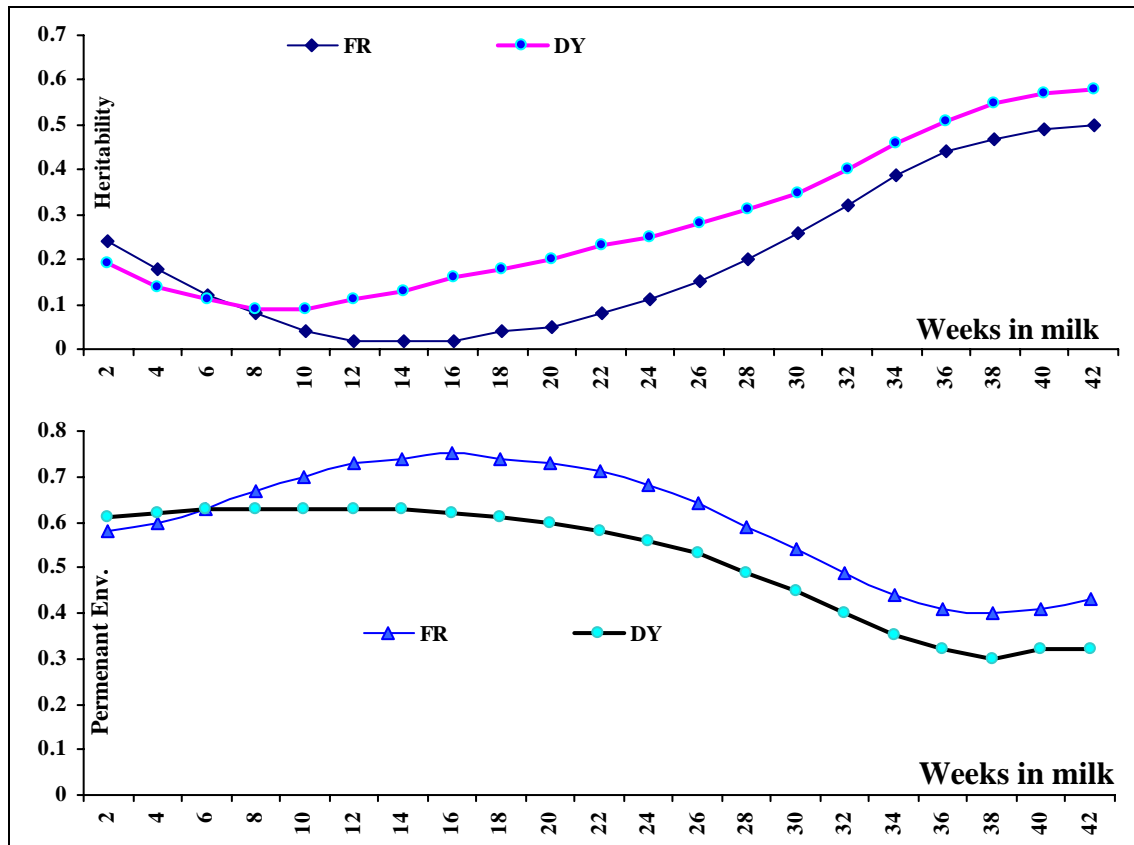


Fig. 1: Estimates of biweekly heritability and permanent environmental effect test-day milk yield (DY) and udder milk flow rate (FR) across lactation (Heritabilitätsschätzwerte und Umwelteffekte für DY und FR in zweiwöchigen Laktationsabschnitten)

Estimates of h_{DY}^2 and C_{DY}^2 within milk flow rate group:

Estimates of overall mean heritability for test-day milk yield within five milk flow rate groups were h_{DY}^2 -very slow: 0.18 ± 0.03 , h_{DY}^2 -slow: 0.17 ± 0.06 , h_{DY}^2 -medium: 0.19 ± 0.06 , h_{DY}^2 -fast: 0.09 ± 0.02 and h_{DY}^2 -very fast: 0.22 ± 0.02 . The highest estimates of h_{DY}^2 were occurred within both of very slow and slow milking flow rate group ($h^2 > 0.45$) during the end of trajectory. On the other hand, the highest frequencies for moderate h_{DY}^2 (0.14 to 0.30) were obtained within medium and very fast milk flow rate groups. While the highest frequencies for the lowest h_{DY}^2 occurred during mid-lactation within fast and slow milk flow rate group.

Estimates of overall mean permanent environmental effect for test-day milk yield within five milk flow rate groups were C_{DY}^2 -very slow: 0.62 ± 0.12 , C_{DY}^2 -slow: 0.60 ± 0.27 , C_{DY}^2 -medium: 0.58 ± 0.12 , C_{DY}^2 -fast: 0.70 ± 0.12 and C_{DY}^2 -very fast: 0.56 ± 0.08 . The highest contribution of C_{DY}^2 obtained within slow flow rate group (0.64 to 0.68) within ^4Wk to ^{20}Wk , more than 0.70 within very slow milk flow rate group during the first ^{24}wk and around 0.80 within early few weeks in milk across fast milk flow rate group as shown in Figure 2. On the other hand C_{DY}^2 were decreased rapidly toward trajectory end (less than 0.05) within slow milking group.

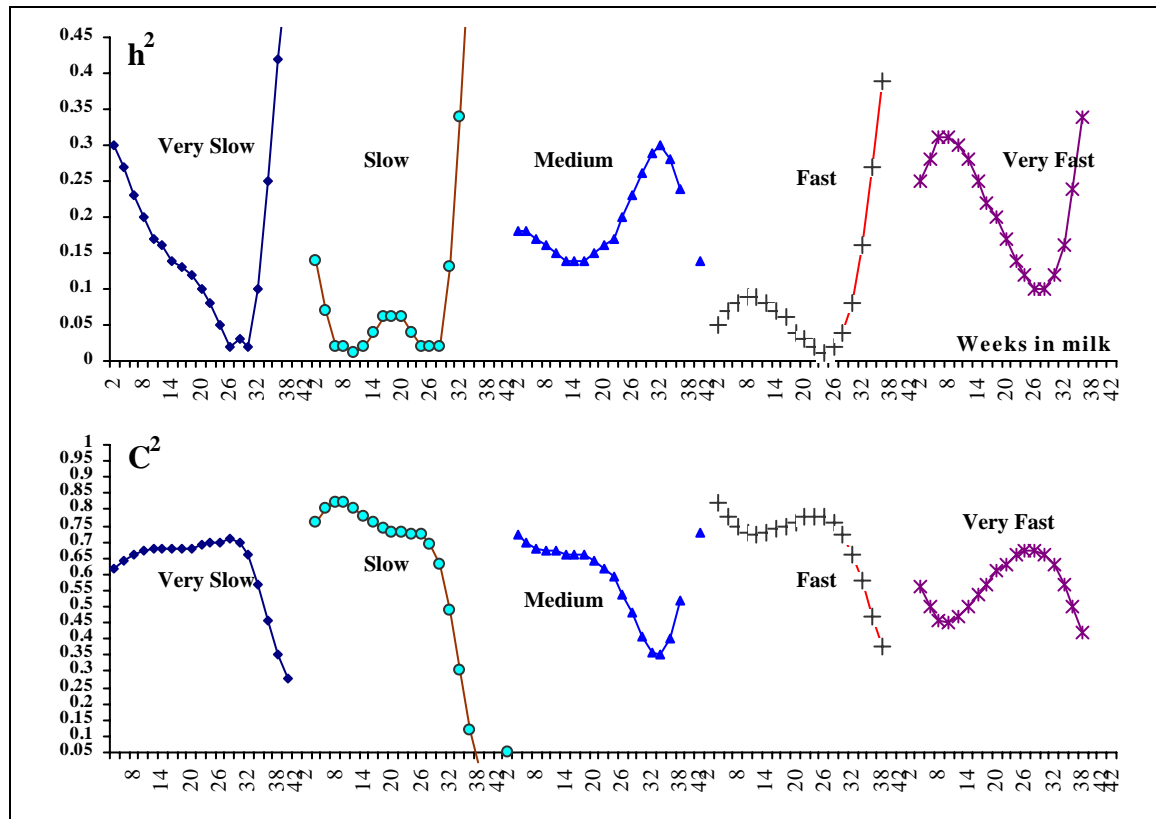


Fig. 2: Estimates of heritability (h^2) and permanent environmental effect (C^2) for test-day milk yield across lactation within different udder milk flow rates (Heritabilitätsschätzwerte und Umwelteffekte für DY innerhalb verschiedener FR während der Laktationsabschnitte)

Estimates of h^2 and C^2 within separate parities:

Weekly derived estimates of h_{DY}^2 , h_{FR}^2 , C_{DY}^2 and C_{FR}^2 within the first three parities are presented in Figure 3-1 and Figure 3-2. Fairly homogenous weekly heritability for milk yield was 0.48 in maximum value and with an average (\bar{X} : 0.45) within early stage of the 2nd lactation Figure 3-1. While the highest values within 1st and 3rd parity were 0.36 and 0.19 with \bar{X} : 0.27 and \bar{X} : 0.12, respectively. Estimates of h_{DY}^2 were high and showed stable values throughout the course of the second lactation.

Estimates of h_{FR}^2 Figure 3-1 were low to moderate across different weeks in milk within the first three parities. The highest h_{FR}^2 were 0.33, 0.31, and 0.34 at early weeks of the 1st parity and at both edges of 2nd lactation, respectively. On the other hand, the maximum value of h_{FR}^2 within the 3rd parity was not more than 0.20 (at 28^{Wk}). Estimates of h_{FR}^2 were decreased greatly from 0.33 to 0.11 with progressing weeks in milk in a linear fashion within the 1st lactation. Most of h_{FR}^2 estimates within the 2nd parity were relatively higher than within the others parities. Differences among lactations in heritability values for FR were significantly higher than the corresponding estimates for DY.

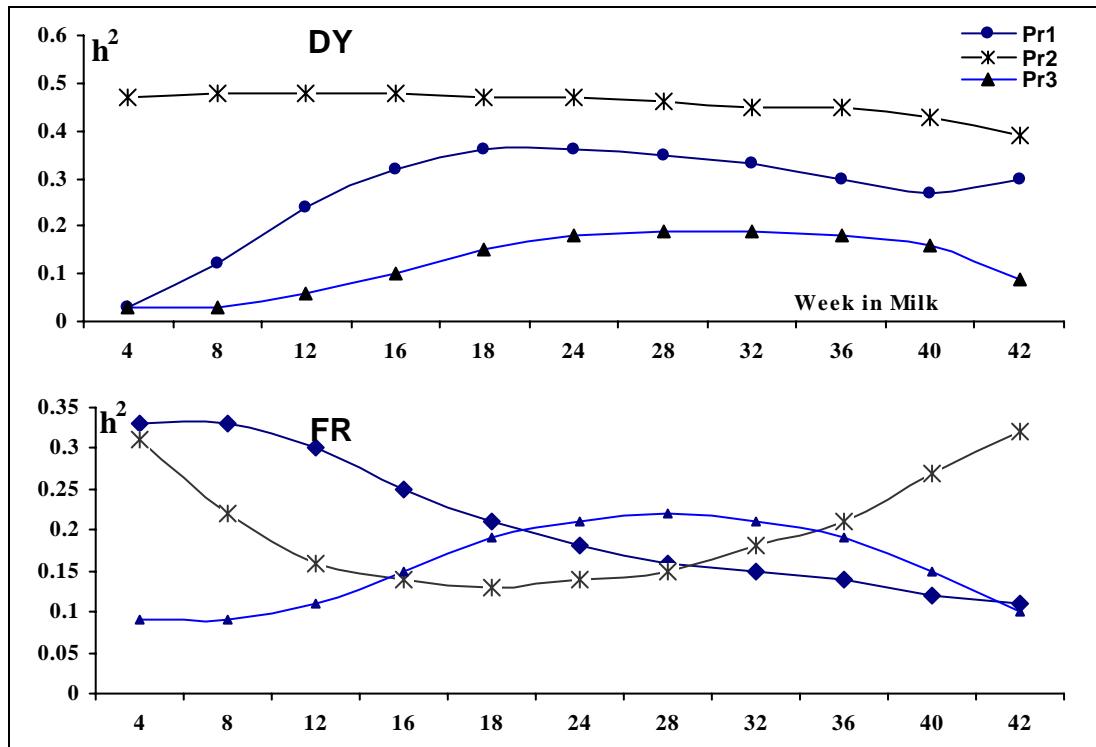


Fig. 3-1: Estimates of heritability (h^2) for test-day milk yield and milk flow rate in the first three parities (Pr1, Pr2, Pr3) across 42 lactation weeks (Heritabilitätsschätzwerte für DY und FR aus den ersten drei Laktationen bei 42 Laktationswochen)

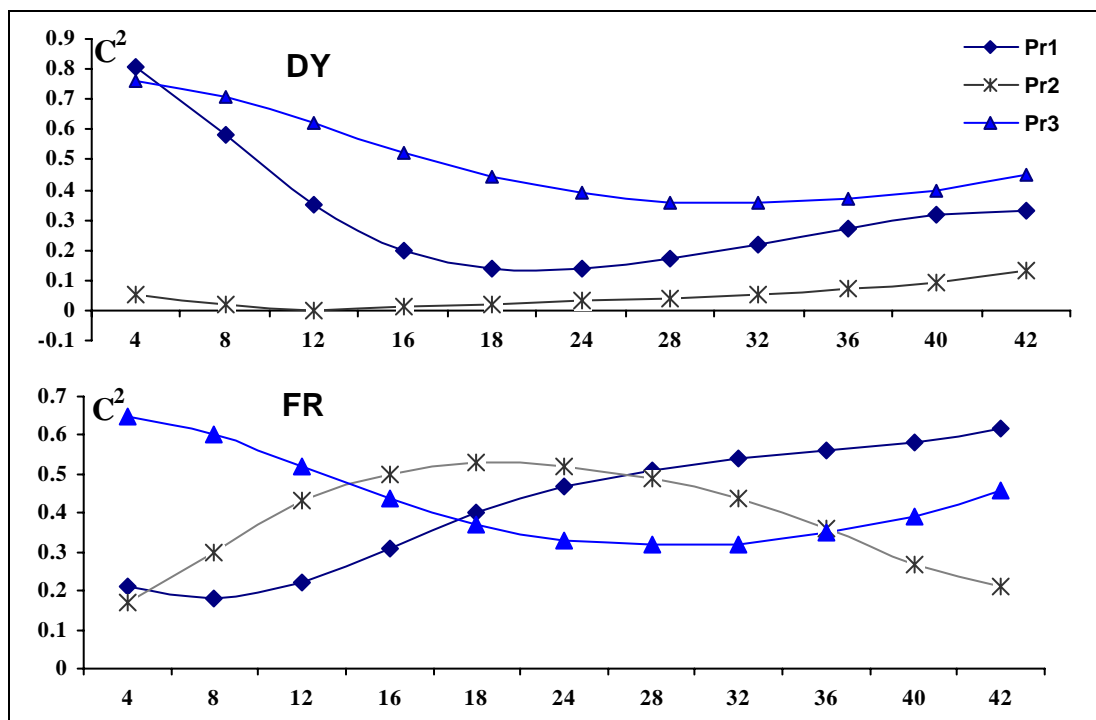


Fig. 3-2: Estimates of permanent environmental effects (C^2) for test-day milk yield and milk flow rate in the first three parities (Pr1, Pr2, Pr3) across 42 weeks in milk (Schätzung der Umwelteffekte für DY und FR aus den ersten drei Laktationen bei 42 Laktationswochen)

Average estimates of the permanent environmental effects were (C_{DY}^2 : 0.32 ± 0.20 , 0.05 ± 0.01 & 0.49 ± 0.14) and (C_{FR}^2 : 0.42 ± 0.16 , 0.38 ± 0.13 & 0.43 ± 0.12) within the first three parities, respectively. Estimates of C_{DY}^2 was accounted the highest contribution during early stage of the 1st and the 3rd lactation. While C_{FR}^2 was arrived to maximum value during the late of the 1st parity and early of the 3rd parity Figure 3-2. Also it can be seen that the middle stages of the second lactation are more affected by permanent environmental conditions for FR (C_{FR}^2 : ranging from 0.43 to 0.52).

Relationships between test-day milk yield and milk flow rate.

Derived estimates of additive (R_A), permanent environmental (R_C) and phenotypic (R_P) correlations among test-daily milk yield and milk flow rate at the same week in milk are illustrated in Figure 4. Estimates of R_A linearly increased with progressing lactation after globule in shape during early weeks in milk. Overall mean of R_A was 0.94 ± 0.06 that ranged from 0.83 to 0.93 and was around unity during the last ¹⁰Wk of lactation. Estimates of R_A accounted the highest relationship across lactation weeks than either R_C or R_P . Weekly permanent environmental and phenotypic correlation values are about 0.85 ± 0.09 , 0.76 ± 0.13 , respectively on average for all lactations. Estimates of R_C and R_P changed in linear fashion across weeks of lactation and ranged from 0.73 to 0.99 and 0.59 to 0.96, respectively. Differences among type of the three correlations decreased with progressing weeks in milk till trajectory end. Estimated genetic correlations varied from 0.31 to 0.41 between daily milk yield and milking speed using test-day random regression model (KARACAOREN et al., 2006).

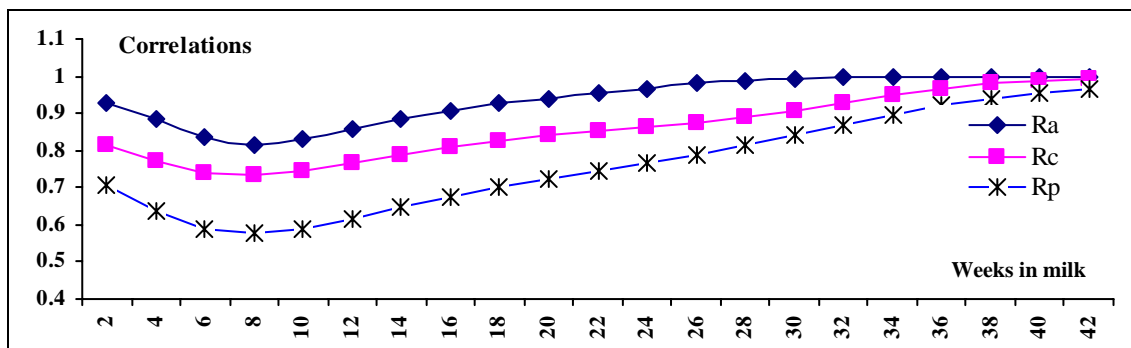


Fig. 4: Additive genetic (R_A), permanent environmental (R_C) and phenotypic (R_P) biweekly correlations among test-day milk yield and udder milk flow rate across lactation (Additiv genetische (R_A), Umwelteffekte (R_C) und phänotypische Korrelationen (R_P) während des Laktationsverlaufes)

Additive and permanent environmental relationships between measurements of DY at ⁴Wk, ²⁴Wk, and ⁴²Wk with milk flow rate during the remaining part of lactation are shown in Figure 5. Overall mean of additive correlations were 0.53 ± 0.04 , 0.82 ± 0.04 , and 0.82 ± 0.03 for relationship among DY and FR during early, mid and late of lactation, respectively. Additive correlations of ⁴WkDY with all measurements of FR were in moderate value but attained some reduction during mid-lactation. DY at ²⁴Wk and ⁴²Wk showed the highest additive correlations with FR during the 2nd half of lactation. Permanent environmental correlations were always lower than additive ones across lactation weeks.

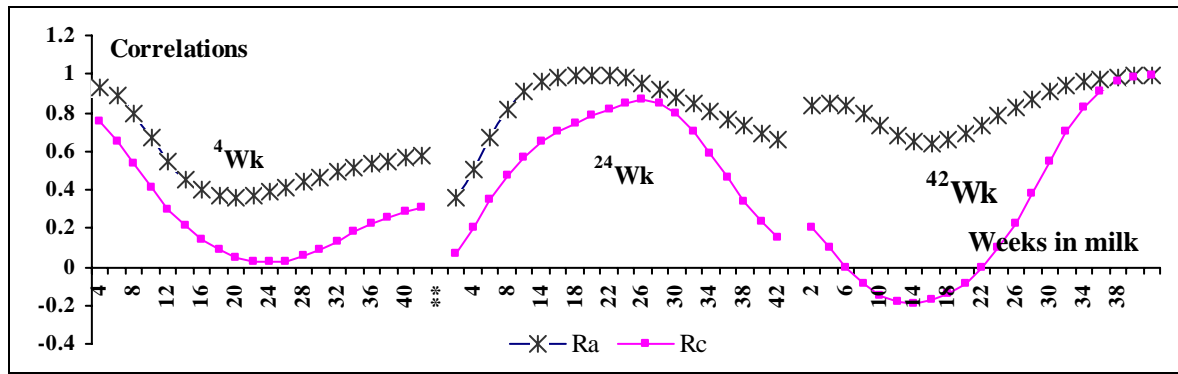


Fig. 5: Additive (Ra) and permanent environmental (Rc) relationships between measurements of test day milk yield at a given weeks in milk with milk flow rate during the remaining part of lactation (Beziehungen zwischen additiven (Ra) und umweltbedingten (Rc) Beziehungen für DY in unterschiedlichen Laktationsabschnitten)

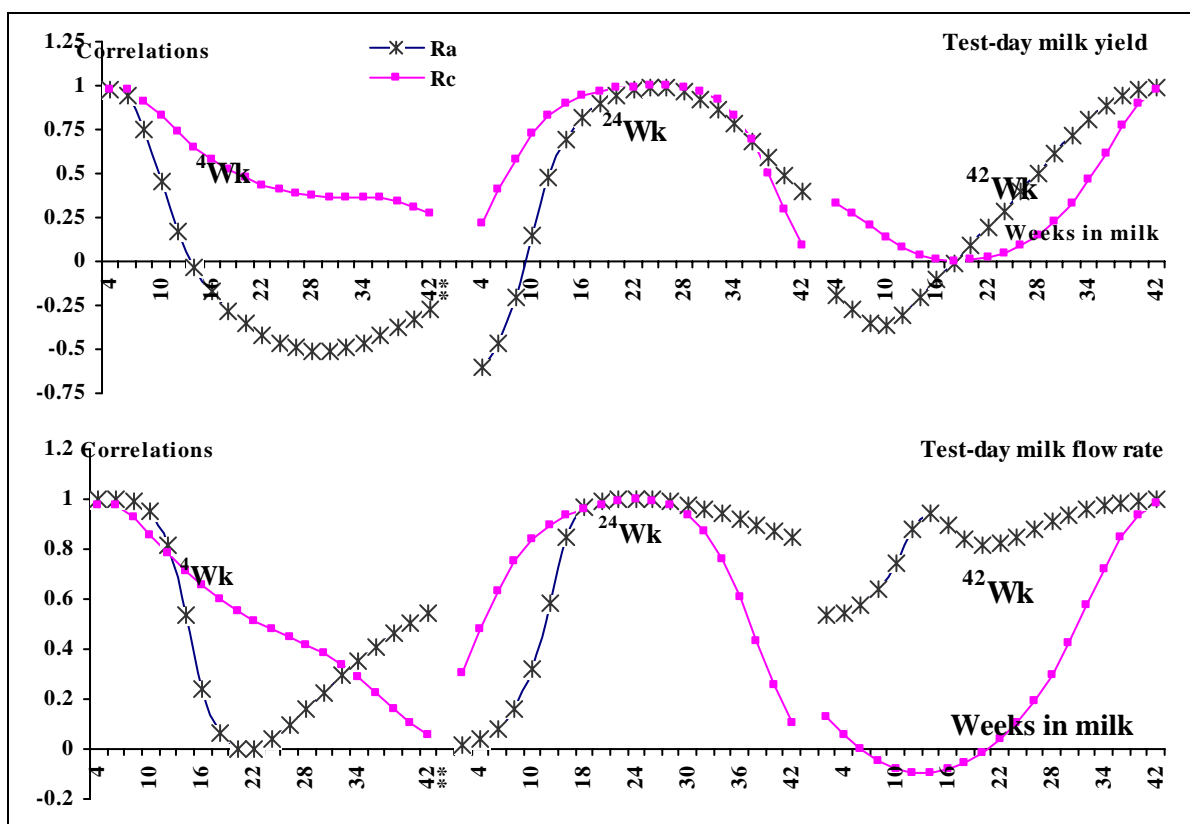


Fig. 6: Additive and permanent environmental correlations between a given weeks in milk and the remaining part of lactation for test-day milk yield and milk flow rate (Additiv und umweltbedingte Korrelationen zwischen Laktationsabschnitten im Laktationsverlauf zwischen DY und FR)

Relationships among observations of the same trait (correlations among repeated measurements) across lactation are provided in Figure 6. Estimates of additive genetic correlations of ^{4Wk}DY with others decreased in magnitude from 0.92 during the ^{2-6Wk}DY to 0.28 at ^{10Wk}DY and then changed to negative (from -0.03 to -0.51) till trajectory end. Performance of ^{24Wk}DY was highly correlated with adjacent measures (reached to unity: ^{14Wk} to ^{34Wk}). On the other hand, DY at ^{42Wk} is strongly correlated with a few measures during the end of lactation. While ^{42Wk}DY was additively correlated in a declining pattern with previous measures.

Permanent environmental correlations among measurements of DY accounted the highest contribution during mid-lactation.

Additive correlation among measures of FR attained different patterns across lactation weeks Figure 6. The highest estimates were located among the measurements at the ⁴Wk with the next three measures (0.82 to 0.99), among ²⁴Wk with the next measures till trajectory end (0.85 to 0.99) and among ⁴²Wk with the pervious measures from ¹⁴Wk (0.84 to 0.99).

Estimated breeding values (EBV):

Estimates of overall mean, minimum and maximum of top 20% for EBV in both traits are presented in Figure 7. Overall mean of top 20% EBV in both traits decreased with progressing weeks in milk till ⁹Wk for DY and till ¹²Wk for FR and then increased gradually in both traits till end of trajectory. Maximum EBV showed more fluctuation differed than minimum EBV. Such differences were observed in a very limited range lying within the interval from ¹⁰Wk to ¹⁸Wk in FR and at ⁸Wk in DY but in a wider range at both edges of lactation.

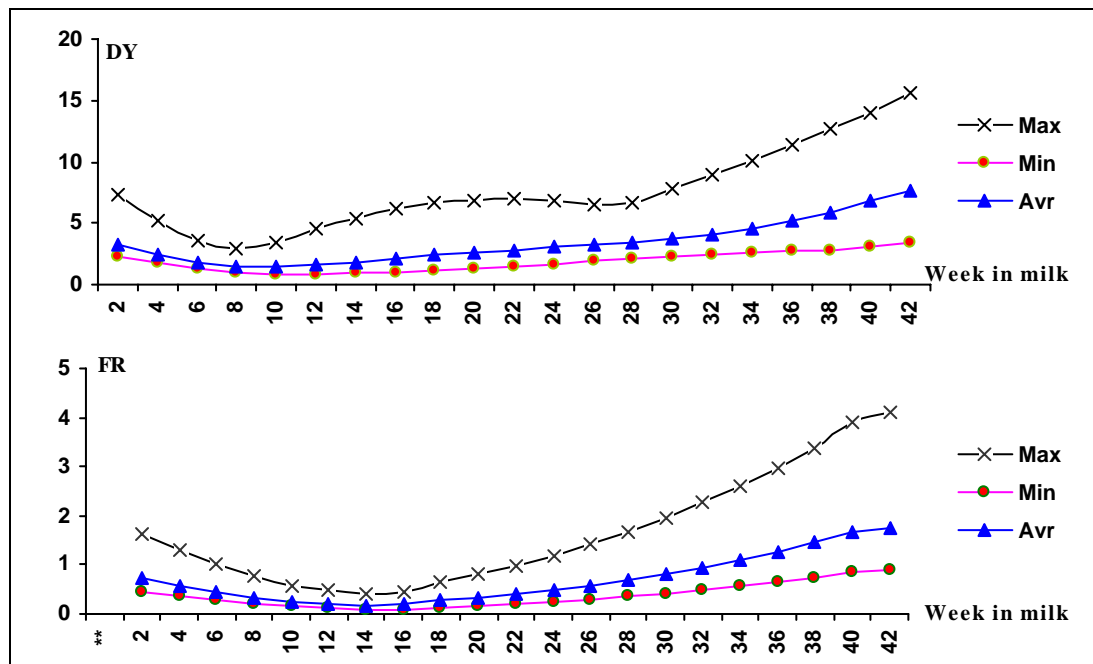


Fig. 7: Estimates of expected breeding value (maximum: Max, minimum: Min, average: Avr) for test-day milk yield and milk flow rate of the top 20% individual within each week in milk (Schätzung der Erwartungszuchtwerte für DY und FR der besten 20 % im Laktationsverlauf)

Estimates of correlations among EBV for both traits at the same week in milk across lactation are presented in Figure 8. Correlation among EBV_{DY} and EBV_{FR} was moderately high 0.56 at the beginning of lactation and then reduced progressively to 0.06 at ⁶Wk of lactation. The optimum interval on lactation curve that attended the highest correlations among EBV of both traits was between ²⁰Wk till lactation end with values ranging from 0.62 to 0.97 (\bar{X} : 0.75 ± 0.02). Critical interval range on lactation curve that showed lowest and negative correlations among EBV of both traits was from ⁹Wk to ¹³Wk.

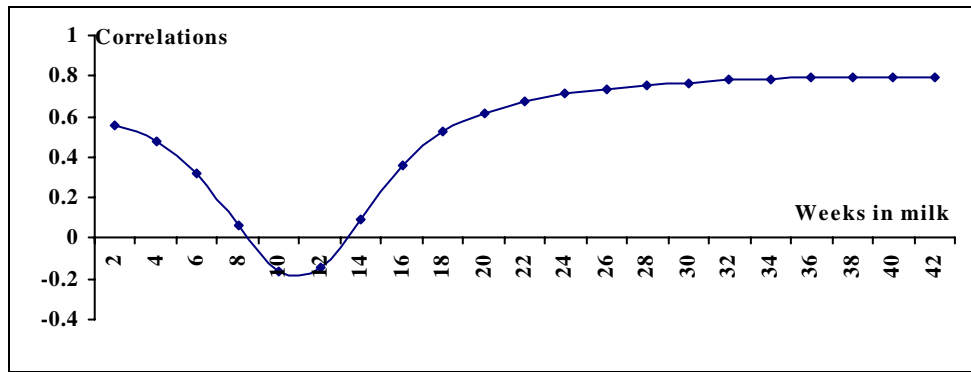


Fig. 8: Correlations among expected breeding value of test-day milk yield and milk flow rate at the same week in milk (Korrelationen zwischen Erwartungszuchtwerten für DY und FR in den gleichen Laktationswochen)

Discussion

Estimates of h_{DY}^2 across different weeks in milk were moderately high during the last few segments of stage of lactation. This reflects a greater role of additive-genetic variance with progressing lactation till the end. High significant differences in heritability estimates of milk yield and milk flow rate were found between the first three lactations. The heritability estimates of the first lactation milk yield for particular days in milk resulting from random regression models ranged between 0.14 to 0.19 (STRABEL and MISZTAL, 1999) and 0.31 to 0.51 (NAUMANN et al., 1998 and OLORI et al., 1999). ZAVADILOVÁ et al. (2005) found that genetic variances were high at the beginning and at the end of lactation. The flattest shapes were observed during early of production life and the rapid increase of genetic variance occurred at the late stages of the older lactations.

Variations in milk yield due permanent environmental conditions were reduced with advancing lactation weeks. This may be due to enhancing adaptability to environmental conditions with progressing lactation weeks. Therefore genetic improvement in DY could be achieved with little efforts to minimize the impact of environmental effects on the measured variance. In general, estimates of h_{FR}^2 were very low across ^{10}Wk to ^{20}Wk corresponding for to increasing influences of C^2 . Therefore, the role of environmental conditions must be taken into account when evaluating performance of milk flow rate. ZAVADILOVÁ et al. (2005) found that variances of the small permanent environmental effect for milking speed went up substantially between the first and subsequent lactations, with the differences between the 2nd and the 3rd lactations. Measuring h_{FR}^2 at lactation end seems more appropriate if it's included in breeding programs for indirect improvement of dairy cattle performance. High h_{FR}^2 herein agreed with those of WILLIAMS et al. (1984) and BANOS and BUMSIDE (1992). ERF et al. (1992) and SCHUTZ and PAJOR (2001) reported that milking speed appears to be more heritable. Estimated heritabilities varied from 0.18 to 0.30 (mean = 0.24) for test daily milk yield and 0.003 to 0.098 (mean = 0.03) for milking speed using test-day random regression model (KARACAOREN et al., 2006). Performance of FR was less heritable than DY within the first three parities. Even though, FR could be considered as genetically selected trait at special points of the lactation curve within different parities. Also the current results indicate that some unfavorable management conditions during milking process must be avoided for

maximizing contribution of milk flow rate in different breeding strategy. Results of genetic analysis within parity suggest that selection could be very effective for improving DY across whole lactation weeks within the 2nd parity. Some authors reported great variability with high heritabilities at the beginning and at the end of lactation (JAMROZIK and SCHAEFFER, 1997; SWALWE, 1999; OLORI et al., 1999). Some other authors found the highest heritabilities in the middle of lactation (BAFFOUR-AWUAH et al., 1996; JAKOBSEN et al., 2002; DRUET et al., 2003). ZAVADILOVÁ et al (2005) reported that additive genetic variances using random regression increased with parity and heritability estimates increased in turn, especially from the 2nd to the 3rd lactation.

Positive relationships among DY and FR across lactation weeks are mainly favorable. That means high lactating cows are faster milking in optimum milk time which increase cow parlor flow rate and minimizing parlor effort and costs. Such favorable relationships must be considered in suitable weight during constructing selection programs.

Most of high lactating cows at the beginning of lactation will become the lowest producers at the end of lactation as evident from negative phenotypic correlation between early and late DY. On the other hand, cows which reached peak of production near to mid-lactation will end their lactation in optimum production level.

Developing genetic control in the relationship among measurements of milk flow rate delimited during the 2nd half of lactation explain. Therefore FR could be considered as the same trait or repeated measurements across interval of ²⁴Wk to ⁴²Wk in milk. While FR during early and mid-lactation could be treated different traits as evident of decreasing genetic relationship among them (near to zero at ²⁰Wk).

Derived results of expected breeding values indicate that both traits tended to be transmitted together among different successive generations. Therefore selection for daily milk yield across early production life could be associated with considerable improvement in milk flow rate as evident from their strong positive genetic correlation.

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