J. Dairy Sci. 84:1899–1912

Overview of Progeny-Test Programs of Artificial-Insemination Organizations in the United States

H. D. Norman,* R. L. Powell,* J. R. Wright,* and C. G. Sattler†,[1]
*Animal Improvement Programs Laboratory, Agricultural Research Service,
USDA, Beltsville, MD 20705-2350
†National Association of Animal Breeders, Columbia, MO 66205-1033

ABSTRACT

Characteristics of progeny-test (PT) programs of artificial insemination (AI) organizations in the United States were examined for changes since 1960. Mean number of bulls that were progeny tested annually by major AI organizations during the mid 1990s was 11 for Ayrshires, 24 for Brown Swiss, 21 for Guernseys, 1261 for Holsteins, 112 for Jerseys, and 3 for Milking Shorthorns. Mean parent age at progeny-test (PT) bull birth decreased except for Milking Shorthorns; mean age of maternal grandsire at bull birth decreased for Holsteins and Jerseys but increased for other breeds. For Holsteins, mean ancestor ages at PT bull birth were 85 mo for sires, 47 mo for dams, and 136 mo for maternal grandsires during the mid 1990s. Percentage of PT bulls that resulted from embryo transfer increased to 78% for Brown Swiss and 80% for Holsteins by 1999. Inbreeding in PT bulls increased over time and ranged from 3.8% for Brown Swiss to 6.4% for Jerseys (5.6% for Holsteins) during the mid 1990s. Mean numbers of daughters and herds per PT bull generally declined except for Holsteins, which increased during the early 1990s to 61 daughters and 44 herds. Mean number of states in which PT daughters are located increased; for Holstein PT bulls during 1994, 22% of daughters were in California, 13% in Wisconsin, 12% in New York, and 10% in Pennsylvania and Minnesota. Percentage of first-lactation cows that were PT daughters increased and ranged from 6% for Milking Shorthorns to 22% for Ayrshires (14% for Holsteins) during 1998. Percentage of PT daughters that were registered declined and was 19% for Holsteins and around 80% for other breeds.
(**Key words:** artificial insemination, generation interval, progeny testing, sire sampling)

Abbreviation key: AIPL = Animal Improvement Programs Laboratory, **ET** = embryo transfer, **NAAB** = National Association of Animal Breeders, **PT** = progeny test.

INTRODUCTION

Attaining a high rate of genetic improvement for dairy cattle often is dependent on the successful operation of a progeny-test (**PT**) program for sires, especially in an internationally competitive environment. Young bulls that are selected for testing should have high genetic potential based on their pedigree merit. Semen from the young bulls should be collected and distributed at the earliest opportunity and used quickly in herds that are enrolled in a milk-recording program. A unique identification must be assigned to each daughter after birth. Daughters' pedigree information must be stored in a database, and those daughters must remain alive until their first lactation information can be recorded.

The effectiveness of a PT program in increasing genetic gain is influenced by the number of daughters that reach milking age and the number of herds in which the daughters are milked (Lush, 1948) as well as the distribution of daughters across herds (Norman et al., 1972). Minimization of environmental effects through random distribution of semen and through use of an appropriate genetic model also is important. The number of bulls in PT programs and the intensity of subsequent culling based on PT results directly impact the rate of genetic improvement (Dekkers et al., 1996; Van Vleck, 1993). Only the most genetically superior bulls should be selected and returned to AI service to become parents of the next generation of cows; an even smaller percentage should be used to sire the next bulls to be progeny tested. However, an increase in inbreeding should be avoided (Smith et al., 1998).

The number of AI organizations in the US grew rapidly to a peak of 97 during 1950 (Miller, 1981). Since then, many companies and cooperatives have consolidated, and only a few large AI organizations are now operating in the United States. With mergers, AI sam-

Received January 2, 2001.
Accepted April 13, 2001.
Corresponding author: H. D. Norman; e-mail: dnorman@aipl.arsusda.gov.
[1]Current address: Select Sires, Inc., 11740 US 42N, Plain City, OH 43064-0143.

pling programs have been modified, and the scope and basic characteristics of recent PT programs have not been examined in detail. Previous studies (Miller, 1981; Norman and Powell, 1986, 1992, 1999) reported the number of young bulls that entered PT programs, but few other characteristics of those programs are easily available. Meinert et al. (1992) examined estimates of genetic trend that were associated with PT herds and found that the mean genetic merit for milk yield of cows and the rate of genetic improvement within herd were higher for herds that participated in AI sampling programs than for other herds. This study summarizes basic characteristics of PT programs of AI organizations in the United States and how those programs have changed over time within breed. Although selection of young bulls with high pedigree merit is important to the success of the PT program, trend in pedigree merit of PT bulls was not examined.

MATERIALS AND METHODS

Data in the national database at the Animal Improvement Programs Laboratory (**AIPL**), USDA (Beltsville, MD), that had been supplied by cooperators from the US dairy industry were examined for characteristics of PT programs. Information from the National Association of Animal Breeders (**NAAB**; Columbia, MO) and its member AI organizations indicated which bulls were enrolled in PT programs, which bulls entered AI service, and when semen was distributed. Production information from DHI was used to confirm which daughters of PT bulls survived and contributed lactation records to PT evaluations. Identification information from DHI and the breed associations was used to determine parentage and birth dates. The breed associations provided codes to indicate whether an animal resulted from embryo transfer (**ET**), including embryo splitting or nuclear transfer. Much of the information used in this study is available to the public at the AIPL web site (http://aipl.arsusda.gov; accessed July 4, 2000) in the USDA-DHIA bull evaluation file (format 38).

To be considered progeny tested through AI, a bull had to have entered AI service between 10 and 29 mo of age with an AI sampling organization that was located in the US and that had an NAAB controller number (National Association of Animal Breeders, 1996) between 1 and 222, excluding 100. Bulls that were sampled exclusively in the US under the ownership of Semex USA (Madison, WI) (Wayne Glaeser, 2000, personal communication) were included even though Semex USA is a subsidiary of the Canadian company Semex Alliance (Guelph, ON). Because the identity of the sampling organization was not documented before 1990 (Sattler, 1990), the NAAB controller number was used for those bulls that did not have an NAAB sampling controller code. Controller codes that are 2000 or higher are reserved for AI organizations that market but do not process semen; AI organizations with a code of 100 or a code of ≥2000 were designated as “marketing-only” AI organizations.

Only cows that were born between 8 and 42 mo after their sires had entered AI sampling were considered to be PT daughters. The upper age limit prevented the inclusion of second-crop daughters, which would have distorted PT characterization. All PT daughters were required to have a first-lactation record that was usable for USDA-DHIA genetic evaluation. If a daughter changed herds, the herd that produced the first-lactation record was used for characterization of PT herds. A few young bulls had semen marketed continuously with little or no restriction on number of units sold. For those bulls, only the first 125 daughters with records that were included in the genetic evaluation of the bull as determined by calving date were considered to be PT daughters. The remaining daughters were not included in PT characterization.

Numbers of bulls that were sampled, ages of ancestors at birth of bull, bull births that resulted from ET, bull inbreeding, and numbers of daughters, herds, and states per PT bull were documented and summarized by breed and by year of bull entry into AI sampling since 1960. Numbers of herds with PT daughters, percentages of herds with PT daughter records that were usable for genetic evaluations, percentages of US cows that were PT daughters, and registry status of PT daughters also were documented and summarized by breed and by year of first calving. For Holsteins, characteristics of PT herds and distribution and registry status of PT daughters also were summarized by state. For each characterization trait, results were reported for the most current year with complete data available at the time of analysis. However, those years often differed because of the various lapse times required for each trait.

RESULTS AND DISCUSSION

Table 1 shows the numbers of bulls in PT programs of AI organizations by breed, organization status, and year of bull entry into AI sampling. Because of changes in how PT information is reported to AIPL from individual AI organizations, the number of PT bulls for earlier years, particularly the 1960s, was less than had been reported by Norman and Powell (1986). Separate counts are given for the bulls that were progeny tested by major and marketing-only AI organization to help explain discrepancies from previously reported num-

Table 1. Numbers of young bulls in progeny-test programs of AI organizations by breed, organization status,[1] and year of bull entry into AI sampling.

		Brown Swiss			Holstein		Jersey		
Year	Ayrshire[2]	Major AI organization	Marketing-only AI organization	Guernsey[2]	Major AI organiztion	Marketing-only AI organization	Major AI organization	Marketing-only AI organization	Milking Shorthorn[2]
1960	2	7	0	19	44	0	12	0	1
1961	3	8	0	20	72	0	13	0	2
1962	2	6	0	16	52	0	16	0	2
1963	1	6	0	23	83	0	13	0	1
1964	2	6	0	15	126	0	15	0	0
1965	4	5	0	17	158	0	10	0	0
1966	1	2	0	13	197	0	16	0	1
1967	6	2	0	11	168	0	15	0	0
1968	6	1	0	18	188	1	14	0	1
1969	3	6	0	10	181	1	22	0	0
1970	2	2	0	19	223	0	17	0	1
1971	1	2	0	12	314	1	26	0	3
1972	2	6	0	20	337	2	29	0	3
1973	7	8	0	20	470	0	42	0	0
1974	7	3	0	25	502	1	41	1	0
1975	3	8	0	20	563	5	35	1	2
1976	3	15	0	19	527	4	28	0	2
1977	4	11	0	18	635	0	21	2	2
1978	2	15	0	26	685	6	29	5	1
1979	5	11	0	16	703	18	27	2	2
1980	13	33	3	23	826	43	23	8	1
1981	10	23	0	25	927	125	35	11	0
1982	11	24	0	32	997	150	53	10	3
1983	13	25	0	44	1068	220	60	38	2
1984	21	14	0	49	981	271	60	48	1
1985	19	16	2	41	969	274	52	49	1
1986	16	18	1	47	1030	310	66	46	4
1987	13	21	5	34	1137	439	71	55	3
1988	12	20	3	31	1225	401	76	34	7
1989	10	20	5	43	1106	453	84	58	0
1990	7	30	4	40	1191	453	103	29	3
1991	13	16	7	38	1249	458	111	24	6
1992	15	28	15	32	1254	367	152	1	4
1993	15	30	8	31	1345	364	142	7	1
1994	11	27	9	26	1317	325	112	1	2
1995	14	30	12	26	1373	286	134	10	3
1996	11	19	20	24	1209	284	117	11	1
1997	11	24	13	17	1244	238	102	2	5
1998	8	21	16	18	1219	194	95	4	2

[1]Major AI organizations had a sampling controller or controller code of 1 through 99 and 101 through 222 as assigned by the National Association of Animal Breeders (Columbia, MO); marketing-only AI organizations had codes of 100 and ≥2000.

[2]Ayrshires and Milking Shorthorns had no bulls in progeny-test programs of marketing-only AI organizations; Guernseys had only one bull in 1986 in a progeny-test program of a marketing-only AI organization.

bers. Some individuals consider bulls that are sampled by marketing-only AI organizations to be AI sampled, whereas others do not. Mean number of bulls that were progeny tested annually by major AI organizations from 1995 through 1998 was 11 for Ayrshires, 24 for Brown Swiss, 21 for Guernseys, 1261 for Holsteins, 112 for Jerseys, and 3 for Milking Shorthorns; corresponding means for marketing-only AI organizations were 15 for Brown Swiss, 250 for Holsteins, and 7 for Jerseys. For major AI organizations, number of Holstein PT bulls increased from 44 during 1960 to a high of 1373 during 1995; other breeds also showed increases through the mid 1990s. The number of PT bulls increased markedly around 1980 for all breeds except Milking Shorthorn. A desire by AI organizations to increase their market share domestically and the opportunity to market more semen internationally probably contributed to this increase. The size of the domestic cattle population and the percentage that is bred through AI also can affect the number of bulls that are progeny tested. The number of Holstein PT bulls declined from 1373 during 1995 to 1219 during 1998 for major AI organizations; for Jerseys, the number of PT bulls peaked at 152 during 1992 and then decreased to 95 during 1998. Some of this reduction may be attributed to a decrease in the amount of semen

(Durfey, 1976; Doak, 1999) necessary to breed a declining domestic dairy cattle population (Majeskie, 1996) in spite of an increase in the units required for the export market. Perhaps some of the recent reduction was the consequence of sampling fewer bulls after organizational mergers. Decreases of this size in the number of PT bulls are likely to reduce the opportunity for continued rapid genetic improvement in the future.

For marketing-only AI organizations, the number of PT bulls tended to increase through the early 1990s and then to decrease. The number of Holstein PT bulls increased from 1 during 1968 to 458 during 1991 and then declined to 194 during 1998; for Jerseys, number of PT bulls increased from 1 during 1973 to 58 during 1989 and then declined rapidly. One reason for this pattern was the initiation and then termination of a sampling program by a number of private AI organizations and Holstein Association USA. Another reason for the later declines may have been the difficulty that was experienced by marketing-only AI organizations in selling semen from their bulls after PT evaluation, which limited the profitability of their PT efforts. In some situations, some of the marketing-only AI organizations became associated with major organizations.

Table 2 shows mean ages of bull ancestors by breed and year of bull birth, which provides an indication of changes in generation interval over time. The most obvious changes were the large decreases in parent ages for all breeds except Milking Shorthorn. Age of Holstein sires at bull birth decreased by 40 mo from 125 mo for bulls that were sampled during the early 1970s compared with 85 mo for bulls that were sampled during the mid 1990s, which indicated a continuation of the decline of 21 mo between 1970 and 1984 that had been reported by Norman and Powell (1986). For other breeds except Milking Shorthorns, sire ages at bull birth decreased by 26 to 69 mo after 1970. Age of Milking Shorthorn sires have generally increased since the mid 1980s, which could be related to long-term use of a few influential bulls as sires of sons or to use of older foreign sires of other breeds. All linear regressions were significant ($P < 0.001$), including the increase for Milking Shorthorns. Both linear and quadratic coefficients also were significant ($P < 0.001$) for all breeds except Milking Shorthorn. In general, the standard deviation of sire age varied directly with the mean and decreased from 47 to 22 mo for Holsteins from the earliest to the latest sampling years.

The change in mean age of dams when bulls were born was dramatic (Table 2). For Holsteins, dam age decreased from 91 mo for bulls sampled during the early 1960s to 47 mo for bulls sampled during the mid

Table 2. Means and standard deviations for ancestor ages at birth of progeny-test bulls by breed and year of bull entry into AI sampling.

Ancestor	Years	Ayrshire		Brown Swiss		Guernsey		Holstein		Jersey		Milking Shorthorn	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
		(mo)											
Sire	1960 through 1964	128	33	93	34	106	40	114	47	92	44	47	15
	1965 through 1969	142	37	132	43	110	39	132	46	127	42	118	102
	1970 through 1974	128	59	147	46	138	37	125	39	147	62	111	19
	1975 through 1979	138	56	137	46	129	47	128	40	148	52	91	50
	1980 through 1984	146	44	121	44	115	34	110	38	124	54	107	62
	1985 through 1989	150	71	132	36	109	26	108	25	95	24	117	24
	1990 through 1994	105	29	102	35	100	24	91	23	88	22	134	94
	1995 through 1998	102	19	90	29	93	28	85	22	78	25	132	110
Dam	1960 through 1964	73	32	88	33	89	39	91	36	88	36	93	23
	1965 through 1969	97	42	92	36	84	30	93	33	92	35	42	1
	1970 through 1974	85	44	81	34	84	29	88	33	92	38	93	37
	1975 through 1979	87	35	93	38	84	36	76	31	83	33	60	26
	1980 through 1984	83	33	87	38	66	29	78	31	79	32	57	18
	1985 through 1989	86	32	75	29	67	23	62	25	61	28	76	30
	1990 through 1994	68	28	70	28	58	20	52	51	49	20	78	34
	1995 through 1998	62	25	58	25	56	20	47	18	48	22	75	35
Maternal grandsire	1960 through 1964	132	42	136	28	141	33	154	35	140	37	145	28
	1965 through 1969	165	54	172	50	162	46	184	44	160	37	116	67
	1970 through 1974	195	58	161	55	160	43	180	53	179	57	187	44
	1975 through 1979	210	66	183	56	170	47	174	42	180	52	134	47
	1980 through 1984	189	55	179	59	165	52	187	45	194	62	168	78
	1985 through 1989	203	79	174	48	161	39	164	36	150	51	177	67
	1990 through 1994	171	63	166	40	156	38	150	32	131	28	180	51
	1995 through 1998	157	63	146	39	152	43	136	28	130	33	158	62

Table 3. Percentage of bulls that entered AI progeny testing that resulted from embryo transfer by breed and year of bull entry into AI sampling.

Year	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey	Milking Shorthorn
	(%)					
1977	0	0	0	<1	0	0
1978	0	0	0	1	0	0
1979	0	0	0	7	0	0
1980	0	15	0	15	0	0
1981	0	26	0	25	6	0
1982	0	46	13	39	15	0
1983	8	44	25	46	28	0
1984	14	36	20	55	30	0
1985	21	44	27	60	35	0
1986	6	44	34	61	24	0
1987	15	33	35	68	46	33
1988	67	60	39	70	36	57
1989	20	45	30	73	36	0
1990	14	60	43	71	50	0
1991	31	56	29	73	38	17
1992	47	61	0	77	57	0
1993	40	60	13	75	57	0
1994	45	52	54	76	46	0
1995	21	80	58	76	53	0
1996	27	74	29	80	59	100
1997	45	71	65	81	61	0
1998	38	67	61	82	59	0
1999	33	78	57	84	56	0

1990s. This trend for younger Holstein bull dams also was reported by Norman and Powell (1986); they found that mean dam age decreased from 90 mo in 1970 to 76 mo in 1984. The same trend occurred for all breeds. Linear regressions and both linear and quadratic coefficients were significant ($P < 0.001$) for all breeds except Milking Shorthorn. For the most recent years, mean age of bull dams was lowest for Holsteins (47 mo) and Jerseys (48 mo) and ranged from 56 to 75 mo for other breeds. The dams of bulls that were sampled in the early 1960s typically had five lactations, whereas dams of recently sampled bulls had fewer than two lactations. The trend toward younger bull dams is encouraging because younger animals have the highest mean genetic merit as a result of past genetic improvement. Nevertheless, the cows that are selected as bull dams should be those with the highest genetic merit regardless of age. As found for bull sires, the standard deviation of dam age when bull was born was related positively to the mean. For Holsteins, the standard deviation of dam age decreased from 36 to 18 mo from the earliest to the latest sampling years; other breeds except Milking Shorthorn showed a similar trend.

The decline in mean age of maternal grandsires when bulls were born (Table 2) was similar to that found for mean sire age for Holsteins and Jerseys ($P < 0.001$); the decreases from the early 1970s to the mid 1990s were 44 and 49 mo, respectively. The most noticeable declines started near 1985 and most likely

Table 4. Mean percentage of inbreeding and standard deviations for progeny-test bulls by breed and year of bull entry into AI sampling.

Years	Ayrshire		Brown Swiss		Guernsey		Holstein		Jersey		Milking Shorthorn	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
	(%)											
1965 through 1969	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	<0.1	<0.1	0.0	0.0
1970 through 1974	1.1	3.1	0.2	0.7	<0.1	0.3	0.2	1.3	0.4	1.6	<0.1	<0.1
1975 through 1979	4.0	4.4	0.4	1.9	0.8	1.8	0.4	1.5	0.7	2.2	0.3	0.5
1980 through 1984	4.0	3.3	1.0	1.7	1.2	2.0	1.2	2.2	1.6	2.6	4.1	4.1
1985 through 1989	5.0	3.1	1.3	1.7	2.2	2.7	2.6	2.8	3.6	2.6	3.6	4.5
1990 through 1994	4.4	2.3	3.0	2.5	4.4	3.1	3.7	2.5	5.2	2.9	4.4	3.5
1995 through 1999	5.2	2.4	3.8	2.4	4.3	2.7	4.6	2.1	6.4	3.4	4.6	3.2

Table 5. Mean numbers and standard deviations of daughters, herds, and states per progeny-test bull by breed and year of bull entry into AI sampling.

Progeny-test trait	Years	Ayrshire		Brown Swiss		Guernsey		Holstein		Jersey		Milking Shorthorn	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
		(no.)											
Daughters	1960 through 1964	57	32	51	40	48	37	67	42	56	38	4	2
	1965 through 1969	100	32	56	38	64	41	55	36	60	42	22	15
	1970 through 1974	72	44	71	47	53	38	47	33	48	36	29	33
	1975 through 1979	93	33	45	33	52	38	48	28	61	41	39	33
	1980 through 1984	61	27	30	19	52	33	48	26	64	33	26	14
	1985 through 1989	44	22	43	26	40	24	56	27	60	30	44	31
	1990 through 1994	44	22	28	17	31	16	61	25	49	29	24	18
Herds	1960 through 1964	35	22	28	20	28	19	48	31	29	18	2	2
	1965 through 1969	52	18	31	19	34	21	40	24	29	20	10	7
	1970 through 1974	42	24	37	24	27	18	33	22	25	19	13	16
	1975 through 1979	53	22	26	19	29	21	33	22	31	24	19	13
	1980 through 1984	35	20	18	11	31	19	34	20	37	20	16	6
	1985 through 1989	26	15	27	14	25	14	40	20	37	19	21	12
	1990 through 1994	28	13	20	11	21	10	44	18	31	18	11	10
States	1960 through 1964	6	3	7	5	4	4	5	4	5	5	2	1
	1965 through 1969	13	5	11	7	8	5	8	5	8	6	5	3
	1970 through 1974	12	7	12	6	8	5	8	5	9	6	7	8
	1975 through 1979	12	5	9	5	8	6	8	5	10	6	9	5
	1980 through 1984	11	4	8	5	10	6	8	6	12	7	8	4
	1985 through 1989	10	5	11	5	9	5	9	6	14	6	10	5
	1990 through 1994	11	5	10	4	9	4	11	6	13	7	6	4

reflect changes in breeding philosophies that would be expected to affect all segments of the pedigree. However, the decline in ancestor age at bull birth occurred earlier for sires than for dams and maternal grandsires. Surprisingly, coefficients for linear regression of age of maternal grandsire on sampling year were also significant ($P < 0.001$) but positive for the remaining breeds. A positive relationship between mean and standard deviation also was obvious for age of maternal grandsire at the birth of the bull. One reviewer suggested that addressing the impact of recent reductions in ancestor age on the conclusions presented in studies on multiple-ovulation ET programs could be of interest because many of those studies assumed much longer generation intervals for traditional breeding programs and reduced intervals would have a major impact on annual genetic progress.

Table 3 shows the percentage of PT bulls that resulted from ET by breed and year of entry into AI sampling. The first ET bulls entered AI sampling during 1977. The percentage of Holstein ET bulls in PT programs increased from 1% in 1978 to 25% in 1981, 60% in 1985, and 80% in 1996. Since the 1990s, the percentage of ET bulls in PT programs has been nearly as high for Brown Swiss as for Holsteins; ET percentages were lower for Ayrshires, Guernseys, and Jerseys. Relatively few Milking Shorthorn ET bulls have been progeny tested in recent years.

Mean inbreeding percentages for PT bulls are in Table 4 by breed and year of entry into AI sampling. Because relationships before 1960 are ignored in inbreeding coefficients that are calculated for dairy cattle by AIPL (Wiggans et al., 1995), the percentages in Table 4 are relative to the 1960 population for each

Table 6. Numbers and percentages of herds with at least one progeny-test daughter by breed for selected years of first calving for herds with lactation records that were usable for national genetic evaluations.

Year	Ayrshire		Brown Swiss		Guernsey		Holstein		Jersey		Milking Shorthorn	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1965	80	10	150	14	487	15	2638	11	365	15	3	2
1975	53	9	118	15	385	24	5893	25	463	30	49	47
1985	303	42	336	30	549	42	13,050	38	926	37	11	8
1990	302	48	359	35	520	52	14,142	44	1149	42	52	32
1995	222	44	345	35	338	52	14,620	54	1152	50	34	24
1998	225	46	330	35	277	55	13,615	55	1022	46	20	14

Table 7. Numbers of Holstein herds with at least one progeny-test daughter by state for selected years of first calving.

State	1965	1975	1985	1990	1995	1998
	(no.)					
Alabama	5	12	38	39	33	27
Arizona	2	11	31	29	30	27
Arkansas	2	5	36	48	25	15
California	11	277	690	682	705	654
Colorado	6	16	35	42	35	36
Connecticut	12	82	107	80	84	75
Delaware	7	14	19	19	24	20
Florida	0	9	26	32	22	21
Georgia	1	23	64	113	99	81
Idaho	14	30	99	97	99	87
Illinois	25	189	312	319	307	261
Indiana	9	83	206	193	193	191
Iowa	71	177	368	498	583	585
Kansas	98	203	219	251	202	162
Kentucky	3	28	82	82	72	85
Louisiana	2	37	103	104	80	54
Maine	68	90	143	110	103	83
Maryland	115	171	281	273	248	225
Massachusetts	25	67	88	72	88	77
Michigan	82	195	442	466	413	388
Minnesota	285	571	1763	1965	2177	1943
Mississippi	2	13	61	62	60	41
Missouri	16	40	134	153	154	145
Montana	7	9	17	13	14	15
Nebraska	1	36	96	109	118	110
Nevada	0	2	11	6	14	10
New Hampshire	64	45	63	56	59	54
New Jersey	5	60	106	89	71	60
New Mexico	0	5	17	14	20	22
New York	614	841	1775	1756	1648	1486
North Carolina	7	105	159	184	146	118
North Dakota	16	8	37	42	28	30
Ohio	143	258	434	424	435	393
Oklahoma	3	26	26	34	42	33
Oregon	6	76	93	101	114	94
Pennsylvania	398	770	1785	2039	2164	2104
Puerto Rico	0	2	8	12	24	22
Rhode Island	0	2	4	4	4	2
South Carolina	12	14	64	54	55	44
South Dakota	15	31	60	108	96	88
Tennessee	2	26	82	142	131	97
Texas	1	22	119	127	147	121
Utah	0	26	113	117	107	89
Vermont	63	136	274	242	267	221
Virginia	77	134	244	260	286	252
Washington	74	131	164	165	163	140
West Virginia	30	54	50	62	54	42
Wisconsin	239	729	1901	2253	2575	2684
Wyoming	0	1	1	0	2	1
US	2638	5893	13,050	14,142	14,620	13,615

breed. Prior to 1965, no inbreeding was found for PT bulls of all breeds. Since 1965, inbreeding in PT bulls has increased for all breeds but not always linearly. During recent years, mean inbreeding in PT bulls was slightly higher than mean inbreeding in the milk-recorded population of each breed (USDA, 2001, unpublished data, http://aipl.arsusda.gov/main/data.html#i-trend; accessed Mar. 28, 2001).

Table 5 shows the mean numbers of daughters per PT bull by year of bull entry into AI sampling. During the early 1990s, mean number of daughters was 61 for Holsteins, 49 for Jerseys, and 44 for Ayrshires and ranged from 24 to 31 for the other breeds. From Vierhout et al. (1998), the overall mean number of daughters can be calculated for Holstein PT bulls that were sampled around 1990. For the nine major AI organizations in that study, the mean was 58 daughters in 44 herds, which is in agreement with this study. Dekkers et al. (1996) reported that the rate of genetic gain was maximized in circumstances typical for Canadian AI firms with 57 to 61 daughters per PT bull when one daughter per herd was assumed. The number of marketable bulls was maximized with 20 to 40 daughters per PT bull, but net return from semen sale was maximized for 95 to 105 daughters per PT bull.

Coefficients for linear regression of number of daughters per PT bull on year of bull entry into AI sampling was negative ($P < 0.001$) for all breeds, which indicates an overall decrease in mean number of daughters per PT bull. However, both linear and quadratic coefficients were significant as well ($P < 0.001$), and mean number of daughters has increased since the mid 1980s for Holstein PT bulls. No attempt was made to determine the optimum number of daughters per PT bull or the optimum number of PT bulls. Historically, the tendency has been to obtain fewer PT daughters per bull in North America than in Europe (K. Weigel, 2000, personal communication). However, recent industry focus has been directed towards obtaining more daughters per PT bull, partially because

Table 8. Percentage of Holstein progeny-test daughters in each state for selected years of bull entry into AI sampling.

State	1960	1970	1980	1985	1990	1994
	(%)					
Alabama	0.3	0.2	0.2	0.3	0.2	0.2
Arizona	0.0	0.1	0.2	0.2	0.1	0.1
Arkansas	0.0	0.5	0.9	0.9	1.5	1.1
California	1.4	15.2	20.2	19.0	20.8	22.0
Colorado	0.0	0.7	0.4	0.4	0.5	1.2
Connecticut	2.9	1.5	0.9	0.6	0.6	0.6
Delaware	0.0	0.0	0.0	0.2	0.1	0.2
Florida	0.1	0.2	0.3	0.5	0.6	0.5
Georgia	0.0	0.5	0.6	0.7	0.7	0.6
Idaho	0.3	0.4	1.1	0.7	1.0	1.9
Illinois	0.6	2.1	1.6	1.6	1.2	1.0
Indiana	0.1	1.7	1.1	1.0	0.8	0.7
Iowa	0.2	1.6	1.6	2.2	2.2	2.7
Kansas	3.1	4.6	1.5	1.6	1.0	0.7
Kentucky	0.0	0.4	0.4	0.5	0.3	0.3
Louisiana	0.2	0.4	0.6	0.8	0.5	0.2
Maine	0.1	1.5	1.2	0.8	0.5	0.4
Maryland	0.0	3.0	1.8	2.6	1.9	1.6
Massachusetts	3.9	1.2	0.8	0.5	0.5	0.5
Michigan	4.0	2.2	3.6	2.9	2.4	2.1
Minnesota	8.4	6.8	10.4	10.2	10.0	9.9
Mississippi	0.1	0.1	0.4	0.3	0.5	0.4
Missouri	0.2	1.4	0.8	0.8	0.6	0.5
Montana	0.7	0.1	0.3	0.0	0.0	0.1
Nebraska	0.0	0.5	0.6	0.7	0.5	0.5
Nevada	0.0	0.0	0.2	0.1	0.2	0.1
New Hampshire	0.0	1.0	0.4	0.3	0.3	0.3
New Jersey	0.3	1.3	0.6	0.7	0.5	0.3
New Mexico	0.0	0.3	0.9	0.4	0.5	0.9
New York	24.3	13.9	11.4	10.7	12.0	12.0
North Carolina	0.1	3.6	1.1	1.5	1.1	0.8
North Dakota	0.4	0.0	0.2	0.1	0.2	0.1
Ohio	3.4	3.7	3.3	2.6	2.1	2.0
Oklahoma	0.0	0.5	0.2	0.2	0.1	0.1
Oregon	0.1	1.4	0.8	0.8	1.3	1.0
Pennsylvania	12.5	7.1	9.2	11.8	10.6	10.5
Puerto Rico	0.0	0.0	0.1	0.1	0.1	0.1
Rhode Island	0.5	0.1	0.0	0.0	0.0	0.0
South Carolina	0.6	0.2	0.3	0.4	0.4	0.4
South Dakota	0.2	0.1	0.3	0.4	0.5	0.4
Tennessee	0.0	0.2	0.5	0.9	0.6	0.4
Texas	0.0	0.2	1.0	1.0	1.0	1.9
Utah	0.1	0.7	1.0	1.1	0.9	0.6
Vermont	2.1	1.5	1.7	1.3	1.3	1.6
Virginia	3.9	1.5	1.9	1.9	1.5	1.3
Washington	9.7	2.9	2.1	2.4	2.3	1.9
West Virginia	0.1	1.1	0.4	0.3	0.3	0.3
Wisconsin	15.0	11.8	11.0	11.0	13.1	13.2
Wyoming	0.0	0.0	0.0	0.0	0.0	0.0

Table 9. Percentages of progeny-test (**PT**) daughters in each of the top five states by breed for bulls that entered AI sampling during 1994.

Breed	State	PT daughters
		(%)
Ayrshire	New York	21.8
	Pennsylvania	17.3
	Vermont	11.2
	Iowa	6.7
	Maryland	5.5
	Top five states	62.5
Brown Swiss	Wisconsin	21.4
	Iowa	14.9
	Ohio	13.0
	Minnesota	7.8
	California[1]	3.8
	Top five states	60.9
Guernsey	Wisconsin	30.5
	Pennsylvania	12.8
	New York	9.6
	Iowa	5.3
	Minnesota	5.2
	Top five states	63.4
Jersey	California	22.7
	New York	8.6
	Pennsylvania	8.2
	Oregon	5.7
	Arizona	5.3
	Top five states	50.5
Milking Shorthorn	Minnesota	46.0
	Wisconsin	16.0
	Vermont	10.0
	South Dakota	6.0
	New Hampshire	6.0
	Top five states	84.0

[1]Tied with Illinois.

of the desire for higher accuracy of genetic estimates for some newly evaluated fitness traits of low heritability.

Standard deviations for numbers of daughters per PT bull has declined, which suggests more uniformity in the size of progeny groups during recent years. That decline may result from more controlled and efficient sampling operations after AI organization mergers compared with the sampling operations of the smaller organizations during earlier years.

Table 5 also shows the mean numbers of herds in which daughters of PT bulls are located. As expected, number of herds per PT bull was highly related to number of daughters but generally was only 50 to 75% as large. The size of this percentage was directly related to breed population. Milking Shorthorns have the smallest population and had about 50% as many herds as daughters per PT bull (mean of two daughters per herd). On the other extreme, Holsteins had about 70% as many herds as daughters per PT bull (mean of 1.4 daughters per herd). The ratio of daughters to herds for individual PT bulls showed a significant ($P < 0.001$) linear increase across time for all breeds except Milking Shorthorn ($P < 0.001$). Both linear and quadratic regression coefficients were significant ($P < 0.001$) as well for all breeds. As numbers of herds decrease and herd sizes increase in the future, the daughter:herd ratio for PT bulls could also increase, but the means in Table 5 show no evidence of such a trend through the 1990s. The standard deviation for number of herds per PT bull declined for Holsteins, which suggests more uniformity in sampling programs. The other breeds often showed declines as well, especially during recent years, but some decrease was expected because of the smaller numbers of daughters per PT bull for those breeds.

The mean numbers of states in which daughters of PT bulls are located are also shown in Table 5. For Holsteins, the mean number of states with daughters increased from 5 to 11 per PT bull from the early 1960s to the mid 1990s, even though the mean number of daughters per PT bull declined from 67 to 61. This trend is welcome because of the reduced likelihood of distorted evaluations from environmental effects when more environments are represented. The more widespread geographic distribution of PT daughters likely is a consequence of marketing agreements and mergers between AI organizations in different parts of the United States and conscious efforts by eastern and Midwest organizations to sample bulls in larger herds in the western United States. Similar trends were evident for the other breeds.

Table 10. Numbers and percentage of milk-recorded US cows of each breed that were progeny-test daughters with a first-lactation record usable for national genetic evaluations for selected years of first calving.

	Ayrshire		Brown Swiss		Guernsey		Holstein		Jersey		Milking Shorthorn	
Year	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1965	133	3.0	262	6.2	843	3.8	4260	2.5	715	4.1	3	0.4
1975	79	2.0	210	4.6	857	5.6	14,830	5.6	1195	6.8	89	13.7
1985	838	18.0	689	10.0	1421	10.9	46,394	7.4	2780	8.4	18	1.7
1990	822	18.7	815	12.5	1713	17.1	58,670	8.7	4232	11.4	119	10.4
1995	599	17.3	815	13.1	1103	18.9	77,774	11.6	6219	17.3	89	8.9
1998	566	21.6	855	15.4	851	20.6	88,305	14.1	6368	18.9	51	5.9

Table 11. Percentage of milk-recorded Holstein cows in each state that are progeny-test daughters for selected years of first calving.

State	1965	1975	1985	1990	1995	1998
	(%)					
Alabama	1.1	3.2	4.9	6.0	10.6	12.0
Arizona	1.3	1.1	5.0	6.5	6.3	5.4
Arkansas	1.2	7.5	9.8	17.5	15.4	12.5
California	1.3	8.9	11.8	11.8	15.4	17.2
Colorado	1.4	2.4	4.6	6.3	9.8	20.4
Connecticut	0.5	6.6	5.9	8.5	12.8	13.6
Delaware	1.4	6.1	5.3	6.7	9.3	18.2
Florida	0.0	7.1	5.9	10.1	22.9	17.0
Georgia	0.1	4.2	4.2	10.3	13.3	12.7
Idaho	1.4	4.5	7.8	7.1	10.3	23.5
Illinois	0.5	5.3	5.7	6.0	7.0	7.5
Indiana	0.6	3.6	4.2	4.8	6.5	7.4
Iowa	1.4	4.3	5.3	7.1	10.4	12.9
Kansas	4.5	10.6	6.6	9.5	9.4	9.6
Kentucky	0.2	4.0	4.1	4.0	5.5	7.1
Louisiana	1.6	6.4	10.3	12.0	11.3	12.5
Maine	4.8	4.9	7.8	8.6	11.7	13.4
Maryland	6.9	6.9	10.7	13.4	14.2	15.4
Massachusetts	1.4	7.0	6.8	7.4	12.3	13.9
Michigan	1.0	4.3	5.1	5.3	5.5	6.8
Minnesota	3.7	4.8	8.5	9.5	13.3	14.5
Mississippi	1.9	3.1	7.1	7.9	12.7	15.3
Missouri	1.2	1.9	3.9	5.2	6.8	7.2
Montana	2.8	3.4	3.3	1.7	4.3	3.7
Nebraska	0.1	2.4	4.8	5.6	8.0	8.5
Nevada	0.0	3.4	8.1	7.6	4.5	5.4
New Hampshire	6.9	5.7	6.2	7.4	8.4	11.7
New Jersey	0.4	4.3	9.7	11.9	12.2	13.3
New Mexico	0.0	2.4	8.5	9.0	11.4	21.0
New York	3.8	5.9	6.6	9.2	13.6	18.2
North Carolina	0.4	6.3	4.7	7.5	10.6	11.6
North Dakota	4.3	1.4	5.8	5.9	5.5	8.4
Ohio	2.6	5.7	6.1	7.5	8.0	9.6
Oklahoma	0.5	3.7	3.4	4.1	6.3	5.8
Oregon	0.9	11.9	7.1	6.9	10.7	11.2
Pennsylvania	2.6	5.6	8.3	10.4	12.6	14.2
Puerto Rico	0.0	2.0	2.3	4.0	5.9	5.8
Rhode Island	0.0	2.1	5.7	4.7	7.4	8.3
South Carolina	4.1	2.2	5.2	9.7	11.4	14.1
South Dakota	3.1	4.4	4.7	7.4	7.5	10.7
Tennessee	0.2	2.6	4.3	6.7	6.0	7.0
Texas	0.1	2.1	5.6	5.9	11.5	22.3
Utah	0.0	4.3	9.8	11.0	8.3	9.6
Vermont	3.0	4.7	5.4	7.1	12.3	15.3
Virginia	1.8	3.3	4.3	5.9	7.5	7.8
Washington	5.7	8.5	6.9	6.2	9.6	12.0
West Virginia	5.6	6.2	5.6	11.0	12.1	15.6
Wisconsin	3.2	5.6	7.6	8.0	11.1	13.9
Wyoming	0.0	1.0	3.4	0.0	4.3	33.3
US	2.5	5.6	7.4	8.7	11.6	14.1

A national sampling program that would be coordinated by NAAB was proposed (Welper, 1995), but such a program was never implemented, partly because of concerns among competing AI organizations. Nevertheless, a joint sampling effort would improve the accuracy of genetic evaluations, primarily from reducing extraneous environmental sources of variation, which can bias evaluations. Other benefits would be a concentration of daughters of young sires in a smaller number of herds, better genetic ties among bulls, and an opportunity to check the accuracy of identification by routine blood typing or DNA testing.

For herds with lactation records that were usable for national genetic evaluations, Table 6 shows the numbers and percentages of herds with at least one PT daughter by breed for selected years of first calving. The number of PT herds grew rapidly for all breeds between 1975 and 1990 but has declined during the

1990s, especially for Guernseys and Milking Shorthorns. Meinert et al. (1997) reported that 19,563 herds of all breeds participated in AI sampling through use of PT semen during 1989 and 1990. Not all those herds would be expected to obtain daughters or even to be participating in production testing when PT daughters were of milking age; in this study, 16,711 and 15,489 herds were found to have at least one PT daughter that first calved during 1995 and 1998, respectively. A large increase in the percentage of herds that participated in PT programs was found through 1990. The largest increases were for Holsteins and Guernseys; increases for Ayrshires and Jerseys were moderate. However, percentages have remained the same since 1990 for all breeds except Holstein. Meinert et al. (1997) found that over half of the herds that were enrolled in DHI test plans that were acceptable for use in genetic evaluation did not participate in PT programs of AI organizations. The percentage of Holstein herds that have contributed to at least one PT evaluation has improved from 44% during 1990 to 54% during 1995 to 55% during 1998 (Table 6).

Table 7 shows the numbers of herds with at least one Holstein PT daughter by state for selected years of first calving. The states with the largest numbers of Holstein herds with at least one PT daughter were Wisconsin, Pennsylvania, Minnesota, and New York. This information was not summarized for other breeds.

The percentages of Holstein PT daughters that are located in various states are in Table 8 for selected years of bull entry into AI sampling. Despite changes among states since 1970, California, Wisconsin, New York, Pennsylvania, and Minnesota remain the major contributors to current Holstein PT programs. Those five states accounted for 55, 62, 66, and 68% of all Holstein PT daughters during 1970, 1980, 1990, and 1994, respectively, and those states had the largest milk-recorded dairy populations as well (King et al., 1970; Wiggans and Hubbard, 1994). The percentages of PT daughters by state for bulls that entered AI sampling during 1994 are in Table 9 for the top five states for each of the other breeds.

Table 10 shows the numbers and percentages of milk-recorded cows that were PT daughters by breed for selected years of first calving. For Brown Swiss, Holsteins, and Jerseys, the number of PT daughters has increased steadily. For the other breeds, the number of PT daughters has decreased since 1990. The percentage of US Holsteins that were PT daughters increased from 2% during 1965 to 14% during 1998. Percentage of cows that were PT daughters also increased for all other breeds except Milking Shorthorn. During 1998, 6% of Milking Shorthorns, 15% of Brown Swiss, 19% of Jerseys, 21% of Guernseys, and 22% of Ayrshires were PT daughters. For Brown Swiss, Holsteins, and Jerseys, the increasing percentages resulted from increasing numbers of PT daughters and declining cattle populations. Further increases in percentages of cows that are PT daughters might be expected if the US dairy population continues to decrease. To remain competitive, non-Holstein breeders must maintain a higher percentage of PT daughters for their populations than do Holstein breeders because of the need to sample more bulls to overcome the disadvantages inherent with smaller population sizes.

To evaluate state contributions to PT evaluations in relation to state dairy populations, percentage of Holstein cows that are PT daughters was documented by state for selected years of first calving (Table 11). Variation is considerable among states, even among those with moderate and large populations. The highest percentages of PT daughters during 1998 were in states with rapidly expanding dairy populations: Wyoming (33%), Idaho (24%), Texas (22%), New Mexico (21%), and Colorado (20%). Percentage of state population that was PT daughters was not examined for the other breeds.

Table 12 shows the percentages of PT daughters that were registered with a breed association for selected years of first calving. Norman and Powell (1983) found that nonregistered (grade) daughters of regis-

Table 12. Percentages of progeny-test daughters that were registered with a breed association for selected years of first calving.

Year	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey	Milking Shorthorn
	(%)					
1965	83	87	79	56	73	100
1975	89	90	82	39	80	99
1985	84	85	82	25	83	94
1990	82	82	85	21	76	92
1995	79	85	84	20	78	85
1998	74	83	82	19	79	80

Table 13. Percentages of Holstein progeny-test daughters in each state that were registered for selected years of first calving.

State	1965	1975	1985	1990	1995	1998
	(%)					
Alabama	. . .[1]	8	23	14	14	16
Arizona	. . .[1]	. . .[1]	52	37	39	63
Arkansas	. . .[1]	17	3	3	2	7
California	14	13	7	5	6	5
Colorado	. . .[1]	13	28	34	27	16
Connecticut	. . .[1]	28	13	26	33	24
Delaware	. . .[1]	69	46	31	42	47
Florida	. . .[2]	39	31	18	23	21
Georgia	. . .[1]	14	21	28	19	23
Idaho	. . .[1]	12	10	10	12	10
Illinois	82	56	39	38	37	39
Indiana	. . .[1]	47	44	36	42	44
Iowa	29	35	19	19	22	17
Kansas	25	18	16	17	17	23
Kentucky	. . .[1]	31	38	38	43	59
Louisiana	. . .[1]	22	14	16	25	26
Maine	59	44	36	26	33	43
Maryland	57	46	32	35	29	35
Massachusetts	38	30	28	29	40	35
Michigan	57	50	29	24	28	28
Minnesota	18	22	14	10	10	10
Mississippi	. . .[1]	15	15	27	17	12
Missouri	. . .[1]	49	23	21	26	28
Montana	. . .[1]	56	29	. . .[1]	20	20
Nebraska	. . .[1]	24	22	15	11	26
Nevada	. . .[2]	. . .[1]	1	1	12	2
New Hampshire	72	63	53	48	40	40
New Jersey	. . .[1]	70	41	33	46	32
New Mexico	. . .[2]	50	1	6	3	14
New York	66	50	36	25	25	20
North Carolina	. . .[1]	27	28	19	15	21
North Dakota	. . .[1]	. . .[1]	16	18	23	35
Ohio	66	64	41	35	46	46
Oklahoma	. . .[1]	43	26	39	33	46
Oregon	. . .[1]	27	14	12	10	17
Pennsylvania	70	62	43	38	36	35
Puerto Rico	. . .[2]	. . .[1]	. . .[1]	8	12	1
Rhode Island	. . .[2]	. . .[1]	. . .[1]	. . .[1]	. . .[1]	. . .[1]
South Carolina	77	31	22	19	30	37
South Dakota	. . .[2]	38	29	28	26	23
Tennessee	. . .[1]	33	28	28	24	27
Texas	. . .[1]	33	26	21	15	11
Utah	. . .[2]	22	19	26	25	20
Vermont	63	48	31	28	30	26
Virginia	41	39	29	24	25	28
Washington	39	28	17	13	9	12
West Virginia	40	26	25	18	38	50
Wisconsin	82	54	33	29	27	24
Wyoming	. . .[2]	. . .[1]	. . .[1]	. . .[2]	. . .[1]	. . .[1]
US	56	39	25	21	20	19

[1]Fewer than 25 progeny-test daughters in state.
[2]No progeny-test daughters in state.

tered bulls contributed extensively to genetic improvement by permitting more bulls to be sampled. They reported that a mean of 65% of daughters were grades for the first released genetic evaluations of Holstein AI bulls between May 1975 and July 1981; mean grade percentages for other breeds ranged from 5 to 20%. Percentage of registered Holstein PT daughters in Table 12 declined sharply from 56% during 1965 to 21% during 1990; however, the decline has slowed, and 19% of Holstein PT daughters that first calved during 1998 were registered.

Historically, percentage of registered animals has been lower for Holsteins than for other breeds (Majeskie, 1996; Meinert and Norman, 1994), and the higher percentages for other breeds are reflected in higher percentages of registered PT daughters (Table 12): >70% for all other breeds regardless of year. Most non-Holstein breeds have shown small declines in the percentages of registered PT daughters since 1975. Of non-Holstein PT daughters that first calved in 1998, approximately 80% were registered for all breeds except Ayrshire (74%).

Table 13 shows the percentages of registered Holstein PT daughters for each state for selected years of first calving. Historically, Pennsylvania, New York, and Wisconsin have had higher percentages of registered cows than some other large dairy states such as California and Minnesota (T. J. Lawlor, 2000, personal communication). Vierhout et al. (1999) reported higher percentages of registered cows in New York than in Minnesota. Percentages in Table 13 confirm this finding; percentages of registered Holstein PT daughters during 1998 were 35% in Pennsylvania, 24% in Wisconsin, and 20% in New York compared with 10% in Minnesota and 5% in California.

CONCLUSIONS

Statistics on the scope and characteristics of PT programs were documented for AI organizations in the US over the last 40 yr. For major AI organizations, numbers of PT bulls increased through the mid 1990s and then began to decline slightly. Mean age of parents at birth of bull decreased for all breeds except Milking Shorthorn; mean age of maternal grandsire at birth of bull decreased for Holsteins and Jerseys but increased for other breeds. Percentage of PT bulls that resulted from ET has increased steadily for Guernseys, Brown Swiss, Holsteins, and Jerseys. The dairy industry has reduced the generation interval for PT daughters by selecting younger parents of PT bulls and using new reproductive technologies.

The percentage of PT daughters that were registered declined and was 19% for Holsteins and around 80% for other breeds. Inbreeding in PT bulls has increased for all breeds and ranged from 3.8% for Brown Swiss to 6.4% for Jerseys for bulls that entered AI sampling during recent years, which is slightly higher than mean inbreeding in the milk-recorded population.

Mean numbers of PT daughters and herds per bull generally declined for all breeds except for slight increases for Ayrshire and Holstein bulls that entered AI sampling during the early 1990s. Percentage of first-lactation cows that were PT daughters increased and ranged from 6% for Milking Shorthorns to 22% for Ayrshires (14% for Holsteins) during 1998; further increases are expected as the US dairy population declines. Mean number of states in which PT daughters are located has increased, which will aid in reducing environmental distortions in genetic evaluations.

Review of the updated statistics by AI organizations should assist in efforts to improve operational efficiency and to anticipate and to prevent possible problems.

ACKNOWLEDGMENTS

Manuscript review by S. M. Hubbard, AIPL, ARS, USDA (Beltsville, MD) is appreciated. Special appreciation is extended to W. Glaeser, Semex USA (Madison, WI), for providing the identification numbers for bulls that were sampled in the United States by Semex USA.

REFERENCES

Dekkers, J. C. M., G. E. Vandervoort, and E. B Burnside. 1996. Optimal size of progeny groups for progeny-testing programs by artificial insemination firms. J. Dairy Sci. 79:2056–2070.
Doak, G. A. 1999. President's report. Pages 6–20 *in* Proc. 53rd Annu. Conv. Natl. Assoc. Anim. Breeders. Natl. Assoc. Anim. Breeders, Columbia, MO.
Durfey, W. M. 1976. Executive Secretary's report. Pages 13–18 *in* Proc. 30th Annu. Conv. Natl. Assoc. Anim. Breeders. Natl. Assoc. Anim. Breeders, Columbia, MO.
King, G. J., F. N. Dickinson, C. A. Rampendahl, J. J. Corbin, and A. H. Kienast. 1970. DHIA participation report, January 1, 1970. DHI Lett. 46(2), ARS-44-215. ARS, USDA, Beltsville, MD.
Lush, J. L. 1948. The genetics of populations. Mimeo. Iowa State Univ., Ames.
Majeskie, J. L. 1996. Status of United States dairy cattle. Natl. Coop. DHI Prog. Handbook, Fact Sheet K-7. Ext. Serv., USDA, Washington, DC.
Meinert, T. R., and H. D. Norman. 1994. Records contributing to national genetic evaluations by year, registration status, herd size, and region. J. Dairy Sci. 77:1466–1476.
Meinert, T. R., H. D. Norman, J. M. Mattison, and C. G. Sattler. 1997. Usability for evaluations of records in progeny test programs of artificial insemination organizations. J. Dairy Sci. 80:2599–2605.
Meinert, T. R., R. E. Pearson, and R. S. Hoyt. 1992. Estimates of genetic trend in an artificial insemination progeny test program and their association with herd characteristics. J. Dairy Sci. 75:2254–2264.
Miller, P. D. 1981. Artificial insemination organizations. J. Dairy Sci. 64:1283–1287.
National Association of Animal Breeders. 2001. Cross reference participants. NAAB Electronic Resource Guide. http://www.naab-css.org/db/xrefpart.html. Accessed Mar. 28, 2001.
Norman, H. D., B. T. McDaniel, and F. N. Dickinson. 1972. Modified herdmate comparison procedure that weights deviation yields considering daughters' distribution across herds. J. Dairy Sci. 55:691–692. (Abstr.).
Norman, H. D., and R. L. Powell. 1983. Use of grade animals in United States Department of Agriculture programs. J. Dairy Sci. 66:1567–1578.
Norman, H. D., and R. L. Powell. 1986. Pedigree selection of dairy bulls in the United States and resultant progeny tests. Proc. 3rd World Congr. Genet. Appl. Livest. Prod. IX:196–201.
Norman, H. D., and R. L. Powell. 1992. Genetic change attained and possible. Pages 59–66 *in* Large Dairy Herd Management. Amer. Dairy Sci. Assoc., Champaign, IL.
Norman, H. D., and R. L. Powell. 1999. Dairy cows of high genetic merit for yields of milk, fat, and protein—a review. Asian-Aus. J. Anim. Sci. 12:1316–1323.
Sattler, C. G. 1990. A.I. sires will be labeled by sampling method. Hoard's Dairyman 135:600.

Smith, L. A., B. G. Cassell, and R. E. Pearson. 1998. The effects of inbreeding on the lifetime performance of dairy cattle. J. Dairy Sci. 81:2729–2737.

Van Vleck, L. D. 1993. Selection Index and Introduction to Mixed Model Methods. CRC Press, Boca Raton, FL.

Vierhout, C. N., B. G. Cassell, and R. E. Pearson. 1998. Influences of progeny test programs on the genetic evaluation of young sires. J. Dairy Sci. 81:2524–2532.

Vierhout, C. N., B. G. Cassell, and R. E. Pearson. 1999. Comparisons of cows and herds in two progeny testing programs and two corresponding states. J. Dairy Sci. 82:822–828.

Welper, R. D. 1995. Do we need to restructure our progeny-test programs? I. Pages 31–32 *in* Natl. Dairy Genet. Workshop, Orlando, FL. D. Funk, ed. Coop. State Res., Edu., Ext. Serv., USDA, Washington, DC.

Wiggans, G. R., and S. M. Hubbard. 1994. NCDHIP participation as of January 1, 1994. Natl. Coop. DHI Prog. Handbook, Fact Sheet K-1. Ext. Serv., USDA, Washington, DC.

Wiggans, G. R., P. M. VanRaden, and J. Zuurbier. 1995. Calculation and use of inbreeding coefficients for genetic evaluation of United States dairy cattle. J. Dairy Sci. 78:1584–1590.