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Understanding Livestock Systems and their Effect on Reproductive Performance of Achai and Jersey Crossbred Cows in Northern Hindukush Mountainous Ranges

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ZUK, AR designed this study, carried out the experiments and measurements and drafted the manuscript. ZI participated in the study's design, coordination, and paper writing. MS contributed in paper writing, review, and preparation. KU assisted with the data collection. AH, MS, SA, AG helped in data analysis and manuscript review.

Key words
Achai cow, Breeding, Farming systems, Traits, Non-genetic factors

ABSTRACT

A detailed survey was conducted to study the adopted farming practices and their effect on the reproductive performance of dairy cows to find out possible aspects of enhancing livestock profitability in high altitudes. For this purpose, 720 livestock households containing pure Mountainous Achai and its crossbreds with Jersey cattle and two state farms were investigated for management, nutrition, breeding practices, and reproductive performances i.e. Postpartum anoestrus interval (PPAI), open period (OP), services per conception (SC), and calving interval (CI) were recorded through a structured questionnaire and physical observations. Age and body condition of animals were considered as dependent variables with the main effect of farming systems and data was analyzed within each and across different farming systems. Results revealed that animals in households that modified their management, nutrition, and breeding approaches (rural progressive farming systems) had significantly improved their reproductive performance than animals in traditional practices. The study also revealed that crossbreeding significantly improved the reproductive performance of the mountainous Achai breed on either management practices. It was also observed that good condition adult (5 to 6 years age) cows of both breeds had shorter intervals (OP, CI, PPAI) and required fewer inseminations for a successful conception in traditional and progressive farming practices. However, it was noticed that introducing Achai cows to intensive farm management as in state farms, deteriorated their reproductive potentials revealing its nomadic nature well adapted to free mountainous ranges. Results from this study indicate that the reproductive performance of local Achai could be further improved through a very systematic and scientific approach to crossbreeding and improved management practices.

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INTRODUCTION

Achai cattle are distributed over the North Western Hindukush Mountainous ranges of Pakistan and adjacent areas of Afghanistan. In these ranges, farmers have substantial relations with livestock and rely on dairy products for basic life support (Saleem *et al.*, 2012). Achai cattle, considered a major breed that farmers prefer as economical livestock in high altitudes, has some promising characteristics like impressive performance on suboptimal quality roughages, enhanced immunity, and in some aspects has shown comparatively good reproductive record than any other cattle breed in Pakistan (Saleem *et al*., 2012). High resistant and well-adaptive to harsh climatic conditions make it more favourable to graze on rugged mountain terrain. However, the priority for increased milk production and accessibility to artificial insemination led to crossbreeding of Achai cows with exotic cattle particularly with the Jersey breed without a scientific approach. Previously, Achai cattle were reared under transhumant and sedentary farming systems (Saleem *et al*., 2012) however our previous study (Khalil *et al*., 2020) reported zero grazing practices with varying management and nutrition inputs resulting in rural traditional and progressive farming systems. Different nutritional and management requirements for livestock particularly crossbred cattle changed the farmer's approach to dairy farming. On one side, the increased demand for milk and meat production for human consumption questioned the potential of the Achai breed. The scenario of poor performance and reliance on crossbreeding of Achai with Jersey as an alternate source for improved performance threatens the existence of pure Achai cattle. On the other side, a question was raised that whether crossbreds of pure Achai cattle would be adaptive to climatic and management conditions of Hindukush mountainous ranges and could express their performance potential. The broader home tract of the Achai cattle is spread over the North-Western Hindukush Mountains with 34° 10N latitude and 72° 20E longitude. The area falls in both a subtropical dry temperate zone as well a moist temperate zone of the Hindukush series in Pakistan. Geographically, Afghanistan lies in the west, Swat in the East, District Chitral in the North, and Malakand Division in the south of the study area (Hazrat *et al*., 2015). The climatic conditions of the area are moderate. Annual precipitation and relative humidity of the study area range from 70-300 mm and 15 to 60%, respectively while temperature ranges from 20 to 33°C and -1 to 15°C during summer and winter, respectively (Fayaz *et al*., 2017). Northwest Frontier Province, nowadays called Khyber Pakhtunkhwa, has diverse agroecological zones. The North-western districts such as Dir, Bajuar, Chitral, and Swat partly cover the Hindukush Mountain ranges and come under the Northern dry mountains of agroecological zones (Hussain and Bangush, 2017). The geographical location of Dir valley (study area) extends from 35° 04' to 35° 46' N-latitude and 71° 32' to 72° 22' E-longitude. Elevation of Dir valley varies from 2100ft to 8000ft with a mild temperate climate, 70–200 mm annual precipitation, and 42 to 70 percent relative humidity. Such areas are fragile with steep gradient topography and diversity of environment, which make them more prone to small changes in climatic variability (Weather Spark, 2019). In this context, negligible research had been conducted on economic traits, particularly the reproductive performance of pure Achai and it's crossbred with Jersey cattle, which is the key source of income in the Northern Hindukush Mountains. The present study was therefore designed with the objectives to understand and document prevailing management practices and compare the reproductive performance of different age and body conditioned pure Achai and its Jersey crossbred cattle under different management practices.

MATERIALS AND METHODS

Structure of questionnaire and data collection

Between December 2016 and November 2017, 720 households and 356 animals at two state farms i.e. Livestock Research and Development Station and Achai Cattle Conservation Farm were surveyed for data collection. Farmers face-to-face interacted with repeated questioning to excerpt concrete information and concerned animals were tracked for confirmation of breed, housing pattern, and management, use of antiparasitic, growth and milk-supporting medicine, nutrition management, and reproductive performance (Table I). Data on reproductive performance recorded were days open (DO), postpartum anoestrus interval (PPI), calving interval (CI), and services per conception (SC). The calving interval was calculated as the interval (in days) between one calving to another calving following the procedure of Fodor and Ozsvari (2015). Days open were calculated as the interval (in days) from calving to successful conception while the interval (in days) from parturition to the onset of first oestrus was considered as postpartum anoestrus interval as per guidelines of Fetrow *et al*. (2007) where oestrus detection was based on bellowing, following by bull, frequent urination, mucus discharge form vulva and restlessness of animal as mentioned by farmers responded to the questionnaire and through visual confirmation wherever needed. Further, the recommendations of Fetrow *et al*. (2007) were followed for the calculation of the number of services per conception.

Classification of animals, feed sampling, and nutrient analysis

Local pure mountainous Achai and its Jersey crossbred cows were selected to study its reproductive performance under the effect of body condition score (BCS) and age in different farming practices (State Farms and rural farming practices). Age and BCS of the cow were determined through dentition as per the guidelines of Pace and Wakeman (2003), respectively. To evaluate the effect of different factors on the reproductive performance of cows, each factor was further categorized into different levels based on 1; Age (young cows; 2-4 years, adult cows; 5-6 years, older cows; 7-8 years) and 2; BCS (cow with BCS<2.50 and BCS>2.50). Seventy-five (250g) randomly collected feed samples (N=10 for each farming system in winter and summer seasons) were analyzed for nutrient composition including dry matter, moisture, crude protein and ash, crude fiber, EE, NFE, and TDN content (AOAC, 1995). All standard protocols for feed sample collection, processing, and chemical analysis were ensured. The quantity of feed offered and nutritive value of feed samples is detailed by Khalil *et al*. (2020), however, mentioned in Tables I and II, respectively, for access.

Data analysis

Initially, data collected were analyzed for variations in housing, management, and nutrition practices, breeding approaches, and other general considerations. Based upon variations observed, households were categorized as rural traditional farming practices (RTFS) and rural progressive farming practices (RPFS) as detailed in Table III of the results. Data were further pooled against different levels of studied factors (BCS and age of cows) in each farming system to study its effect on the reproductive performance of Achai and crossbred cows. To assess overall breed performance regardless of the success of the management system, two sample t-tests with a 5% confidence level were initially applied to mean values of reproductive traits of pure Achai and Jersey crossbred cows in the first phase. Upon significantly better results regarding the reproductive performance of Jersey crossbred cows, further comparison with pure Achai across management systems remained unnecessary, and Individual breed performance under dependent variables within and across management systems was analyzed. Therefore, in second phase, ANOVA was conducted separately for Achai and crossbred cows to find out the effect of farming systems on reproductive performance. The least significant test (LSD) was used to separate mean values across

Table I. Quantity of feed (kg) received by animals during different seasons in study area.

Feed ingredients (kg)	Achai in RTFS[1]	CB in RPFS[2]	Achai in RTFS[1]	CB in RPFS[2]
Summer season				
Concentrate	1.00	0.86	1.53	1.95
Dry bread	0.50	0.53	1.06	1.00
Green fodder	7.00	10.56	7.85	14.68
Wheat straw	1.00	1.03	1.00	0.50
Weed thinning	0.00	0.00	1.00	0.00
Tree leaves	2.50	2.67	2.53	4.00
Maize stover	0.00	0.52	1.00	0.00
Winter season				
Concentrate	1.00	2.00	2.00	3.00
Dry bread	0.73	1.40	1.00	2.00
Green fodder	0.00	1.38	0.00	0.00
Wheat straw	5.33	7.05	5.03	6.64
Weed thinning	1.73	0.52	1.50	1.39
Tree leaves	0.60	0.61	1.52	1.89
Maize stover	2.60	4.57	4.20	5.50

[1]RTFS, rural traditional farming system, [2]RPFS, rural progressive farming system. CB, crossbred

Table II. Nutritive value of feed ingredients provided to animals in studied area.

	DM %	Moisture	CP %	CF %	Ash	EE %	NFE %	TDN %
Grasses								
Poa alpine	92.73	07.27	21.20	19.67	09.01	06.20	51.74	-
Trifolium repens	90.13	09.87	22.62	19.64	08.32	04.60	44.62	-
Plectranthus rogusus	93.20	06. 80	13.11	21.63	08.87	05.40	42.50	-
Concentrates								
Wheat bran	88.72	09.37	12.03	09.84	04.63	03.12	68.73	74.05
Cotton seed cake	90.95	09.13	22.37	28.41	06.58	07.62	34.60	64.52
Mustard seed cake	91.76	08.32	32.08	19.84	12.02	09.64	26.21	84.63
Commercial concentrates	90.73	09.63	17.17	10.16	04.14	04.95	52.97	72.48
Crop residues								
Wheat straw	89.94	9.06	03.21	41.81	10.9	00.12	44.23	43.63
Maize stover	93.66	6.42	04.60	45.72	12.3	01.75	39.72	54.38
Fodder								
Barseem	13.64	86.36	19.34	21.41	16.28	01.86	43.47	61.65

DM, dry matter; CP, crude protein; CF, crude fiber; EE, ether extract; NFE, nitrogen free extract; TDN, total digestible nutrient

Table III. Attributes of the rural farming systems observed during study.

Factors	RTFS (n= 395)	RPFS (n= 325)
Altitude	6747±265.25	4343±152.60
Location	Mostly hilly areas	Slightly plain areas
Herd size (cattle)	3-5 cattle	4-10 cattle
Herd type	Mixed herd, including sheep and goats	Only cattle, Occasionally small ruminant
Management practices	Extensive	Intensive
Marketing situation (Various livestock inputs and outputs)	No orientation toward proper market, replacement practiced on cash, cereal crops or forage land use within neighbourhood	Milk and different products e.g. yogurt, cheese, krudh (a dried product produced from yogurt etc) are sold at community markets at good price,
Farming objectives	Milk production, animal sale, gifts at different ceremonies, bulls for plough, replacement, slaughter at different occasion	Milk production, Animal Sale
Milk production	Home consumption	Home consumption, Sale, Processing
Breeding plan	Indiscriminate breeding, Mostly natural with Achai bull, Occasional crossbreeding with *Jersey* Semen, No seasonal reproduction management.	Mostly crossbreeding with *Jersey* Semen, Occasional natural with Achai bull selected on phenotypic expressions, cows are generally mated or inseminated in pleasant weather of June-July to receive parturition in feed abundant months i.e. March-May.
Housing management	Sheds are made of clay walls mostly with soil flooring, occasionally bricks flooring with roof made of wood planks covered by mostly with hay and mud. In summer, animals chained with tree trunks are considered as open paddock. In winter season, animals are confined to shed for entire harsh (Dec-Feb) winter months.	Shed constructed with stones or cemented blocks mostly with brick flooring, occasionally cemented. Animals freely move in open paddock framed with wooden planks and tree branches from March-November. In winter animals are confined to sheds.
Feeding management (Detailed in **Table I** and **II** of materials and methods section)	Animals are left free in morning to graze on natural grasses. On return in afternoon, animals are stall fed with wheat straw, leftover bread, and dry grasses or tree leaves. Usually animals are fed less than required quantity, concentrate are offered occasionally or according to physiological condition of cow. supplementation for increased production is rare	Mostly two time (per day) stall feeding with optimum quantity and quality of feed is provided, concentrate and supplementation of increased production is regularly practiced. Forages are commonly grown for animals.
Health Management	Mainly homemade remedies are frequently used for deworming and ecto-parasites, occasional vaccination, veterinary treatment only due to extreme health condition. For freshly parturated cow, a local remedy of oil cooked wheat flour mixed with different locally produced sugar and grinded herbs are offered for 2-5 days to recover form parturition stress.	Professional veterinary treatment + Homemade remedies, Regular vaccination

different farming systems. In the third phase, within breed combined analysis of variance technique was followed separately for Achai and crossbred cows to study the effect of all levels of dependent variables across farming systems according to Annicchiarico (2002). In 4th phase, the data was further analyzed among different levels of dependent variables with each management system. Mean separation was carried out using the LSD test following Steel and Torrie (1984) where required.

RESULTS

Figure 1 shows the comparison between reproductive performance i-e OP (Fig. 1A), S/C (Fig. 1B), CI (Fig. 1C), and PPAI (Fig. 1D) of indigenous purebred Achai and its Jersey crossbred cows. Regardless of management and dependent variable effect, Jersey crossbred cows had significantly ($P<0.05$) 24 days shorter OP, PPI, and CI than pure Achai cows. However, the difference in services/ conception ratio between Achai and crossbred cows was not significant ($P>0.05$). Figure 2 shows theeffect of different management systems on the OP (Fig. 2A), S/C ratio (Fig. 2B), CI (Fig. 2C), and PPAI (Fig. 2D) of indigenous purebred Achai cows. Achai cows reared in RPFS had significantly 43 days shorter OP ($P<0.02$),40 days shorter PPI ($P<0.04$), and 49 days shorter CI ($P<0.01$) and better S/C ratio ($P<0.01$) than cows kept under other farming systems (RTFS and SF). It also revealed that introducing Achai cows to intensive farming systems i.e., SF significantly affected their reproductive performances. Figure 3 shows the effect of different management systems on the studied parameters i.e., OP (Fig. 3A), S/C ratio (Fig. 3B), CI (Fig. 3C) and PPAI (Fig. 3D) of Jersey crossbred cows. Different farming systems showed a significant (P<0.00) effect on the reproductive performances of crossbred cows where better results were observed in RPFS. The average difference of 12 days shorter (P=0.01, P=0.001, respectively) OP and CI, 20 days shorter (P=0.001) PPAI interval and 0.3 (P=0.02) ratio better services/conception ratio was observed in crossbred cows reared in RPFS compared to other farming systems. Table IV shows the effect of body condition and age on OP of pure Achai and its crossbreds with Jersey cattle under different management systems. Within management systems effect of BC was observed in SF and RTFS where pure Achai cows with BCS>2.50 had significantly (P=0.00 and P=0.01) 17 days shorter OP compared to cows with BCS<2.50 in both systems. Across management systems effect of BC was observed in both conditioned Achai cows.

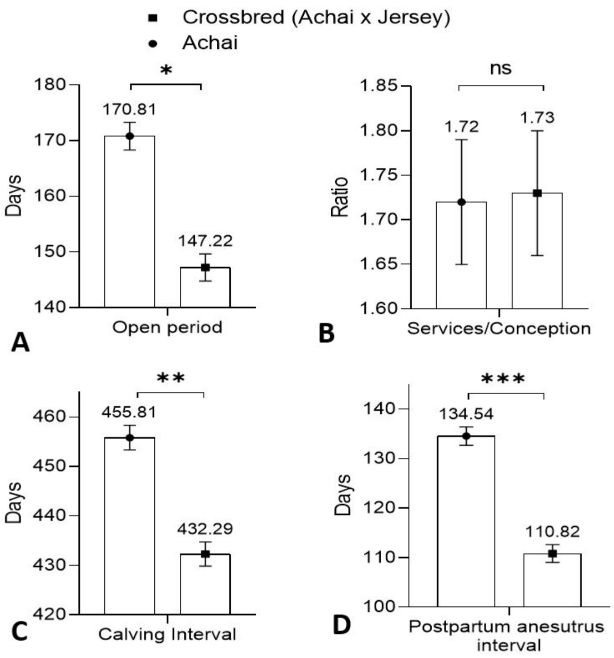

Fig. 1. The overall reproductive performance of studied animals where crossbred of mountainous Achai cows with had shorter (A) open period (*P=0.00), (B) sevices conception ratios; (C) calving interval (**P=0.02) and (D) postpartum anoestrus interval (***P=0.01) interval than pure Achai breed.

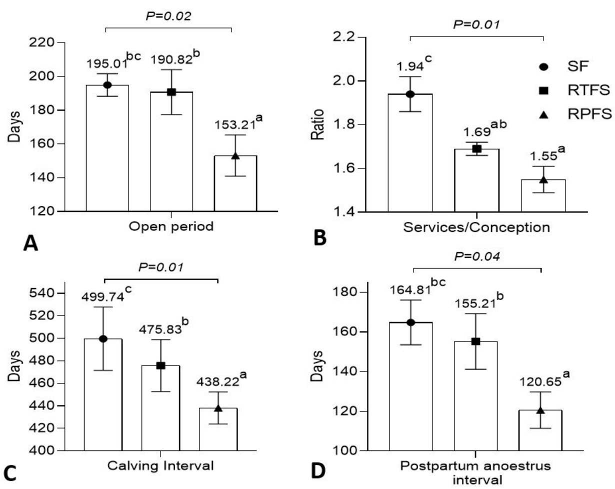

Fig. 2. The reproductive performance of mountainous Achai breed cows under state farming practices (SF), rural traditional farming practices (RTFS) and rural progressive farming practices (RPFS) and reveals that cows in RPFS had shorter (A) open period (P=0.02), where cows required less (B) services per conception (P=0.01), resulted in shorter (C) calving interval (P=0.01) and (D) postpartum anoestrus interval (P=0.04) interval than Achai cows reared under SF and RTFS.

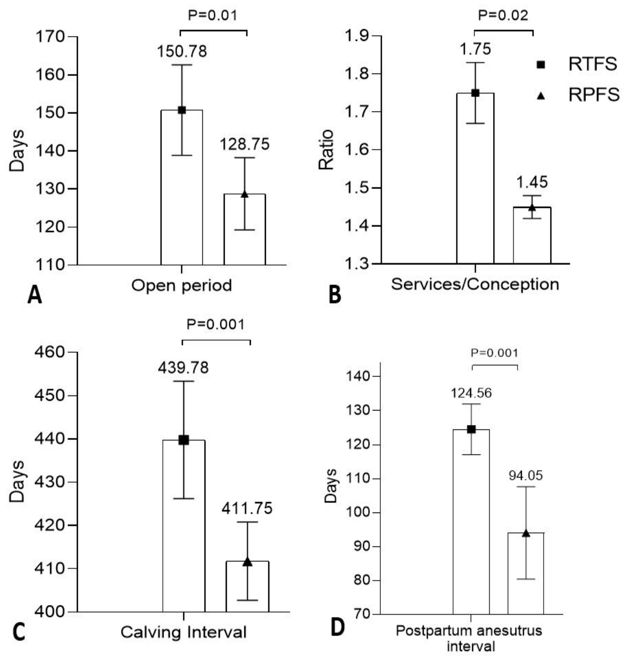

Fig. 3. The reproductive performance of mountainous *Jersey* breed cows under rural traditional farming practices (RTFS) and rural progressive farming practices (RPFS) and reveals that cows in RPFS had shorter (A) open period (P=0.01), where cows required less (B) services per conception (P=0.02), resulted in shorter (C) calving interval (P=0.001) and (D) postpartum anoestrus interval (P=0.001) interval than cows reared under RTFS.

Table IV. Effect of body condition score (BCS) and age on open period (days) of Achai and crossbred cows under different management systems.

	Levels	SF	RTFS	RPFS	P value
Achai cows					
BCS	<2.5	192±5.44^{a}	185.1±2.89^{ab}	157.3±4. 23^{c}	0.04
	>2.5	175.6±7.22^{a}	168.4±3.44^{ab}	161.5±7.32^{bc}	0.07
	P-value	0.00	0.01	0.08	
Age	< 4 years	177.3±21.0^{Aba}	161.4±9.53^{ABb}	146.2±12.2^{ABc}	0.00
	4-6 years	158.7±19.5^{Ca}	154.6±11.5^{BCab}	139.8±23.3^{BCc}	0.04
	7-8 years	189.4±26.1^{Aa}	173.2±09.21^{Ab}	157±27.2^{Ac}	0.02
	P-value	0.02	0.03	0.04	
Crossbred cows					
BCS	<2.5	*	156.2±8.63	151.5±7.32	0.08
	>2.5	*	132.3±5.79	136.4±9.47	0.06
	P-value		0.00	0.04	
Age	< 4 years	*	174.4±09.6^{A}	145.8±13.2^{AB}	0.00
	4-6 years	*	143.2±14.8^{C}	125.1±10.5^{C}	0.03
	7-8 years	*	161.4±11.0^{B}	149.6±13.1^{A}	0.06
	P-value		0.02	0.04	

Significantly different means at P<0.05 within rows are expressed with small alphabets whereas means if significantly different at P<0.05 within columns are expressed with capital alphabets. * Data regarding crossbred cows was not available in state farms. SF, State farms; RTFS, Rural traditional farming system; RPFS, Rural progressive farming systems. For abbreviations see Table I and IV.

In lean cows (BCS<2.50), significantly (P=0.04) 35 and 28 days shorter OP interval was observed in cows under RPFS versus SF and RTFS, respectively. Within management systems effect of age was observed in all systems where adult (4-6 years of age) pure Achai cows in SF had significantly (P=0.02) 30 days shorter OP versus old (7-8 years of age) and 19 days shorter versus young (<4 years age) cows. In RTFS, old (7-8 years) Achai cows had 19 days longer (P=0.03) OP versus adult (4-6 years age) cows. In RPFS, adult cows had 18 days longer (P=0.04) OP compared to old cows. Across management systems effect of age was observed in all age groups. Young (<4 years of age) cows in RPFS had 15 and 31 days shorter OP versus RTFS and SF, respectively. Adult (4-6 years of age) cows in RPFS had 15 and 19 days shorter OP versus RTFS and SF, respectively. Old (7-8 years age) cows in RPFS had 16 and 32 days shorter OP versus RTFS and SF, respectively. For Jersey vs Achai crossbred cows, the within management systems effect of BC on OP was significant (*P*<0.05). Good condition (BCS>2.50) cows had 15 and 24 days shorter (P=0.02), (P=0.04) OP compared to lean cows (BCS<2.50) in RPFS and RTFS, respectively. Across management systems effect of BC was not observed in any BC group of crossbred cow.

Within management systems effect of age was observed (P<0.05) in both RTFS and RPFS. Adult (4-6 years age) crossbred cows in RTFS had 31 and 20 days shorter (P=0.02) OP versus young (<4 years age) and old (7-8 year age) cows, respectively. In RPFS, adult cows had 20 and 24 days shorter (P=0.04) OP compared to young and old crossbred cows, respectively. The effect of age on OP across management systems was observed in young and adult crossbred cows. Young and adult cows in RPFS had 29 and 19 days shorter (P=0.00, P=0.03) OP than same-age cows in RTFS. Table V shows the effect of body condition and age on the PPI of pure Achai and its crossbreds with Jersey cattle under different management systems. Within management systems effect of BC was observed in RTFS and RPFS where pure Achai cows with BCS>2.50 had significantly (P=0.00, P=0.04) 22 and 16 days shorter PPI compared to cows with BCS<2.50, respectively. Across management systems effect of BC was observed in both conditioned Achai cows. In lean cows (BCS<2.50), significantly (P=0.00) 40 and 25 days shorter PPI was observed in cows under RPFS versus SF and RTFS, respectively. Good-conditioned (BCS>2.50) cows in RPFS had 47 and 19 days shorter (P=0.01) OP compared to the same conditioned cows in SF and RTFS, respectively. Within management systems effect of age was observed in all systems where adult (4-6 years of age) pure Achai cows in SF had significantly (P=0.03) 22 days shorter PPI versus old (7-8 years of age) and 12 days

Table V. Effect of body condition score and age on PPI (days) of Achai and crossbred cows under different management systems.

	Levels	SF	RTFS	RPFS	P value
Achai cows					
BCS	<2.5	164.8±11.3[a]	149.5±12.1[b]	124.6±12.2[c]	0.00
	>2.5	155.2±5.05[a]	127.9±8.16[b]	108.6±14.8[c]	0.01
	P-value	0.06	0.00	0.04	
Age	< 4 years	146.2±23.7[ABa]	135.9±13.3[ABab]	121.5±15.6[ABc]	0.04
	4-6 years	134.7±19.5[Ca]	127.2±23.5[Cab]	112.2±11.2[Cc]	0.04
	7-8 years	156.1±16.3[Aa]	148.2±15.4[Aab]	124.7±07.3[Ac]	0.00
	P-value	0.03	0.04	0.04	
Crossbred cows					
BCS	<2.5	*	129.1±5.69	125.4±5.22	0.06
	>2.5	*	105.4±3.27	103.4±4.82	0.09
	P-value		0.00	0.02	
Age	< 4 years	*	141.1±19.6[A]	116.6±13.5[AB]	0.02
	4-6 years	*	121.6±16.5[BC]	111.3±10.9[BC]	0.06
	7-8 years	*	128.2±13.8[B]	128.3±18.5[A]	0.08
	P-value		0.09	0.06	

Significantly different means at P<0.05 within rows are expressed with small alphabets whereas means if significantly different at P<0.05 within columns are expressed with capital alphabets. For abbreviations see Table I and IV. PPI, post partun anoestrous interval.

shorter versus young (<4 years age) cows. In RTFS, adult (4-6 years age) cows had 8 and 21 days shorter (P=0.04) PPI versus young (<4 years age) and old (7-8 years) Achai cows. In RPFS, adult cows had 09 and 12 days shorter (P=0.04) PPI versus young and old Achai cows. Across management systems effect of age was observed (P<0.05). Young (<4 years of age) cows in RPFS had 14 and 25 days shorter (P<0.04) PPI versus RTFS and SF, respectively. Adult (4-6 years age) cows in RPFS had 15 and 22 days shorter (P<0.04) PPI versus RTFS and SF, respectively. Old (7-8 years age) cows in RPFS had 24 and 32 days shorter PPI versus RTFS and SF, respectively. For Jersey vs Achai crossbred cows, within management systems effect of BC on PPI was significant (P<0.05). Good condition (BCS>2.50) cows had 25 and 24 days shorter (P<0.00, P<0.02) PPI compared to lean cows (BCS<2.50) in RPFS and RTFS, respectively. The effect of BC across management systems was not observed in the present study. The effect of age within management systems was not significant (P<0.09, P<0.06) however adult (4-6 years age) cows in RTFS had 27 days shorter PPI than young (<4 years age) cows and 17 days shorter than old (7-8 years age) cows in RPFS. The across management systems effect of age was observed only in young crossbred (<4 years of age) cows. Young cows in RPFS had 25 days shorter PPI than same-age cows under RTFS. Table VI shows the effect of body condition and age on CI of pure Achai and its crossbreds with Jersey cattle under different management systems. Within management systems effect of BC was observed in SF and RPFS where pure Achai cows with BCS>2.50 had significantly (P=0.02, P=0.04) 20 and 18 days shorter CI compared to cows with BCS<2.50, respectively. Across management systems effect of BC was observed in both conditioned Achai cows. In lean cows (BCS<2.50), significantly (P=0.02) 41 and 18 days shorter CI was observed in cows under RPFS versus SF and RTFS, respectively. Good condition cows (BCS>2.50) under RPFS had 39 and 25 days shorter (P=0.04) CI than same conditioned cows under SF and RTFS, respectively. Within management systems effect of age was observed in all systems where adult (4-6 years of age) pure Achai cows in SF had significantly (P=0.04) 32 days shorter CI versus old (7-8 years of age) and 20 days shorter CI versus young (<4 years age) cows. In RTFS, adult (4-6 years age) cows had 9 and 23 days shorter (P=0.02) CI versus young (<4 years age) and old (7-8 years) Achai cows, respectively. In RPFS, adult (4-6 years age) cows had 09 and 20 days shorter (P=0.04) CI versus young and old Achai cows, respectively. Across management systems effect of age was observed (P<0.05) in all age group cows. Young (<4 years of age) cows in RPFS had 15 and 31 days shorter (P=0.02) CI compared to same-age cows under RTFS and SF, respectively. Adult (4-6 years age) cows in RPFS had 13 and 18 days shorter (P=0.04) CI versus same-age cows

Table VI. Effect of BC and age on CI (days) of Achai and crossbred cows under different management systems.

	Levels	SF	RTFS	RPFS	P value
Achai cows					
BCS	<2.5	483.7±15.4^{a}	460.1±17.8^{b}	442.3±13.9^{c}	0.01
	>2.5	463.4±11.4^{a}	449.4±12.3^{b}	424.4±9.22^{c}	0.04
	P-value	0.03	0.07	0.04	
Age	< 4 years	457.3±12.2^{Bba}	441.4±23.5^{Bb}	426.2±15.5^{Bc}	0.02
	4-6 years	437.7±15.2^{Ca}	432.6±17.3^{Cab}	419.8±16.5^{BCc}	0.04
	7-8 years	469.6±08.5^{Aa}	455.2±15.8^{Ab}	439.5±19.2^{Ac}	0.01
	P-value	0.04	0.02	0.04	
Crossbred cows					
BCS	<2.5	*	441.1±8.34	436.3±9.7	0.07
	>2.5	*	416.2±5.35	412.2±6.44	0.06
	P-value		0.00	0.00	
Age	< 4 years	*	454.4±22.4^{A}	427.8±23.1^{AB}	0.00
	4-6 years	*	424.2±18.7^{C}	402.1±16.7^{C}	0.01
	7-8 years	*	441.3±16.9^{B}	430.6±21.4^{A}	0.06
	P-value		0.03	0.02	

Significantly different means at P<0.05 within rows are expressed with small alphabets whereas means if significantly different at P<0.05 within columns are expressed with capital alphabets. CI, calving interval. For abbreviations see Table I and IV.

Table VII. Effect of body condition score and age on services per conception ratio of Achai and crossbred cows under different management systems.

	Levels	SF	RTFS	RPFS	P value
Achai cows					
BCS	<2.5	1.88±0.03^{a}	1.76±0.06^{ab}	1.56±0.05^{c}	0.04
	>2.5	1.78±0.10^{a}	1.54±0.07^{b}	1.53±0.02^{bc}	0.03
	P-value	0.41	0.12	0.26	
Age	< 4 years	1.49±0.24^{B}	1.42±0.25^{AB}	1.44±0.06^{AB}	0.09
	4-6 years	1.38±0.13^{BC}	1.29±0.11^{C}	1.31±0.13^{BC}	0.06
	7-8 years	1.88±0.09^{Aa}	1.67±0.32^{Aab}	1.48±0.17^{Ac}	0.02
	P-value	0.03	0.01	0.07	
Crossbred cows					
BCS	<2.5	*	1.88±0.06	1.82±0.14	0.07
	>2.5	*	1.27±0.04	1.36±0.12	0.06
	P-value		0.04	0.00	
Age	< 4 years	*	1.67±0.12^{AB}	1.43±0.19	0.06
	4-6 years	*	1.32±0.06^{C}	1.33±0.35	0.08
	7-8 years	*	1.70±0.21^{A}	1.39±0.42	0.04
	P-value		0.01	0.06	

Significantly different means at P<0.05 within rows are expressed with small alphabets whereas means if significantly different at P<0.05 within columns are expressed with capital alphabets. For abbreviations see Table I and IV.

reared under RTFS and SF, respectively. Old (7-8 years age) cows in RPFS had 16 and 30 days shorter (P=0.01) CI versus cows kept in RTFS and SF, respectively. For Jersey vs Achai crossbred cows, within management systems effect of BC on CI was significant *(*P<0.05*)*. Good condition (BCS>2.50) cows had 25 and 24 days shorter (P=0.00) CI compared to lean cows (BCS<2.50) in RPFS and RTFS, respectively. The effect of BC on CI of Jersey x Achai crossbred cows across management systems was not observed. Within management systems effect of age on CI was observed (P<0.05) in RTFS and RPFS. Adult (4-6 years age) crossbred cows in RTFS had 30 and 17 days shorter (P=0.03) CI versus young (<4 years age) and old (7-8 year age) cows, respectively. In RPFS, adult cows had 25 and 28 days shorter (P=0.02) OP compared to young and old crossbred cows, respectively. The across management systems effect of age was observed in young (<4 years age) and adult (4-6 years age) crossbred cows. Young cows in RPFS had 27 days and adult cows had 22 days shorter (P=0.01, P=0.01) PPI than same-age cows under RTFS. Table VII shows the effect of body condition and age on the S/C ratio of pure Achai and its crossbreds with Jersey cattle under different management systems. Within management systems effect of BC was not observed in any management system. Across management systems effect of BC was observed in both conditioned Achai cows. In lean cows (BCS<2.50), significantly (P=0.04) 0.32 times more services were required for cows under SF compared to cattle reared in RPFS. Good condition cows (BCS>2.50) under SF also required 0.25 times more (P=0.03) services than cows under RPFS. Within management systems effect of age was observed in SF and RTFS where old (7-8 years of age) pure Achai cows in SF required 0.50 times higher (P=0.03) services for successful conception. In RTFS, old (7-8 years age) Achai cows required 0.38 times more (P=0.01) services for successful conception compared to adult cows (4-6 years age). Across management systems effect of age on the S/C ratio was observed only in old (7-8 years of age) where cows in RPFS required 0.40 times fewer services for successful conception. For Jersey vs Achai crossbred cows, within management systems effect of BC on the S/C ratio was significant (P<0.05). Good condition (BCS>2.50) crossbred cows required 0.61 and 0.46 less *(*P<0.05*)* services for successful conception CI compared to lean cows (BCS<2.50) in RTFS and RPFS, respectively. The effect of BC on the S/C ratio of crossbred cows across management systems was not observed. Within management systems effect of age on the S/C ratio was observed (P<0.05) in RTFS only. Adult (4-6 years age) crossbred cows in RTFS required 0.35 and 0.38 times less (P=0.01) services for conception versus young (<4 years age) and old (7-8 years age) cows, respectively. Across management systems effect of age on the S/C ratio was found in old cows. Old cows in RPFS required 0.31 times less (P=0.04) services for successful conception as compared to same-age cows in RTFS.

DISCUSSION

Improving genetic makeup through crossbreeding has been very encouraging, predominantly for reproductive performances (Weigel and Barlass, 2003; Heins *et al.*, 2006). The same approach of crossing local pure Achai with the Jersey breed for improved performance was initiated in the Northern Hindukush region. However, certain protocols necessary for crossbreeding at the farmer's level were not systematically investigated and adopted. As a result, no prime findings, based on scientific grounds were observed. In this study, the northern Hindukush region was surveyed comprehensively to gather exact information regarding livestock farming through a detailed questionnaire. Interestingly, two management systems in addition to government state farms were broadly recognized upon dynamics in farming practices. Each system had unique characteristics where nutritional and management practices were majorly dissimilar. Results showed significant (P<0.05) improvement in the reproductive performance of the local Achai breed post-crossing with Jersey cattle. Several studies (Abera, 2016; Haque *et al*., 2015; Berry and Evans, 2014; Yifat *et al*., 2012) documented genetic variation in the postpartum reproductive efficiency of dairy cattle. The results obtained in the present study are higher than recommended values of different reproductive parameters which may be due to the severe winter season (Kaewlamun *et al*., 2011), feed scarcity (Mhamdi, 2012), poor management practices (Tekerli *et al*., 2001) and failure in heat detection (Belay *et al*., 2012) which were commonly observed in the study area. Haque *et al*. (2011) and Asimwe and Kifaro (2007) reported similar conclusions regarding the effect of genotype on the same traits. Although, their estimates varied from the findings of the present study which may due to variations in genetic makeup, nutritional status, environmental conditions, and management practices. The calving interval generally comprises gestation length and days open. The calving interval is less or more the same through all conditions in dairy cattle while days open have a significant association with breeding plans, housing, and nutrition (Sasaki *et al*., 2016). Some studies showed better reproductive performance including shorter days open and calving intervals in pasture-based cattle with different grazing management and supplementation (Rhodes *et al*., 2003). Various farming and management practices significantly affect the services per conception ratio. Several researchers (Rhodes *et al*., 2001a; Lamb *et al*., 2001; Royal *et al*., 2000; Moreira *et al*., 2001; Opsomer *et al*., 2000a) concluded the direct relationship between farming practices (pasture-based dairying vs stall-fed) with services per conception ratio in dairy cattle. Proper bedding and housing aid more and clear estrus behavior resulting in early heat detection and successful conception (Bewley *et al*., 2017). Some researchers (Pryce *et al*., 2004; Do *et al*., 2013) also reported a negative relationship between milking frequency and the onset of postpartum estrus, successful conception, and calving interval. The significantly shorter PPI in Achai and crossbred cows with a body condition score of more than 2.50 may be due to the proper functioning of dominant follicles which improves the fertility of cows (Hess *et al*., 2005). Good-condition cows also have frequent LH levels and higher concentrations of glucose and IGF-1 a factor that boosts the secretion of estrogen by dominant follicles and subsequently initiates estrus thus reducing the PPI of cattle (Pushpakumara *et al*., 2003). In addition, ovulatory responses to GnRH increases with increased BCS. Yavas and Walton (2000) demonstrated a positive correlation between BCS at calving, follicular development, and LH secretion and reported shorter PPI in good-condition cows due to improved follicles and LH secretion. Shorter PPI in good conditions cows has been reported by many researchers (Looper *et al*., 2003; Lents *et al*., 2003). The significantly shorter PPI observed in Achai cows of age group 4-6 years may be due to cow maturity in copping nutritional and environmental stress as mature cows are more adapted to such conditions (Mulliniks *et al*., 2015). The greater tendency of losing body reserves to support calving, lactation, and maintenance in young and old cows delays the PPI due to failure in estrus resumption and successful pregnancy rate. In young cows, the greater concentrations of NEFAs have been linked with decreased immunological functions as well as uterine diseases that delay ovulation and extend postpartum estrus resumption (Hammon *et al*., 2006). Briefly, the extended PPI in young and old cows might be the sensitivity against metabolic and endocrine signaling associated with several factors like nutrient intake and body reserve loss (Santos *et al*., 2009). The significantly better SC ratio in crossbred cows of body condition more than 2.5 may be due to quality oocyte production (Tiezzi *et al*., 2013) and secretion of other reproductive hormones (Kadannideen and Wegmann, 2003). According to Gillund *et al*. (2001), cows that lose more body condition scores had 56% low services per conception ratio than that cows lose less BCS. Some studies reported an increase in SC ratio by more than 50% in cows gaining body reserves at the third month of lactation (Straten *et al*., 2009; Krpalkova *et al*., 2014). Gatiusal *et al*. (2003) reported decreased (10%) pregnancy rate in poor-condition cows. Better conception rates in good conditions cows have also been reported in other studies (Gebregziabher *et al*., 2005). The significantly better SC rates in mature (4-6 years) Achai and crossbred cows may be due to adaptability to various physiological, nutritional, and environmental stresses (Mulliniks *et al*., 2015). Greater losses of body reserves in primiparous and older cows affect the reproductive hormonal profile which delays estrus resumption and cows to fail to conceive (Spitzer *et al*., 1995). Nishi *et al*. (2018) stated that markedly variations in hypothalamic hormone secretion and ability to respond to ovarian activities in different age cows may be the result of different SC rates in cows. Hauque *et al*. (2015) reported that a higher incidence of body losses in young cows and a greater risk of subclinical uterine infections in old cows are of major concern in increasing the SC rates in dairy cattle. The significantly shorter OP in Achai and crossbred cows of body condition more than 2.5 may be due to early postpartum estrus resumption, early ovulation, production of quality oocytes, decrease in embryo mortality, and less incidence in uterine diseases because of readily available energy as body reserves associated with balanced nutrition (Roche *et al*., 2007b; Rossi *et al*., 2008; Zadeh and Akbarian, 2015). BCS has been considered an influential factor in estrus resumption and successful conception that significantly reduces the OP interval of cattle (Spitzer *et al*., 1995). Cows with low body conditions have lower reproductive hormones which eventually results in extended OP due to late estrus resumption and successful conception (Manzoor *et al*., 2018). Pryce *et al*. (2004) reported that HF dairy cows losing 1 point BCS in early lactation have 5.4 days longer estrus resumption period and 6.2 days longer days to first estrus thus extending the overall OP of cattle. Reduction in OP of cattle with improved body condition has been reported in many studies (Looper *et al*., 2003; Lents *et al*., 2003; Mulliniks *et al*., 2015; Nafissatou *et al*., 2022). The significantly shorter OP in 3-4 years age Achai and crossbred cows may be due to better adaption to lactation stress associated with nutritional and environmental stresses (Mulliniks *et al*., 2015). The inability of young and old cows to perform normal reproductive activities during varying kind of stress conditions cause negative effect on different kind of reproductive hormones affecting the initiation of estrus (Bahmani *et al*., 2011), shortening estrus duration (Hammon *et al*., 2006), increased the services required for successful conception (Nishi *et al*., 2018) thus consequently extends the OP of dairy cows. The significantly shorter CI in good condition (BCS > 2.5) Achai and crossbred cows may be due to the proper development of follicles (Hess *et al*., 2005), the higher concentration of glucose, IGF-1 and frequent LH surges (Pushpakumaraa *et al*., 2003) which remarkably reduces CI by early estrus resumption. Cows with good body reserves produce quality oocytes and have a balance reproductive hormonal profile which helps in successful conceptions with a minimal number of services (Kadannideen and Wegmann, 2003; Tiezzi *et al*., 2013). In addition, cows with good body conditions have lower risks of early embryonic losses and uterine diseases thus chances of prolonged CI are decreased (Rossi *et al*., 2008; Zadeh and Akbarian, 2015). The significant effect of body condition on the CI of dairy cattle has also been reported in many studies (Looper *et al*., 2003; Hess *et al*., 2005; Krpalkova *et al*., 2014; Mulliniks *et al*., 2015). The significant effect of calving season on CI with better results in pleasant climatic conditions has been reported in many studies (Hansen and Seykora, 2006b; Santos *et al*., 2009; Asimwe and Kifaro, 2007; Bahmani *et al*., 2011). The significantly shorter CI in Achai and crossbred cows of 4-6 years of age may be due to cow maturity to face certain physiological conditions associated with nutrition and environmental stresses (Mulliniks *et al*., 2015). Adoption to these stresses is reflected in comparatively balanced reproductive hormonal profile in mature cows which results in early estrus initiation (Spitzer *et al*., 1995), successful conception, higher pregnancy rates, and shorter OP (Nishi *et al*., 2018) ultimately reducing the CI in cattle. According to Hammon *et al*. (2006) higher NEFA concentrations and uterine infections in young primiparous cows significantly affect the CI interval in dairy cows by extending the postpartum estrus duration. Furthermore, the greater losses of body reserves in young cows significantly increase the number of services for successful conception Mufti *et al*. (2010) which prolongs the CI in cows. The significant effect of age on CI of dairy cows with the shorter interval in mature cows has also been reported in many studies (Saha *et al*., 2014; Meikle *et al*., 2004; Woldu *et al*., 2011).

CONCLUSION

Achai x Jersey (crossbred) cows had significantly better reproductive performance than pure Achai cows. Improving management practices significantly improved the reproductive performance of both breeds as observed in the rural progressive farming system (RPFS). Achai and crossbred cows with a body condition score of more than 2.5 had better reproductive performance in all farming systems, particularly RTFS and RPFS. Introducing Achai cows to confined farming practices as observed in state farming systems during the study, significantly affected its performance.

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IRB approval

The experimental work was approved by the Board of study (BOS) meeting (September, 2019), The University of Agriculture Peshawar, KP, Pakistan

Ethical statement

The experimental procedures used in the study were according to the guidelines of the Ethical Review Committee of the Faculty of Animal Husbandry and Veterinary Sciences, The University of Agriculture Peshawar. Proper approval was taken by the aforementioned authority before the start of the experimental trial.

Statement of conflict of interest

The authors have declared no conflict of interest.

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