Interbull Routine Genetic Evaluation for Females Fertility Traits

August 2014

Introduction

The latest routine international evaluation for females fertility traits took place as scheduled at the Interbull Centre. Data from seventeen (18) countries were included in this evaluation.

International genetic evaluations for female fertility traits of bulls from Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Netherlands, New Zealand, Norway, Poland, Spain, Sweden, Switzerland, South Africa, the United Kingdom and the United States of America were computed. Brown Swiss, Guernsey, Holstein, Jersey, Red Dairy Cattle and Simmental breed data were included in this evaluation.

Based on a decision made by Interbull Steering committee in August 2007, female fertility traits are classified as follows:

T1 (HC): Maiden (H)eifer's ability to (C)onceive. A measure of confirmed conception, such as conception rate (CR), will be considered for this trait group. In the absence of confirmed conception an alternative measure, such as interval first-last insemination (FL), interval first insemination-conception (FC), number of inseminations (NI), or non-return rate (NR,preferably NR56) can be submitted;

T2 (CR): Lactating (C)ow's ability to (R)ecycle after calving. The interval calving-first insemination (CF) is an example for this ability. In the abscence of such a trait, a measure of the interval calving-conception, such as says oprn (DO) or calving interval (CI) can be submitted;

T3 (C1): Lactating (C)ow's ability to conceive (1), expressed as a rate trait. Traits like conception rate (CR) and non-return rate (NR, preferably NR56) will be considered for this trait group;

T4 (C2): Lactating (C)ow's ability to conceive (2), expressed as an interval trait. The interval first insemination-conception (FC) or interval first-last insemination (FL) will be considered for this trait group. As an alternative, number of inseminations (NI) can be submitted. In the abscence of any of these traits, a measure of interval calving-conception such as days open (DO), or calving interval (CI) can be submitted. All countries are expected to submit data for this trait group, and as a last resort the trait submitted under T3 can be submitted for T4 as well.

T5 (IT): Lactating cow's measurements of (I)nterval (T)raits calving-conception, such as days open (DO) and calving interval (CI).

Based on the above trait definitions the following traits have been submitted for international genetic evaluation of female fertility traits.

Country	Traits	Submitted traits and their definitions
AUS	T2=CY	Calving interval converted to 42 days pregnancy rate
	T4=C2	Calving interval converted to 42 days pregnancy rate
	T5=IT	Calving interval converted to 42 days pregnancy rate
BEL	T2=CY	PR=Pregnancy Rate (=[21/(DO-45+11)]*100, with DO=days open)
	T4=C2	PR=Pregnancy Rate (=[21/(DO-45+11)]*100, with DO=days open)
	T5=IT	PR=Pregnancy Rate (=[21/(DO-45+11)]*100, with DO=days open)
CAN	T1=HC	NR=Non Return Rate after 56 Days in heifers (NRR), %
	T2=CY	CF=Interval from Calving to First Service in cows(CF)
	T3=C1	NR=Non Return Rate after 56 Days in cows(NRR), %
	T4=C2	FC=Interval first insemination-conception in cows
	T5=IT	DO=Days open
CHE	T2=CR	CF=Interval from Calving to First Service (ICF), days
	T3=C1	NR=Non Return Rate after 56 Days (NRR), %
	T4=C2	NR=Non Return Rate after 56 Days (NRR), %
CHR	T2=CR	CF=Interval from Calving to First Service (ICF), days
	T3=C1	NR=Non Return Rate after 56 Days (NRR), %
	T4=C2	NR=Cows' Non Return Rate after 56 Days (NRR), binary
CZE	T1=HC	CR=Heifers' Conception rate (pregnant or not after 3 months)
	T3=C1	CR=Cows' Conception rate (pregnant or not after 3 months)
	T4=C2	CR=Cows' Conception rate (pregnant or not after 3 months)
AUT/DEU	T1=HC	NR=Heifers' Non Return Rate after 56 days
	T2=CY	CF=Interval from calving to first insemination cows (days)
	T3=C1	NR=Cows' Non Return Rate after 56 days
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	DO=Days open (days)
DFS	T1=HC	NR=Heifers' Non Return Rate after 56 days
	T2=CY	CF=Interval from calving to first insemination cows (days)
	T3=C1	NR=Cows' Non Return Rate after 56 days
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	DO=Days open (days)
ESP	T2=CY	DO=Days open
	T4=C2	DO=Days open

	T5=IT	DO=Days open
FRA	T1=HC	CR=Heifers' Conception rate (binary trait) for maiden heifers
	T2=CY	Interval between calving and first AI
	T3=C1	CR=Cows' Conception rate (binary trait) for cows
	T4=C2	CR=Cows' Conception rate (binary trait) for cows
GBR	T2=CY	CI=days between 1st and 2nd calvings
	T3=C1	NR=1st lactation non return at 56 days
	T4=C2	CI=days between 1st and 2nd calvings
	T5=IT	CI=days between 1st and 2nd calvings
IRL	T2=CY	CI=Calving interval
	T4=C2	CI=Calving interval
	T5=IT	CI=Calving interval
ISR	T3=C1	CR=Inverse of the number of insemination to conception (%)
	T4=C2	CR=Inverse of the number of insemination to conception (%)
ITA	T2=CY	CF=Days to first service
	T3=C1	NR=Non-return rate at 56 days (%)
	T4=C2	CI=Calving Interval (days)
	T5=IT	CI=Calving interval (days)
ITA(BSW)	T2=CY	CF=Interval calving to first insemination
	T4=C2	Days Open
	T5=IT	CI=Calving interval
NLD	T2=CY	CF=Interval calving to first insemination (days)
	T3=C1	NR=Non-return rate 56 days (binary trait)
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	CI=Calving Interval (days)
NOR	T1=HC	NR=NR=Non-return rate 56 days (heifers)
	T2=CY	CF=Interval calving to first insemination (days)
	T3=C1	NR=NR=Non-return rate 56 days (cows)
	T4=C2	CI=Calving Interval (days)
	T5=IT	CI=Calving Interval (days)
NZL	T2=CY	PM=Lactating cow's ability to start cycling
	T4=C2	PC=Lactating cow's ability to conceive (CR42)
	T5=IT	PC=Lactating cow's ability to conceive (CR42)
POL	T1=HC	Non return rate at 56 days for heifer
	T2=CR	Interval from calving to first insemination
	T3=C1	Non return rate at 56 days for cows
	T4=IT	Days open

	T5=IT	Days open
USA	T1=HC	CR=Conception rate (heifer)
	T2=CY	CF=Interval from calving to first insemination
	T3=C1	CR=Conception rate (cow)
	T4=C2	DP=Daughter Pregnancy Rate
	T5=IT	DP=Daughter Pregnancy Rate
ZAF	T4=IT	CI=Calving Interval
	T5=IT	CI=Calving Interval

CHANGES IN NATIONAL PROCEDURES

Changes in the national genetic evaluation of female fertility traits are as follows:

NOR (RDC): The rolling definition of hys is causing the daughters to distribute somewhat differently over hys-classes at each evaluation. Therefore some bulls occasionally may loose EDC although the number of daughters stay the same.

GBR (ALL): Base change

DEU (HOL): There is no longer a distintion nationally between 1st and 2nd crop of daughters (as conseuencs of genomically proven bulls), thus type of proof is either 11 (German bull) or 21 (foreign bull), there are quite a number of bulls mentioned as "missing", however most of these appear now with another (correct) ID, these are mostly danish bulls

CHE (BSW): Implemented the changes tested in January. New traits are NR56 heifers (hco), interval between first and last insemination (cc2). In previous runs NR56 cows was submitted for both cc1 and cc2. New genetic parameters (h2 and rg) for all fertility traits were applied. New restriction for first insemination records of cows to be included in the evaluation. Therefore, a lot of bulls loose daughters/edc/herds, change in reliabilities of proofs and change from official to unofficial, and are even not included any more in the evaluation.

INTERBULL CHANGES COMPARED TO THE DECEMBER ROUTINE RUN

No changes.

DATA AND METHOD OF ANALYSIS

Data were national genetic evaluations of AI sampled bulls with at least 10 daughters or 10 EDC (for clinical mastitis and maternal calving traits at least 50 daughters or 50 EDC, and for direct calving traits at least 50 calvings or 50 EDC) in at least 10 herds. Table 1 presents the amount of data included

in this Interbull evaluation for all breeds.

National proofs were first de-regressed within country and then analysed jointly with a linear model including the effects of evaluation country, genetic group of bull and bull merit. Heritability estimates used in both the de-regression and international evaluation were as in each country's national evaluation.

Table 2 presents the date of evaluation as supplied by each country in the 01x-proof file.

Estimated genetic parameters and sire standard deviations are shown in APPENDIX I and the corresponding number of common bulls are listed in APPENDIX II.

SCIENTIFIC LITERATURE

The international genetic evaluation procedure is based on international work described in the following scientific publications:

International genetic evaluation computation:
- Schaeffer. 1994. J. Dairy Sci. 77:2671-2678
- Klei, 1998. Interbull Bulletin 17:3-7

Verification and Genetic trend validation:
- Klei et al., 2002. Interbull Bulletin 29:178-182.
- Boichard et al., 1995. J. Dairy Sci. 78:431-437

Weighting factors:
- Fikse and Banos, 2001. J. Dairy Sci. 84:1759-1767

De-regression:
- Sigurdsson and G. Banos. 1995. Acta Agric. Scand. 45:207-219
- Jairath et al. 1998. J. Dairy Sci. Vol. 81:550-562

Genetic parameter estimation:
- Klei and Weigel, 1998, Interbull Bulletin 17:8-14
- Sullivan, 1999. Interbull Bulletin 22:146-148

Post-processing of estimated genetic correlations:
- Mark et al., 2003, Interbull Bulletin 30:126-135
- Jorjani et al., 2003. J. Dairy Sci. 86:677-679
- https://wiki.interbull.org/public/rG%20procedure?action=print

Time edits
- Weigel and Banos. 1997. J. Dairy Sci. 80:3425-3430

International reliability estimation
Harris and Johnson. 1998. Interbull Bulletin 17:31-36

NEXT ROUTINE INTERNATIONAL EVALUATION

The next routine evaluation of Interbull for production, conformation, udder health, longevity, calving, female fertility and workability traits is scheduled for November 2014. Deadline for sending data to the Interbull Centre is Tuesday November 11, 2014, 17:00 CET; confidential distribution of results is targeted for Thursday 20 Nov, 2014, with earliest possible official release of results on November 2, 2014. Please remark the three week turn around time.

NEXT TEST INTERNATIONAL EVALUATION

The next test run for production, conformation, udder health, longevity, calving, female fertility and workability traits will take place in September 2014.

Countries planning to introduce changes in their national evaluation procedures and wishing to have them included in the routine Interbull evaluation, should have their data examined in this test run. New data and validation results should be sent to the Interbull Centre no later than September 2, 2014, 17:00 CET.

PUBLICATION OF INTERBULL TEST RUN

Test evaluation results are meant for review purposes only and should not be published.

^LTable 1. National evaluation data considered in the Interbull
evaluation for fertility (August Routine Evaluation 2014).
Number of records for lactating cow's ability to conceive (cc2) by breed

Country	BSW	GUE	HOL	JER	RDC	SIM
ARG						
AUS		112	6823	1398	567	
BEL			957			
CAN	112	34	6759	321	403	
CHE	2432		1129			
CHR			1666			
CZE			3118			
DEA	4819					
DEU			22638		300	
DFS			11629	2158	8010	
ESP			2502			
EST						
FRA	297		14274			
FRM						
FRR			127			
GBR	66	195	5327	448	284	
HUN						
IRL			2135	103	41	
ISR			1118			
ITA	1384		8440			
JPN						
KOR						
LTU						
LVA						
NLD	137		13087	110	49	
NOR					3424	
NZL	39	55	6234	3849	1115	
POL			4961			
PRT						
SVK						
SVN						
URY						
USA	919	692	31925	3576	563	
ZAF		31	1096	613	134	
No.Records	10205	1119	145945	12576	14890	
Pub. Proofs	9732	934	126196	10616	13851	0

^LAPPENDIX I. Sire standard deviations in diagonal and genetic correlations below diagonal

BSW hco

	CAN	DEA	FRA	USA	CHE
CAN	8.37				
DEA	0.84	11.79			
FRA	0.64	0.63	0.94		
USA	0.68	0.79	0.82	3.06	
CHE	0.77	0.91	0.86	0.79	12.83

BSW crc

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	7.04								
CHE	0.87	11.00							
DEA	0.86	0.94	14.68						
NLD	0.87	0.89	0.87	3.19					
NZL	0.55	0.58	0.54	0.56	9.88				
USA	0.86	0.86	0.89	0.86	0.56	3.48			
GBR	0.78	0.82	0.84	0.81	0.61	0.87	4.24		
FRA	0.87	0.96	0.91	0.91	0.57	0.86	0.82	1.69	
ITA	0.86	0.86	0.85	0.87	0.62	0.87	0.84	0.88	14.63

BSW cc1

	CAN	CHE	DEA	NLD	USA	GBR	FRA
CAN	7.32						
CHE	0.73	11.79					
DEA	0.80	0.96	11.54				
NLD	0.68	0.73	0.63	3.80			
USA	0.66	0.58	0.56	0.56	3.02		
GBR	0.61	0.77	0.74	0.73	0.57	0.04	
FRA	0.62	0.60	0.55	0.57	0.92	0.64	0.95

BSW cc2

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	6.51								
CHE	0.65	10.87							
DEA	0.85	0.72	13.51						
NLD	0.85	0.61	0.86	3.50					
NZL	0.52	0.38	0.51	0.50	7.06				
USA	0.76	0.50	0.89	0.84	0.59	1.69			
GBR	0.70	0.45	0.79	0.76	0.65	0.85	4.24		
FRA	0.74	0.72	0.83	0.72	0.40	0.77	0.68	0.95	
ITA	0.73	0.40	0.82	0.78	0.61	0.90	0.87	0.60	16.44

BSW int

	CAN	DEA	NLD	NZL	USA	GBR	ITA
CAN	6.44						
DEA	0.86	11.45					
NLD	0.87	0.87	3.43				
NZL	0.64	0.61	0.61	7.06			
USA	0.87	0.87	0.88	0.61	1.69		
GBR	0.86	0.87	0.89	0.63	0.85	4.24	
ITA	0.86	0.92	0.88	0.62	0.89	0.88	15.63

GUE crc

	CAN	GBR	NZL	USA	AUS
CAN	6.99				
GBR	0.74	4.72			
NZL	0.57	0.63	11.40		
USA	0.85	0.87	0.58	3.87	
AUS	0.71	0.86	0.69	0.71	6.99

GUE cc1

	CAN	GBR	USA
CAN	6.87		
GBR	0.65	0.03	
USA	0.77	0.68	3.65

GUE cc2

	CAN	GBR	NZL	USA	ZAF	AUS
CAN	6.95					
GBR	0.71	4.72				
NZL	0.41	0.65	8.17			
USA	0.78	0.86	0.62	1.91		
ZAF	0.75	0.87	0.64	0.90	13.78	
AUS	0.71	0.86	0.73	0.88	0.85	6.82

GUE int

	CAN	GBR	NZL	USA	ZAF	AUS
CAN	6.76					
GBR	0.86	4.72				
NZL	0.60	0.63	8.17			
USA	0.89	0.85	0.62	1.91		
ZAF	0.86	0.87	0.64	0.91	13.78	
AUS	0.86	0.86	0.71	0.88	0.88	6.82

HOL hco

	CAN	CZE	DEU	DFS	FRA	USA	POL	FRR
CAN	7.41							
CZE	0.76	17.72						
DEU	0.87	0.81	4.60					
DFS	0.89	0.83	0.93	17.85				
FRA	0.74	0.83	0.81	0.81	0.85			
USA	0.78	0.91	0.85	0.83	0.93	2.59		
POL	0.70	0.59	0.75	0.70	0.56	0.53	18.23	
FRR	0.71	0.70	0.54	0.65	0.74	0.73	0.57	0.79

HOL crc

	BEL	CAN	CHE	CHR	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	FRA	FRR	AUS
BEL	4.65																
CAN	0.73	6.63															
CHE	0.79	0.89	12.98														
CHR	0.79	0.85	0.96	14.68													
DEU	0.74	0.86	0.91	0.88	5.77												
DFS	0.81	0.88	0.94	0.91	0.91	12.49											
ESP	0.87	0.75	0.78	0.76	0.78	0.77	11.28										
GBR	0.87	0.74	0.76	0.75	0.75	0.80	0.92	4.76									
IRL	0.85	0.70	0.70	0.70	0.70	0.70	0.85	0.85	3.69								
ITA	0.80	0.86	0.91	0.87	0.90	0.91	0.87	0.83	0.70	8.19							
NLD	0.83	0.87	0.93	0.91	0.92	0.94	0.77	0.80	0.70	0.89	4.18						
NZL	0.64	0.57	0.62	0.57	0.55	0.58	0.64	0.63	0.60	0.68	0.56	8.44					
USA	0.86	0.85	0.86	0.85	0.85	0.86	0.88	0.88	0.76	0.88	0.86	0.57	3.39				
POL	0.73	0.87	0.90	0.88	0.85	0.88	0.73	0.71	0.70	0.88	0.85	0.57	0.84	13.69			
FRA	0.77	0.87	0.95	0.91	0.93	0.92	0.80	0.80	0.70	0.92	0.95	0.59	0.85	0.87	1.17		
FRR	0.79	0.89	0.90	0.89	0.94	0.90	0.77	0.78	0.75	0.87	0.94	0.62	0.85	0.86	0.91	1.39	
AUS	0.85	0.70	0.70	0.70	0.70	0.70	0.85	0.85	0.88	0.70	0.70	0.60	0.70	0.69	0.70	0.74	4.93

HOL cc1

	CAN	CHE	CHR	CZE	DEU	DFS	FRA	GBR	ISR	ITA	NLD	USA	POL	FRR
CAN	6.55													
CHE	0.88	13.46												
CHR	0.85	0.96	13.28											
CZE	0.77	0.72	0.74	18.04										
DEU	0.79	0.94	0.95	0.73	5.86									
DFS	0.74	0.85	0.84	0.57	0.88	12.32								
FRA	0.72	0.72	0.68	0.87	0.66	0.54	1.00							
GBR	0.63	0.70	0.72	0.64	0.74	0.71	0.67	0.03						
ISR	0.64	0.67	0.65	0.80	0.62	0.61	0.79	0.68	3.08					
ITA	0.73	0.89	0.88	0.67	0.93	0.84	0.60	0.71	0.67	0.05				
NLD	0.72	0.91	0.88	0.59	0.91	0.89	0.59	0.77	0.66	0.87	3.88			
USA	0.76	0.70	0.68	0.96	0.65	0.53	0.88	0.58	0.87	0.67	0.55	2.87		
POL	0.67	0.79	0.74	0.51	0.77	0.76	0.51	0.57	0.59	0.78	0.77	0.51	17.63	
FRR	0.73	0.67	0.64	0.68	0.54	0.64	0.69	0.66	0.77	0.64	0.58	0.75	0.58	1.07

HOL cc2

	BEL	CAN	CHE	CHR	CZE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	NLD	NZL	USA	POL
ZAF	FRR	AUS															
BEL	4.65																
CAN	0.70	6.14															
CHE	0.26	0.69	13.46														
CHR	0.25	0.62	0.94	13.28													
CZE	0.60	0.80	0.71	0.69	18.04												
DEU	0.78	0.87	0.63	0.61	0.88	5.36											
DFS	0.81	0.85	0.58	0.58	0.78	0.91	13.58										
ESP	0.88	0.70	0.26	0.24	0.65	0.77	0.80	11.28									
FRA	0.62	0.83	0.76	0.66	0.85	0.84	0.72	0.60	1.00								
GBR	0.89	0.70	0.25	0.25	0.60	0.75	0.82	0.92	0.59	4.76							
IRL	0.85	0.70	0.35	0.26	0.64	0.74	0.74	0.85	0.69	0.85	3.69						
ISR	0.43	0.65	0.63	0.56	0.79	0.70	0.59	0.50	0.70	0.46	0.58	3.12					
ITA	0.86	0.73	0.31	0.28	0.73	0.82	0.85	0.95	0.63	0.89	0.85	0.57	18.13				
NLD	0.75	0.85	0.60	0.59	0.82	0.91	0.90	0.77	0.80	0.76	0.79	0.68	0.83	4.26			
NZL	0.70	0.40	0.24	0.24	0.45	0.46	0.45	0.68	0.39	0.66	0.72	0.31	0.64	0.48	5.70		
USA	0.87	0.79	0.39	0.36	0.82	0.88	0.87	0.89	0.76	0.86	0.86	0.64	0.94	0.87	0.60	1.69	
POL	0.83	0.69	0.24	0.21	0.59	0.70	0.75	0.85	0.48	0.84	0.81	0.52	0.88	0.70	0.63	0.83	12.83
ZAF	0.86	0.75	0.40	0.33	0.74	0.85	0.83	0.93	0.72	0.86	0.89	0.67	0.95	0.84	0.65	0.92	0.84
18.52																	
FRR	0.67	0.71	0.58	0.61	0.71	0.84	0.72	0.51	0.66	0.58	0.60	0.65	0.59	0.73	0.39	0.64	0.57
0.61	1.07																
AUS	0.85	0.70	0.36	0.27	0.66	0.70	0.70	0.85	0.72	0.85	0.87	0.57	0.85	0.72	0.69	0.85	0.83
0.88	0.56	4.97															

HOL int

	BEL	CAN	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	ZAF	AUS
BEL	4.65													
CAN	0.85	6.09												
DEU	0.86	0.85	8.17											
DFS	0.88	0.85	0.93	12.78										
ESP	0.87	0.85	0.90	0.86	11.27									
GBR	0.87	0.85	0.86	0.89	0.92	4.76								
IRL	0.85	0.85	0.85	0.85	0.85	0.85	3.69							
ITA	0.85	0.85	0.91	0.89	0.96	0.88	0.85	18.14						
NLD	0.90	0.86	0.93	0.93	0.89	0.89	0.85	0.90	4.52					
NZL	0.64	0.60	0.60	0.60	0.63	0.62	0.66	0.62	0.60	5.70				
USA	0.85	0.89	0.89	0.88	0.89	0.85	0.85	0.92	0.88	0.60	1.69			
POL	0.86	0.85	0.85	0.86	0.86	0.85	0.86	0.87	0.85	0.63	0.85	12.82		
ZAF	0.85	0.85	0.86	0.85	0.94	0.85	0.87	0.95	0.87	0.63	0.92	0.88	18.53	
AUS	0.85	0.85	0.85	0.85	0.85	0.85	0.87	0.85	0.85	0.64	0.85	0.86	0.88	4.96

JER hco

	CAN	DFS	USA
CAN	7.64		
DFS	0.87	17.15	
USA	0.78	0.71	2.73

JER crc

	CAN	DFS	GBR	NLD	NZL	USA	AUS	IRL
CAN	6.40							
DFS	0.87	13.41						
GBR	0.72	0.84	4.06					
NLD	0.87	0.90	0.76	3.37				
NZL	0.52	0.59	0.64	0.54	6.67			
USA	0.85	0.88	0.81	0.86	0.69	2.76		
AUS	0.71	0.71	0.85	0.71	0.60	0.70	3.67	
IRL	0.72	0.71	0.86	0.71	0.60	0.74	0.87	2.06

JER cc1

	CAN	DFS	GBR	NLD	USA
CAN	6.57				
DFS	0.69	14.04			
GBR	0.65	0.59	0.03		
NLD	0.69	0.78	0.68	3.08	
USA	0.67	0.66	0.65	0.54	2.82

JER cc2

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	6.54								
DFS	0.86	17.44							
GBR	0.71	0.75	4.06						
NLD	0.86	0.88	0.75	3.44					
NZL	0.50	0.48	0.69	0.52	4.45				
USA	0.75	0.85	0.85	0.84	0.64	1.42			
ZAF	0.72	0.77	0.86	0.77	0.69	0.90	11.85		
AUS	0.71	0.71	0.85	0.72	0.66	0.85	0.86	3.64	
IRL	0.72	0.74	0.86	0.77	0.64	0.86	0.88	0.87	2.06

JER int

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	6.32								
DFS	0.86	15.17							
GBR	0.85	0.87	4.06						
NLD	0.87	0.90	0.88	3.61					
NZL	0.60	0.62	0.64	0.60	4.45				
USA	0.87	0.86	0.85	0.87	0.63	1.42			
ZAF	0.83	0.82	0.82	0.82	0.75	0.89	11.85		
AUS	0.85	0.86	0.85	0.86	0.66	0.85	0.86	3.64	
IRL	0.86	0.86	0.86	0.86	0.62	0.86	0.87	0.87	2.06

RDC hco

	CAN	DEU	DFS	NOR	USA
CAN	7.06				
DEU	0.85	4.20			
DFS	0.86	0.84	15.03		
NOR	0.83	0.73	0.79	12.89	
USA	0.84	0.83	0.90	0.84	2.94

RDC crc

	CAN	DEU	DFS	GBR	NOR	NZL	USA	NLD	AUS	IRL
CAN	6.36									
DEU	0.87	4.97								
DFS	0.87	0.91	12.93							
GBR	0.73	0.75	0.76	4.36						
NOR	0.90	0.88	0.88	0.75	12.74					
NZL	0.55	0.56	0.53	0.62	0.54	10.05				
USA	0.85	0.85	0.86	0.82	0.88	0.64	3.17			
NLD	0.87	0.92	0.92	0.79	0.87	0.57	0.86	2.62		
AUS	0.71	0.71	0.71	0.85	0.73	0.61	0.73	0.71	4.70	
IRL	0.71	0.70	0.71	0.85	0.72	0.61	0.77	0.71	0.88	2.52

RDC cc1

	CAN	DEU	DFS	GBR	NOR	NLD	USA
CAN	6.58						
DEU	0.79	5.16					
DFS	0.81	0.86	15.45				
GBR	0.61	0.74	0.75	0.03			
NOR	0.79	0.66	0.71	0.69	12.52		
NLD	0.72	0.89	0.80	0.76	0.63	3.30	
USA	0.80	0.65	0.66	0.58	0.64	0.56	2.92

RDC cc2

	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	6.19										
DEU	0.87	4.37									
DFS	0.85	0.91	13.65								
GBR	0.71	0.75	0.77	4.36							
NOR	0.76	0.75	0.71	0.88	13.43						
NZL	0.51	0.48	0.49	0.63	0.61	6.90					
USA	0.81	0.87	0.85	0.86	0.87	0.64	1.54				
ZAF	0.73	0.85	0.83	0.86	0.88	0.66	0.91	19.94			
NLD	0.84	0.90	0.86	0.77	0.87	0.50	0.87	0.83	3.70		
AUS	0.71	0.71	0.70	0.85	0.87	0.65	0.85	0.86	0.74	4.64	
IRL	0.71	0.74	0.75	0.85	0.86	0.70	0.86	0.89	0.79	0.87	2.52

RDC int

	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	6.16										
DEU	0.86	7.14									
DFS	0.86	0.92	12.90								
GBR	0.86	0.87	0.88	4.36							
NOR	0.90	0.89	0.86	0.88	13.43						
NZL	0.62	0.61	0.60	0.62	0.61	6.90					
USA	0.88	0.89	0.87	0.86	0.87	0.65	1.54				
ZAF	0.86	0.87	0.87	0.86	0.91	0.68	0.91	19.94			
NLD	0.87	0.93	0.92	0.89	0.87	0.61	0.89	0.87	3.35		
AUS	0.86	0.86	0.85	0.86	0.87	0.63	0.85	0.87	0.86	4.64	
IRL	0.86	0.85	0.86	0.85	0.86	0.61	0.86	0.89	0.86	0.88	2.52

^LAPPENDIX II. Number of common bulls

BSW

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DEA	FRA	USA	CHE
CAN	0	55	36	59	61
DEA	45	0	151	140	471
FRA	32	110	0	63	125
USA	53	98	45	0	160
CHE	49	376	90	134	0

BSW

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	0	81	75	29	14	86	38	51	65
CHE	64	0	475	65	15	218	46	121	305
DEA	62	377	0	105	22	179	44	150	395
NLD	24	60	97	0	13	38	27	56	80
NZL	13	13	17	8	0	13	11	14	16
USA	83	190	138	36	11	0	46	76	122
GBR	36	36	33	23	8	46	0	34	42
FRA	43	85	108	43	10	48	28	0	124
ITA	56	248	258	63	12	83	32	90	0

BSW

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	CHE	DEA	NLD	USA	GBR	FRA
CAN	0	81	75	29	86	38	57
CHE	64	0	472	64	218	47	131
DEA	62	374	0	102	179	46	163
NLD	24	59	95	0	38	26	62
USA	83	190	138	36	0	47	83
GBR	36	37	34	22	47	0	37
FRA	49	95	123	51	57	32	0

BSW

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	0	74	69	27	13	90	38	53	61
CHE	58	0	464	65	15	276	46	131	305
DEA	56	370	0	104	22	275	43	162	388
NLD	22	60	97	0	13	59	27	62	80
NZL	12	13	17	8	0	21	11	15	16
USA	82	257	245	51	19	0	56	104	167
GBR	34	36	33	23	8	56	0	36	42
FRA	45	95	123	51	11	71	31	0	136
ITA	51	248	256	63	12	113	32	102	0

BSW
----
 common bulls below diagonal
 common three quarter sib group above diagonal
       CAN DEA NLD NZL USA GBR ITA

  CAN   0   69   28   13   90   38   61
  DEA   56   0 106   22 275   43 424
  NLD   23   99   0   13   60   27   82
  NZL   12   17   8   0   21   11   16
  USA   82 245   54   19   0   56 175
  GBR   34   33   23   8   56   0   43
  ITA   51 272   64   12 117   32   0

GUE
----
 common bulls below diagonal
 common three quarter sib group above diagonal
       CAN GBR NZL USA AUS

  CAN   0   13   1   25   17
  GBR   10   0   13   35   28
  NZL   0   11   0   8   23
  USA   24   32   6   0   18
  AUS   12   22   22   15   0

GUE
----
 common bulls below diagonal
 common three quarter sib group above diagonal
       CAN GBR USA

  CAN   0   13   27
  GBR   10   0   36
  USA   26   34   0

GUE
----
 common bulls below diagonal
 common three quarter sib group above diagonal
       CAN GBR NZL USA ZAF AUS

  CAN   0   9   0   26   1   15
  GBR   5   0   13   66   5   28
  NZL   0   11   0   27   3   23
  USA   23   67   29   0   10   49
  ZAF   1   4   1   6   0   5
  AUS   11   22   22   46   4   0

GUE

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	GBR	NZL	USA	ZAF	AUS
CAN	0	9	0	26	1	15
GBR	5	0	13	66	5	28
NZL	0	11	0	27	3	23
USA	23	67	29	0	10	49
ZAF	1	4	1	6	0	5
AUS	11	22	22	46	4	0

HOL

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	CZE	DEU	DFS	FRA	USA	POL	FRR
CAN	0	711	1484	762	816	1593	561	0
CZE	457	0	1358	804	866	946	594	7
DEU	855	897	0	1993	1831	1853	983	64
DFS	581	412	984	0	1208	983	601	12
FRA	517	445	831	521	0	1151	695	1
USA	1516	643	1028	664	532	0	803	2
POL	377	369	583	348	279	623	0	22
FRR	0	3	44	2	0	0	21	0

HOL

common bulls below diagonal
common three quarter sib group above diagonal

	BEL	CAN	CHE	CHR	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	FRA	FRR	AUS
BEL	0	351	222	176	608	414	324	441	285	424	648	276	369	161	480	9	387
CAN	301	0	368	246	1574	817	796	1008	361	1179	877	470	1791	471	861	2	759
CHE	200	257	0	260	484	317	282	350	219	325	356	212	359	96	307	3	278
CHR	162	206	275	0	437	188	159	200	128	227	344	125	271	77	176	11	179
DEU	504	881	366	352	0	2122	1066	1605	696	2112	2555	751	2116	854	1940	72	1207
DFS	313	589	246	151	981	0	686	1109	575	1234	1426	614	1110	524	1243	12	880
ESP	289	457	229	123	626	440	0	761	370	866	747	391	885	347	756	2	581
GBR	371	962	307	173	1002	676	582	0	717	1209	1295	698	1243	451	1183	4	978
IRL	253	343	213	113	572	414	339	708	0	524	686	539	443	169	579	2	538
ITA	310	767	251	184	1107	685	592	766	413	0	1369	609	1650	580	1492	1	896
NLD	659	739	320	311	1978	949	614	993	607	916	0	799	1332	616	1474	35	1045
NZL	198	430	179	101	527	376	281	572	437	411	698	0	560	201	623	0	931
USA	296	1711	269	243	1131	692	495	997	394	893	962	464	0	698	1312	2	880
POL	97	308	49	55	459	283	152	223	94	307	388	123	477	0	605	20	313
FRA	415	532	267	158	805	480	495	627	420	624	726	324	570	226	0	1	919
FRR	7	1	2	4	50	3	0	1	1	1	10	0	0	20	0	0	2
AUS	289	624	225	147	714	466	388	745	429	516	802	886	706	143	519	1	0

HOL

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	CHE	CHR	CZE	DEU	DFS	FRA	GBR	ISR	ITA	NLD	USA	POL	FRR
CAN	0	369	246	740	1571	816	856	1060	62	1183	870	1807	494	2
CHE	258	0	260	208	484	317	310	352	23	325	353	360	107	3
CHR	206	275	0	143	433	188	179	203	10	227	343	271	89	11
CZE	477	120	99	0	1345	801	847	716	63	900	994	1026	552	8
DEU	866	367	347	900	0	2112	1929	1654	98	2103	2509	2096	912	71
DFS	586	246	151	403	970	0	1237	1132	83	1227	1416	1105	551	12
FRA	539	272	161	428	815	486	0	1206	83	1486	1469	1297	622	1
GBR	1008	306	172	392	1017	683	641	0	85	1249	1320	1297	478	4
ISR	44	16	6	49	80	61	44	58	0	89	97	81	43	0
ITA	768	251	184	508	1098	683	636	779	63	0	1359	1648	607	1
NLD	727	320	311	757	1929	940	734	1012	81	903	0	1316	655	34
USA	1741	270	243	680	1098	688	576	1044	63	893	944	0	729	2
POL	327	54	65	349	527	311	242	242	25	335	435	506	0	19
FRR	1	2	4	3	50	3	0	1	0	1	10	0	20	0

HOL

common bulls below diagonal
common three quarter sib group above diagonal

	BEL	CAN	CHE	CHR	CZE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	NLD	NZL	USA	POL	ZAF	FRR	AUS
BEL	0	344	223	176	279	594	414	324	483	441	286	36	423	648	276	477	158	197	9	400
CAN	294	0	365	239	703	1467	787	791	824	982	354	60	1101	838	456	1906	446	340	2	787
CHE	201	254	0	260	209	478	318	282	310	350	219	24	324	356	212	417	93	170	3	290
CHR	162	198	275	0	144	426	188	159	179	200	128	10	223	345	125	344	72	97	11	188
CZE	175	445	120	99	0	1323	806	523	850	696	321	65	881	1002	399	1160	505	245	8	571
DEU	487	756	360	341	872	0	2077	1062	1904	1580	689	101	2021	2447	745	2737	822	466	71	1248
DFS	313	558	247	151	404	931	0	689	1245	1110	575	87	1218	1429	616	1487	510	407	12	922
ESP	289	451	229	123	309	615	440	0	765	764	370	67	864	751	392	1074	345	345	2	601
FRA	421	519	272	161	428	794	487	507	0	1185	584	87	1475	1476	629	1996	596	388	1	957
GBR	371	935	307	173	383	965	676	582	639	0	717	87	1201	1297	698	1611	442	405	4	1019
IRL	253	332	213	113	206	557	414	339	429	708	0	62	523	687	539	604	164	265	2	549
ISR	20	45	16	6	49	80	63	44	45	59	51	0	89	100	72	105	42	47	0	69
ITA	309	703	249	181	497	1022	663	591	630	754	411	61	0	1349	605	2083	563	414	1	925
NLD	659	692	320	311	764	1797	953	615	738	994	607	81	887	0	802	1880	596	400	34	1090
NZL	198	412	179	101	243	513	379	281	332	572	437	61	403	700	0	842	197	298	0	952
USA	347	1750	308	310	742	1359	797	626	880	1237	495	82	1011	1367	757	0	712	517	6	1370
POL	93	282	48	50	304	426	272	148	217	214	90	23	292	367	122	459	0	122	19	325
ZAF	154	314	145	80	151	337	283	303	253	344	229	33	297	330	237	477	66	0	2	379
FRR	7	1	2	4	3	50	3	0	0	1	1	0	1	10	0	1	20	1	0	2
AUS	298	651	233	152	301	738	511	397	563	790	445	48	541	852	919	1170	160	315	1	0

HOL

common bulls below diagonal
common three quarter sib group above diagonal

	BEL	CAN	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	ZAF	AUS
BEL	0	344	591	410	322	438	284	419	644	274	473	156	195	398
CAN	294	0	1465	788	789	982	354	1101	840	456	1906	444	339	786
DEU	487	756	0	2079	1056	1579	689	2021	2455	744	2739	815	463	1246
DFS	313	559	935	0	686	1111	573	1219	1431	615	1491	506	405	919
ESP	289	451	615	440	0	761	367	860	749	390	1069	341	343	598
GBR	371	935	965	677	582	0	715	1199	1299	698	1610	438	403	1018
IRL	253	332	558	414	339	707	0	521	685	538	602	160	265	548
ITA	309	703	1023	664	591	753	410	0	1350	605	2081	555	413	924
NLD	661	698	1813	959	620	998	607	891	0	801	1882	583	398	1089
NZL	198	412	513	377	281	572	437	403	701	0	842	197	297	951
USA	347	1750	1366	801	626	1237	495	1011	1373	757	0	705	515	1367
POL	93	282	428	272	147	214	90	292	362	122	459	0	121	321
ZAF	154	314	337	283	303	344	229	297	331	237	477	66	0	377
AUS	298	651	739	511	397	790	445	541	855	919	1170	159	315	0

JER

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DFS	USA
CAN	0	45	168
DFS	34	0	82
USA	154	60	0

JER

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	AUS	IRL
CAN	0	48	92	21	103	191	118	5
DFS	34	0	109	61	109	92	94	23
GBR	94	98	0	53	150	138	142	35
NLD	16	53	49	0	55	49	47	15
NZL	109	74	151	47	0	187	322	65
USA	190	68	150	51	208	0	232	25
AUS	115	54	146	42	346	240	0	33
IRL	4	18	35	15	71	27	30	0

JER

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	USA
CAN	0	48	93	20	198
DFS	34	0	109	59	91
GBR	94	98	0	52	136
NLD	15	51	48	0	48
USA	194	68	148	50	0

JER

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	0	45	90	21	96	194	82	127	5
DFS	33	0	109	61	109	142	104	99	23
GBR	91	98	0	53	151	164	126	153	35
NLD	16	53	49	0	56	62	54	51	15
NZL	102	74	151	48	0	285	163	340	65
USA	192	105	182	66	355	0	229	371	29
ZAF	80	76	127	50	168	242	0	182	26
AUS	122	59	157	45	367	400	171	0	34
IRL	4	18	35	15	71	31	27	31	0

JER

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	0	45	90	22	96	194	82	127	5
DFS	33	0	109	63	109	142	104	99	23
GBR	91	98	0	57	151	164	126	153	35
NLD	18	56	53	0	58	66	56	53	16
NZL	102	74	151	51	0	285	163	340	65
USA	192	106	182	71	355	0	229	371	29
ZAF	80	76	127	53	168	242	0	182	26
AUS	122	59	157	47	367	400	171	0	34
IRL	4	18	35	15	71	31	27	31	0

RDC

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DEU	DFS	NOR	USA
CAN	0	8	92	4	69
DEU	7	0	41	12	8
DFS	86	32	0	98	97
NOR	4	11	76	0	31
USA	65	8	91	30	0

RDC

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DEU	DFS	GBR	NOR	NZL	USA	NLD	AUS	IRL
CAN	0	10	84	46	4	47	92	3	54	2
DEU	9	0	45	4	12	11	9	9	20	2
DFS	79	36	0	38	88	132	97	30	139	8
GBR	47	4	37	0	11	39	42	9	36	6
NOR	4	11	69	12	0	30	33	21	34	38
NZL	47	11	127	38	29	0	51	7	104	6
USA	90	9	94	40	32	52	0	17	49	9
NLD	3	8	30	9	20	7	16	0	12	6
AUS	53	19	118	35	29	105	47	10	0	7
IRL	2	2	6	6	38	6	9	5	6	0

RDC

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DEU	DFS	GBR	NOR	NLD	USA
CAN	0	9	84	48	4	3	93
DEU	8	0	43	4	12	9	8
DFS	79	34	0	39	90	30	97
GBR	49	4	38	0	11	9	43
NOR	4	11	70	12	0	21	33
NLD	3	8	30	9	20	0	17
USA	90	8	94	41	32	16	0

RDC

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	0	8	83	43	4	45	110	63	3	52	2
DEU	7	0	39	4	8	10	7	1	9	22	2
DFS	77	31	0	41	76	133	113	45	30	148	8
GBR	44	4	40	0	11	39	55	32	9	39	6
NOR	4	8	58	12	0	29	33	0	20	38	38
NZL	45	10	128	38	28	0	73	32	7	109	6
USA	112	7	110	55	32	74	0	61	18	77	12
ZAF	67	1	43	30	0	30	57	0	1	33	2
NLD	3	8	30	9	19	7	17	1	0	14	6
AUS	51	21	125	38	32	110	77	34	12	0	8
IRL	2	2	6	6	38	6	12	2	5	7	0

RDC

common bulls below diagonal
common three quarter sib group above diagonal

	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	0	9	83	43	4	45	110	63	4	52	2
DEU	8	0	41	4	8	11	9	1	9	22	2
DFS	77	33	0	41	76	133	113	45	30	148	8
GBR	44	4	40	0	11	39	55	32	9	39	6
NOR	4	8	58	12	0	29	33	0	21	38	38
NZL	45	11	128	38	28	0	73	32	7	109	6
USA	112	9	110	55	32	74	0	61	20	77	12
ZAF	67	1	43	30	0	30	57	0	1	33	2
NLD	4	8	30	9	20	7	18	1	0	14	6
AUS	51	21	125	38	32	110	77	34	12	0	8
IRL	2	2	6	6	38	6	12	2	5	7	0