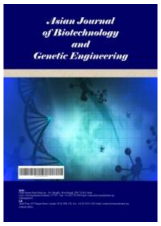

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Genetic Improvement Strategy of Indigenous Cattle Breeds: Effect of Cattle Crossbreeding Program on Their Reproductive Performances

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Authors' contributions

This work was carried out in collaboration between both the authors. Author TM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MS managed the analyses of the study. Author TM also managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The aim of the review is to summarize the fragmented information on the effects of cattle crossbreeding on reproductive performance of cattle in different parts of the globe. The performance of animals depends not only on their genetic merit but also on other factors such as feeding, health management and other environmental factors. All breeds have strong and weak traits; there is no single best breed in all traits. Crossbreeding native cattle of *Bosindicus* type and exotic *Bostaurus* cattle is now a widely used method of improving reproduction of cattle in the tropics and subtropics. Crossbreeding is the reverse of inbreeding and is economically important practice in livestock breeding. Crossbreeding is an attractive option for livestock genetic improvement because of the quick outputs obtained. Crossbreeding is a crucial genetic improvement option for the lowly heritable traits of animals such as fertility of cows. Crossbreeding programme should respect the principle of "the right animal in the right place". Under extensive management system of the tropics and subtropics, exotic cattle blood level inheritance should be

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from 50-62.5% for a maximum reproductive efficiency. Reproductive efficiency is a determinant factor for dairy and beef production efficiencies.Crossbreeding of highly productive and adapted breeds can improve overall performance. Heterosis is highest in F_1 generation than in F_2, F_3 and F_4 crossbred generations because the heterosis level is halved in each of the subsequent generations. Backcrossing reduces heterosis effects and thus reduces the advantages obtained from heterosis. However, it should be emphasized that heterosis cannot improve all traits, for example,carcass traits such as rib-eye area, marbling and meat tenderness. Calving interval affects total milk production of the dairy herd and the number of calves born, and is the most important index of reproductive performance.

Keywords: Crossbreeding; age at first calving; calving interval; days open.

1. INTRODUCTION

Most *Bos-indicus* indigenous cattle breeds are found in Africa [1]. Ethiopian cattle populations are grouped into Humpless Shorthorn and Longhorn (Bostaurus), humped Zebu (Bosindicus), Sanga (interbreed of Zebu and humpless cattle) and Zenga (interbreed of Sanga and Zebu type) ([2,3]). Reproductive performance is often a major determinant of biological and economic efficiency of livestock production in the tropics. Production of milk also depends heavily on reproductive performance of cows [4]. Age at first service (AFS), age at first calving (AFC), calving to first service interval and calving interval (CI) are the most important parameters that determine cattle reproductive efficiency and are important factors in terms of economics of dairy management [5]. Reproductive efficiency of dairy cows is influenced by different factors including: gene, season, age, production system, nutrition, management, environment and disease [6]. Benefits of crossbreeding have been known within many of the commercial livestock productions for many years ([7,8]). Because no one breed is superior in all traits, a planned crossbreeding program can significantly increase herd productivity [9] because properly designed crossbreeding system allows the cattle producer to take advantage of appropriate combinations of the superior traits of several different breeds and it also yields heterosis [10]. Heterosis is an essential factor in crossbreeding strategies [11]. Today the interest in crossbreeding increases [12] because crossbreeding is one option for improvement of milk composition, health, fertility, and survival due to much greater differences between breeds than the differences within breed and extra benefits can be achieved from heterosis [13]. Heterosis is the main benefit of crossbreeding which is the improvement in performance of crossbred offspring above the average of the parent breeds [14]. Crossbreeding resulted in 25% crossbred advantage (heterosis) in lifetime productivity of beef cattle [15]. Purebred cows are less profitable compared to crossbred dairy cows ([8,16]). The simplest model of crossbreeding is the two way cross where two different breeds are crossed [11]. However, [14] review work indicatedthat the breeding system with the highest economic profit seems to be the three-way rotational crossbreeding system.

Crossbreeding could be used as a tool for value addition to local breeds as long as the contributory local breeds are not threatened [17]. Crossbreeding in tropical countries is practiced to combine superior hardiness, heat tolerance, disease resistance and environmental adaptability of indigenous cattle with superior high milk yield, faster growth rates and early maturity of exotic, temperate breeds ([18,19]). It should be noted that the animal should fit for purpose and be the right animal in the right place [20]. The performance of animals depends not only on their genetic merit but also on other factors such as feeding, health management and other environmental factors. Both production traits (like daily milk yield and lactation length) and reproductive traits such as age at first calving and calving interval are crucial factors determining the profitability of dairy production [21]. Delayed age at sexual maturity and first calving, high number of services per conception (NSC) and longer calving interval are major areas of reproductive loss in cattle ([22,23]). Calving interval (CI) of 365 days is usually considered ideal for profitable milk production [24]. The performance of crossbred animals can be affected by the climate, temperature, region-specific breeds, on farmconditions, nutrition and breeding and management practices ([25,26]). [27] indicated that crossbreeding in the absence of clear-cutbreeding plans and programmes, further breeding of F1 progeny has resulted in marked deterioration of the advantages observed in F1 generation in the subsequent generations of F2 and beyond [1]. The highest level of individual heterosis is always observed in the F1 generation, and the heterosis level always decreases in thesubsequent generations. If F1 cattle are crossed to produce the second generation (F2), heterosis is halved compared to the level in the F1 and it continues to be halved in every of thefollowing generations of backcrossing to the parent breeds [11]. First generation crossbreds have zero inbreeding coefficients and will benefit from heterosis, particularly for reproduction and health traits. Thus, problems in purebreds due to inbreeding can be avoided or, at least reduced by crossbreeding [28]. The level of heterosis changes depending on the number of breeds in the cross ([7,29,8]). However, it also appears important to estimate the expected level of heterosis for traits of economic interest in dairy cattle in order toevaluate the profitability of crossbreeding [30]. Africa is endowed with a very wide range of mostly *Bosindicus* indigenous cattle breeds [1]. *Bosindicus* and *Bostaurus* breeds have different biological and economical attributes ([31, 32]). Crossbreeding native cattle (*Bosindicus*) and exotic (*Bostaurus)* cattle is now a widely used method of improving reproduction and production of cattle in the tropics [33]. Exotic cattle breeds and crossed with the indigenous cattle breeds, are mainly Holstein Friesian and Jersey [34].

Introduction of crossbreeding in smallholder systems is an indication that the major objectives of keeping cattle will change from multipurpose production to market-oriented production. Crossbreeding of exotic and indigenous cattle breeds is a major driving force for livestock intensification in developing countries [35]. Dairy production systems in most developed countries exclusively consisted of pure breeds of Holstein [36]. The domination ofHolstein was caused by its high production and good conformation traits ([25,7]). Crossbreeding is a worldwide programme which is undertaken without sufficient knowledge on the positive and negative effects on food production, genetic diversity, environment, resource use and the social and economic sustainability of the majority of farming systems and rural livelihoods ([37,38,39,40]).

1.1 Objective

To summarize the fragmented information on the effects of cattle crossbreeding on reproductive performances of cattle.

2. EFFECT OF CATTLE CROSS-BREEDING ON REPRODUCTIVE PERFORMANCE

Many authors reported that there is close interrelationship and effect between genotype and environment factors on the reproductive performances of beef and dairy cattle ([41,42,43]). Holstein Friesian, Simmental and Jersey crosses with inheritances of 50 to 62.5% was recommended as appropriate for smallholder dairy production in Ethiopia [44]. Delayed age at first calving (AFC) increases the cost of rearing and decreases lifetime milk production [45]. The reproductive performances of different indigenous and crossbred cattle are presented (Tables 1 and 2) hereunder. A number of studies revealed that selecting for high milk production led to a concurrent decrease in fertility ([46,47,48]). Crossbreeding is a worldwide genetic improvement option to overcome specific problems in dairy herds, notably to improve fertility in dairy cows [49]. Crossbred cattle exhibit fast growth rate, reduced ages at puberty and at first calving and calving interval [50]. F1 of 50% Friesian 50% Borana, F2 of 75% Friesian 25% Borana, F3 of 87.5% Friesian 12.5% Borana and F4 of 93.75% Friesian 6.25% Borana in BishoftuAda`a district were evaluated and F4 genetic group exhibited mean age at first service (23.7±4.08 months), AFC (33.36±4.6 months) were lower than the other genetic groups ($P<0.05$). The lowest mean of calving interval (13.2±1.45 months) ($P>0.05$) and number of services per conception (1.2±0.34) ($P<0.05$) was observed in F2 as compared to the other genetic groups [51]. Reproductive performance of indigenous and HF crossbred dairy cows in and around Gondar, Ethiopia maintained under farmer's management system were evaluated that the genetic constitutionof the animals influenced days open (DO), calving interval (CI) and number of services per conception (NSC) and were significantly ($P<0.01$) different [52].

As presented in Table 1, the mean AFC for 524 heifers born on the station was 32.9±0.3 months. ¾ Exotic ¼ Local exhibit earlier AFC than the other genotypes [4]. The longest CI (525 days) occurred among the 7/8 Friesian 1/8 Local breed group, these being the highest grade. The ½ Jersey ½ Arsi (403 days) and the ½ Exotic ½ Arsi (393 days) had shorter calving intervals than the pure Arsi (439 days) (Table 1). As presented in Table 2, the CI of local and crossbred dairy cows in Chacha town was 24.94±4.1 months and 22±4.4 months, respectively. CI of crossbred cows was shorter than local cows, however, the reproductive efficiencies of local cows was better than the crossbred cows [53]. The average interval from calving to first AI of Sanga(158.8±8.9 days) and crossbred cows (115.7±19.2 days) was delayedin the Sanga cows and may be due to prolonged postpartum anoestrusof Sanga cows which is most likely a consequence of inadequate nutrition (grazed sole on natural pastures) and suckling management [54]. The mean interval from calving to conception of Sanga cows (177.5±9.5 days)and crossbred cows (138.6±16.3 days)was longerin Sanga cows. The conception rates at first service of the Sanga cows (42.6%)and the crossbred cows (54.5%) was lower in Sanga cows. The major reasonsfor this low conception rate may be due to poor heat detection and inappropriate timing of AI [55]. The DO period of cows should not exceed 80-85 days if a CI of 12 months is to be achieved [56]. Niraj et al. [57] reported that the crossbred cows in and around DebreZeit, Ethiopia exhibited longer DO compared to the local cows.As presented in Table 1, local×Sahiwal×Friesian crossbred genotypes exhibited excellent reproductive performances compared to the indigenous and crossbred genotypes [58].

Table 1. Reproductive performance of purebred and crossbred cattle

Cattle genotype	Location	AFS	AFC	CI	DO	Author(s)
Arsi	On-station, Ethiopia	-	34.4^{a} months	439^{cd} days	-	[4]
Zebu	On-station, Ethiopia	-	-	451^{cde}	-	[4]
½ Jersey ½ Arsi	On-station, Ethiopia	-	33.7^{a}	403^{ab}	-	[4]
½ Friesian ½ Arsi	On-station, Ethiopia	-	33.9^{a}	427^{abc}	-	[4]
½ Friesian ½ Zebu	On-station, Ethiopia	-	34.8^{a}	458de	-	[4]
½ Exotic ½ Arsi	On-station, Ethiopia	-	-	393^{a}	-	[4]
¾ Friesian ¼ Arsi	On-station, Ethiopia	-	33.7^{a}	464de	-	[4]
¾ Friesian ¼ Zebu	On-station, Ethiopia	-	33.6^{a}	475^{e}	-	[4]
¾ Exotic ¼ Arsi	On-station, Ethiopia	-	31.3^{b}	425^{abc}	-	[4]
7/8 Friesian 1/8 Local	On-station, Ethiopia	-	35.7^{a} months	525^{f} days	-	[4]
Local cows (N=32)	Amhara, Ethiopia		47.16±8.7 months (N=33)	24.94±4.1 months (N=32)		[53]
Crossbred cows (54)	Amhara, Ethiopia		37.95±9.4 months (N=70)	22±4.4 months (N=54)		[53]
Holstein	On the station, SA	15.4±0.3	26.4 ±0.37^{a}	422 ± 6^{a}	153.1± 6.8^{a}	[59]
Fleckvieh x Holstein	On the station, SA	15.5±0.33	26.5 ±0.38^{a}	410 ± 6^{a}	135.3±7.1^{b}	[59]
50% Indigenous and 50% HF	Farta, South Gondar, Eth		1.86±0.43^{a} years	1.59±0.37^{a} years		[60]
25% Indigenous and 75% HF	Farta, South Gondar, Eth		2.09±0.46^{b}	1.47±0.38^{b}		[60]
50% Indigenous and 50% HF	Gondar Zuria, Eth		2.16±0.41^{a}	1.55±0.38^{a}		[60]
25% Indigenous and 75% HF	Gondar Zuria, Eth		1.89±0.33^{b}	1.46±0.36^{b}		[60]
50% Indigenous and 50% HF	Bahir Dar Zuria, Eth		2.04±0.36^{a}	1.51±0.38^{a}		[60]
25% Indigenous and 75% HF	Bahir Dar Zuria, Eth		1.91±0.22^{b}	1.44±0.35^{b}		[60]
Horro	On-station and on-farm	48.9±8.20 months	59.7±10.22 months			[61]

Cattle genotype	Location	AFS	AFC	CI	DO	Author(s)
HorroX Jersey	On-station and on-farm	33.3±10.9	42.2±11.45			[61]
Frisian X Fogera	Ethiopia	36.8±0.8				[62]
HF×Zebu	Jimma town	24.3±8	36.5±1.64	21.36±3.84		[63]
HF×Zebu	Gondar town	23.2±0.8	32.4±0.7	21.5 ±8.5		([64], [65])
HFx Zebu	Adigrat, Tigray (Urban)	24.4±0.26	33.9±0.26			[66]
HFx Zebu	Adigrat, Tigray (Peri-urban)	26.5±0.32	35.6±0.32			[66]
Crossbred	Asella town, Ethiopia	24.9±3.8	34.8±4	372.8±5.9 days	85.6±5.6	[67]
Friesian X Zebu=25%	Sudan		43.79±4.56^{ab}	386.48±29.22		[68]
Friesian X Zebu=37.5%	Sudan		41.56±2.16^{b}	379.87±19.12		[68]
Friesian X Zebu=50%	Sudan		43.74±1.40^{ab}	394.60±16.33		[68]
Friesian X Zebu=62.5%	Sudan		49.01±1.29^{c}	382.40±17.52		[68]
Friesian X Zebu=75%	Sudan		47.64±1.82^{abc}	367.85±21.38		[68]
Friesian X Zebu=87.5%	Sudan		-	-		[68]
LO	On-farm, Bangladesh	29.48±.51^{a}	38.84±.60	404.40±5.61	120.48±5.82	[58]
LO x FN	On-farm, Bangladesh	25.58±.34^{b}	36.96±.40	395.77±3.16	121.3±3.87	[58]
LO x SL	On-farm, Bangladesh	26.31±.42^{bc}	38.32±.44	398.88±5.92	115.90±4.16	[58]
LO x SL x FN	On-farm, Bangladesh	27.08±.65^{b}	37.87±.88	400.16±6.75	106.37±5.85	[58]
LO x JR	On-farm, Bangladesh	29.86±.64^{a}	39.17±.72	399.65±7.65	105.38±5.64	[58]
PO	Lowland, on-farm	2.17±0.82^{a} Year	2.85±0.49^{a} Year	14.11±1.23 months	4.28±0.88 months	[69]
Lim x PO	Lowland, on-farm	2.06±0.29^{a}	2.82±0.34^{a}	14.15±1.73	4.49±0.29	[69]
PO	highland, on-farm	1.74±0.38^{b}	2.68±0.34^{b}	14.57±1.54	4.89±0.83	[69]
Lim x PO	highland, on-farm	1.67±0.31^{b}	2.56±0.30^{b}	14.34±0.30	4.85±0.77	[69]
Jersey	Intensive management, Sri Lanka	769±180^{a} days	1098±203^{a} days	403±24^{c} days		[70]
Crossbred	Intensive management, Sri Lanka	754±203^{ab}	1058±224^{ab}	428±85^{a}		[70]
Ayrshire	Intensive management, Sri Lanka	699±127^{bc}	1010±135^{b}	408±29^{bc}		[70]
Friesian	Intensive management, Sri Lanka	679±134^{c}	998±145^{b}	423±99^{ab}		[70]
Indigenous	On-farm	44.97±7.57^{a} months	53.97±7.57^{a} months	23.91±4.97^{a} months	7.40±2.98^{a} months	[71]
Crossbred	On-farm	28.27±5.66^{b}	37.32±5.66^{b}	17.91±3.11^{b}	4.43±2.40^{b}	[71]
LO x(LO x FN)	On-station			432.26^{b}± 96.26 days		[72]
LO x JR	On-station			411.18^{b}± 136.87		[72]
(LO x Hariana) x FN	On-station			440.78^{ab}± 124.36		[72]

Cattle genotype	Location	AFS	AFC	CI	DO	Author(s)
(LO x FN) x (LO x FN)	On-station			461.78[a]± 152.73		[72]
(LO x JR) x (LO x JR)	On-station			461.10[a]±1 58.09		[72]

SA= South Africa, HF= Holstein Friesian, Eth=Ethiopia, LO = Local, FN= Friesian, SL = Sahiwal, JR = Jersey, PO=PeranakanOngole, Lim=Limousin

Table 2. Reproductive performance of purebred and crossbred cattle

Cattle genotype	Location	AFS	AFC	CI	DO (days)	Author(s)
Boran	Ethiopia	32.4±1.4[c] months	43.5±1.5[b] months	439±10[b] days	141±7[b]	[73]
Holstein Friesian X Boran 50%	Ethiopia	26.7±0.7[a]	39.1±0.6[a]	422±10[a]	127±7[a]	[73]
Holstein Friesian X Boran 62.5%	Ethiopia	28.2±1.0[ab]	40.8±1.0[ab]	446±12[b]	135±8[ab]	[73]
Holstein Friesian X Boran 75%	Ethiopia	28.4±0.9[b]	40.4±0.9[a]	443±11[b]	142±8[b]	[73]
Holstein Friesian X Boran 87.5%	Ethiopia	27.6±1.2[ab]	38.9 ± 1.3[a]	423±21[ab]	134±14[ab]	[73]
Local	Gondar and Bahr Dar, Ethiopia	-	4.6 years	2.4 years		[74]
Crossbred	Gondar and Bahr Dar, Ethiopia	-	3.0 years	1.3 years		[74]
N'Dama x Montbéliarde (F1)	Côte D'Ivoire, SIM	-	32.2[a]	421[a]	122[a]	[75]
N'Dama x Holstein (F1)	Côte D'Ivoire, SIM	-	30.2[b]	453[b]	131[a]	[75]
Indigenous cows	On-farm, Ethiopia	-		453.22[a]±71.81 days	148.33[a]±38.44	[52]
HF crossbred cows	On-farm, Ethiopia	-		428.11[b]±64.32	93.11[b]±43.87	[52]
Jersey	Cameroon	-	1025 days	210 days		[76]
Jersey x White Fulani F1	Cameroon	-	1582	317		[76]
3/4Jersey, 1/4White Fulani	Cameroon	-	1538	296		[76]
7/8Jersey, 1/8 White Fulani	Cameroon	-	1452	344		[76]
Holstein	Cameroon	-	1288	250		[76]
Holstein x Red Fulani F1	Cameroon	-	877	301		[76]
Holstein x Gudali F1	Cameroon	-	1440	287		[76]
Boran (B)	On station	-	42.5 months	473 days		[77]
Holstein Friesian (HF)	On station	-	37.3	459		[77]
F1 (HF x B)	On station	-	36.0	417		[77]
F2 (HFB x HFB)	On station	-	39.6	435		[77]
B1 (5/8HF3/8B)	On station	-	38.5	426		[77]
B2 (3/4HF1/4B)	On station	-	36.7	444		[77]
½ HF	Peri-urban, Bangladesh	28.03[a]±0.28	37.3[a]±0.3	378.13[a]±8.63		[78]
5/8 HF	Peri-urban, Bangladesh	28.69[a]±0.25	38[a]±0.28	394.17[a]±8.93		[78]

Cattle genotype	Location	AFS	AFC	CI	DO (days)	Author(s)
¾ HF	Peri-urban, Bangladesh	36.16[b]±0.29	44.99[b]±0.32	437.8[b]±10.53		[78]
Friesian x Zebu		25.6 month	36.2 month	17.8 month		[79]
Friesian x Zebu		23.1	34.7	13.93		[80]
Friesian x Zebu		24.30±8.01	36.6±7.6	21.36±3.84		[81]
Friesian x Horro		33.44±0.7	43.69±0.7	13.43±0.2		[82]
Jersey x Horro		31.32±1.0	42.02±1.1	12.76±0.3		[82]
Indigenous	On-farm, Bangladesh	725.11[c]±7.74 days		472.55[c]±169.17 days		[83]
Friesian cross	On-farm, Bangladesh	662.44[a]±2.52		413.77[a]±53.87		[83]
Sahiwal cross	On-farm, Bangladesh	712.55[b]±2.24		454.00[b]±87.17		[83]
Sindhi cross	On-farm, Bangladesh	735.88[d]±1.77		459.33[b]±87.68		[83]
Pure local	Rural production	46.35±.062	54.22±0.068	748.25±0.05	235.8±23	[84]
<50% crossbred	Rural production	42.68±.091	51.02±0.106	557.5±0.01	205.9±10	[84]
50-75% crossbred	Rural production	23.04±.037	31.92±0.068	441.65±0.05	90.8±0.1	[84]
>75% crossbred	Rural production	22.80 months	30.52±0.06 months	441.6±0.05 days	90.0±0.85	[84]
Pure local	Urban production	38.1±.098	49.50±.108	724.53±.03	207.3±15	[84]
<50% crossbred	Urban production	30.83±.144	40.57±.168	547.6±.02	164.4±17	[84]
50-75% crossbred	Urban production	19.5±.058	30.37±.107	410.63±.03	88.1±.66	[84]
>75% crossbred	Urban production	18.37 months	28.13±.09 months	389.8±0.02 days	88.1±.53	[84]
Local	On-farm		4.4±0.90 years	2.5±0.62 years		[85]
Crossbred	On-farm		2.8±0.78	1.3±0.33		[85]
Red Sindhi (RS)	Zero grazing	616.850±23.50 days	928.35±31.80 days	413.050±10.362 days		[86]
HF x RS crossbred (50%)	Zero grazing	451.650±21.66	796.5±39.77	372.200±7.486		[86]
Kenana × Friesian (F1)	Zero grazing			597[b]±0.42 days		[87]
F1 x F1	Zero grazing			471[a]±1.36		[87]

*SIM=Semi-Intensive Management, *P < 0.05, **P < 0.01*

3. CONCLUSION AND RECOMMENDATION

Crossbreeding is economically important genetic improvement strategy and is the opposite of inbreeding depression. Crossbreeding of cattle breeds in *Bos-taurus* and *Bos-indicus* cattle species significantly improved reproductive efficiency of the crossbreds. Crossbreeding is the most profitable breeding strategy with a high level of heterosis for traits associated with fertility, health and overall fitness of the animals. On-station fixation of exotic cattle breed type and blood level inheritances across all production systems and agro-ecologies should be the prerequisite for the on-farm implementation of crossbreeding programme at small scale and large scale farm levels. Cattle genetic and reproductive efficiency improvement through crossbreeding alone is impossible. Hence, crossbreeding should be integrated with good practices which comprise nutrition, health and other management practices.Crossbreeding must be practiced in controlled condition to prevent genetic dilution of indigenous cattle genetic resources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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