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Differences between performance of F_1 crossbreds and Holsteins at different production levels

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ABSTRACT

Crossbreeding in dairy cattle has recently become of increased interest. However, farmers in Scandinavian countries are reluctant to implement crossbreeding in their herds, and one reason is the common opinion that only herds at a poor level of management can benefit from crossbreeding. The Danish Cattle Database (SEGES, Aarhus, Denmark) provided data on 14 traits regarding milk yield, udder health, fertility traits, stillbirth, and survival. The data were collected from 103,307 pure Holstein cows and 14,832 F_1 crosses (Holstein dam and Nordic Red sire). The cows were born between 2008 and 2014 and originated from 424 herds that contributed data from at least 5 purebreds and 5 crossbreds across the years. We split the animals into 3 production levels: high, average, and low according to the herd's average production (kg) of 305-d fat plus protein in the given birth year of the cow. We estimated least squares means of breed group (purebred and crossbred) performance within each production level. Crossbred performance in 305-d fat yield in first-parity cows was greater than that of Holstein across all herd production levels; the gain was greater in high- (9 kg more than Holstein) and average-producing herds (7 kg more than Holstein) than in low-producing herds (3 kg more than Holstein). Regardless of production level or parity, crossbreds did not outperform Holstein in terms of 305-d protein yield (0 to 8 kg less). Crossbreds had relatively better udder health than Holstein in both first and second parity (up to 15% less mastitis) within any of the production levels. In terms of fertility, stillbirth, and survival, crossbreds performed better than purebreds, and improved performance was independent of herd production level. We conclude that differences in performance between F_1 crossbreds and Holstein are independent of production level.

Key words: dairy cow, crossbreeding, herd management

INTRODUCTION

In many livestock species, crossbred animals have shown to be more robust and economically beneficial than the parental pure breeds, and this is true for crossbred dairy cattle as well (Heins et al., 2006a; Sørensen et al., 2008; Clasen et al., 2017). Systematic crossbreeding is a common approach across the world in some species, particularly pig and poultry. Interest in crossbreeding in dairy cattle has increased in the last decade, but the use of systematic crossbreeding differs between countries. In New Zealand, systematic crossbreeding in dairy cattle is the most widely used breeding system, where 56% of the dairy cows in first parity are crosses between Holstein and Jersey (LIC/Dairy NZ, 2016). In comparison, crossbreds make up only 12% of the overall dairy cow population in Denmark (Lauritsen and Flagstad, 2017) and around 8% in Sweden (Växa Sverige, 2018).

Despite the increasing interest in crossbreeding in dairy cattle and recent research showing the benefits, many dairy farmers in the Scandinavian countries remain reluctant to implement crossbreeding in their herds. There may be many reasons for this skepticism, and one of them is the common opinion that crossbreeding is only beneficial under poor management conditions. Penasa et al. (2010) supported this opinion when they found the largest heterosis estimates associated with the most stressful environments. However, Bryant et al. (2007), Kargo et al. (2012), and Lembeye et al. (2015) disagreed and showed evidence of the lowest heterosis occurring under the poorest production levels and the greatest occurring under intermediate production levels.

The aim of this analysis was to compare Nordic Red × Holstein crossbreds with purebred Holsteins and compare the effect of crossbreeding in herds with different production levels to confirm or reject the farmers' opinion.

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MATERIALS AND METHODS

Data on milk yield, udder health, calving traits, fertility traits, and survival were provided from the Danish Cattle Registry (SEGES, Aarhus, Denmark). The data were retrieved for 103,307 Holstein (**HOL**) and 14,832 F_1 crossbred cows out of a Holstein dam and a Nordic Red sire (**RHX**). The cows were born between 2008 and 2014. Each cow had calved at least once and contributed data to at least one trait. The cows originated from 424 Danish herds that contributed data from at least 5 HOL and 5 RHX across the years. The herds were split in 3 production levels to represent management level: high, average, and low according to the average herd production of 305-d kilograms of fat plus kilograms of protein yield (**FP**) in first-parity cows per year. The cows were assigned to the given production level in the herd in their year of birth. Table 1 presents the number of herd × birth year levels, number of HOL and RHX animals, and mean and standard deviation of FP in the first parity within the 3 production levels. The average FP levels for first-parity cows within herd shown in Table 1 matches the national average of FP in first parity Danish Holstein cows of 635 kg (SEGES, 2016).

We analyzed 14 traits for differences between HOL and RHX within the 3 production levels, including 4 milk production traits: 305-d kg of fat yield (**FY**) and 305-d kg of protein yield (**PY**) in first and second parities; 5 reproduction traits: interval in days from first to last service (**IFL**) in heifers, first-parity, and second-parity cows, and days open in first- and second-parity cows; 2 udder health traits: frequency of mastitis treatments between 15 d before and 50 d after calving in first- and second-parity cows (1 if they were treated for mastitis at least once in the period or 0 if no treatments were given); 2 survival traits: survival to second or third calving (1 if they survived to the next calving or 0 if they did not survive); and rate of stillbirth, which accounted for calves that died within 24 h after birth out of first-parity cows (1 if the newborn calf survived within that period or 0 if it died).

We estimated least squares means using the PROC MIXED approach in SAS software (version 9.4, SAS Institute Inc., Cary, NC) within the 3 levels of production using a linear model:

$$Y_{ijkl} = B_i + HY_j + N_{k(l)} + e_{ijkl},$$

where Y_{ijkl} = record on individual trait, B_i = fixed effect of breed group i (HOL or RHX), HY_j = fixed effect of herd × year of first calving j, $N_{k(l)}$ = random effect of the current total merit index (**NTM**) k of the dam of the animal nested within a fixed effect of the birth year of the animal l, and e_{ijkl} = random residual. We used a simple t-test method to test the differences between performance of crossbreds and Holstein between production levels.

It is preferable to extract the NTM of the dam at the time of birth of the animal. However, this was not possible to do because only current breeding values were available in the database. The correction for NTM of dam was considered necessary because there is a tendency to use the cows with the highest NTM for pure-breeding and the cows with lowest NTM for crossbreeding in herds applying both pure- and crossbreeding. We assume that the best available sires were used regardless of breeding purpose; therefore, we did not find it necessary to include the NTM of the sire.

RESULTS AND DISCUSSION

The least squares means of the 14 traits divided in herds at high, average, and low production levels are presented in Table 2 for RHX as deviations from HOL. The values in the table should be interpreted as the relative phenotypic deviation of crossbred animals within herd and birth-year at 3 production levels.

Production Traits

In first parity, RHX deviations for FY were significant and favorable at all production levels. Furthermore, there was a significant ($P < 0.05$) difference between RHX deviations in herds at high and average production level compared with herds at the low production level. Within production level, RHX had a significantly ($P < 0.05$) larger FY relative to HOL in first parity,

Table 1. Number of herd × birth year levels, purebred animals (HOL), crossbred animals (RHX), and mean levels of 305-d fat plus protein yield (FP) of first-parity cows in 3 production levels

Production level	Herd × birth year levels, no.	HOL, no.	RHX, no.	Mean (SD) FP
High	903	44,075	5,931	675 (33)
Average	854	35,960	4,346	611 (15)
Low	868	23,272	4,555	532 (44)

Table 2. Least squares means (SE of differences in parentheses) of 305-d fat and protein yields (kg), stillbirth, days from first to last service, frequency of mastitis treatments, and survival for Nordic Red × Holstein crosses (RHX) relative to Holstein (HOL) in 3 levels of production (high, average, low)

	High		Average		Low	
Trait	HOL	RHX	HOL	RHX	HOL	RHX
305-d fat yield, kg						
First parity	360	+9*[a] (0.95)	331	+7*[a] (1.03)	295	+3*[b] (0.97)
Second parity	417	+3*[a] (1.62)	391	−4*[b] (1.68)	354	−2[ab] (1.65)
305-d protein yield, kg						
First parity	307	−2*[a] (0.78)	280	0[a] (0.84)	246	0[a] (0.80)
Second parity	357	−7*[a] (1.32)	332	−8*[a] (1.37)	296	−5*[a] (1.34)
Days from first to last service						
Heifers	25	−1*[a] (0.75)	26	−4*[a] (0.91)	22	0[a] (1.04)
First parity	48	−7*[a] (1.27)	46	−7*[a] (1.49)	50	−9*[a] (1.67)
Second parity	55	−8*[a] (1.78)	55	−10*[a] (1.96)	56	−4[a] (2.19)
Days open						
First parity	74	−9*[a] (0.57)	75	−10*[a] (0.73)	76	−16*[a] (0.87)
Second parity	74	−8*[a] (0.81)	68	−10*[a] (0.94)	75	−11*[a] (1.14)
Stillbirth, relative, %						
First parity	—	−30*[a]	—	−38*[a]	—	−35*[a]
Mastitis, relative, %						
First parity	—	−15*[a]	—	−15*[ab]	—	0[b]
Second parity	—	−14*[a]	—	−11[a]	—	−6*[a]
Survival, relative, %						
First to second calving	—	+3.6*[a]	—	+1.2[a]	—	+5.1*[a]
First to third calving	—	+15*[a]	—	+7.5*[a]	—	+11*[a]

[a,b]Deviations for RHX within a production level and trait with the same superscript are not significantly different ($P \leq 0.05$).

*$P \leq 0.05$: significantly different from HOL.

and the largest difference was found in herds at high production level (+9 kg), whereas it decreased through lower production levels.

For second-parity cows, RHX deviations for FY were significant ($P < 0.001$) only between herds with high and average production levels. Similar to first parity, RHX had larger FY compared with HOL within the herds with high production level (+3 kg). However, within herds with an average production level, RHX had 4 kg less FY. In contrast, RHX and HOL did not differ within herds with a low production level.

The RHX deviations for PY in both first and second parity did not differ significantly between production levels. However, the benefits of crossbreeding on PY showed the opposite tendency in first and second parities: crossbreeding tended (P-values between 0.16 and 0.21) to be most beneficial in PY in herds with average or low production level. Within production levels, RHX in herds at average and low production levels did not differ from HOL in first-parity PY. Within herds with a high production level, RHX produced 2 kg less PY than did HOL. In second parity, the PY of RHX was significantly ($P < 0.05$) less: −7, −8, and −5 kg relative to HOL in herds at high, average, and low production levels, respectively.

Combining PY and FY, RHX did well in productive performance in first parity compared with HOL, but they were outperformed by HOL in the second parity at all production levels. This is probably because HOL tends to have a larger increase in yield from first to second parity than other breeds (Sundberg et al., 2009). The results are in accordance with Heins et al. (2006a) and Heins and Hansen (2012), who found an insignificant difference in FP yield between Scandinavian Red × Holstein and Holstein in first-parity cows. Hazel et al. (2017b) drew the same conclusion on FP yield in first-parity Viking Red × Holstein crossbreds compared with purebred first-parity Holstein. Furthermore, crossbreds in second parity were significantly inferior to the purebreds in the study by Heins and Hansen (2012), which supports our findings. At the time of our study, only limited data were available on crossbreds in third and later parities. Therefore, we could not determine whether the trend of decreasing FP continues after second parity.

The estimates of RHX deviations in FY between production levels are in accordance with those of Bryant et al. (2007), who found the largest heterosis estimates for both FY and PY in crosses between Holstein-Friesian and New Zealand Jersey in herds at average and high production levels. Kargo et al. (2012) drew similar conclusions on crosses between lines of Danish Jersey and US Jersey in the Danish Jersey population. They are, however, in contradiction to the results of Penasa et al. (2010), who found less heterosis in high-level herds for both PY and FY in crosses between Holstein-Friesian and Dutch Friesian. The authors of that study suggested that the contradictory results compared with Bryant et al. (2007) were due to higher FP levels in the latter study. However, our study showed even higher FP levels (see Table 1) compared with Penasa et al. (2010) and Bryant et al. (2007), rejecting that theory. However, comparisons should be made with caution, as our estimates are not heterosis estimates, unlike the earlier studies.

Fertility and Stillbirth

None of the RHX deviations for days open, IFL, and stillbirth differed significantly between production levels. In IFL for heifers and second-parity cows, the benefit tended (P-values between 0.07 and 0.18) to be largest in herds at average and high production levels, whereas for first-parity cows, the benefit favored herds at the low production level. Penasa et al. (2010) studied another fertility trait—age at first calving—and found, despite very low estimates, the greatest heterosis in herds at average and high production levels.

Nevertheless, there were generally significant ($P \leq 0.05$) benefits of crossbreeding on fertility within any level of production. Crossbreds had, in general, decreased or equal IFL and fewer days open than HOL. The RHX heifers had 1 d less in IFL compared with HOL within herds with high level of production, whereas first- and second-parity cows in these herds had 7 and 8 d less in IFL. Also in herds with an average production level, RHX had relatively fewer days IFL across ages: −4, −7, and −10 for heifers, first-parity cows, and second-parity cows, respectively. However, in herds with a low level of production, only RHX first-parity cows outperformed HOL in IFL (−9 d). Within herds with high production, first- and second-parity RHX cows had 9 and 8 fewer days open, respectively, relative to HOL. Within herds with an average production level, RHX cows had 10 fewer days open compared with HOL in both first and second parity. The relative number of days open in RHX compared with HOL in herds with a low level of production was −16 and −11 for first- and second-parity cows, respectively. The results are in accordance with Hazel et al. (2017b), Heins and Hansen (2012), and Jönsson (2015), who found improved fertility in Viking Red × Holstein, Scandinavian Red × Holstein, and Swedish Red × Swedish Holstein, respectively, versus purebred Holstein.

Regardless of production level, RHX had markedly fewer stillbirths at all levels of production compared with HOL. The frequency of stillbirths in calves born to RHX was reduced by 38% relative to HOL in herds at average production level; herds at high and low production levels had reductions of 30 and 35%, respectively. In a US study, Heins et al. (2006b) found a similar reduction (36%) in stillbirths in Scandinavian Red × Holstein crossbreds compared with pure Holstein. In a recent US study comparing Viking Red × Holstein crossbreds and purebred Holstein, there was a 44% reduction of stillbirths in crossbred animals, but this estimate was only slightly significant (Hazel et al., 2017b). Jönsson (2015) made a large analysis on the performance of reciprocal crosses between Swedish Red and Swedish Holstein compared with purebred Swedish Holstein. She found reductions of stillbirth to be 27 and 37% in crossbreds relative to purebreds depending on whether the sire breed was Swedish Holstein or Swedish Red.

Udder Health

In herds with a high compared with low production level, we found a significant ($P = 0.049$) difference in frequency of mastitis in first-parity cows between RHX deviations. Even though the reduction in mastitis in RHX relative to HOL was equal (−15%) in herds at high compared with average production, there was no significant difference between RHX deviations at average compared with low production level. This was probably because the number of RHX with data was greater in herds with a high versus average production level, and mastitis frequencies were generally low in the herds. For mastitis frequency in second-parity cows, we detected no significant differences between production levels but the tendency favored a high production level. Penasa et al. (2010) investigated SCS for Holstein Friesian and their crosses with Dutch Friesian, and found the greatest heterosis expression in herds with a high production level. However, the results were based on substantially fewer animals than the current study.

In herds with a high production level, RHX had a significantly ($P \leq 0.05$) lower incidence of mastitis: −15% in first parity and −14% in second parity compared with HOL. In herds with an average level of production, the incidence of mastitis was 15% lower in RHX in first parity compared with HOL. However, we detected no significant difference between RHX and HOL in second parity, even though it was an estimated 11% numerical reduction in RHX. However, within herds with a low level of production, there was no difference between RHX and HOL in first lactation, whereas the incidences of mastitis in second parity was 6% less for RHX.

Udder health can be defined as mastitis incidence; for example, as a binary trait (as in this study) or as SCC or SCS. The latter definition was used by Heins and Hansen (2012), who found Scandinavian Red × Holstein crosses to have significantly lower SCS across lactations compared with purebred Holstein, whereas Hazel et al. (2017b) did not find any difference between first-parity Viking Red × Holstein versus Holstein. Defining incidences of mastitis between −10 d before and 150 d after calving (binary trait), Jönsson (2015) found that crossbreds had a significantly lower incidence of mastitis in both first and second parities if the cows were sired by a Swedish Holstein bull, but no difference if the sire was a Swedish Red bull. This is in contradiction to the findings in the current study. Interestingly, Jönsson (2015) found that estimates on SCC in first parity showed the opposite result from mastitis: crossbreds sired by a Swedish Red bull had significantly lower SCC than purebred Swedish Holstein, whereas those sired by a Swedish Holstein did not differ. In second parity, both combinations of crossbreds differed significantly from purebreds.

Survival

For survival from first to second or third calving, RHX deviations between the production levels did not differ significantly. However, compared with HOL, more RHX survived until second calving within herds at high and low production levels (3.6 and 5.1%), whereas there was no significant difference in herds with an average level of production. Hazel et al. (2017a) did not find a significant difference in survival until second calving between Viking Red × Holstein crossbreds versus purebred Holstein. Usually, most cows survive until second calving, which is why the insignificant findings in our study and that of Hazel et al. (2017a) are not surprising. In contrast, Heins et al. (2012) found a significant and relatively large increase (+13.4%) in survival to second calving in Scandinavian Red × Holstein crosses compared with purebred Holstein.

In survival from first to third calving, 15% more RHX cows survived in herds with a high production level, and relatively more RHX cows in herds with average and low production levels survived this period (7.5 and 11%, respectively). The large improvement in longevity in RHX is due to improvement of the functional traits described earlier: fertility, stillbirth, and udder health. Heins et al. (2012) found a much greater survival rate (+39% relative) for Scandinavian Red × Holstein crosses relative to purebred Holstein.

General Discussion

Only a few studies have investigated heterosis effects in different environments in traits other than production. Penasa et al. (2010) concluded that heterosis is expressed more largely in the most stressful environments. In that study, they found the largest heterosis for production in herds with a low production level, whereas the largest heterosis estimates for udder health and fertility were found in herds with a high production level. This assumes that the most stressful environment is not necessarily in herds with the lowest level of production and may depend on the individual trait. However, the current study and others (Bryant et al., 2007; Kargo et al., 2012) report heterosis levels for yield that are actually greater in high-producing herds and fitness heterosis levels that are independent of herd production level; such results do not support the hypothesis that greater stress results in more hybrid vigor.

Different breeds or lines do not always perform the same in different environments for different traits (genotype × environment interaction, G × E; Fikse et al., 2003; Bryant et al., 2005; Strandberg et al., 2009). However, studies suggest that environment may also influence the expression of heterosis (H × E) for different traits (Penasa et al., 2010; Norberg et al., 2014). Thus, different crossbreeds or lines may perform differently under different environments, which might explain in part why studies disagree on the relative heterosis expression under different environments. The estimates found in our study were based on phenotypic performance, which means that the differences between RHX and HOL are the sum of G × E and H × E. Additionally, these results do not separate additive genetic and heterosis effects. This requests further analyses on G × E and H × E separately, as well as heterosis in RHX crosses.

CONCLUSIONS

We showed that performance in F_1 crossbreds between Nordic Red × Holstein compared with Holstein was independent of production level for most traits. Thus, these results disprove the common opinion among farmers that crossbred animals perform best in herds with a poor management level. Our results are consistent with those of previous studies, showing that F_1 crossbreds outperform Holstein cows in traits for fertility, udder health, stillbirth, and survival. Investigations of the economics of crossbreeding at the herd level, as well as more studies on different breeds crossed in different herd levels, may strengthen the general trust of crossbreeding of dairy cattle.

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REFERENCES

Bryant, J., N. López-Villalobos, C. Holmes, and J. Pryce. 2005. Simulation modelling of dairy cattle performance based on knowledge of genotype, environment and genotype by environment interactions: current status. Agric. Syst. 86:121–143. https://doi.org/10.1016/j.agsy.2004.09.004.

Bryant, J. R., N. López-Villalobos, J. E. Pryce, C. W. Holmes, D. L. Johnson, and D. J. Garrick. 2007. Short communication: Effect of environment on the expression of breed and heterosis effects for production traits. J. Dairy Sci. 90:1548–1553. https://doi.org/10.3168/jds.S0022-0302(07)71640-5.

Clasen, J. B., E. Norberg, P. Madsen, J. Pedersen, and M. Kargo. 2017. Estimation of genetic parameters and heterosis for longevity in crossbred Danish dairy cattle. J. Dairy Sci. 100:6337–6342. https://doi.org/10.3168/jds.2017-12627.

Fikse, W. F., R. Rekaya, and K. A. Weigel. 2003. Genotype × environment interaction for milk production in Guernsey cattle. J. Dairy Sci. 86:1821–1827. https://doi.org/10.3168/jds.S0022-0302(03)73768-0.

Hazel, A. R., B. Heins, and L. Hansen. 2017a. Fertility, survival, and conformation of Montbéliarde x Holstein and Viking Red x Holstein crossbred cows compared with pure Holstein cows during first lactation in 8 commercial dairy herds. J. Dairy Sci. 100. https://doi.org/10.3168/jds.2017-12824.

Hazel, A. R., B. J. Heins, and L. B. Hansen. 2017b. Production and calving traits of Montbéliarde × Holstein and Viking Red × Holstein cows compared with pure Holstein cows during first lactation in 8 commercial dairy herds. J. Dairy Sci. 100:4139–4149. https://doi.org/10.3168/jds.2016-11860.

Heins, B. J., and L. B. Hansen. 2012. Short communication: Fertility, somatic cell score, and production of Normande × Holstein, Montbéliarde × Holstein, and Scandinavian Red × Holstein crossbreds versus pure Holsteins during their first 5 lactations. J. Dairy Sci. 95:918–924. https://doi.org/10.3168/jds.2011-4523.

Heins, B. J., L. B. Hansen, and A. De Vries. 2012. Survival, lifetime production, and profitability of Normande× Holstein, Montbéliarde× Holstein, and Scandinavian Red× Holstein crossbreds versus pure Holsteins. J. Dairy Sci. 95:1011–1021.

Heins, B. J., L. B. Hansen, and A. J. Seykora. 2006a. Production of pure Holsteins versus crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. J. Dairy Sci. 89:2799–2804.

Heins, B. J., L. B. Hansen, and A. J. Seykora. 2006b. Calving difficulty and stillbirths of pure Holsteins versus crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. J. Dairy Sci. 89:2805–2810.

Jönsson, R. 2015. Estimation of heterosis and performance of crossbred Swedish dairy cows. MS Thesis. Department of Animal Breeding and Genetics, SLU/Swedish University of Agricultural Sciences. Uppsala, Sweden.

Kargo, M., P. Madsen, and E. Norberg. 2012. Short communication: Is crossbreeding only beneficial in herds with low management level? J. Dairy Sci. 95:925–928.

Lauritsen, U., and P. Flagstad. 2017. Ydelseskontrollens Månedsstatistik Alle Besætninger. Accessed Sep. 15, 2017. https://www.landbrugsinfo.dk/Kvaeg/Tal-om-kvaeg/Sider/mndstatmain12.aspx.

Lembeye, F., N. Lopez-Villalobos, J. L. Burke, and S. R. Davis. 2015. Effects of production level on the expression of breed and heterosis for lactation yields of milk, fat and protein in cows milked once- and twice-daily. Proc. Assoc. Advmt. Breed. Genet. 21:197–200.

LIC/Dairy NZ. 2016. New Zealand Dairy Statistics. Livestock Improvement Corp. and Dairy NZ. Accessed June 26, 2017. https://www.dairynz.co.nz/media/5416078/nz-dairy-statistics-2015-16.pdf.

Norberg, E., P. Madsen, G. Su, J. E. Pryce, J. Jensen, and M. Kargo. 2014. Short communication: Heterosis by environment and genotype by environment interactions for protein yield in Danish Jerseys. J. Dairy Sci. 97:4557–4561.

Penasa, M., M. De Marchi, R. Dal Zotto, G. De Jong, G. Bittante, and M. Cassandro. 2010. Heterosis effects in a black and white dairy cattle population under different production environments. Livest. Sci. 131:52–57.

SEGES. 2016. Årsstatistik Avl. Accessed Apr. 28, 2016. https://www.landbrugsinfo.dk/Kvaeg/Avl/Avlsstatistik/Sider/aarsstat_2015.pdf.

Sørensen, M. K., E. Norberg, J. Pedersen, and L. G. Christensen. 2008. Invited review: Crossbreeding in dairy cattle: A Danish perspective. J. Dairy Sci. 91:4116–4128.

Strandberg, E., S. Brotherstone, E. Wall, and M. P. Coffey. 2009. Genotype by environment interaction for first-lactation female fertility traits in UK dairy cattle. J. Dairy Sci. 92:3437–3446. https://doi.org/10.3168/jds.2008-1844.

Sundberg, T., B. Berglund, L. Rydhmer, and E. Strandberg. 2009. Fertility, somatic cell count and milk production in Swedish organic and conventional dairy herds. Livest. Sci. 126:176–182. https://doi.org/10.1016/j.livsci.2009.06.022.

Växa Sverige. 2018. Cattle statistics. Uppsala, Sweden. Accessed Apr. 25, 2018. https://www.vxa.se/globalassets/dokument/statistik/husdjursstatistik-2018.pdf.