ARTIFICIAL INSEMINATION OF CATTLE IN SRI LANKA: STATUS, PERFORMANCE AND PROBLEMS

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Abstract

ARTIFICIAL INSEMINATION OF CATTLE IN SRI LANKA: STATUS, PERFORMANCE AND PROBLEMS.

Artificial insemination (AI) has been accepted as the primary breeding tool in genetic upgrading programmes of cattle in Sri Lanka. Three studies were conducted, to determine the coverage and performance of AI at national, provincial and district levels (Study 1), the success rate and factors affecting success rate of AI in wet zone mid-country smallholder farms (Study 2) and in wet zone up-country large multiplier farms (Study 3). The objective was to design, implement remedial measures and/or determine future studies necessary to improve the efficiency of AI services. Study 1 revealed that at national level the AI service reached less than 15% of the breedable cattle and accounted for less than 6% of estimated annual calvings. The coverage reached above 50% of the breedable cattle only in the wet zone while in the intermediate and dry zone areas it was negligible. Study 2 revealed that the mean calving to first service interval (CFSI) in cattle of the wet zone mid-country small holdings was 183 ± 87.1 days (n = 211) and the calving to conception interval (CCI) was 194 ± 93.9 days (n = 143). The first service conception rate (FSCR) was 45% and the overall conception rate (OCR) was 50.2%, with an average of 1.99 services per conception (S/C). Study 3 showed that the mean CFSI and CCI in wet zone up-country multiplier farmers were 111.2 ± 74.2 days (n = 133) and 156 ± 92.7 days (n = 170) respectively. The average FSCR and OCR were 50.4% and 53.6% respectively and the average S/C was 1.9. Study 1 showed that the AI coverage of the island is very low and the proportion of calvings from AI is too low to have a significant impact on genetic composition of the national cow population. Studies 2 and 3 showed that the success rate of the AI service in the more favourable and extensively covered wet zone areas was also low. These studies revealed that factors associated with the chain of events from farmer, cow, semen to the technician contributed to poor fertility.

1. INTRODUCTION

Artificial insemination (AI) could be regarded as one of the oldest and robust biotechnological applications that has made a significant impact in animal agriculture throughout the world. It was first carried out in farm animals at the beginning of the twentieth century by the Russian scientist Ivanoff and, by the 1930s, had spread to Europe and Northern America.

AI was first introduced into Sri Lanka in 1938 by T.M.Z. Mahamooth [1] and after successful trials, was offered to private breeders around Peradeniya. However, the acceptance by the breeders was very low. After independence from British rule in 1948, improvement of peasant agriculture and livestock was undertaken as a major strategy for development of the rural agrarian economy [2] and AI services commenced field operations in 1951 [1, 3]. Initially it was provided through the main centre at Peradeniya and two sub-centres in Colombo and Galle. By 1955, the number of sub-centres had increased to 17 and all were located in close proximity to railroads as it was necessary to transport processed liquid semen with minimum delay from the processing centre at Peradeniya. In 1960, semen collection and processing activities were transferred to Central Artificial Insemination Service Centre (CAIS) at Kundasale. This was followed by the establishment of two regional semen processing laboratories, one at Tinneveli and the other at Polonnaruwa. The deep frozen semen technology was introduced into the country on an experimental basis in 1966 and came into commercial operation in 1968 [4]. By 1975, there were 65 AI sub-centres in operation, spread across most regions of the country except the dry zone. Extension to the dry zone was gradual, and by 1997, there were 168 Veterinary Offices with 137 AI sub-centres operating the service with 357 technicians (258 government technicians and 99 private technicians). The number of AI services per annum increased from 72 in 1951 to around 108 338 in 1996. This expansion of the AI service was supported by several international donor programmes [5].

Although the AI service is in operation on an island wide basis, few scientific studies have been conducted to assess its performance [6, 7]. One study [6] reported that the efficiency of heat detection by smallholder farmers was less than 65% and nearly a third of inseminations were carried out during the wrong time with respect to oestrus. The other [7], a limited scale study in the wet zone mid-country area, showed that the conception rate (CR) was lower than expected and suggested that this was most likely due to poor heat detection by the farmers and delays in getting the cow served. Two consultancy reviews [8, 9] have also highlighted the poor performance of the AI service at national level.

Today the challenges to the farmer, extension worker and livestock researcher are many. The current level of productivity of livestock is too low to retain resources (land, labour and capital) in animal agriculture. Yet the rural resource poor have no skills to venture into any other economic pursuit. As such they will continue to remain in peasant-based agriculture and continue to perform poorly unless interventions are introduced. Therefore the need at this crucial juncture is to improve the productivity of animal agriculture so as to sustain the rural economy and maximise the welfare of the society. Within animal agriculture, the dairy sector forms the largest component. Its productivity has to increase several-fold in order to sustain this valuable industry and genetic improvement of the national cattle population is an obligatory step towards this goal. Today AI is recognised as the primary tool for genetic improvement in cattle breeding. Therefore, a series of studies was undertaken, to determine the coverage and performance of AI at national, provincial and district levels (Study 1), the success rate and factors affecting it in wet zone mid-country smallholder farms (Study 2) and in wet zone up-country large multiplier farms (Study 3). The objective was to design, implement remedial measures and/or determine future studies necessary to improve the efficiency of AI services.

2. MATERIALS AND METHODS

2.1. Study 1: Assessment of national, regional and district level coverage and performance of AI services [10]

2.1.1. Data collection

The records at the Division of Animal Breeding in the Department of Animal Production and Health (DAPH) and the Division of Planning and Monitoring in the Ministry of Livestock Development and Estate Infrastructure (MLDEI) were examined and the following data were extracted for the country, agro-ecological zones, provinces and districts: i) total number of AI service centres; ii) total number of cattle; and iii) number of AIs and recorded calvings. The published reviews and consultancy reports available at the data bank of DAPH were also reviewed.

2.1.2. Data analysis

A map of Sri Lanka depicting the agro-ecological zones, provincial boundaries, districts, locations of semen processing centres, veterinary surgeon's (VS) offices providing AI service and AI sub-centres centres was drawn up. Estimates of total breedable cattle and annual calvings at national, provincial and district levels from 1983 to 1996 were calculated. Percentages of breedable cattle covered by AI and proportion of estimated calvings due to AI at national, provincial and regional levels were calculated. The same data was rearranged according to three major agro-ecological zones of the country. For analytical purposes, the following assumptions were made: i) all recorded AIs were considered as first services, ii) 60% of the total cattle population were considered as females, iii) 55% of the females were considered as breedable; and iv) the annual calving rate of the breedable cattle population was considered as 50%. These assumptions were applied across the island, agro-ecological zones, provinces and districts.

2.2. Study 2: Survey on success rate of AI in smallholdings of the wet zone mid-country region [11]

2.2.1. *Location*

The study was conducted in the wet zone mid-country region since it is the one where the highest percentage of cattle belonging to smallholdings are bred artificially. It is located between 600–800 metres above sea level, with an annual rainfall of 2000–3000 mm, temperature of 25–28°C and humidity of 75–80% during the year. The dairy production system is characterised by smallholdings (1–2 cows/herd) of *Bos taurus* genotype, managed under zero grazing with natural grasses and supplemented with limited quantities of commercial concentrate feed. Five VS ranges (Gampola, Kundasale, Teldeniya, Udunuwara, and Yatinuwara) from this region were purposively selected for the study.

2.2.2. *Longitudinal study*

A sample of cows was monitored by performing a longitudinal field study during the period January 1996 to June 1997. In liaison with the VS offices and the inseminators serving these five ranges, dairy cows receiving first inseminations following a recorded calving were monitored until they were confirmed as pregnant. One investigator accompanied the inseminator to smallholder farms when there was a call for an AI. At the time of AI (day 0), the following detailed information relating to the farm, cow, semen and inseminator were recorded.

2.2.3. *Farm data*

Information was recorded regarding total land extent, herd size, the type of management, feeding systems and breeding practices, including the voluntary waiting period from detection of oestrus to insemination, housing system and herd composition.

2.2.4. *Cow data*

For cows presented to AI the identification number, date of birth, parity, last calving date, last calving type, date of first postpartum heat, body weight, service number, dates of AI, interval between heat detection and AI, time of day at which AI was done, observed heat signs, degree of vulval swelling, colour of mucous discharge, degree of uterine tone, site of semen deposition, code of semen, lactation state, body weight, body condition score (BCS) at time of AI and average daily milk yield were recorded.

2.2.5. *Semen/bull data*

For each AI performed the breed of semen donor, identification number, source of semen (local/imported), volume, type of semen (chilled/frozen), quality of semen (if available) and sperm dose were recorded.

2.2.6 *AI technician data*

Information on age, highest level of education, duration of formal training in AI, years of experience, average number of AI per month, type of employment, method of thawing semen and other non-AI work performed were recorded for each technician participating in the study.

2.2.7. *Milk sampling for progesterone measurement*

On day 0, a milk sample (10 mL) was collected into a bottle containing a potassium dichromate tablet as preservative. A second milk sample was collected 10–12 days later from the same cow and, if the cow was not presented for a repeat AI, a third milk sample was collected at 21–23 days after the AI. Dates of subsequent services if any were recorded for cows presented for repeat services. In all cases, those not returning to service within 60–90 days after the last service were examined for pregnancy by rectal palpation and the findings were entered in record sheets.

2.2.8. *Milk progesterone assay*

Milk samples were placed in a refrigerator (4°C) within 6 hours of collection and transferred to the laboratory for processing within 7 days. They were centrifuged at 4°C and 1000 × g for 10 minutes, the fat-free fraction (skim milk) was drawn off and stored at –15°C until assayed for progesterone using a direct solid-phase radioimmunoassay (RIA) employing antibody-coated tubes, ^{125}I-progesterone as tracer and standards (0, 1.25, 2.5, 5, 10, 20 and 40 nmol/L) prepared in skim milk (kits supplied by the FAO/IAEA Sub-programme on Animal Production and Health, Vienna). The intra-assay and inter-assay coefficients of variation were 9% and 14.5% respectively.

2.2.9. *Data tabulation and analysis*

Data were recorded and partially analysed using a computer database named AIDA (Artificial Insemination Database Application) which was developed by the FAO/IAEA Sub-programme. For further analysis data was exported to Systat (V.6.0 for Windows, SPSS).

2.3. Study 3: Survey on success rate of AI in state multiplier farms [12]

2.3.1. *Location*

Four multiplier farms, namely Ambewela, Bopaththalawa, Dayagama and New Zealand, were selected purposively for the study. They are located at 2000 metres above sea level, with an annual rainfall of 2000–2500 mm distributed throughout the year. The mean temperature ranges from 10°C in December to 25°C in April, with relative humidity of 75–80%. The dairy production system is based on pure *Bos taurus* genotypes, managed under zero grazing in one farm (New Zealand) and daytime grazing with stall-feeding at night in the other three. Feeding of commercial concentrates and mineral mixture is done on all farms.

2.3.2. *Longitudinal study*

Following the same procedures described in Section 2.2, two hundred cows receiving first insemination following calving were monitored during the period from April 1997 to December 1997. A sample of 200 cows bred artificially were studied longitudinally. The recording of data, collection and analysis of milk samples, and the recording and analysis of data were done as described previously.

3. RESULTS

3.1. Coverage and performance of AI service

A map of Sri Lanka depicting the agro-ecological zones, provincial and district boundaries, spread of semen processing centres, VS offices and AI sub-centres, total land extent and cattle population is given in Fig. 1. The total land extent of the island is 65 610 sq. km and the dry zone accounts for 62.9% of the total land area, while the intermediate and wet zone accounts for 13% and 24.1%, respectively. The total number of cattle is estimated at 1.7 million with 48%, 36.7% and 15.3%, respectively in dry, intermediate and wet zones. The largest concentration of AI service is in the wet zone region, followed by intermediate zone with the lowest coverage in the dry zone. The cattle density is lowest in the dry zone, followed by the intermediate zone with the highest concentration in the wet zone. Administratively the country is divided into 7 provinces; Central province (CP), Western province (WP), Southern province (SP), Eastern province (EP), Northern province (NP), North-western province (NWP), North-central province (NCP) and Sabaragamuwa province (Sab.P). The total number of administrative districts and divisions are 25 and 302 respectively and are served by 194 VS offices and 207 AI sub-centres (Internal Reports of the Department of Animal Production and Health).

3.1.1. *At national level*

The total number of AI performed in the country rose from 47 318 in 1983 to 109 008 in 1996 and the number of recorded calvings from AI rose from 2724 in 1983 to 18 183 in 1996. The increase in the total number of services paralleled the expansion of the veterinary service across the country, provinces and districts.

	Agro-ecological Zone	Land extent (Sq.km)	Number of Cattle	Density of cattle population (No./sq.km)	Command area/VS office/AI sub-centre (Sq.km)	Number of breedable cattle/VS Office/AI sub-centre
	Wet zone	41,300	844,200	20.4	555.0	3714
	Int. zone	8,500	646,600	76.1	71.8	1778
	Dry zone	15,810	269,200	17.0	177.6	998

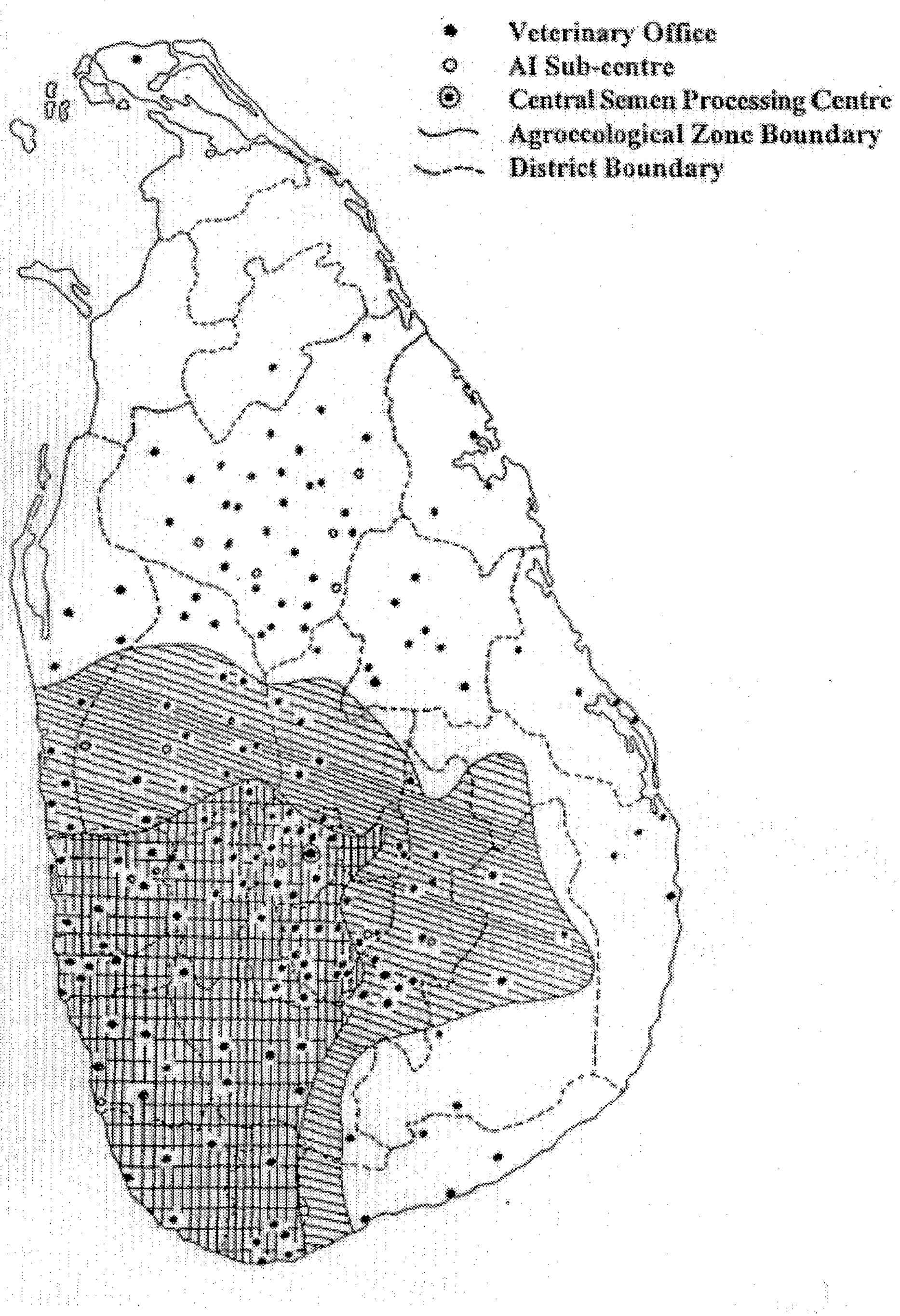

FIG.1. Map of Sri Lanka depicting the agro-ecological zones, district boundaries and locations of artificial insemination service points (veterinary offices and AI sub-centres).

The percentage of breedable cows covered by AI gradually increased from 8.6% in 1983 to 18.8% in 1996 and the proportion of AI calvings from the total estimated calvings rose from less than 1% in 1983 to 6.3% in 1996. The number of estimated female calves produced from AI in 1996, assuming that 50% calvings result in female calves and with 5% calf mortality was estimated to be 8642. The number of male calves produced appears to be less than this because of higher mortality among male calves. Empirical evidences suggest that only a small percentage of male calves reach adulthood and of them very few enter into the breeding population.

3.1.2. At agro-ecological zone level

The total number of AI done, coverage of breedable cows and performance criteria during 1996 for the wet, intermediate and dry zones are given in Table I.

TABLE I. NUMBER OF AI, COVERAGE AND PERFORMANCE IN DIFFERENT AGRO-ECOLOGICAL ZONES IN 1996

Agro-ecological Zone	Number of breedable cattle	Number of AI performed	Percentage of Breedable cows served by AI	Number of Recorded AI calvings	Calving rate from AI (%)	Number of estimated calvings	Percentage of calvings due to AI
Wet	88 836	60 913	68.6	12 228	20.1	44 418	27.5
Intermediate	213 378	35 989	16.9	4 616	12.8	106 689	4.3
Dry	278 586	12 106	4.3	1349	11.1	139 293	<0.1
Total	580 800	10 9008	18.8	18 193	16.7	290 400	6.3

Source: Department of Animal Production and Health (1997)

In 1996, the wet zone had recorded the highest number of inseminations, the highest coverage in terms of the proportion of breedable cows served by AI, highest number of calvings due to AI and the highest percentage of estimated calvings due AI. The dry zone had the lowest figures for all these parameters.

3.1.3. At provincial level

The total number of AI done, coverage of breedable cows and performance criteria during 1996 at provincial and district levels are shown in Table II. The highest number of AIs were done in CP and the lowest were recorded in EP and NP. The coverage in terms of the proportion of breedable cattle was highest in CP followed by WP, Sab.P, NWP, NCP, UP and SP. Lowest coverages were recorded in EP and NP. The highest calving rate was recorded in WP, followed by SP, CP, Sab.P, NWP, UP and NCP. The percentage of total estimated calvings after AI was highest in CP, followed by WP and was low in Sb.P, NWP, SP, UP and NCP. The proportion of calvings from AI was negligible in EP and NP.

3.1.4. At district levels

As shown in Table II, the coverage in wet zone districts was relatively high and ranged from about 10% in Matara to 100% in Kandy and Nuwaraeliya. In the intermediate zone areas the coverage was relatively low, lowest being in parts of Hambantota and Moneragala and high in Badulla. In most of the dry zone the coverage was very low (less than 0.1%) except in Anuradhapura, Polonnaruwa and Puttalam. The success rate as measured by the calving rates ranged from 30.4% in Gampaha to negligible levels in districts of EP and NP. Highest proportion of calvings from AI was recorded in Nuwaraeliya, followed by Kandy, Gampaha and Kegalle with other districts recording low percentages. Most wet zone districts recorded high proportion of calvings due to AI (>15%) while the intermediate zone areas recorded low proportions (<10%) with negligible levels in all dry zone districts except in Polonnaruwa and Anuradhapura districts which recorded around 3%.

TABLE II. NUMBER OF AI, COVERAGE AND PERFORMANCE IN DIFFERENT PROVINCES AND DISTRICTS IN 1996

Province	District	Total AI	Percentage coverage	Calving rate following AI	Percentage calvings due to AI
Central province	Kandy	21 744	100	18.8	45.9
	Matale	2831	20.3	14.7	4.5
	N'Eliya	15 182	100	28.1	49.9
Sub-total		*39 757*	*88.1*	*21.7*	*34.3*
Western province	Colombo	2227	28.1	12.2	6.7
	Gampaha	11 253	66.2	30.4	37.5
	Kalutara	2639	19.4	25.2	6.8
Sub-total	.	*16 179*	*42*	*26.6*	*17.8*
North western province	Kurunegala	15 600	23.4	13.4	4.5
	Puttalam	4560	14.1	29.2	6.4
Sub-total		*20 160*	*20.3*	*17.1*	*5.2*
North central province	Anuradhapura	7075	15.1	11.6	3.2
	Polonnaruwa	3077	17.5	11.2	3.1
Sub-total		*10 152*	*15.7*	*11.5*	*3.2*
Sabaragamuwa province	Kegalle	4058	54.4	23.4	24.7
	Rathnapura	1420	10.4	7.4	1.3
Sub-total		*5478*	*26*	*20.6*	*8.9*
Southern province	Galle	3810	32.5	18.7	7.8
	Matara	1147	18.4	45.5	11.3
	Hambantota	763	2.4	<0.1	<0.1
Sub-total		*6020*	*11.4*	*22.1*	*4*
Uva province	Badulla	8726	33.3	13.5	7.5
	Moneragala	642	3.6	<0.1	<0.1
Sub-total		*9368*	*12.4*	*11.5*	*4.5*
Eastern province	Ampara	528	1.4	29.5	<0.1
	Batticoloa	230	<0.01	<0.1	<0.1
	Trincomalee	331	<0.01	<0.1	<0.1
Sub-total		*1089*	*<0.01*	*18.6*	*<0.1*
Northern Province	Jaffna	214	<0.01	<0.1	<0.1
	Kilinochchi	0	<0.01	<0.1	<0.1
	Mannar	0	<0.01	<0.1	<0.1
	Mulativu	0	<0.01	<0.1	<0.1
	Vavuniya	652	<0.1	30.1	<0.1
Sub-total		*865*	*<0.1*	*2.8*	*<0.1*
Island total		*109 008*	*18.8*	*16.7*	*6.3*

Source: Department of Animal Production and Health (1997)

3.2. Success rate of AI in smallholdings

3.2.1. Fertility

The fertility indices of cattle subjected to AI in four veterinary ranges, based on 211 first inseminations on smallholder farms, are given in Table III.

TABLE III. FERTILITY INDICES IN CATTLE SUBJECTED TO AI IN FOUR VETERINARY RANGES IN THE MID-COUNTRY WET ZONE OF SRI LANKA

Veterinary	Mean (± SD) interval (days) from calving to:		Conception rate (%) to:		Services per
Range	First service	Conception	First service	All services	conception
Gampola	131 ± 51.5 (n = 34)	113 ± 50.6*(n = 17)	50 (n = 34)	50 (n = 34)	2
Kundasale	170 ± 114 (n = 52)	188 ± 74.8 (n = 39)	34.6 (n =52)	45.9 (n = 85)	2.2
Udunuwara	186 ± 80.8 (n = 84)	200 ± 89.3 (n = 73)	53.6 (n = 84)	60.8 (n = 120)	1.6
Yatinuwara	242 ± 103.3 (n = 45)	265 ± 131 (n = 15)	33.3 (n = 45)	31.3 (n = 48)	3.2
Overall	183 ± 87.1 (n = 211)	194 ± 93.9 (n = 143)	45 (n = 211)	50.2 (n = 287)	1.99

* Based on first service conceptions only

The average calving to first service interval (CFSI) was well over 6 months and the average calving to conception interval (CCI) was nearly 200 days, with significant differences ($P < 0.05$) due to location in both parameters. Cows at Yatinuwara VS rage recorded longest CFSI and CCI while the cows at Gampola VS range recorded the shortest CFSI and CCI. Similarly, first service conception rate (FSCR) and the overall conception rate (OCR) were significantly different ($P < 0.05$) among three locations; with Yatinuwara recording the lowest and Udunuwara recording the highest values. At the time of the first postpartum service, the mean body weight of the cows was 321.2 ± 77.5 kg, the body condition score (BCS, on a 1–5 scale) was 2.7 ± 0.4, and the average milk production was 7.7 ± 4.1 L per day.

3.2.2. Interpretation of progesterone data

Results from milk progesterone assay for day 0 samples (n = 258) revealed that 79.4% of the AIs were done when progesterone was below 1 nmol/L, indicating that the cow could have been in heat, but 13.2% of AIs were done when progesterone was above 3 nmol/L, when the cow could not have been in heat. The remainder of the samples (8.5%) had values in the inconclusive range (>1 and <3 nmol/L). Progesterone values for samples collected on days 0 and 10–12 (n = 258) showed that only 64.3% of the animals had a normal ovulatory cycle, while 10.5% were in anoestrous, 5% were pregnant and 5.4% were in luteal phase. Intermediate progesterone values were found in 14.7% of samples. The progesterone values from all three samples (days 0, 10–12 and 21–23) were available for 237 services and these along with data from pregnancy diagnosis (PD) by rectal palpation 60–90 days after service indicated that 44.3% conceived to that service. In 8.9% AI was done in the follicular phase but they failed to conceive or had early embryonic death and were not detected in heat until PD was done. Late embryo mortality or persistent corpus luteum (CL) occurred in 3.8%. In 2.1% of cases AI had been done during pregnancy while 6.3% were done in anoestrous cows. Intermediate level of progesterone with doubtful rectal findings at 60–90 days post-service was found in 23.6% while in 11% the results were not physiological meaningful.

The overall analysis of progesterone data revealed that 25.5% of AIs were performed at an erroneously detected heat. Of these, 13.2% were done in cows with an active CL where nearly half of them were pregnant at the time of AI, while 12.3% were done in anoestrous cows. Nearly 20% of the cows submitted for PD were found to be non-pregnant, while 5% of the cows which became pregnant had subsequently suffered late embryonic mortality.

3.2.3. Effect of different factors on success of AI in smallholder farms

Farm factors: No differences in CRs were evident in animals managed semi-intensively and intensively. However, tendency for higher, but statistically non significant, CRs were observed in animals fed concentrates (40%) than in those not fed concentrates (27%). When farms were grouped according to percentage of family income from dairy farming, those with less than 25% had an average CR of 26%, while those with higher proportions had CRs above 40%, but this difference was not statistically significant. For AIs performed 6, 12, 18, 24 and 30 hours after first detection of heat, the CRs were 25, 34.7, 38.1, 68.4 and 37.5%, respectively. The highest CRs (>60%) were recorded during the months of June, July, August and September, while the lowest (<30%) were recorded in March, April and November.

Cow factors: A tendency was seen for declining CRs from parity 1 up to a parity of 5; thereafter the numbers were too small for comparisons. Cows receiving their first service before 60 days postpartum had lower CR ($P < 0.05$) than those receiving the first service after 60 days. The data on other cow factors such as breed, body weight, body condition, milk yield at AI and intensity and type of oestrous signs were inconclusive.

Bull/semen factors: Semen from 22 bulls had been used in the sample under study. Of these, semen from seven bulls had been used for more than 20 services and their CRs ranged from 18.2–70.4% ($P < 0.05$). Semen originating at the Kundasale AI station gave higher ($P < 0.05$) CR (49%, n = 181) than imported semen (30%, n = 166). Data on effects of volume and dose of semen, type of semen (chilled or frozen) and motility before processing was inconclusive.

Inseminator: In the present study, only one technician was monitored in each of three veterinary ranges (Gampola, Kundasale and Udunuwara), while two were monitored in the fourth range (Yatinuwara). Technician had a significant effect ($P < 0.05$) on conception rate, with the overall CRs achieved by them ranging from 27.8% in Yatinuwara to 58.5% in Udunuwara. However, the technician factor is confounded within location and hence true effects cannot be separated.

3.3. Success rate of AI in large farms

3.3.1. Fertility

As shown in Table IV, the overall average CFSI and CCI were over 4 and 5 months, respectively. The longest CFSI was recorded at New Zealand farm while the shortest interval was at Dayagama. The longest CCI was recorded at New Zealand farm while the shortest was at Bopaththalawa. Both the FSCR and OCR were lowest at New Zealand farm and highest at Bopaththalawa farm

TABLE IV. FERTILITY INDICES OF CATTLE SUBJECTED TO AI

Farm	Mean interval (days) from calving to		Conception rate (%) to		Services per Conception
	First service	Conception	First service	All services	
Ambawela	102 ± 63.2 (n = 13)	159 ± 103.6 (n = 23)	53.8 (n = 13)	65.7 (n = 35)	1.5
Bopaththalawa	109 ± 66.3 (n = 34)	136 ± 65.6 (n = 42)	70.5 (n = 34)	69.3 (n = 62)	1.4
Dayagama	91 ± 33.5 (n = 35)	148 ± 101.5 (n = 45)	57.1 (n = 35)	60 (n = 75)	1.7
New Zealand	128 ± 96.5 (n = 51)	175 ± 96.1 (n = 60)	31.3 (n = 51)	40.8 (n = 147)	2.5
Overall	111.2 ± 74.2 (n = 133)	156 ± 92.7 (n = 170)	50.4 (n = 133)	53.6 (n = 319)	1.9

3.3.2. Interpretation of progesterone data

Results from milk progesterone assay for day 0 samples (n = 199) revealed that 79.4 % of the AIs s were performed when progesterone concentration was below 1 nmol/L indicating that the cow could have been in heat, but 9.5% of AIs were done when progesterone concentration was above 3 nmol/L, indicating that the cow could not have been in heat. The remainder of the samples (11.1%) had values in the inconclusive range (>1 to < 3nmol/L). Progesterone values of samples collected on day 0 and 10–12 (n = 199) showed that only 67.3% of the animals had normal ovulatory cycles. In 4.5% of cases AI was done in anoestrous cows, in 5.5% cases in pregnant cows and in 2.0% during the luteal phase. Intermediate progesterone values were found in 20.6% of the samples.

The progesterone values from all three samples (Days 0, 10–12 and 21–23) were available for 166 services. Progesterone data along with rectal palpation findings at PD indicated that 50% had conceived; 6.6 % most likely had non-fertilisation or early embryonic death or had gone into post-AI anoestrous; 4.2% had late embryonic death, luteal cyst or persistent CL; 1.2% were inseminated during pregnancy; and 2.4% were inseminated during anoestrus. None of these animals were detected in heat until PD. Intermediate progesterone values and inclusive rectal findings were found in 26.5% of the animals.

Overall analysis of progesterone data suggested that 16.4% of the AIs were done at an erroneously detected heat. Of these, 13.2% were done in cows with an active CL where more than half of them were pregnant at the time of AI.

3.3.3. Effect of different factors on AI

Farm factors: The farm had significant effect ($P < 0.05$) on the CR, with highest OCR observed at Bopaththalawa farm and the lowest at New Zealand farm. Farms which coupled visual heat detection with use of teaser bulls had higher CRs (64.5%) than those using only visual detection (40.8%). When the time from heat detection to AI was grouped as 0–6, 6–12, and 12–24 h, the respective CRs were 60%, 49.2% and 51.4%. Higher CRs (>50%) were recorded during the months of

August, June, July and September while the lower CRs (<40%) were recorded in April and March. But neither the time of AI nor the time of the year effect was statistically significant

Cow factors: There was a significant breed effect ($P < 0.05$) on CR. Among the pure breeds kept in these farms the Ayrshire breed had the highest CR (Ambewela, 65.7%), with the Jersey breed intermediate (60%) and the Friesian breed having the lowest (New Zealand, 40.3%). However, the breed effect is compounded within farms and hence true effects cannot be delineated. Parity had significant effect ($P < 0.05$) on CR, with a steady increase from parity 1 to 6 followed by a decline to the lowest CR in parity 10. A tendency for higher CRs were seen in animals with BCS of 2.5 and above and lower CRs in those with BCS below 2.5, but this was not reflected in the pooled data across farms. Type of heat sign noted at the time heat detection or service had significant effect ($P < 0.05$) on CR; cows which were observed to be at 'standing heat' at the time of AI had the highest CR (64.2%, n = 81) whereas those with signs of 'mounting others' and 'mucus discharge' had CRs of 47.4% and 42.5%, respectively.

Bull/semen factors: Imported deep frozen semen from five donor bulls (Ayrshire, Friesian and Jersey) were used on the cows in this study. The resulting CRs ranged from 34.2 to 68.9% with significant difference ($P < 0.05$) among donors; semen identification number Fr-390-1997 had achieved the highest CR (68.9%, n = 61) while the semen identification number Fr-387-1997 achieved the lowest CR (34.2%, n = 114). Semen code numbers Jr-208-1997, Fr-388-1997 and Ay-85105 had CRs of 59.5% (n = 74), 59.1% (n = 22) and 63.6% (n = 33), respectively.

Inseminator related factors: Three farms (Ambewela, Dayagama and New Zealand) had one AI technician per farm while the other (Bopaththalawa) had 2 technicians and all were resident on the respective farms. The technician factor was significant, with CRs ranging from 40.6% for the technician at New Zealand farm to 72.3% for one at Bopaththalawa. However, as the technician factor was confounded within farm factor, true effect of technician cannot be isolated.

4. DISCUSSION

4.1. AI service at national level

Although AI has been considered as the primary tool for cattle breeding in the country, it still reaches less than 20% of the breedable cattle population and accounts for less than 10% of the annual calvings in the country. Considering that only half of the calves born are females, coupled with the known high rate of wastage of male calves, the infusion of new genetic material into the national cattle population is therefore extremely low.

It was evident that although the AI service is in operation throughout the island, this service has gained grounds and established itself as a primary breeding technique only in a few provinces. In terms of numbers of cattle only about 10% of the estimated breedable cattle population (approximately 600 000 cattle) is provided with a coverage above 50%. The rest of the population (90%) are provided with very marginal coverage and more than two-thirds are still be bred naturally, mostly by scrub bulls.

This low level of coverage on a national basis as well as in some areas of the country appear to be due to many factors. The most significant factor is the variation in the infrastructural facilities, which is closely related to land use patterns coupled with the agro-ecology.

In the dry zone, which covers nearly two-thirds of the land mass and carries nearly half the cattle population, the coverage is less than 10% with a negligible level of coverage in many areas, particularly in the NCP, UP, SP, EP and NP. These areas have remained underdeveloped with respect to roads, transport and communication due to their low population density and harsh climatic conditions. Cattle are reared under extensive systems with dependence on communal grazing grounds which are often located far away from the farmers' dwellings. Further, the predominant genotypes are indigenous and the expression of heat signs is not well marked. Farmers in these areas rely on traditional knowledge rather than on modern technologies. This creates a problem for AI services as the intended recipients are not well motivated to get the benefits of such a service and are unable to detect heat signs and get the animals served in time. This clearly shows that the farmers need to be educated. However, the relatively few veterinarians in such areas are unable to fulfil this task due to the low resources in terms of trained personnel, mobility and operational budgets at their disposal. Most parts of the intermediate zone too have similar problems. Though the infrastructural facilities are relatively better compared with the dry zone, farmers in this zone are not willing to invest time and labour for an activity which does not bring enough returns. It is well known that the milk market is heavily distorted and the producers lack bargaining power at the present time. The combined effect of all these factors is the low AI coverage of animals in the dry and intermediate zones of the country.

In the wet zone areas with relatively better infrastructure and reasonably well informed farmers, such as in CP and WP, the majority of the animals are covered by AI. In these areas the predominant genotype is *Bos taurus* pure or crosses, the herd size is small, animals are managed with more care and farmers are compelled to use AI due to the absence of bulls for natural mating. Yet the success rate is lower than it ought to be.

The disparity in coverage and also the poor performance of AI in the different agro-ecological zones poses a serious question to development workers in the livestock sector. AI has been declared as the primary breeding tool in efforts towards genetic up-grading. However, in the light of continuous poor coverage and performance, particularly in most areas of the dry and intermediate zones, this policy may need to be re examined. This concern has also been expressed in many previous consultancy reports [8, 9].

4.2. Smallholder farms

In about a quarter of smallholdings in the mid-country wet zone of Sri Lanka, cattle farming for dairy production is an integral component of a mixed farming system [13]. The animals are predominantly *Bos taurus* genotypes and the system of management is semi-intensive or intensive. Most farmers resort to AI for breeding their cows, due either to the awareness of the value of AI for obtaining a calf of higher dairy potential or the unavailability of good quality stud bulls in their villages. The present study revealed that the majority of farmers had no specific preferences for breeds or type of semen indicating their lack of appreciation of the relative merits and suitability of different breeds for their particular farming environment. This points to an important need to educate the farmers on breeding goals and the appropriate use of AI to achieve these goals. The calving to first service interval was well over 4 months and this may most likely stem from the poor knowledge of farmers on reproductive management of cattle. The majority did not breed their cows until several months after calving because of the misconception that early re-breeding adversely affects the milk yield of the cow as well as the growth of the calf. The average calving to first service interval in this study was 183 days, whereas in a previous study in this area [14], the average interval from calving to first rise in plasma progesterone was around 75 days. While one of the reasons for the delay in first service could have been postpartum anoestrous due to poor nutrition as evident from the study, it is also likely that even those which returned to oestrus early in the postpartum period were kept unbred by the farmers due to the above misconceptions.

As evidenced from progesterone measurement in milk samples, the accuracy of oestrous detection has been significantly low, with 13.2% having an active CL and 12.3% being anoestrous at AI. Even in those with low progesterone levels at AI, only 64% appeared to have had a normal ovulatory oestrus. There is no doubt that these errors in oestrous detection would have contributed significantly to the observed low success rates of AI in this study. These results reinforce the findings of previous studies [6, 7] and indicate the need for farmer education, training and extension in this area.

The average first service CR was 45%, which can be considered to be within the lower range of acceptability for a developing country. However, two of the veterinary ranges studied had CRs below 35%, which is below acceptability. A large number of factors relating to the farm, cow, semen and inseminator were recorded in this study. However, given the highly heterogeneous nature of the sample, many of these factors did not have sufficient records in their different categories to allow for accurate interpretation. Also, several of the factors were interrelated and therefore produced confounding effects. However, a few factors, as discussed below, were perceived to be of practical importance and were found to have an overriding influence on CRs. These provide insights to ways in which the fertility of cattle in this region, as well as the AI service, might be improved.

Tendency for higher CR was found in animals fed concentrates as a supplement to roughages than in those not fed concentrates. The importance of nutrition is also evidenced by the finding that cows with good BCS had a tendency to show higher CR than those with poor BCS. Thus improved nutrition will not only reduce the postpartum anoestrous period as shown in many studies, but also improve CR. While recognising the possibility of direct effect of nutrition on fertilisation and subsequent events, the finding that farms with higher proportions of their total family income from dairying had shown tendency for higher CR than those with lower proportions, nevertheless indicate that these families attached more importance, and hence paid more attention, to the care of their cows. Presumably, this may include better feeding and heat detection, getting the cow served at the right time with respect to oestrus, resulting in higher fertility.

It is well known that the timing of insemination relative to first detection of heat is of a critical nature for achieving high CR [15]. In the present study, a trend in CR was shown with time from detection of oestrus to service; the CR increased as the interval increased from 6 up to 24 hours, and then declined. In theory, the optimum time for service is 12–18 hours after onset of "standing" heat. However, in the present study, the animals were housed or tethered and there was no opportunity for them to exhibit standing heat. Thus, it is likely that the farmer's reliance on signs such as vaginal mucous discharge and bellowing may have resulted in animals being detected during pro-oestrus, several hours before the actual onset of oestrus. This could explain the above results, since AI done 18–24 hours after detection by the farmer would mean 12–18 hours after onset of standing heat. Incorrect timing of AI can be a major constraint in many regions of Sri Lanka. This stems from the ignorance of farmers regarding the importance of correct timing of service and the poor communication between smallholdings which are scattered and the AI service centres which are few in number. Attention therefore needs to be focused on addressing these deficiencies.

Variations in fertility due to bulls were also observed. Of the seven bulls from which semen had been used for at least 20 inseminations, one had very poor CR (18.2%), while two others had CRs below 45%. The continued use of such bulls in an AI programme is clearly unwarranted. A regular programme should therefore be instituted to monitor each bull used in AI and to cull those that have low fertility. Semen produced locally gave higher CR than imported semen. Assuming that the imported semen was of good quality at the point of origin, problems during subsequent transport, storage and/or handling could be responsible for the decline in fertility. Although the number of observations was low, a tendency for higher CR with chilled than with frozen semen was seen. This further stresses the need for special care in all operations associated with frozen semen. The findings of this study emphasise the need for provision of optimal conditions for transport and storage of semen, and also for routine monitoring of quality at the point of receipt and during storage.

The influence of the technician on the outcome of AI is well documented. Not only their skill, but also motivation, attitudes and the facilities available have profound influence on the outcome of AI. In the present study, only one technician was monitored in each of three veterinary ranges, while two were monitored in the fourth range (Yatinuwara). Thus location was a confounding factor in interpreting the influence of technicians on CR in this study. However, the wide range of CR seen between individual technicians (27.8–58.5%) is noteworthy. Also, both technicians monitored at Yatinuwara (the location which recorded lowest FSCR and OCR) had the lowest CRs. Although further studies are needed to partition the effects of factors such as location, bull, semen type and technician in order to evaluate the true effects of technicians on CR, it is very conceivable that technicians may have contributed substantially to the variation in CRs in the present study.

4.3. Large farms

Of the four farms studied only one has achieved CRs at least in the lower level of the acceptable range, while the other farms recorded even lower rates. This is a matter for concern as these farms are the premier state farms for multiplication of *Bos taurus* cattle in the country and are kept for the purpose of providing superior breeding animals to the smallholder farmers.

A recent study has shown that less than 75% of total potential land extent on these farms have improved pasture and the stocking rate is much lower than the potential [12]. In one farm, the body weights of the mature animals are much lower than those expected for that genotype. This may be most likely due to sub-optimal nutrition and lack of a regular selection and culling policy for desired breed characteristics and performance. The sub-optimal feeding of animals was reflected in BCS, with most animals recorded at less than 2.5. In general all four farms do not appear to practice a regular systematic culling programme on the basis of age, productivity and reproductive performances as reflected in the heterogeneity of the cattle population in terms of parity. As shown in the present study, the older animals tend to be less fertile. Therefore, sound management coupled with regular culling is of paramount importance to achieve higher fertility in these multiplier farms.

The average CFSI in all farms were well over three months. This delay may be due to long periods of postpartum anoestrus and, judging from the body condition of these animals, this is most likely caused by poor nutrition, particularly during the early postpartum period. Though the animals on New Zealand farm had relatively better body condition, yet their production levels were higher than those of animals at other farms. Presumably, these high yielding animals may have run into nutritional limitations particularly during the immediate post-calving period because of a greater drain of nutrients through milk. With overall average of two services per conception, the overall CCI was well over 5 months. At this level of efficiency of postpartum fertility, the average inter-calving interval was estimated to be 18 months, which cannot be considered to be satisfactory for a multiplier farm.

Although the average milk production was superior at New Zealand farm, the indices of fertility were inferior to those in the other three farms, where these were in any case lower than the desired level. Many factors may have contributed to this situation: firstly, sub-optimal nutritional management; secondly, a high proportion of older animals; and thirdly, as discussed later, poor heat detection.

As evidenced from progesterone concentration in milk samples, the accuracy of heat detection and the timing of insemination at all farms was less than optimal. Based on progesterone levels on day of AI (day 0), 10% of the animals could not have been in oestrus. When progesterone levels in the two samples on days 0 and 10–12 were considered, only 67% appeared to have had a normal ovulatory oestrus. If the samples with inconclusive progesterone data are also included, 36% of the cows presented for AI were not correct candidates to receive an AI; they were either anoestrous, pregnant or had an abnormal oestrous cycles. Thus oestrous detection efficiency appears to be a major factor contributing to the low success rate of AI. This point is supported by the finding that the farms which coupled visual heat detection with teaser bulls had higher CRs compared to those farms that relied only on visual heat detection.

The timing of AI relative to first detection of heat is known to be critical for achieving high CRs [15]. In theory, higher conception rates can be achieved if animals are inseminated between 12–18 hrs after detection of heat. In the present study AIs were performed at time intervals ranging from 1 to 24 hours and, when grouped into 3 time intervals (0–6, 6–12, and 12–24), the respective CRs were 60, 49 and 51%. This pattern of conception in relation to timing of AI could have been most likely due to the herdsmen's inability to differentiate prooestrus and oestrus, and to make a correct judgement of the time of onset of oestrus.

Another factor which appears to have a significant effect on CR following AI is semen quality. It is apparent that factors relating to the chain of activities in performing AI such as transport, storage and handling of semen during thawing and the AI technique itself are very important determinants of CR [15]. Findings of on-going research in our laboratory indicate that there is significant reduction in quality of semen during storage and transport. There was a drop of sperm motility from 55 to 50% upon dispatch from the point of production to point of use. At the point of use there was again a significant reduction of motility with time, dropping to less than 30% over a 3 month storage period. As we have not looked into this aspect in the present study, conclusions cannot be made on the possible contribution of semen quality to recorded conception rates. With regard to technique of insemination, there appear to be differences between technicians, which may be related to skill, motivation, attitudes and facilities available to them. A wide difference was seen in CRs achieved by individual technicians. The lowest fertility was seen at the farm which was served by the technician with lowest achievement in CR. Whether this is a reflection of the technician's poor performances or the result of sub-optimal management factors related to heat detection, timing of insemination or semen factors cannot be determined for certainty at this point. Of the 5 bulls from which semen was used in at least 20 inseminations, one had very poor CR (34%). It is clear that there is an influence of the semen donor in the observed variation in fertility. Further studies are in progress to partition the effects of factors such as heat detection efficiency, timing of insemination, bull and semen type, and technician in order to evaluate the true effects of these factors on the observed fertility status of artificially bred cattle in Sri Lanka.

5. CONCLUSIONS

In conclusion, the findings of the first study indicate that the proportion of breedable cattle served by AI and the overall success rate of AI are too low to make a measurable impact on the genetic composition of the national cattle population. Many factors have contributed to this low level of performance and efficiency, including farmer's ignorance and low motivation, poor infrastructural facilities, inadequate veterinary coverage and resources, low motivation and mobility of field staff. The findings of the second study indicate that the overall success rate of AI in small-holder farms in the mid-country wet zone of Sri Lanka is in the lower range of acceptability, with high variability in CR between locations. Findings of the third study indicate that the overall success rate of AI in the four state multiplier farms studied was also lower than optimal. Both smallholder and large farm studies suggest that many factors appear to contribute to this low level of efficiency. Of these, poor heat detection and delays in getting the AI done stand out as the most important contributory factors. Results also indicate that the quality of semen, technical efficiency in its handling and storage, and the skill of AI technicians also contribute to this low success rate.

ACKNOWLEDGEMENTS

This study was conducted under an FAO/IAEA Research Contract (SRL-8301/RB) and we wish to acknowledge the financial assistance, RIA kits and computer software provided under the grant. We thank the officers in the Division of Livestock Resources Development in the Department of Animal Production and Health and National Livestock Development Board for providing information for Study 1. We also thank the officers in the Division of Livestock Resources Development in the Department of Animal Production and Health, the field veterinarians and the AI technicians in the five study areas for the assistance provided during Study 2. We record our gratitude to Mr. M.G. Chandrasena and Dr. Sarath Kaduwela of the National Livestock Development Board for permission to conduct Study 3. We are also very thankful to the Managers, Assistant Managers and AI technicians at Ambewela, Bopaththalawa, New Zealand and Dayagama farms for their cooperation and assistance provided during study 3. The technical services of Mr. A.M. Karunarathna, Mr. Janaka Herath and Ms. Ramani Ruwanpathirana are acknowledged with thanks. We are also grateful to Drs. J.A.de S. Siriwardena and D.H.A. Subasinghe for their advice and constructive criticism during the preparation of the manuscript.

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