



Genetic Improvement Strategy of Indigenous Cattle Breeds: Effect of Cattle Crossbreeding Program in Production Performances

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Authors' contributions

This work was carried out in collaboration among all authors. Author TM conceived the review paper idea, organizing literature review, wrote the first draft of the manuscript and finalize the review paper. Author YT reviewed and shaping the paper. Author SM reviewed and commented the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The aim of the review is to summarize the fragmented production performance information on the effects of cattle crossbreeding in different parts of the globe. Most studies indicated that cattle crossbreeding practices conducted under extensive management system for small scale dairy farms is attractive because the optimum requirement (50-62.5%) of exotic cattle blood level inheritance was maintained. However, most developing countries do not use systematic crossbreeding programme. For example, dairy cattle crossbreeding programme in Ethiopia lacks clear breeding policy regarding the breed type to be used and the level of exotic blood inheritance across different agro-ecology and production system. Heterosis is an essential advantage of crossbreeding and maximum heterosis is realized in the first cross (F1) of distinctly different breeds.

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The purpose of crossbreeding in beef cattle is partly to combine breed differences and partly to make use of heterosis to improve production. Heterosis is highest in F₁ generation compared to F₂, F₃ and F₄ crossbred generations. Therefore, terminal crossbreeding is very important in livestock production particularly in beef production. Holstein Friesian dairy cattle produce 40-60% lowered milk yield under tropical and subtropical conditions compared to temperate conditions, and this is due to the exposure of the animals to the different stress factors in the tropical and subtropical conditions. The review also revealed that crossbreeding programme has significant effect in birth weight because all F₁ crossbred calves have highest birth weight compared to the purebred calves of Zebu, Sanga and Zenga breeds. Heterosis in a sound crossbreeding program could increase productivity in the beef cow herd by as much as 26% over a comparable straight breeding program. In general, crossbreeding in tropical countries is undertaken to combine superior hardiness, heat tolerance, disease tolerance and/or resistance and environmental adaptability of indigenous cattle with superior milk yield and faster growth rates of exotic temperate breeds. Crossbreeding is one tool to minimize the negative impacts of inbreeding depression in livestock sector. Through crossbreeding there is a chance to have highly productive and adapted breeds. Crossbreeding also affects milk fat and protein compositions of purebred cattle. However, if crossbreeding is indiscriminate and uncontrolled, it may result in poor production performance. Furthermore, a number of studies indicated that indiscriminate and uncontrolled crossbreeding is a major threat to sustainable conservation and utilization of indigenous cattle breeds. Therefore, crossbreeding must be introduced in controlled farms.

Keywords: Crossbreeding; heterosis; performance; milk yield; birth weight.

1. INTRODUCTION

Domestication and breeding of animals began around 9000 B.C. Indigenous livestock breeds in Ethiopia are valuable source of genetic material which adapted to harsh climatic conditions; limited and poor quality feed resources utilization and tolerance to a range of diseases though there is little attention given to characterize, identify and conserve the diversity of the various classes of livestock [1]. There are four main groups of Ethiopian cattle populations which comprise the Humpless Shorthorn and Longhorn (*Bos taurus*), the humped Zebu (*Bos indicus*), the Sanga (interbreed of Zebu and humpless cattle) and the Zenga (interbreed of Sanga and Zebu type) [2,3].

Production of milk depends heavily on reproductive performance of cows [4]. Straight-forward upgrading to a temperate dairy breed, crossbreeding between a temperate breed and local strains to produce a new breed, selection within an improved local strain and rotational crossbreeding are the approaches of livestock breeding programs. Which approach to choose depends on the climatic stress and on the available local resources and infrastructure [5]. The introduction of crossbreeding in smallholder systems implies that the major objectives of keeping cattle will change from multipurpose production to market-oriented production. Crossbreeding with exotic breeds is a major

driving force for livestock intensification in developing countries [6]. Crossbreeding is implemented throughout the world without sufficient knowledge of 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 [7,8,9,10]. Heterosis in a sound crossbreeding program could increase productivity in the beef cow herd by as much as 26% over a comparable straight breeding program [11,12,13,14,15,16,17]. The genetic effects of crossbreeding are the opposite of the genetic effects of inbreeding. Inbreeding depression results in lowered production performances. Crossbreeding is not a substitute for good management, and it cannot cure for unproductive cattle [18].

Population growth, urbanization, economic progress and changing consumer preferences of developing countries boosted the demand for livestock products [19,20]. The world demand for meat is expected to rise by more than 200% from 229 million ton in 1999 to 465 million ton in 2050 [21], and global numbers of meat animals and their productivity will have to increase to meet such demand. Self-sufficiency in milk and dairy products is an issue faced by most countries in the tropics, mainly those of West Africa [22]. Secondary production (i.e. milk, meat, wool and eggs) in animal production systems is a function of complex interactions between animal potential

and the environmental conditions which is the interaction of biotic and abiotic factors [23]. A major factor limiting secondary production is animal nutrition. Ethiopia has about 300,000 crossbred or upgraded cows which are used for milk production under relatively improved management conditions in urban and peri-urban areas [24]. Most dairy breeds of the tropics and sub-tropics are slow maturing and low milk producers. This inferiority is partly inherited through generation and partly due to the malnutrition, management and environment to which they are exposed [25]. The milk production of Holstein Friesian in tropical and subtropical conditions was 40% to 60% lower than in the temperate conditions [26]. The comfortable temperature of lactating Holstein cattle is in the range of 4-24°C [27]. Heat stress effects on the cattle can be observed above 24°C, and milk yield markedly decreases above 27°C [28]. Nevertheless, crossbreeding in tropical countries is practiced combining superior heat tolerance, disease tolerance/resistance and environmental adaptability of indigenous cattle with superior milk yield, faster growth rates and early maturity of temperate breeds [29,30]. Dairy production systems in most developed countries exclusively consisted of pure breeds of Holstein [31]. This domination was caused by its high production and good conformation traits [32,33].

The performance of high-yielding imported breeds to developing countries from countries of highly advanced production systems is often negatively affected due to genotype-environment interactions [34,35,36,37]. Several authors [38] and [39] reported that the average lactation milk yield of the Ethiopian indigenous cows was 494 to 850 kg under optimum management level. The per capita milk consumption of Ethiopia was only about 16 kg/year, which is much lower than African and world per capita consumption averages of 27 kg/year and 100 kg/year, respectively [40]. MoA [41] also reported per capita milk consumption of Ethiopia at 19.2 kg, which is below African and world per capita consumptions. Hence, selective breeding and crossbreeding are the main tools to enhance the milk production potential of tropical indigenous cattle. Marked improvement in dairy cattle production has been reported through crossbreeding [42]. Crossbreeding systems are mainly employed to improve the efficiency of beef production. Beef producers derive income from the total weight of weaned calves [43,44]. Crossbreeding can take advantage of breed complementarity, since a weakness of one breed

can be offset by combining it with a breed strong in that trait. The resulting crossbred may not be superior in any single trait but superior in overall performance [45].

Different crossbreeding practices are adopted in different parts of the globe. However, there is no summary of the different fragmented production performance information on the effects of cattle crossbreeding programmes.

2. SPECIFIC OBJECTIVES

- ❖ To review the effects of cattle crossbreeding in production performances
- ❖ To identify the most common exotic cattle breeds used for crossbreeding programme in different parts of the globe.
- ❖ To identify the most recommended exotic cattle blood level specific for each agro-ecology and production system.

3. INTRODUCTION OF CROSSBREEDING

Exotic breeds have been introduced in many developing regions for crossbreeding with local breeds. *Bos-taurus* sires for beef cattle crossbreeding may result in higher growth rates and larger carcasses, at least under improved management conditions [46,47]. Scholtz et al. [47] also reported that crossbreeding programs will never succeed in harsh environments unless adequate fodder production is available. On the contrary, [48] reported that where managerial skills are better, but conditions are often harsh, with relatively poor pastures, crossbreeding with small framed indigenous or adapted cows may succeed in improving the output of beef cattle farming. Crossbred animals generally exhibit enhanced performance relative to the average of their parent breeds. The percentage increase differs markedly between traits, species, and the breeds or lines involved. Heterosis values for production traits are usually in the range of 0% to 10% [49].

4. EFFECT OF CATTLE CROSSBREEDING IN PRODUCTION PERFORMANCE

Subha et al. [50] reported that for replacing nondescript animals in India, Holstein Friesian and Jersey inheritance with nondescript animals should be maintained around 50-62.5% exotic inheritance level for better production performance. However, [51] review report in India indicated that exotic inheritance of around

50% blood level is the most ideal for growth, reproduction and milk production. Crossbreeding of cattle improved milk production and per capita milk availability, lactation length and growth rate [52]. Milk production of crossbred cows is generally higher than of local cows [4,53,54]. Crossbreeding Holstein-Friesian with Ethiopian Boran cattle in a tropical highland environment at Holetta Research Center was observed up on preliminary estimates of additive and heterosis effects on milk production traits, and the result revealed that in an average lactation, the purebred Holstein Friesian cattle produced 4.5 times more milk than Boran and nearly 1000 kg more milk than the best producing B2 (3/4H1/4HB) crossbred cattle ($P < 0.01$). All the crossbred groups produced at least three times more milk per lactation than the Boran ($P < 0.01$). The yield difference per day followed a similar pattern to that of total lactation yield. The Boran had the lowest ($P < 0.01$) lactation length while the rest of the genotypes had more or less similar lactation lengths. The individual heterotic advantages of the crosses were 51%, 21% and 27% above the average of both Boran and Holstein Friesian for lactation milk yield, daily milk yield and lactation length, respectively [55]. It was also noted that different crossbreds in Canada produced less milk, but more fat and protein than purebred Holsteins [56].

The birth weight and lactation performances of different indigenous and crossbred cattle are presented (Tables 1, 2 and 3). Holstein Friesian dairy cattle produce lower (40-60%) milk production under tropical and subtropical conditions compared to temperate conditions. Dual-purpose breeds are more suited for crossbreeding in dairy herds to improve beef production as the milk yield of crossbred cows is not affected negatively, with the added advantage of bull calves being more acceptable for the beef market [57]. Crossbreeding can be used successfully at all management levels except in low management herds. About 36% of New Zealand dairy cows are reported to be crossbred dairy cows [58]. Several authors [15] and [16] reported that commercial beef production is economically most efficient due to heterosis effect and result in an increase of 26% in weaning weight per cow exposed whilst feed energy requirement only increases by 1%. Moreover, [59] concluded from a crossbreeding of Holsteins and Guernseys that crossbreeding has merit due to a 14.9% increase in income per lactation. Inbreeding in most of the dairy breeds is increasing at a rate of 2-3% per decade [60].

Comparison of performances of different grades of crosses indicated that various reports showed different results. Most of the scientific studies indicated that performance is always improving until 50% inheritance of *Bos taurus* genes [53,30,61]. Further upgrading (>50% *Bos taurus* genes) did not show a clear trend of performance [53,29,61]. For example, increasing *Bos taurus* genes beyond 75% resulted in decreased lactation milk yield [62,61]. Cunningham and Syrstad [63] analyzed 46 data sets from different tropical countries and concluded that there was a nearly linear improvement of milk yield up to 50% *Bos taurus* inheritance and F2 was inferior to F1 in milk yield.

It has also been claimed that heterosis in a sound crossbreeding program could increase the productivity in the beef cow herd by as much as 26% over a comparable straight breeding program [64]. An experiment at Kilifi Plantation Ranch of Kenya on crossbreeding systems and appropriate levels of exotic blood using the exotic breeds Ayrshire, Brown Swiss and, later the Friesian have been used for crossbreeding with Sahiwal cattle for commercial dairy production, and the results revealed a considerable improvement in lactation milk yield and lactation length when the percentage of exotic blood level inheritance was increased. On the other hand, the change for the economic traits, there is an increase in feed costs with increasing level of exotic genes up to about 80% which is expected because of the linear relationship between feed intake and mature body weight of the crossbred animals [65]. A study was undertaken in Holstein Friesian and local crossbreeding reared for milk production under Sudan condition in particular at the University of Khartoum farm with the objective to evaluate the productive performance of crossbred in terms of milk yield and lactation length. The experiment was conducted in 62.5% and 50% Holstein Friesian cows of two experimental groups. The lactation milk yield (LMY) and lactation length (LL) (mean \pm SE) of the 50% Holstein Friesian cows were 1847 \pm 175 Kg and 316 \pm 28 days whereas that of 62.5% Holstein Friesian blood was 2231 \pm 124 Kg and 313 \pm 18 days, respectively [66]. On the contrary, [67] reported that daily milk yield of crossbred cattle decreased as exotic blood inheritance increased (Table 3). Another investigation was made on the reproductive and lactation performances of Holstein Friesian and local crossbred dairy cows in Chacha town and nearby selected Kebeles, North Shoa Zone, Amhara Region of Ethiopia. As presented in Table 2, the

lactation milk yield of local cows was 457.87 ± 86.4 L, and the lactation milk yield for crossbred cows was 1511.5 ± 1092.1 L. Crossbred cows exhibited longer lactation length than local cows [68]. Mulugeta and Belayneh [69] reported that the average daily milk yield of crossbred dairy cows in Amhara region was 4.73 ± 3.2 L whereas that of local cows was 1.67 ± 0.41 L (Table 1).

The growth performance of Ethiopian Boran and their crosses with Holstein Friesian indicated that Ethiopian Boran were consistently lighter ($P < 0.01$) than all the Holstein Friesian and Ethiopian Boran crossbreds for birth weight, weaning weight, six months weight, yearling weight, 18 months weight, and two years weight. Ethiopian Boran also gained lower weight than all Holstein Friesian and Ethiopian Boran crossbreds [68]. It was also noted that milk compositions of protein percent and fat percent of purebred Holstein dairy cows and Fleckvieh x Holstein crossbred dairy cows were significantly ($P < 0.05$) different, however, there was no significance difference in lactation milk yield between breeds [70]. A study was made on impact distribution of Friesian-Horro crossbred heifers on livelihoods per-urban dairy farm of Nekemte, Bako and Gimbi towns, Western Oromia, Ethiopia, and dairy products particularly from the improved genotypes supported by relatively better management inputs, extend the family income through daily milk sales in the form of fresh milk. The results revealed that the total daily milk yield improved by fivefold through improving the gene of Horro breeds. The overall mean daily milk yield of crossbreds of Friesian and Horro cows was 12.4, 6.9 and 7.8 L/day at Nekemte, Bako and Gimbi respectively [71]. On the contrary, crossbreeding Holstein Friesian cows with Brown Swiss, Dutch Friesian, Groningen White Headed, Jersey, Meuse Rhine Yssel, Montbeliard or Fleckvieh breeds decreased milk production, but improved fertility and udder health [72]. Subhaet al. [50] reported that the advantages observed in the F1 generation of crossbreds have markedly deteriorated in the F2 and above generations of crossbreeding.

First generation (F1) crossbreds of Holstein-Friesians and Jersey cattle of over 25 years revealed that Holstein Friesian x Jersey crossbreds require 10% less feed than Holstein Friesians purebreds. Jersey-Holstein crossbreds generate a greater return on investment than Holstein Friesians, and Jersey x Holstein

crossbred produce more fat and protein than Holstein Friesian in which a milk fat (%) of 4.38, 5.75 and 5.01, and milk protein (%) of 3.55, 4.12 and 3.82 for Holstein Friesian, Jersey and Holstein Friesian and Jersey crossbred, respectively (<http://clunyexports.com/about/export-inquiries/>, 24 April 2015).

Mature Hereford cows (766) were mated to 97 sires from seven breeds consisted of Jersey, Wagyu, Angus, Hereford, South Devon, Limousin, and Belgian Blue in 4 years indicated that four heavy breed crosses of Angus, South Devon, Limousin, and Belgian Blue averaged 284 kg carcass weight, followed by purebred Hereford (268 kg), Wagyu (244 kg) and Jersey (236 kg) [108]. It is also indicated that crosses of Ethiopian Boran with Hereford, Aberdeen or Charolais exhibited 20-30% higher body weight than the pure Ethiopian Boran [39]. 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 Bishoftu Ada'a district were evaluated and F4 genetic group exhibited highest mean for LL (12.68 ± 3.12 months) and LMY (3579 ± 842 liters) than the other genetic groups though it was reported that increased blood level exotic inheritance was not significantly ($P > 0.05$) different [109]. On the contrary, [51] reported that LMY declined with lower (<50%) and higher (>75%) levels of Holstein inheritances. [51] also reported that the optimum level of temperate inheritance should be between $\frac{1}{2}$ and $\frac{5}{8}$. Productive performance of indigenous and HF crossbred dairy cows in Gondar, Ethiopia was evaluated that the indigenous cattle was with LL of 204.33 ± 70.35 days and LMY of 403.21 ± 90.34 liters and the HF crossbred was with LL of 325.12 ± 61.28 days and LMY of 2123.43 ± 65.67 liters and were significantly different ($P < 0.05$) [110]. Several authors [111] and [112] reported that Ethiopia produced incomparable amount of daily milk yield per cow (1.85 Kg) with New Zealand (11.2 Kg), Germany (19.5 Kg) and USA (23 Kg). The shortest lactation lengths were in Arsi (272 days), Zebu (303 days), $\frac{1}{2}$ Exotic $\frac{1}{2}$ Arsi (282 days) and $\frac{1}{2}$ Jersey $\frac{1}{2}$ Arsi (334 days) breed groups which did not differ significantly from each other. All breed groups with Friesian milked longer lactation lengths (Table 1). Multiple breeds' milk yield performance evaluation revealed that the crossbreeding of exotic bulls (Holstein, Montbeliard and Jersey) and local breeds (Kuri and Bokolodji) are more favorable to improve milk production in the peri-urban area of

Table 1. Birth weight and lactation performance of purebred and crossbred cattle

Genotype	Location	Birth weight (Kg)	DMY	LL	LMY	Author(s)
Boran (B) (N=108)	Holeta ARC, Ethiopia	-	3.4±0.2 Kg	198±11 days	771±99 Kg	[55]
Holstein Friesian (HF) (N=601)	Holeta ARC, Ethiopia	-	9.8±0.2	335±9 b2	3311±76	[55]
F1 (N=213)	Holeta ARC, Ethiopia	-	6.2±0.1 ^{ab}	374±8 ^a	2278±65 ^{b2}	[55]
F2 (91)	Holeta ARC, Ethiopia	-	5.6±0.2 ^a	348±13 ^{ab}	1947±110 ^a	[55]
B1 (5/8H3/8B) (32)	Holeta ARC, Ethiopia	-	6.3±0.4 ^{ab}	339±21 ^{ab}	2194±178 ^{ab}	[55]
B2 (3/4H1/4HB) (50)	Holeta ARC, Ethiopia	-	6.9±0.3 ^b Kg	348±16 ^{ab} days	2312±135 ^b Kg	[55]
Local cows (N=33)	Amhara, Ethiopia	-	1.67±0.41 L	9.13±2.63 months	457.87±86.4 L	[69]
Crossbred cows (70)	Amhara, Ethiopia	-	4.73±3.2	11.13±4.84 months	1511.5±1092.1 L	[69]
Arsi	On-station, Ethiopia	21.5 ^a	2.7 ^d Kg	272 ^e days	809 ^a Kg	[4]
Zebu	On-station, Ethiopia	23 ^{ab}	2.8 ^d	303 ^{cde}	929 ^a	[4]
½ Jersey ½ Arsi	On-station, Ethiopia	21.9 ^a	5.2 ^c	334 ^{bcd}	1741 ^{bc}	[4]
½ Friesian ½ Arsi	On-station, Ethiopia	24.4 ^{bc}	5.7 ^{abc}	356 ^{abc}	1977 ^{cd}	[4]
½ Friesian ½ Zebu	On-station, Ethiopia	27.1 ^d	6.3 ^a	378 ^{ab}	2352 ^e	[4]
½ Exotic ½ Arsi	On-station, Ethiopia	24.2 ^{bc}	5.6 ^{bc}	282 ^{dc}	1672 ^b	[4]
¾ Friesian ¼ Arsi	On-station, Ethiopia	25.5 ^c	6 ^{ab}	408 ^a	2374 ^e	[4]
¾ Friesian ¼ Zebu	On-station, Ethiopia	27.2 ^d	6.2 ^{ab}	378 ^{ab}	2356 ^e	[4]
¾ Exotic ¼ Arsi	On-station, Ethiopia	24.1 ^{bc}	6 ^{ab}	384 ^{ab}	2193 ^{de}	[4]
7/8 Friesian 1/8 Local	On-station, Ethiopia	28.4 ^d	5.9 ^{ab} Kg	411 ^a days	2318 ^e Kg	[4]
Bunaji (white Fulani)				311.50 ^b days	1322.30 ^b Kg	[73]
Friesian x Bunaji (F1)				339.23 ^a	2126.10 ^a	[73]
Holstein	On station, SA	37.4±0.71 ^a Kg (HC)			6330±117 ^a kg	[70]
Fleckvieh x Holstein	On station, SA	37.7±0.65 ^a (HC)			6108±97 ^a	[70]
Local	SI, Ethiopia		2.06±0.89 ^d			[74]
F1	SI, Ethiopia		7.22±0.74 ^b			[74]
F1 x Local	SI, Ethiopia		5.90±0.22 ^{bc}			[74]
F1 x Exotic	SI, Ethiopia		10.8±0.15 ^a			[74]
Angus (A)	On station, South Africa	32.7±0.35 ^a				[75]
Bonsmara (B)	On station, South Africa	35.0±0.37 ^{cd}				[75]
Hereford (H)	On station, South Africa	33.4±0.27 ^c				[75]
Charolais (C)	On station, South Africa	38.4±0.26	-	-	-	[75]
½A½C	On station, South Africa	37.6±0.45 ^f				[75]
½H½A	On station, South Africa	33.9±0.31 ^b				[75]
½C½B	On station, South Africa	37.7±0.75 ^{fg}				[75]
½H½B	On station, South Africa	34.7±0.68 ^{bcd}				[75]

Genotype	Location	Birth weight (Kg)	DMY	LL	LMY	Author(s)
½H½C	On station, South Africa	36.6±0.51 ^{ef}				[75]
½C¼A¼H	On station, South Africa	35.9±0.44 ^{de}				[75]
¾C¼A¼H	On station, South Africa	38.3±0.76 ^f				[75]
¾H¼A	On station, South Africa	35.9±0.68 ^{cdeg}				[75]
¾H¼C	On station, South Africa	37.1±0.94 ^{ef}				[75]
MT x AR	Pasture based, Chad		7.00 ± 0.7 ^a			[76]
MT x MB	Pasture based, Chad		6.50 ± 0.5 ^a			[76]
MT x BK	Pasture based, Chad		13.00 ± 1.0 ^b			[76]
MT x KU	Pasture based, Chad		12.50 ± 2.5 ^b			[76]
HL x AR	Pasture based, Chad		9.33 ± 1.1 ^a			[76]
HL x BK	Pasture based, Chad		12.50 ± 2.5 ^b			[76]
HL x KU	Pasture based, Chad		14.00 ± 0.6 ^b			[76]
JS x AR	Pasture based, Chad		9.20 ± 0.8 ^b			[76]
JS x MB	Pasture based, Chad		6.00 ± 0.1 ^a			[76]
JS x BK	Pasture based, Chad		12.00 ± 0.4 ^c			[76]
JS x KU	Pasture based, Chad		12.00 ± 0.1 ^c			[76]
BS x MB	Pasture based, Chad		9.00 ± 1.0 ^b			[76]
BS x BK	Pasture based, Chad		6.00 ± 0.2 ^a			[76]
BS x KU	Pasture based, Chad		10.00 ± 0.2 ^c			[76]
HL	On-station (Iden), Germany		29.25±1.22			[77]
HL x BS	On-station (Iden), Germany		29.06±1.19			[77]
HL	On-station (Brandenbur) Germany		21.02±0.27			[77]
SRB x HL	On-station (Brandenbur) Germany		22.27±0.46			[77]
BS x HL	On-station (Brandenbur) Germany		20.62±0.53			[77]
HL	On-station				7,266 kg	[78]
½ JS ½ HL	On-station				6,693	[78]
Normande x HL					8865	[79]
MT x HL					9432	[79]
Scandinavian Red x HL					9450	[79]
BS x (MT x HL)					9297	[79]
MT x (Scandinavian Red x HL)					9461	[79]

Genotype	Location	Birth weight (Kg)	DMY	LL	LMY	Author(s)
Scandinavian Red x (Normande x HL)					8809	[79]
LO	On-farm, Bangladesh	17.65±.38 ^c	1.64±7.55 ^c	274.00±3.78 ^b	499.07±20.49 ^c	[80]
LO x FN	On-farm, Bangladesh	23.16±.32 ^b	6.65±.19 ^a	274.80±2.79 ^b	1636.81±.47.38 ^b	[80]
LO x SL	On-farm, Bangladesh	24.44±.32 ^{ab}	5.92±.18 ^b	279.61±3.37 ^{ab}	1538.46±63.08 ^b	[80]
LO x SL x FN	On-farm, Bangladesh	24.32±.48 ^{ab}	7.02±.46 ^a	281.98±5.33 ^{ab}	1833.58±112.87 ^a	[80]
LO x JS	On-farm, Bangladesh	22.38±.59 ^b	5.54±.30 ^b	292.08±7.88 ^a	1595.65±114.18 ^b	[80]
50% Friesian and 50 % Kenana	On-station		11.01±0.399 ^a			[81]
75% Friesian and 25 % Kenana	On-station		9.20±0.726 ^b			[81]
Indigenous	On-farm		1.67±0.51 ^a	8.93±2.97 ^a	281.0±111.48 ^a	[82]
			liters	months		
Crossbred	On-farm		4.60±1.09 ^b	9.72±1.58 ^b	1208.3±322.0 ^b	[82]

DMY=daily milk yield, LL=lactation length, LMY=lactation milk yield, n.d=no date, SA= South Africa, HC= Heifer Calves, SI=Semi-Intensive, AR: Arab; MB: M'Bororo; BK: Bokolodji; KU: Kuri; MT: Montbeliarde; HL: Holstein; JS: Jersey; BS: Brown Swiss; SRB: Swedish Red Breed, LO = Local, FN= Friesian, SL = Sahiwal

Table 2. Birth weight and lactation performance of purebred and crossbred cattle

Genotype	Location	Birth weight (Kg)	DMY	LL	LMY	Author(s)
Holstein (n=76)					9043 Kg	[83], [84]
Jersey X Holstein (73)					8134	[83], [84]
Holstein (1773)					11105	[85]
Brown Swiss X Holstein (132)					10910 Kg	[85]
Friesian x Arsi	Ethiopia		6.38±0.09 litre	306.94±3.58 days		[86]
Friesian x Boran	Ethiopia		7.02± 0.11	307.47 ±3.92 days		[86]
Horro	On-station and on-farm	17.5 ±2.25 ^a				[87]
Horo x Jersey	On-station and on-farm	18.2 ±2.03 ^b				[87]
Horro x Jersey	Ethiopia		5.6±0.07			[88]
Friesian X Zebu=25%	Sudan		7.21± 0.83 ^a	267.99±18.14 ^a	2067.20±241.62 ^a	[89]
Friesian X Zebu=37.5%	Sudan		7.99 ±.42 ^a	273.11± 9.25 ^a	2192.68±122.66 ^a	[89]
Friesian X Zebu=50%	Sudan		9.77± 0.30 ^b	278.75 ± 6.52 ^a	2721.10±87.36 ^b	[89]
Friesian X Zebu=62.5%	Sudan		9.57± 0.35 ^b	283.82±07.55 ^b	2686.27±101.14 ^b	[89]
Friesian X Zebu=75%	Sudan		10.17±0.49 ^b	305.09±10.63 ^c	2955.54±142.83 ^b	[89]
Friesian X Zebu=87.5%	Sudan		9.09±1.38 ^{ab}	347.07±30.14 ^d	2973.74±405.12 ^b	[89]
Boran	Ethiopia	23.3±0.36 ^e Kg	1.7±0.1 ^e Kg	240±4 ^c days	507±39 ^c Kg	[68]

Genotype	Location	Birth weight (Kg)	DMY	LL	LMY	Author(s)
Holstein Friesian X Boran 50%	Ethiopia	26.0±0.15 ^a	6.0±0.1 ^a	337±3 ^a	2019±26 ^a	[68]
Holstein Friesian X Boran 62.5%	Ethiopia	29.2±0.36 ^{bc}	5.7±0.1 ^b	341±6 ^{ad}	1918±51 ^a	[68]
Holstein Friesian X Boran 75%	Ethiopia	31.1±0.28 ^{cd}	6.3 ± 0.1 ^c	351 ± 6 ^{bd}	2182±45 ^b	[68]
Holstein Friesian X Boran 87.5%	Ethiopia	31.4±0.27 ^{cd}	6.9±0.1 ^d	355 ± 11 ^{ad}	2366±91 ^b	[68]
Local	Gondar and Bahr Dar, Ethiopia		2.2 liter			[90]
Crossbred	Gondar and Bahr Dar, Ethiopia		8			[90]
Jersey	Cameroon			236 days	1744 Kg	[91]
Jersey x White Fulani F1	Cameroon			210	1320	[91]
3/4Jersey, 1/4White Fulani	Cameroon			224	1488	[91]
7/8Jersey, 1/8 White Fulani	Cameroon			247	1744	[91]
Holstein	Cameroon			280	2321	[91]
Holstein x Red Fulani F1	Cameroon			204	1474	[91]
Holstein x Gudali F1	Cameroon			260	1827	[91]
N'Dama x Montbéliarde (F1)	Côte D'Ivoire, SIM	31±1 ^a Kg (F)	5.76 ^a Kg	264 ^a days	1582 ^a	[92]
N'Dama x Holstein (F1)	Côte D'Ivoire, SIM	23±1 ^b Kg (F)	6.84 ^b	276 ^a	1932 ^b	[92]
Bonsmara		38.8±1.04 Kg				[93]
Brahman x Bonsmara		39.4 ±1.52				[93]
Charolais x Bonsmara		45.4±1.45				[93]
Hereford x Bonsmara		39.6±1.17				[93]
Simmentaler x Bonsmara		38.0±1.37				[93]
Indigenous	Gondar, Eth			204.33±70.35 ^a	403.21±90.34 ^a	[94]
HF crossbred	Gondar, Eth			325.12±61.28 ^b	2123.43±65.67 ^b	[94]

SIM= Semi-Intensive Management, (F)=Female weight, Eth=Ethiopia

Table 3. Birth weight and lactation performance of purebred and crossbred cattle

Genotype	Location	Birth weight (Kg)	DMY	LL	LMY	Author(s)
Local	West Gojam, Amhara, Ethiopia		2.7±0.8	239.3±5 days	311.6±4 liters	[95]
25% Exotic	West Gojam, Amhara, Ethiopia		4.5±2	277.9±34	398.2±129	[95]
50% Exotic	West Gojam, Amhara, Ethiopia		7.3±3	310.9 ±42	631.7±223	[95]
75% Exotic	West Gojam, Amhara, Ethiopia		8.8±2	303.4±46	762.7±147	[95]
100% Holstein	On-satation, Northern Italy		31.13 Kg			[96]
50% Montbéliarde and 50% Holstein	On-satation, Northern Italy		31.52			[96]
50% Swedish Red and 50% Holstein	On-satation, Northern Italy		30.82			[96]
HO x HO	On-satation, Northern Italy		32.3±0.51 ^a			[96]
MO x HO	On-satation, Northern Italy		29.5±0.74 ^b			[96]
VR x HO	On-satation, Northern Italy		29.7±1.12 ^b			[96]
MO x (VR x HO)	On-satation, Northern Italy		30.1±1.81 ^b			[96]
VR x (MO x HO)	On-satation, Northern Italy		28.4±0.92 ^b			[96]
HO x [MO x (VR x HO)]	On-satation, Northern Italy		30.5±0.73 ^b			[96]
HO x [VR x (MO x HO)]	On-satation, Northern Italy		29.5±1.2 ^b			[96]
Boran	On station			155 days	494 Kg	[97]
Horro	On station			285	559	[97]
Arsi	On station			272	809	[4]
Barka	On station			128 ^a	552 ^a	[98]
Fogera	On station			353 ^a	613	[98]
Friesian X Boran	On farm			350	1554	[99]
Friesian X Arsi	On farm			350	1040	[100]
Friesian X Arsi	On station			356	1977	[4]
Friesian X Arsi (25-62.5%)	On farm			366	1547	[101]
Friesian X Arsi (75%)	On farm			361	2924	[101]
Friesian X Barka	On farm			301	1488	[102]
Jersey X Barka	On farm			257	970	[102]
Jersey X Arsi	On station			334	1741	[4]
Friesian	On station			323	3796	[103]
Jersey	-			273	1619	[99]
Tswana cows	US		1.4 kg			[104]
Simmental-Tswana crossbred cows	US		2.2 kg			[104]
½ HF	Peri-urban, Bangladesh		8.32±0.42 ^a Kg			[105]
5/8 HF	Peri-urban, Bangladesh		8.60±0.41 ^a			[105]

Genotype	Location	Birth weight (Kg)	DMY	LL	LMY	Author(s)
¾ HF	Peri-urban, Bangladesh		7.42±0.42 ^a			[105]
Nguni	South Africa	26.8 ^a ±0.2				[106]
Charolais	Loskop South farm, South Africa	46.8 ^d ±0.9				[106]
Chianina	Loskop South farm, South Africa	34.0 ^c ±1.7				[106]
Charolais X Nguni	Loskop South farm, South Africa	32.2 ^c ±0.6				[106]
Simmentaler X Nguni	Loskop South farm, South Africa	31.3 ^{bc} ±0.8				[106]
Chianina X Nguni	Loskop South farm, South Africa	29.6 ^{ab} ±0.8				[106]
Afrikaner	Vaalhartz RS, South Africa	35 ^a ±0.8				[106]
Charolais	Vaalhartz RS, South Africa	47 ^c ±0.9				[106]
Simmentaler	Vaalhartz RS, South Africa	43 ^b ±1.1				[106]
Hereford	Vaalhartz RS, South Africa	36 ^a ±0.9				[106]
Brahman	Vaalhartz RS, South Africa	33 ^a ±1.1				[106]
Charolais X Afrikaner	Vaalhartz RS, South Africa	42 ^b ±1.1				[106]
Simmentaler X Afrikaner	Vaalhartz RS, South Africa	40 ^b ±0.9				[106]
Hereford X Afrikaner	Vaalhartz RS, South Africa	37 ^a ± 0.9				[106]
Brahman X Afrikaner	Vaalhartz RS, South Africa	41 ^b ±0.9				[106]
50% Indigenous and 50% HF	Farta, South Gondar, Eth		9.15±4.32 ^a			[67]
25% Indigenous and 75% HF	Farta, South Gondar, Eth		6.99±3.49 ^b			[67]
50% Indigenous and 50% HF	Gondar Zuria, Eth		6.28±2.75 ^a			[67]
25% Indigenous and 75% HF	Gondar Zuria, Eth		6.91±2.48 ^b			[67]
50% Indigenous and 50% HF	Bahir Dar Zuria, Eth		6.95±2.33 ^a			[67]
25% Indigenous and 75% HF	Bahir Dar Zuria, Eth		6.46±2.03 ^b			[67]
BCB-1 x BCB-1	Bangladesh	18.4±1.09				[107]
Limousine x BCB-1	Bangladesh	19.8±1.39				[107]
Simmental x BCB-1	Bangladesh	21.9±1.78				[107]
Charolais x BCB-1	Bangladesh	27.5±1.52				[107]
Brahman x BCB-1	Bangladesh	24.1±1.23				[107]

a= first lactation, Source: Desta, 2002, *US*=Under the Same management condition, *RS*: Research Station, *Eth*=Ethiopia, *HO*=Holstein, *MO*= Montbéliarde, *VR*=Viking Red

N'Djamena, Chad. Local×Sahiwal×Friesian genotypes in Bangladesh had excellent productive performances compared to the indigenous and crossbred genotypes [80] (Table 1).

5. CONCLUSION AND RECOMMENDATION

Cattle are the most important livestock species. The review revealed that the most common exotic cattle breeds used for crossbreeding in developing countries include Holstein Friesian, Jersey and Hereford. Crossbreeding native cattle of *Bos indicus* type and exotic *Bos taurus* cattle is now a widely used method of improving production of cattle in the tropics and subtropics. Crossbreeding is the opposite of inbreeding depression. Crossbreeding should use the right combination of breeds to get the good result. Thus, it introduces and combines favorable genes from the breeds and removes inbreeding depression, and maintains the gene interactions that cause heterosis. The basic objective of crossbreeding systems is to optimize simultaneously the use of heterosis and breed differences within a given production and marketing environment. Heterosis and breed complementarity are advantages in crossbreeding of cattle breeds. Heterosis is highest in F₁ generation compared to F₂, F₃ and F₄ crossbred generations. Backcrossing to either parental breed will increase the level of inbreeding and reduces heterosis level. Systematic crossbreeding of cattle breeds is very important to increase productivity. However, mass introduction of exotic cattle is threat for conservations and sustainable utilizations of indigenous cattle breeds. Many studies involved in small scale dairy farms under extensive management system indicated that production performance of crossbred cattle was low when blood level of exotic genotype was greater than 75%. It was noted that as the blood level of exotic genotype increases, the milk production decreased. Therefore, small-scale farmers who rear crossbred cattle under extensive management system should maintain an optimum of 50-62.5% exotic blood level inheritance. It has been reported that crossbred cattle have resulted with higher milk yields and increased lactation lengths.

Crossbreeding systems are mainly employed to improve the efficiency of beef production. Nevertheless, it must be noted that crossbreeding is not the appropriate solution for

herds with low management levels. Many studies revealed that the nutrient requirement of crossbreds of exotic and indigenous cattle is higher than nutrient requirement of indigenous cattle. Crossbreeding of highly productive exotic breeds and adapted indigenous breeds can, under its optimum exotic cattle blood level inheritance, improve overall production performances. However, if crossbreeding is indiscriminate and uncontrolled, it may result in poor production performance. It should be clearly noted that breed type and blood level of exotic cattle inheritances should be studied across all production systems and/or agro ecologies prior to their mass introduction to urban, peri-urban and rural areas of a country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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