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Reproductive Performance of Holstein, Brown Swiss and Their Crosses under Subtropical Environmental Conditions with Brief Reference to Milk Yield

[1]Hany Abdalla and [2]Mahmoud S. El-Tarabany

[1]Department of Theriogenology, Faculty of Veterinary Medicine, Zagazig University, Egypt
[2]Department of Animal Wealth Development, Faculty of Veterinary Medicine, Zagazig University, Egypt

Abstract: The objective of this study was to evaluate the reproductive performance of pure Holstein (HO), pure Brown Swiss (BS), BH crossbred (BS sire x HO cow) and HB crossbred (HO sire x BS cow) under Egyptian conditions with reference to their milk yield. The pregnancy per AI at 30 and 75 days post insemination, embryonic loss rate, days open, calving interval, number of inseminations per parturition, the 305- milk yield (305-MY) and the total milk yield for different genotypes were measured and the effect of temperature humidity index level (THI) on reproductive performance was investigated. All reproductive indexes of the pure BS cows were better than that of the pure HO cows but its milk yield was significantly lower. The pregnancy/AI 75 of the HB and the BH crossbred (33.1 and 35.2; respectively) was significantly higher than that of the pure HO cows (23.2) and comparable to that of the pure BS cows (33.3). The calving interval and the days open of the HB and the BH crossbred were non-significantly shorter than that of the pure HO cows (P= 0.06 to 0.08). The fertility of the pure BS cows was not affected by the level of the THI but pregnancy/AI 30 and 75 the pure HO cows decreased from (35.7 and 29.3; respectively) at low THI to (16.2 and 11.9; respectively) at high THI. Both the HB and the BH crossbreds seem to tolerate the moderate and high THI better than the pure HO. The 305-MY of the BH and the HB crossbred were comparable and lower to that of the pure HO cows, respectively. In conclusion, pure BS, BH and HB crossbred showed better adaptability and fertility under Egyptian conditions and the milk yield of the BH crossbred is comparable to that of the pure HO cows.

Key words: Holstein · Brown Swiss · Fertility · Cross Breeding · Heat Stress · THI

INTRODUCTION

Selective breeding of Holstein (HO) cows greatly improved its production traits and turned it the most popular breed in dairy farms. However, selective breeding for productivity while ignoring other traits had resulted in appearance of undesirable traits as lower fertility, higher health problems and shorter longevity [1, 2]. To overcome these problems, higher consideration must be given to improve such traits during selective breeding [3]. Alternatively, HO may be crossbred with another breed [4]. In the crossbred cows, desirable trait of one breed will mask the undesirable one of the other breed. Additionally, the crossbred cows will have superior performance over the average of the purebred parents due to hybrid or heterosis effect [5]. The heterosis effect is variable among different traits and greatly affected by the genetic diversity between the parents breeds and the system of crossbreeding [6]. Therefore, choosing the parents and the crossbreeding system must be done according to the required improvement otherwise an impractical and/or unproductive animals can be produced.

Crossbreeding HO with different temperate breeds had resulted in crosses having higher fertility than the pure HO. For example Brown Swiss (BS) x HO [7-9], Normande × HO and Montbéliarde x HO [10, 11], Scandinavian Red × HO [9-11] and Jersey x HO [9, 12, 13]. However, except for Dechow *et al*. [7] and Blöttner *et al.* [14] who reported that the milk yield of the BS x HO cross was similar to that of the pure HO, all the previously mentioned crosses found to have lower milk production ability.

Corresponding Author: Hany Abdalla, Department of Theriogenology, Faculty of Veterinary Medicine, Zagazig University, El-Zeraa str. 114; 44511-Zagazig, Egypt. Tel: +20160369532. E-mail: hlabdallah@zu.edu.eg - lotfi_hany@yahoo.com.

All the previously mentioned crossbreeding trials had been conducted under temperate conditions. However, tropical, subtropical or even moderate temperate climate greatly affected the productive and the reproductive performance of the temperate breeds [15-20]. Several trials were applied to improve the reproductive ability and the productivity of dairy cows under heat stress conditions [21, 22]. To overcome such problem temperate breeds were crossbred with native breeds to produce crosses having higher adaptability to tropical or subtropical conditions [23-25]. Crossbreeding HO with native breed usually resulted in a cross that has a comparatively lower productivity than the pure HO. because the main aim of crossbreeding is to produce a cross showing better functional traits without a great reduction in milk production, crossbreeding HO with another highly producing temperate breed that has higher resistance to stressful environmental conditions is an alternative method. To our knowledge no previous reports had investigated the reproductive and the productive performance of crosses originated from two temperate breeds and reared under subtropical conditions. It turned out that the environment and the management greatly affected the heterosis and the efficiency of the crossbreds [13, 26, 27].

The aim of the current study was to evaluate the reproductive performance of pure HO, pure BS and their crosses under subtropical Egyptian conditions and to investigate if the crosses will be more adaptable to the subtropical conditions in comparison to their pure temperate parents. Additionally, due to the importance of the productivity we introduced a brief reference to the milk production ability of each genotype.

MATERIALS AND METHODS

Animals Management and Crossbreeding: The data were generated at AL-Qasem farm, Ismailia road, Cairo. The herd consisted mainly from pure HO and BS cows. Due to lower fertility and higher health problem of the pure HO cows the owner decided to crossbreed the pure HO cows with the BS sires and vice versa. The pure cows were randomly used to produce pure or crossbred heifers.

The data used in the current study were generated from the records of 80 BH crossbred (BS sires x HO cows), 65 HB crossbred (HO sires x BS cows), 88 pure BS cows and 500 pure HO present in the farm between September 2010 and June 2013. All pure and crossbred cows included in the current study delivered their first calve at 2010 or latter and were comparable in age and lactation season.

All pure and crossbreed cows were housed in a free stall supplied with a cooling system consisted of water splashing system and large fans. The animals had a free access to water and were feed a total mixed ration. The ration was adjusted according to the NRC [28] to meet the nutritional requirement of a lactating cow weighting 650 kg and producing 40 kg milk. The cows were milked 3 times per day. The cows were supplied with pedometers. All production (milk yield) and reproductive (calving, insemination, pregnancy diagnosis…ect,) data were recorded and tracked using a commercial on-farm computer software programs (AfiFarm version 4.1).

Reproductive Performance: Parturient cows were given a 60 days voluntary waiting period before insemination. Cows showed excessive activities recorded by the pedometer were introduced to inseminator 10-16 hrs later. Upon examination, cows showed estrus mucus and turgid uteri were inseminated and received 10 µg GnRH (Buserelin; Receptal; Intervet) at the time of insemination. All cows were inseminated by three proven inseminators have nearly the same efficiency. The HO and the BS semen were imported from progeny or genetically tested bulls. The main consideration during selection of the bull for cows and heifers was given to the predicted transmitted ability for milk production and the calving ease index; respectively. The same bulls were used to produce pure and crossbred heifers. All crossbred heifers or cows were backcrossed with HO semen. Pregnancy diagnosis was done using ultrasonogarphy examination at 30 days post-insemination and confirmatory pregnancy diagnosis was done at 75 days post-insemination.

The reproductive indexes were the pregnancy per AI at day 30 (pregnancy/AI 30) and day 75 post insemination (Pregnancy/AI 75), the days open, the calving interval and the number of insemination per parturition. The pregnancy/AI 30 and pregnancy/AI 75 were calculated as a number of cows diagnosed pregnant at day 30 and day 75 post insemination respectively divided by the number of cows inseminated. The embryonic losses was calculated as a number of cows diagnose non-pregnant at 75 days post-insemination divided by the number of cows diagnosed pregnant at 30 days post-insemination.

Climatic Conditions: The breeding season extend from September till June. The daily ambient temperature and the daily relative humidity recorded in the farm area were collected from the nearest meteorological station. These data were used to calculate the daily

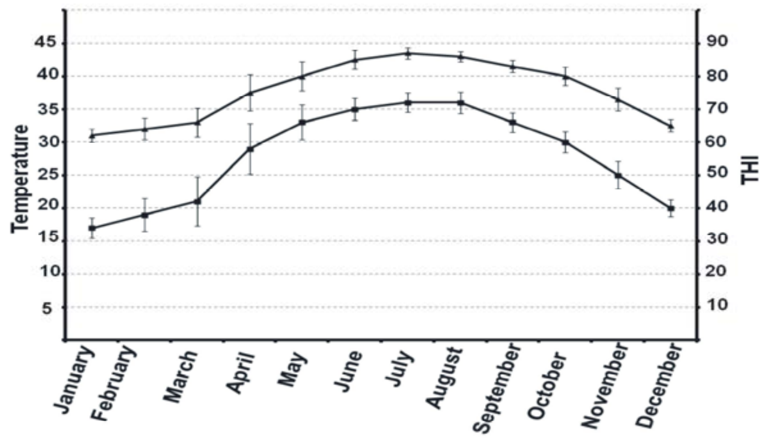

Fig. 1: The monthly average temperature (■) and temperature humidity index (THI) (▲) in the area of the farm

temperature humidity index (THI) according to the equation reported by Kendall and Webster [29] THI= (1.8 * AT + 32) - ((0.55 - 0.0055 * RH) x (1.8 * AT - 26)).

The monthly average temperature and THI is showed in Figure 1. To investigate the effect of the THI on reproductive performance, the cows in all genotypes were grouped according to the monthly average of THI into one of following conditions. The mild conditions include the months with THI average less than 70 (December, January, February and March). The moderate conditions include the months with THI average over 70 and less than 75 (November and April). The high conditions include the months with THI average over 80 and up to 85 (September, October, May and June). Due to prolonged experience with very low conception rate during the period with monthly THI average over 85 (July and August), the insemination was stopped during this period.

Milk Yield: All the cows included in the current study were in the first to the fourth milk season. The 305 days actual milk yield (305-DMY), the actual total milk yield (total-MY) and the peak milk yield (Peak-MY) were recorded for all crosses and pure breed cows. Only complete milk season (305 days or more) were included. The actual 305-DMY is referred to the amount of milk given during the first 305 days postpartum without any correction equation. The actual total-MY is referred to the amount of milk given from parturition till drying. The number of milk season records for HO, BS, BH, HB were 2800, 200, 100, 103; respectively.

Statistical Analyses: Data were analyzed using SAS statistical system package [30]. Least squares means were tested for significance using one way ANOVA. The differences in conception, pregnancy and embryonic loss rate percentages were tested for significant difference using Chi- square. Significant results were followed by multiple Z-tests to compare corresponding proportions. P-value for all pairwise comparisons was adjusted using the Bonferroni correction. Heterosis or hybrid vigor was estimated for different traits in both crossbreds according to the genetic model of Dickerson [31].

RESULTS

Reproductive Performance

General Reproductive Performance: During the period of the study, pure HO and BS cows-HB and BH crossbred cows received 3000,528,282 and 321 inseminations; respectively. The pregnancy/AI 30 and 75 of the pure BS cows (38.4 and 33.3; respectively) were significantly higher than pure HO cows (28.2 and 23.2; respectively) but the embryonic loss was similar in the both breeds. The pregnancy/AI 30 (34.6 and 37.5) and the pregnancy/AI 75 (33.1 and 35.2) rate of HB and BH crossbred cows respectively were similar to those recorded in pure BS cows but higher than those recorded in pure HO cows. The embryonic loss rate of the crossbred cows was numerically and statistically lower than that of pure BS and HO cows; respectively (Table 1).

The calving interval of pure BS cows and BH crossbred cows (405 and 414; respectively) was significantly shorter than pure HO cows (433) but the calving interval of the HB crossbred cows tended to be shorter than pure HO cows (P= 0.085). The days open of the pure BS cows was significantly shorter than that of

Table 1: Pregnancy per AI 30 and 75 and embryonic loss in different genotypes

Genotype	Insemination number	Pregnancy/AI 30	Pregnancy/AI 75	Embryonic loss (%)
HO	3000	28.2^{b}	23.2^{b}	19.4 ^{a}
BS	528	38.4^{a}	33.3^{a}	13.2 ^{ab}
HB	282	34.6^{ab}	33.1^{a}	4.3 ^{b}
BH	321	37.5^{a}	35.2^{a}	6.1 ^{b}

Values with different superscripts in the same column are significantly different (p<0.05)

HO: Pure Holstein

BS: Pure Brown Swiss

HB : Crossbred cows originated from Holstein sire x Brown Swiss cow.

BH: Crossbred cows originated from Brown Swiss sire x Holstein cow.

Table 2: The calving interval, days open and average insemination per parturition in different genotypes (mean ± SE).

Genotype	Calving interval (days)	Days open	Average insemination /parturition
HO	433 ± 1.9 ^{a}	158 ± 1.89 ^{a}	3.54 ± 0.04^{a}
BS	405 ± 7.12^{b}	123 ± 7.19 ^{b}	2.92 ± 0.19^{b}
HB	417 ± 12.74^{ab}(- 0.4)*	142 ± 12.92 ^{ab} (1.1)*	3.37 ± 0.44 ^{a} (4.3)*
BH	414 ± 10.20 ^{b} (-1.3)*	139 ± 10.26 ^{ab} (- 1.0)*	2.96 ± 0.34 ^{b} (-8.4)*

Values with different superscripts in the same column are significantly different (p<0.05)

HO: Pure Holstein

BS: Pure Brown Swiss

HB : Crossbred cows originated from Holstein sire x Brown Swiss cow.

BH: Crossbred cows originated from Brown Swiss sire x Holstein cow.

*Heterosis percentage for each traits in different crosses are shown between practice

the pure HO cows (123 and 158; respectively). The days open of HB and BH crossbred cows were 16 and 19 days shorter than that of the pure HO cows (P= 0.067). The average insemination per parturition in the pure BS cows and the BH crossbred cows (2.92 and 2.96; respectively) was significantly lower than in the pure HO cows and the HB crossbred cows (3.54 and 3.37; respectively). In comparison to the average of the pure breeds, the heterosis percentages for the BH crossbred cows indicated improvement in all traits but that of the HB crossbred cows indicated improvement in the calving interval and retardation in the days open and the insemination per parturition (Table 2).

Effect of THI on Reproductive Performance of Different Genotypes: At low THI, the pregnancy/AI 30 were similar for all genotypes and the pregnancy/AI 75 and the embryonic loss rate in the BH crossbred cows (42.3 and 2.3; respectively) was significantly different from that recorded in the pure HO cows (29.3 and 17.8; respectively). At moderate THI, the pregnancy/AI 30 were similar for all genotype and the pregnancy/AI 75 of the pure BS cows and the BH crossbred cows (34.1 and 38.2; respectively) was significantly higher than that recorded in the pure HO cows (21.9). At high THI the pregnancy/AI 30 in the pure BS, the HB and the BH crossbred cows (36.7, 23.7 and 24.4; respectively) was higher than that of the HO cows (16.2) and the difference reached a significant level when comparing the pure BS with the pure HO. Additionally, the pregnancy/AI 75 in the pure BS and the HB crossbred cows (29.2 and 23.6; respectively) was significantly higher than in the pure HO cows (11.9). Moreover, the pregnancy/AI 75 in the BH crossbred cows was 6% above that recorded in pure HO cows (Table 3).

The pregnancy/AI 30 and 75 in the pure BS cows were not affected by the level of the THI. Otherwise the pregnancy/AI 30 and 75 of the pure HO cows were greatly adversely affected by higher THI level. In comparison to the low THI, the moderate THI did not affect the pregnancy/AI 30 and 75 in the BH crossbred cows but the high level did. In the HB crossbred cows, the moderate THI slightly retard the pregnancy/AI 30 but significantly affect the pregnancy/AI 75 but the high THI adversely affect the pregnancy/AI 30 and 75 (Table 3).

Milk Yield: The pure HO and BH crossbred cows had significantly higher 305-DMY (9175 and 9141 kg; respectively) than the pure BS cows (7538 kg) and the HB crossbred cows (8454 kg). The BH crossbred cows gave significantly higher 305-DMY than the pure BS cows. The total-MY were significantly different among all genotypes with the pure HO cows gave the highest amount and the pure BS cows gave the lowest one. The peak-MY was comparable among the pure HO, the HB and the BH crossbred cows otherwise the pure BS

Table 3: Effect of the temperature humidity index (THI) on pregnancy/ AI 30 and 75 and embryonic loss rate in different genotypes.

Genotype	Pregnancy/AI 30			Pregnancy/AI 70			Embryonic loss (%)		
THI	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
HO	35.7 ^{A}	27.3 ^{B}	16.2 ^{bcC}	29.3 $^{b\,A}$	21.9 $^{b\,B}$	11.9 $^{b\,C}$	17.8 $^{a\,B}$	19.7 $^{a\,B}$	26.2 $^{a\,A}$
BS	40.1	36.5	36.7 ^{a}	34.8 ^{ab}	34.1 ^{a}	29.2 ^{a}	13.1 ^{a}	6.4 ^{ab}	20.7 ^{a}
HB	43.1 ^{A}	26.9 ^{AB}	23.7 $^{ab\,B}$	41.6 $^{ab\,A}$	23.1 $^{ab\,B}$	23.6 $^{a\,B}$	3.2 ^{ab}	14.3 ^{a}	0.0 ^{b}
BH	43.3 ^{A}	38.3 ^{A}	24.4 $^{ab\,B}$	42.3 $^{a\,A}$	38.2 $^{a\,A}$	17.8 $^{ab\,B}$	2.3 $^{b\,B}$	0.0 $^{b\,B}$	27.3 $^{a\,A}$

Values with different superscripts (a,b) in the same column are significantly different and values with different superscripts (A,B) in the same row within the same comparison item (conception, pregnancy and embryonic loss) are significantly different ($p<0.05$).

Low: THI less than 70

Moderate: THI is over 70 and less than 75

High: THI above 80 and up to 85

HO: Pure Holstein

BS: Pure Brown Swiss

HB : Crossbred cows originated from Holstein sire x Brown Swiss cow.

BH: Crossbred cows originated from Brown Swiss sir x Holstein cow.

Table 4: Milk yield in different genotypes (mean ± SE)

Genotype	305-DMY	Total- MY	Peak- MY
HO	9175 ± 358 ^{a}	10702 ± 66 ^{a}	45 ± 0.18 ^{a}
BS	7538 ± 121 ^{c}	8517 ± 183 ^{d}	36 ± 0.66 ^{b}
HB	8454 ± 249 ^{b}(1.2)*	9216 ± 336 ^{c} (-4.1)*	42 ± 2.53 ^{a} (4.5)*
BH	9141 ± 196 ^{a}(9.4)*	10028 ± 298 ^{b} (4.4)*	45 ± 1.73 ^{a} (10.8)*

Values with different superscripts in the same column are significantly different at level ($p<0.05$)

HO: Pure Holstein

BS: Pure Brown Swiss

HB : Crossbred cows originated from Holstein sire x Brown Swiss cow.

BH: Crossbred cows originated from Brown Swiss sire x Holstein cow.

*Heterosis percentage for each traits in different crosses are shown between practice

305-DMY: The amount of milk given during the first 305 days postpartum without any correction equation

Total-MY: The amount of milk given from parturition till drying

Peak-MY: The highest amount given by the cow in one day

cows had a significantly lower peak-MY. In comparison to the mean of the pure parents, the Heterosis percentages for all traits in both crosses indicated improvement in all traits except for total milk yield in the BH crossbred cows (Table 4).

DISCUSSION

Except for December, January, February and March the Egyptian climatic conditions are considered to be stressful for the pure HO cows. Therefore, out of the previously mentioned months the fertility of the pure HO is greatly retarded. In the current study the BH and the HB crossbred cows showed better fertility especially during the months characterized by high THI. In the same time the milk yield of the BH crossbred is comparable to that of the pure HO.

Better fertility of the pure BS cows recorded in current study is in agreement with Ruvuna *et al.* [32] but it is in disagreement with Dechow *et al.* [7] who reported similar days open for the pure HO and the pure BS cows. However, the pure BS cows showed lower productivity which is in agreement with Gergovska *et al.* [33] and De Marchi *et al.* [34]. Because both breeds are reared under the same environmental and managerial conditions, these differences may be refereed mainly to genetic characteristic.

In contrast to the pure HO cows, fertility of the pure BS cows did not affected by the level of the THI. This indicates higher heat stress tolerance. Similar findings were previously reported [32, 35, 36]. Otherwise, Lacetera *et al.* [37] reported that peripheral blood mononuclear cells from the pure BS cows are less tolerant to chronic heat exposure than those from the pure HO cows. The effect of heat stress on reproduction occurs at different stages beginning from folliculogenesis, steriodogenic activity of the follicle, quality of the oocytes, steroidogenic activity of the corpus luteam, embryo survival, secretory activity of endometrium [15, 17]. At stressful environment, the ability of the cow to maintain its body temperature in a thermoneutral zone and in a physiological homeostasis is depend on its ability to dissipate heat to the environment and to decrease the heat gain from surrounding environment [38]. The heat increment is depending on the food intake and the metabolic rate while the heat dissipating ability is affected by the surface area, the character of the hair coat, the number of sweat glands and the fat distribution [16]. Moreover, presence of a special mechanism that resulted in genes controlling the resistance to cellular heat shock was suggested [39]. From all of the above, it is clear that the pure BS has one or more of the previously mentioned mechanisms that make them more tolerant to heat stress.

In comparison to the pure HO cows, better fertility recorded in BH crossbred is in agreement with previous reports [7-9]. The days open for the pure HO cows and the BH crossbred cows recorded in the current study are comparatively longer than that reported by Blöttner *et al*. [8] but it is comparable to that reported by Dechow *et al*. [7]. This may be due to different managerial and environmental conditions in which the experiments were carried out or due to the fact that Dechow *et al.* [7] and Blöttner *et al.* [8] set the maximum days open to 250 days but in our study we used the actual data without any modification. The number of services recorded in the current study for the pure HO cows and HB crossbred is comparatively higher than that recorded by Blöttner *et al*. [8]. This may be due to that Blöttner *et al.* [8] calculated the number of services per conception and set the maximum number of services to 6 but in the current study we calculated the number of services per parturition and used the actual data without any modification. Better fertility of the BH crossbred is accompanied with comparable milk yield which is in agreement with previous reports [7, 14]. The only difference in the milk yield between the BH crossbred and the pure HO cows appeared in the total-MY. This mostly may be due to lower fertility in the pure HO cows that resulted in longer days in milk. The fertility of the HB crossbred cows was better than pure HO cows which is in agreement with Ruvuna *et al.* [32], while the milk yield was lower than that of pure HO cows which is in disagreement with Ruvuna *et al.* [32].

Both crossbreds investigated in the current study showed better fertility than the pure HO cows either at moderate or high THI. Different temperate crosses showed better performance than the pure HO during the warm season [32]. Cross breeding pure HO with local breed resulted in a cross that had higher ability to accommodate with heat stress and this ability decreased when crossbreds have higher than 87.5% HO genetics [23]. The results of the current study indicate that using the pure BS as a sire or dam will improve the heat stress tolerance ability of the cross in the same way.

In the cross breeding system, using a breed as a sire or a dam may influence the characteristic of the cross. The heterosis percentages for the BH crossbred indicate improvement in all reproductive traits and milk yield. This is in agreement with Dechow *et al.* [7]. The heterosis percent recorded in the current study is different form that recorded by Dechow *et al.* [7]. Environment with low nutrition or high heat load index found to greatly suppress the heterosis [26]. The positive effect of hetrosis arises from allelic interactions between parental genomes, leading to altered programming of genes that promote the performance of the hybrids [40]. Heterosis percentages for the HB crossbred indicate improvement of the 305-DMY and the peak-MY by a lower percentage than that in the BH crossbred. This indicates that using the pure HO as dam greatly improved the milk yield ability of the cross than using the pure HO as a sire. The heterosis percentages of the HB crossbred indicate little improvement in the calving interval and retardation in the days open and the average insemination per parturition. The negative effect of heterosi is caused by separation of favorable gene combinations that are accumulated in the parental breeds or recombination effect. Genetic analysis is required to understand and explain the different performance of the BH and HB crossbreds.

In conclusion, crossbreeding the pure BS sires with the pure HO dams and vise versa resulted in crosses that have higher fertility and higher adaptability to Egyptian subtropical environment. The BH crossbred cows has the advantage that it produce comparable milk yield to the pure HO cows.

Conflict of Interest Statement: None of the authors have any conflict of interest to declare.

Author Contributions: Both authors have been involved in designing the study, analyzing the data and drafting the manuscript.

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REFERENCES

1. Hansen, L.B., 2000. Consequences of selection for milk yield from a geneticist's viewpoint. J. Dairy Sci., 83: 1145-1150.
2. Lucy, M.C., 2001. Reproductive loss in high-producing dairy cattle: where will it end. J. Dairy Sci., 84: 1277-1293.
3. Butler, S.T., 2013. Genetic control of reproduction in dairy cows. Reprod. Fertil. Dev., 26: 1-11.
4. Buckley, F., N. Lopez-Villalobos and B.J. Heins, 2014. Crossbreeding: implications for dairy cow fertility and survival. Animal, 8(Suppl. 1): 122-133.
5. Van Raden, P.M. and A.H. Sanders, 2003. Economic merit of crossbred and purebred US dairy cattle. J. Dairy Sci., 86: 1036-1044.
6. McAllister, A.J., 2002. Is crossbreeding the answer to questions of dairy breed utilization. J. Dairy Sci., 85: 2352-2357.
7. Dechow, C.D., G.W. Rogers, J.B. Cooper, M.I. Phelps and A.L. Mosholder, 2007. Milk, fat, protein, somatic cell score and days open among Holstein, Brown Swiss and Their Crosses. J. Dairy Sci., 90: 3542-3549.
8. Blöttner, S., B.J. Heins, M. Wensch-Dorendorf, L.B. and H.H. Swalve, 2011. Brown Swiss × Holstein crossbreds compared with pure Holsteins for calving traits, body weight, back fat thickness, fertility and body measurements. J. Dairy Sci., 94: 1058-1068.
9. Schaeffer, L.R., E.B. Burnside, P. Glover and J. Fatehi, 2011. Crossbreeding results in Canadian dairy cattle for production, reproduction and conformation. The Open Agriculture Journal, 5: 63-72.
10. Heins, B.J., L.B. Hansen and A.J. Seykora, 2006. Fertility and survival of pure Holsteins versus crossbreds of Holstein with Normande, Montbeliarde and Scandinavian Red. J. Dairy Sci., 89: 4944-4951.
11. 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.
12. Heins, B.J., L.B. Hansen, A.R. Hazel, A.J. Seykora, D.G. Johnson and J.G. Linn, 2012. Short communication: Jersey × Holstein crossbreds compared with pure Holsteins for body weight, body condition score, fertility and survival during the first three lactations. J. Dairy Sci., 95: 4130-4135.
13. de Haas, Y., E.A. Smolders, J.N. Hoorneman, W.J. Nauta and R.F. Veerkamp, 2013. Suitability of cross-bred cows for organic farms based on cross-breeding effects on production and functional traits. Animal, 7: 655-665.
14. Blöttner, S., B.J. Heins, M. Wensch-Dorendorf, L.B. Hansen and H.H. Swalve, 2011. Short communication: A comparison between purebred Holstein and Brown Swiss × Holstein cows for milk production, somatic cell score, milking speed and udder measurements in the first 3 lactations. J. Dairy Sci., 94: 5212-5216.
15. Wolfenson, D., Z. Roth and R. Meidan, 2000. Impaired reproduction in heat-stressed cattle: basic and applied aspects. Anim. Reprod. Sci., 60-61: 535-547.
16. Kadzere, C.T., M.R. Murphy, N. Silanikove and E. Maltz, 2002. Heat stress in lactating dairy cows: a review. Livestock Prod. Sci., 77: 59-91.
17. De Rensis, F. and R.J. Scaramuzzi, 2003. Heat stress and seasonal effects on reproduction in the dairy cow- a review. Theriogenology, 60: 1139-1151.
18. West, J.W., 2003. Effects of heat stress on production in dairy cattle. J. Dairy Sci., 86: 2131-2144.
19. Boni, R., L.L. Perrone and S. Cecchini, 2014. Heat stress affects reproductive performance of high producing dairy cows bred in an area of southern Apennines. Livestock Science, 160: 172-177.
20. Schüller, L.K., O. Burfeind and W. Heuwieser, 2014. Impact of heat stress on conception rate of dairy cows in the moderate climate considering different temperature- humidity index thresholds, periods relative to breeding and heat load indices. Theriogenology, 81: 1050-1057.
21. Berman, A., 2011. Invited review: Are adaptations present to support dairy cattle productivity in warm climates. J. Dairy Sci., 94: 2147-2158.
22. Kadokawa, H., S M. Akatani and P.J. Hansen, 2012. Perspectives on improvement of reproduction in cattle during heat stress in a future Japan. Animal Science Journal, 83: 439-445.
23. Boonkum, W., I. Misztal, M. Duangjinda, V. Pattarajinda, S. Tumwasorn and S. Buaban, 2011. Short communication: Genetic effects of heat stress on days open for Thai Holstein crossbreds. J. Dairy Sci., 94: 1592-1596.

24. Mellado, M., F. Coronel, A. Estrada and F.G. Ríosb, 2011. Lactation performance of Holstein and Holstein X Gyr cattle under intensive conditions in a subtropical environment. Tropical and Subtropical Agroecosystems, 14: 927-931.
25. Hailu, A., 2013. Cross breeding effect on milk productivity of Ethiopian indigenous cattle: Challenges and opportunities. Scholarly Journal of Agricultural Science, 3: 515-520.
26. Bryant, J.R., N. Lo´pez-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.
27. Kargo, M., P. Madsen and E. Norberg, 2102. Short communication: Is crossbreeding only beneficial in herds with low management level. J. Dairy Sci., 95: 925-928.
28. NRC., 2001. National Research Council. Nutrient Requirements of Dairy Cattle: Seventh Revised Edition, 2001. Washington, DC: The National Academies Press.
29. Kendall, P.E. and J.R. Webster, 2009. Season and physiological status affects the circadian body temperature rhythm of dairy cows. Livestock Sci., 125: 155-160.
30. SAS., 2002. SAS/STAT users guide. SAS Institute INC, Cary, NC 27513, USA.
31. Dickerson, G.E., 1969. Experimental approaches in utilizing breed resources. Animal Breeding Abstract, 37: 191-202.
32. Ruvuna, F., B.T. McDaniel, R.E. McDowell, J.C. Jr. Johnson, B.T. Hollon and G.W. Brandt, 1983. Crossbred and purebred dairy cattle in warm and cool seasons. J. Dairy Sci., 66: 2408-2417.
33. Gergovska, Z., J. Mitev, T. Angelova, D. Yordanova and T. Miteva, 2011. Effect of changes in body condition score on the milk yield of Holstein-Friesian and Brown Swiss cows. Bulg. J. Agric. Sci., 17: 837-845.
34. De Marchi, M., G. Bittante, R. Dal Zotto, C. Dalvit and M. Cassandro, 2008. Effect of Holstein Friesian and Brown Swiss breeds on quality of milk and cheese. J. Dairy Sci., 91: 4092-4102.
35. Badinga, L., R.J. Collier, W.W. Thatcher and C.J. Wilcox, 1985. Effects of climatic and management factors on conception rate of dairy cattle in subtropical environment. J. Dairy Sci., 68: 78-85.
36. Correa-Calderon, A., D.V. Armstrong, D.E. Ray, S.K. DeNise, R.M. Enns and C.M. Howison, 2005. Productive and reproductive response of Holstein and Brown Swiss heat stressed cows to different cooling system. J. Anim. Vet. Adv., 6: 572-578.
37. Lacetera, N., U. Bernabucci, D. Scalia, L. Basirico, P. Morera and A. Nardone, 2006. Heat stress elicits different responses in peripheral blood mononuclear cells from Brown Swiss and Holstein Cows. J. Dairy Sci., 89: 4606-4612.
38. Maia, A.S.C., R.G. daSilva and C.M. Battiston Loureiro, 2005. Sensible and latent heat loss from the body surface of Holstein cows in a tropical environment. Int. J. Biometeorol, 50: 17-22.
39. Paula-Lopes, F.F., C.C. Chase Jr, Y.M. Al-Katanani, C.E. Krininger, C.E. Rivera, R.M. Tekin, S. Majewski, A.C. Ocon, O.M. Olson and T.A. Hansen, 2003. Genetic divergence in cellular resistance to heat shock in cattle: differences between breeds developed in temperate versus hot climates in responses of preimplantation embryos, reproductive tract tissues and lymphocytes to increased culture temperatures. Reproduction, 125: 285-294.
40. Chen, Z.J., 2013. Genomic and epigenetic insights into the molecular bases of heterosis. Nat. Rev. Genet., 14: 471-482.