◀Review▶

Crossbred Chicken for Poultry Production in the Tropics

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The aim of the present review is to assess the potential usefulness of crossbred chickens in tropical environment. Poultry is a promising and emerging sector for poverty alleviation as well as an animal protein source in Bangladesh. Poultry production is yet lies in rural scavenging poultry in tropical country. Crossbreds are reared in scavenging, semi-intensive or intensive systems resulting in birds with good adaptability to tropical climate, highly resistant to disease and performing even better than pure exotic or indigenous chickens. Better growth performances are determined in indigenous naked neck (D. Nana) with Rhode Island Red (RIR), White Leghorn (WLH) or Fayoumi crossbreds in comparison with pure exotic, indigenous or other crossbreds. With respect to egg production, WLH × Fayoumi, RIR × Fayoumi, RIR × WLH and Fayoumi × WLH appear to be suitable combinations. However, crossbreds of D. Nana with RIR or Fayoumi produce more eggs than that of RIR or Fayoumi under scavenging conditions in a tropical climate. The best quality egg is found in WLH chickens but the highest egg shell thickness is found in D. Nana which affects hatchability of eggs. Of the above crosses, RIR × Fayoumi and their reciprocal crosses are found to be the best for fertility and hatchability. Accordingly D. Nana crossed with RIR or WLH or D. nana (indigenous full feathered chicken) results in improved fertility and hatchability of eggs. Although D. Nana crossed with an exotic broiler strain performs the best for meat yield traits, crossbred of D. Nana with RIR, WLH or Fayoumi improve meat yield traits. Therefore, the present review reveals that crossbreds of RIR × Fayoumi or D. Nana cockerels with RIR, WLH and Fayoumi hens may be considered for poultry production in tropical climate. This review emphasizes the use of D. Nana and its crosses with RIR, WLH or Fayoumi for their suitability in tropical regions.

Key words: chicken, crossbred, potentiality, production, tropics

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Introduction

Bangladesh is one of the tropical countries in the world in which agriculture is the backbone of the nation, where population is increasing day by day and about 86% of people are directly or indirectly involved with agriculture. Among the various components of agriculture, poultry, which provides meat and egg as animal protein sources, is one of the most important components, preferred by all kinds of people. The requirement of meat and eggs for human beings is 120 g/day/head and 2 eggs/week/head, in a country where availability of meat and eggs is 12.6 g/day/head and 0.46 eggs/week/head, respectively (Huque, 1992). Therefore, this wide gap between demand and supply of animal protein as meat and eggs can be improved easily by poultry keeping (Das *et al.*, 2008). This suggests that emphasis needs to be placed on increasing

poultry production to provide required animal protein to human beings as well as to decrease unemployment. Therefore, scientists are trying to obtain maximum production, involving landless or marginal farmers with a minimum land, investment and time. A number of breeding techniques, methods and technology have been applied to achieve this goal. Some poultry industries have imported improved exotic varieties of chickens into Bangladesh which originated in temperate countries where they produce well. In tropical climate like Bangladesh, the production performance of these improved chickens is often below the standard of the breeder company because of their genetic make up inherent for temperate region, genotype × environment interaction, unsophisticated scientific management, inadequate nutrition and harsh environment, as well as high susceptibility to disease and lack of availability of good quality vaccines and therapeutics (Hutt, 1958; Al-Soudi and Al-Azzawi, 1974; Okoye and Aba-Adulugba, 1996; Tadelle *et al.*, 2000; Singh *et al.*, 2004). About 89% of poultry production continues to be under rural scavenging conditions in Bangladesh (Huque, 1996). Besbes (2009) showed that indigenous and local

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breeds share 90% of the total population in developing countries. Therefore, some NGO's, foreign aid projects and governmental organizations have concentrated on adopting a model for using crossbred chickens in scavenging or semi intensive systems to increase family poultry production (Das *et al.*, 2008). Under extensive or traditional systems of poultry rearing, indigenous chickens performed better with respect to survivability, fertility and hatchability, although they have poor productivity (Huque and Haque, 1990; Barua *et al.*, 1998b; Islam, 2000, 2006) which does not encourage farmers to extend the present level of their poultry operations. Indigenous chicken is low in productivity due to their inherent genetic characteristics, poor husbandry practices, seasonal effects, low level of nutrition, and broodiness (Sarkar and Bell, 2006; Besbes, 2009). Many studies have found that cross breeding of exotic with indigenous chickens resulted in birds that performed better, even superior to pure exotic chickens, with respect to body weight, egg production, survivability, fertility, hatchability and egg quality (Islam *et al.*, 1981; Barua and Howlader, 1990; Khondoker *et al.*, 1996; Rahman *et al.*, 1998). Research carried out for the production of crossbreds, '*Sonali*' from RIR and Fayoumi chickens reported increased egg production (Rahman *et al.*, 1997; Fattah, 1999; Das *et al.*, 2008). Rahman *et al.* (1997) reported 156 eggs/year in '*Sonali*' crossbred hens. Lower productivity of indigenous chickens seems to be caused, at least in part, by management. A recent report stated that the productivity of indigenous chickens may be doubled in an improved management system (Chowdhury *et al.*, 2006). In Bangladesh, numerous range of crossbreeding research studies has been done but there is no consensus among the findings. Crossbreeding is performed for the purpose of suitable genetic blending to fit under a given environment, break through in genetic limit and to have heterotic effect. Besbes (2009) reported improved body weight, egg production and survivability in crossbred chickens. Although to maintain crossbreeding program is too complex under village condition in most cases the cock has been used to utilize high-yielding breeds to upgrade local chicken (Besbes, 2009). Considering the above facts, the present review will evaluate the potential of using crossbreds for poultry production and the development of a suitable genetic resource for future poultry production in hot-humid climate.

Environment and Adaptability of Chickens

Hot-humid climates are more detrimental than dry climate for chicken production (Horst and Petersen, 1981). Indigenous chickens are well adapted to harsh tropical environments and nutrition compared to the exotic chickens (Barua and Howlader, 1990; Horst, 1991; Ali *et al.*, 1993). They can protect themselves and chicks from predatory animals (Khan, 1983) and can thrive under adverse environmental conditions such as poor housing and feeding, poor management and fluctuating temperature and humidity. They are also resistant to different diseases

(Barua and Howlader, 1991; Islam, 2000). Among the varieties of non-descript (not characterized) indigenous chickens, the naked neck type (tropically relevant major gene) is also available which has been found very promising, as it has a heat dissipation mechanism and is heat tolerant and therefore better adapted to warm climates (Merat, 1986; Horst, 1988; Deeb and Cahaner, 1996; Horst *et al.*, 1996; Islam, 2000). On the other hand, exotic chickens suffer severely in the harsh tropical environment, showing reduced productivity and survivability and high susceptibility to disease and heat (Bohren *et al.*, 1982; Barua *et al.*, 1998a). Crossbred chickens have improved adaptability to tropical environments and are resistant to disease and heat compared to exotic pure breeds (Islam *et al.*, 1981; Khondoker *et al.*, 1996; Rahman *et al.*, 1997; Barua *et al.*, 1998a; Islam, 2006). Ali *et al.* (1993) reported improved productive adaptability of RIR×Fayoumi crossbreds compared to pure exotic chickens in Bangladesh. Crossbreds from indigenous naked neck (D. Nana) with exotic chickens are well adapted to harsh hot-humid climate compared to pure exotic chickens (Huque, 1999).

Crossbreeding research studies have been performed by different scientists but no final conclusion has been reached. The present study has reviewed update crossbreeding findings and concluded for future using of chicken genotypes in hot-humid climate.

Performance of Exotic, Indigenous and Crossbred Chickens

Growth Performance

Table 1 shows the growth performance of indigenous, exotic and crossbred chickens at different ages, where the broiler strain was found to be better for growth, feed conversion ratio (FCR) and mortality at 8 weeks of age compared to the exotic egg type, indigenous or crossbred chickens. However, broiler growth rate was severely depressed at high ambient temperature compared to Nana (improved naked neck) birds, as reported by Deeb and Cahaner (1996). Some authors reported that D. Nana chickens showed improved body weight and reduced mortality at hot-humid climate (Horst and Petersen, 1981; Merat, 1986; Barua and Yoshimura, 1997; Islam and Nishibori, 2009) and were superior to non-descript (not characterized) full feathered chickens in terms of growth, FCR and mortality. Singh *et al.* (1996) also observed better growth performance in Nana chickens compared to their full feathered counterparts in India. Naked neck chickens perform well in productive adaptability at hot-humid climate, because of their association with the reduction in feather coverage, which can increase heat loss, and so indirectly increase feed intake and productive adaptability (Merat, 1986; Islam and Nishibori, 2009). Aseel×Australorp is found to show the tendencies to increase body weight compared to Australorp×Hampshire cross at 12 weeks of age (Table 1). The crossbreds from Bovan Brown×local chickens in Uganda were superior to local chickens in terms of daily gain though

Table 1. Growth performance of indigenous, exotic and crossbreds chicken at different ages in Bangladesh

Genetic resources	Rearing system	Age (week)	BW (g/bird)	FI (g/bird)	FCR	Mortality (%)	Reference
Indigenous full feathered (D. nana)	Intensive (FM)	8	316.5	1246.0	4.49	16.15	Islam <i>et al.</i> (2002b)
Indigenous naked neck (D. Nana)			341.3	1495.2	4.85	16.10	
Redbro (R)			1292.3	3599.9	2.90	16.10	
D. nana×D. Nana			354.0	1498.0	4.97	9.50	
D. nana×Redbro			614.4	2086.0	3.47	22.90	
D. Nana×D. nana			388.9	1540.0	4.70	14.50	
D. Nana×Redbro			645.0	2119.6	3.52	—	
Redbro×D. nana			622.8	2282.0	3.80	17.30	
Redbro×D. Nana			705.6	2206.0	3.21	4.40	
Significance level (Season×genetic group factorial exp. in CRD)			***	***	***	*	
Starbro broiler	Intensive (FM)	8	1629.1	5570.9	3.39	6.00	Hossain <i>et al.</i> (1991)
Australorp Nana broiler			1150.1	3227.3	2.80	2.04	
Significance level (genotype×weight factorial exp. in CRD)			**	**	**	**	
Hilly	Intensive (FM)	8	291.0	1293.6	4.44	16.25	Islam and Nishibori (2009)
Yasine			250.0	1660.4	6.64	11.35	
Aseel×Australorp	Intensive (FM)	12	1006.4	2816.5	2.80	19.04	Howlider and Ahmed (1982)
Australorp×New Hampshire			953.9	2637.5	2.76	14.28	
Significance level (CRD)			NS	**	NS	*	
D. nana	Intensive (FM)	16–17	833.2	4609.0	5.71	44.00	Khondoker <i>et al.</i> (1996)
RIR			973.2	5927.3	6.33	37.20	
D. nana×RIR			964.7	4988.1	5.38	25.50	
Significance level (CRD)			**	NS	NS	*	
D. Nana	Intensive (FM)	16–17	1213.8	5831.0	5.40	20.40	Haque <i>et al.</i> (1999)
WLH			987.7	5093.2	5.40	13.60	
Fayoumi			975.8	6080.9	6.20	3.30	
D. Nana×RIR			1142.4	5854.0	5.10	32.50	
D. Nana×WLH			1082.9	5640.6	5.20	19.00	
D. Nana×Fayoumi			1094.8	5712.0	5.25	8.30	
Significance level (CRD)			*	**	**	*	
Fayoumi	Intensive (FM)	20–24	1200.0	5844.0	7.46	0.00	Miah <i>et al.</i> (2002)
WLH			1278.0	5806.0	6.87	7.70	
RIR			1560.0	6386.0	5.46	0.00	
Fayoumi×WLH			1309.0	6072.0	7.04	7.70	
Fayoumi×RIR			1462.0	6060.0	6.15	8.77	
Significance level (CRD)			***	NS	**	**	
RIR×D. Nana	Intensive (FM)	20–24	1294.5	7864.7	6.19	10.00	Barua <i>et al.</i> (1998b)
WLH×D. Nana			1291.2	8042.0	6.35	12.50	
Significance level (CRD)			NS	*	NS	*	
RIR	Intensive (FM)	20–24	1469.5	6896.4	4.69	20.00	Ali <i>et al.</i> (1993)
Fayoumi			1175.0	7089.1	6.03	25.00	
RIR×Fayoumi			1445.3	6832.0	4.73	15.00	
Significance level (CRD)			**	NS	**	**	

BW=Body weight, FI=Feed intake, FCR=Feed conversion ratio, WLH=White Leghorn, RIR=Rhode Island Red, FM=Floor Management, CRD=Completely randomized design, *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; NS=Non significant (Significance level is shown column wise for comparing among the genotypes of individual reference).

decreased the superiority gradually to zero at 6 months of age in case of 25% Bovan crosses (Sorensen and Ssewanyana, 2003). Bairagi *et al.* (1992) found better survivability in the crossbred of RIR or WLH male with indigenous Nana female compared to RIR or WLH chicken. Crossbred of RIR or WLH male with D. Nana female are heavier with lower FCR and mortality (Shivaprasad *et*

al., 1994; Table 1). D. Nana, and D. Nana × RIR showed the better growth and feed conversion efficiency compared to pure exotic and other crosses at 16–17 weeks of age (Table 1). However, RIR × Fayoumi and Fayoumi × RIR are found to be the best performer among the crossbreds in terms of body weight and FCR at 20–24 weeks of age (Table 1). Azharul *et al.* (2005) reported that RIR ×

Fayoumi crossbred ('*Sonali*') performed better in terms of growth performances in intensive system under rural condition of Bangladesh compared to pure breed Fayoumi. Therefore, the crossbred of RIR×Fayoumi, Fayoumi×RIR, RIR or WLH male with D. Nana female may be useful for their improved growth and feed conversion efficiency, and lower mortality at hot-humid climate.

Egg Production Performance

WLH×Fayoumi is found to be the highest egg producing combination among the available genetic resources in Bangladesh when reared in intensive management systems, but not in scavenging or semi-scavenging systems (Table 2). Although indigenous chickens have lower egg production (45 eggs/year) and egg weight (35 g/egg) (Islam, 2006) under the scavenging system, they attained sexual maturity earlier (D. nana-148 days and D. Nana-145 days) with a lower mortality under the intensive system (Table 2). However, D. Nana performed better in terms of sexual maturity, egg production, egg weight and

mortality, compared to D. nana chickens (Islam, 2000; Islam and Nishibori, 2009, Table 2). Islam *et al.* (1981) reported 45 eggs/hen/year, 35 g/egg and delayed sexual maturity (177 days) in D. nana chickens. The crosses of RIR×Fayoumi, Fayoumi×RIR, Fayoumi×WLH and RIR×WLH resulted in earlier sexual maturity, and higher egg production (Ambar *et al.*, 1999; Rahman *et al.*, 2004). Rahman *et al.* (2004) found that sexual maturity of Fayoumi×RIR, and RIR×Fayoumi occurred at 151 and 147 days, and their hen-day egg production were 52.3% and 48.2%, respectively (Table 2). Miah *et al.* (2002) reported sexual maturity, and hen-day egg production of Fayoumi×RIR at 150 days, and 51.0%, respectively (Table 2). Ambar *et al.* (1999) suggested using the crossbred of RIR×Fayoumi called '*Sonali*' for its superior egg production and livability under semi-intensive systems. Haque and Howlider (2000) showed better egg production in D. Nana×Fayoumi and D. Nana×RIR under scavenging condition compared to exotic chickens.

Table 2. Egg production performance of indigenous, exotic and crossbreds chicken in Bangladesh

Genetic resources	Rearing system	Laying period	Sexual maturity (day)	Hen day egg production (%)	Egg weight (g)	Mortality (%)	Reference
D. nana	Intensive (FM)	1 year	195	12.05	38.20		Huque <i>et al.</i> (2001)
D. Nana			195	26.84	42.55		
Hilly				25.10	42.00		
Yasine				16.00	44.00		
Aseel				9.40	45.00		
WLH×Fayoumi				61.63	49.45	10.50	
WLH×Australorp				53.12	56.15	11.12	
WLH×RIR				58.71	55.10	15.00	
RIR×BPR				56.79	57.27	16.50	
RIR×WLH				55.85	57.89	17.50	
Fayoumi×D. Nana			168	41.00	46.00		
Fayoumi×Hilly			162	35.00	45.00		
BPR×Fayoumi				58.13	49.66	14.60	
D. autosomal dwarf	Intensive (FM)	1 year		33.50	39.12		Yeasmin and Howlider (1998)
D. nana				24.69	39.99		
Significance level (<i>t</i> -test)				**	**		
Fayoumi	Intensive (FM)	1 year	126	52.66	35.51	12.00	Miah <i>et al.</i> (2002)
WLH			164	42.00	48.58	12.53	
RIR			164	43.33	53.12	25.00	
Fayoumi×WLH			148	50.66	45.90	15.00	
Fayoumi×RIR			150	51.00	44.34	12.50	
Significance level (CRD)			**	*	**	NS	
RIR×Fayoumi	Intensive (cage)	1 year	147	48.20	49.40	16.20	Rahman <i>et al.</i> (2004)
Fayoumi×RIR			151	52.30	48.70	13.40	
Significance level (<i>t</i> -test)			NS	**	NS	NS	
D. nana	Intensive (FM)	5 months	148	12.60	37.90	24.45	Islam <i>et al.</i> (2000)
D. Nana			145	16.73	40.50	18.86	
Redbro			172	31.53	60.50	8.50	
Significance level (strain×sex factorial exp. in CRD)			NS	**	***	NS	

D. nana=Indigenous full feathered, D. Nana=Indigenous naked neck, WLH=White Leghorn, RIR=Rhode Island Red, BPR=Barred Plymouth Rock, FM=Floor Management, CRD=Completely randomized design, *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; NS=Non significant (Significance level is shown column wise for comparing among the genotypes of individual reference).

Naked neck with exotic crossbred chicken performs better in productivity, because of higher genetic distance between indigenous and exotic breed and in environmental stress situation a higher degree of heterosis should be expected (Horst, 1991). However, exotic breeds, WLH $\times$ WLH, RIR $\times$ RIR chickens perform better under intensive systems than D. Nana or the crossbreds from D. Nana with RIR or WLH.

Exotic breeds like RIR, WLH and Fayoumi, which are typically used for crossbreeding, were imported into Bangladesh many decades ago. So the purity of such imported breeds is doubtful and continuous inbreeding may now have caused them to be less productive (Latif, 2001). In developing countries, crossbreds from indigenous with exotic chickens perform better under scavenging or semi-scavenging condition (Das *et al.*, 2008). Crossbred from indigenous and exotic chicken perform better for improving productivity because of their combining ability, genetic make up and reproductive fitness (Besbes, 2009). But in Ethiopia, an experimental crossbreeding program which involved exchanging cockerels or pullets or fertile eggs of exotic birds to village farmers resulted in adverse alterations in the genetic make up of indigenous chickens (Tadelle *et al.*, 2000). However, this conclusion certainly should not over rule the gene $\times$ environment interaction. Several major genes such as Na (naked neck), f (frizzle), adw (autosomal dwarf), dw (sex-linked dwarf), are still segregating in indigenous population (Yeasmin and Howlider, 1998). D. autosomal dwarf is found to be better for egg production than that of D. nana. However, of the indigenous chickens, D. Nana is the best performer in terms of egg production, egg weight and mortality (Table 2).

Horst (1991) found improved egg production in cross-breeds of Nana $\times$ Dahlem Red (German strain) and WLH $\times$ Kadaknath (Indian) chickens. Egyptian local chickens (Dandarawi and Fayoumi) were lower for egg production (202.2 and 212.5 eggs/year, respectively) in temperate conditions compared to Dahlem Red (279 eggs/year) but, in warm climates, egg production was depressed in both, although the depression was lower in Egyptian chickens (137.9 and 161.0 eggs, respectively) than in Dahlem Red chickens (181.7 eggs) (Valle-Zarate *et al.*, 1988). Investigations proved that pure exotic breed Lohmann Brown produced 303 eggs/year under the optimal conditions but only 140 eggs under semi-scavenging conditions, while the crossbred-'Sonali' produced 156 eggs under semi-scavenging condition (Sorensen, 1997). In India a crossbred hen from Aseel $\times$ CARI Red, called 'CARI Nirbheek' has been developed for improving egg production under traditional condition. This crossbred was able to produce 163 eggs annually with a survival rate of 90–95% (Singh *et al.*, 2004). Therefore, RIR $\times$ Fayoumi, Fayoumi $\times$ RIR, WLH $\times$ Fayoumi and D. Nana $\times$ RIR or WLH or Fayoumi under scavenging or semi-intensive system in tropical climate may be worthy combinations for improving egg production.

Egg Quality Traits

Research on egg quality in Bangladesh is scarce. Egg quality is influenced by genetic and non-genetic factors such as season, environment and feed (Salahuddin and Howlider, 1991). Overall the best quality egg was for WLH chickens (Table 3). D. adwarf is found to be the tendencies to increase Haugh unit, albumen and yolk dry matter compared to D. nana (Table 3). But statistically

Table 3. Egg quality traits of indigenous and exotic chicken in Bangladesh

Genetic resources	Egg weight (g)	Shape index	Yolk index (YI)	Albumen index (AI)	Haugh unit (HU)	Yolk (%)	AI%	Shell thickness (mm)	Al: Yolk ratio	Al dry matter (%)	YI dry matter (%)	Reference
RIR	52.50	71.63	0.446	0.068	82.55	32.25	58.36	34.35	1.80			Salahuddin and Howlider (1991)
WLH	54.59	70.28	0.460	0.076	83.49	30.16	60.51	34.55	2.00			
Fayoumi	38.37	61.04	0.430	0.067	77.87	31.59	59.85	32.82	1.89			
Starcross	54.73	69.50	0.471	0.076	83.12	31.93	58.51	33.55	1.81			
D. Nana	53.53	70.81	0.443	0.069	82.50	32.00	58.77	33.46	1.82			
Sig. level	**	**	**	**	**	**	**	**	**			
D. nana	38.05							33.50		13.75	51.15	Islam <i>et al.</i> (2001a)
D. Nana	40.35							35.00		13.60	48.50	
Redbro	64.25							32.00		12.10	55.30	
Sig. level	***							NS		NS	NS	
D. nana	39.99	76.64	0.390	0.080	82.23					14.24	52.27	Yeasmin and Howlider (1998)
D. adwarf	39.12	76.87	0.390	0.080	81.26					13.43	51.03	
Sig. level	**	NS	NS	NS	NS					NS	NS	

RIR=Rhode Island Red, WLH=White Leghorn, D. nana=Indigenous full feathered, D. Nana=Indigenous naked neck, D. adwarf=Indigenous autosomal dwarf chicken, **, $p < 0.01$; ***, $p < 0.001$; NS=Non significant (Significance level is shown column wise for comparing among the genotypes of individual reference), Rearing system: Intensive (floor management), Data were analysed using breed $\times$ season, and season $\times$ genotype factorial exp. in Completely randomized design, and t -test by the Authors of Salahuddin and Howlider (1991), Islam *et al.* (2001a) and Yeasmin and Howlider (1998), respectively.

no differences were found among the eggs of indigenous chickens for the traits of Haugh unit, albumen and yolk dry matter (Table 3). However, the highest egg shell thickness is found in D. Nana chickens which affect the hatchability of the eggs (Al-Soudi and Al-Jebouri, 1979) (Table 3). Al-Soudi and Al-Jebouri (1979) reported the highest percentage of egg shell thickness in the Iraqi indigenous chicken. However, D. Nana is superior to D. nana with respect to egg quality. Therefore, WLH or D. Nana is found to be suitable genotype for producing better quality egg.

Fertility and Hatchability

Table 4 shows the fertility and hatchability of different genetic resources of chickens. Exotic chickens show better fertility than indigenous chickens in intensive systems. In a hot-humid environment, scavenging indigenous chickens had better fertility than exotic chickens because of heat stress (Al-Soudi and Al-Jebouri, 1979). These authors reported better fertility (91.3%) and hatchability (38.6%) in Iraqi chicken than in New Hampshire (83.4%

fertility and 33.4% hatchability). Kamble *et al.* (1996) reported the fertility of 85% and 66% in Indian full-feathered Kadakanath and Nana chickens, respectively. However, D. nana is better than D. Nana for fertility and hatchability and comparable to exotic chickens (Table 4). Among the crosses, RIR $\times$ Fayoumi and Fayoumi $\times$ RIR crosses are the best combinations for fertility and hatchability of eggs. Fertility and hatchability of RIR $\times$ Fayoumi crosses are 96.9% and 81.1%, respectively (Table 4). D. Nana crossed with exotic Redbro or D. nana chickens had improved hatchability compared to exotic Redbro chickens (Table 4). Islam *et al.* (1981) observed the increased fertility from crosses of exotic males with D. nana female chickens. The hatchability of WLH $\times$ D. nana crosses is 80.61% (Table 4). Hatchability is also affected by egg shell quality, with the hatchability of thin shelled eggs being 3–9% lower than the thicker shelled eggs (Bennet, 1992). Thin egg shells result in reduced hatchability and weakening of the embryo (Peebles and Brake, 1987). Therefore, RIR $\times$ Fayoumi, Fayoumi $\times$ RIR and D. Nana

Table 4. Fertility and hatchability of indigenous, exotic chicken and their crosses

Genetic resources	Rearing system	Fertility (%)	Hatchability on set eggs (%)	Hatchability on fertile eggs (%)	Reference
D. nana (Indigenous full feathered)	Intensive (FM)	87.22	56.67	58.20	Khondoker, <i>et al.</i> (1996)
D. nana $\times$ RIR		81.07	60.57	74.80	
Significance level (CRD)		*	*	**	
D. Nana (Indigenous naked neck)	Intensive (FM)	71.50		43.10	Huque and Salahuddin (2001)
Hilly		52.00		46.10	
Yasine		57.08		60.70	
Aseel		53.00		26.00	
RIR	Intensive (FM)	93.55	80.99	86.58	Ali <i>et al.</i> (1993)
Fayoumi		91.88	77.08	83.85	
RIR $\times$ Fayoumi		96.90	78.59	81.11	
Significance level (CRD)		NS	NS	*	
Fayoumi	Scavenging		75.00		Barua <i>et al.</i> (1998a)
Fayoumi $\times$ RIR			87.50		
RIR			80.80		
Significance level (breed $\times$ diet factorial exp. in CRD)			*		
D. nana	Intensive (FM)	92.70		71.80	Islam <i>et al.</i> (2001b)
D. Nana		87.60		68.20	
Redbro		84.40		59.40	
D. nana $\times$ Redbro		85.40		55.50	
D. nana $\times$ D. Nana		85.50		64.80	
D. Nana $\times$ D. nana		83.90		66.90	
D. Nana $\times$ Redbro		65.00		80.00	
Redbro $\times$ D. nana		59.50		70.20	
Redbro $\times$ D. Nana		66.30		73.80	
Significance level (season $\times$ genotype factorial exp. in CRD)		***		NS	
dw-(i-757) (Sex-link dwarf)	Intensive (FM)	94.49	89.37	94.62	Islam (2004)
Arbor Acre		84.12	76.91	84.17	
MPK (Broiler strain)		82.51	71.00	82.37	
Significant level (CRD)		***	***	***	

RIR=Rhode Island Red, WLH=White Leghorn, FM=Floor Management, CRD=Completely randomized design, *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; NS=Non significant (Significance level is shown column wise for comparing among the genotypes of individual reference).

Table 5. Meat yield of different genetic resources of chicken at different ages

Genetic resources	Rearing system	Age group (days)	Live weight (g/bird)	Dressing (%)	Total meat (%)	Reference
D. nana×D. nana	Intensive (FM)	56	358.3		30.0	Islam <i>et al.</i> (2002a)
D. nana×D. Nana			374.2		31.5	
D. nana×Redbro			732.7		32.0	
D. Nana×D. nana			391.3		31.0	
D. Nana×D. Nana			364.5		31.5	
D. Nana×Redbro			795.0		31.5	
Redbro×D. nana			670.7		31.5	
Redbro×D. Nana			832.1		33.5	
Redbro×Redbro			1224.2		32.0	
Significant level (S×G factorial exp. in CRD)			***		***	
D. Nana	Intensive (FM)	84	1120.0	59.4	26.2	Haque and Howlider (2000)
RIR			1147.0	57.6	22.3	
WLH			910.0	59.0	23.0	
Fayoumi			970.0	62.2	24.5	
D. Nana×RIR			1275.0	58.7	24.3	
D. Nana×WLH			1130.0	64.7	26.8	
D. Nana×Fayoumi			1103.0	63.1	27.1	
Significant level (CRD)			**	*	**	
D. nana	Intensive (FM)	120		60.9	25.1	Howlider <i>et al.</i> (1995)
D. Nana				62.9	30.1	
Significant level (Regression method)				**	**	
D. nana	Scavenging	150	970.0	53.6	29.9	Barua and Howlider (1991)
D. Nana			1010.0	57.1	37.3	
Significant level (Regression method)			**	**	**	
D. Nana	Intensive (FM)	120	697.0	54.3	26.9	Haque <i>et al.</i> (1999)
RIR			732.0	54.4	25.8	
WHL			659.0	51.2	24.2	
Fayoumi			806.0	54.0	25.3	
D. Nana×RIR			666.0	55.8	26.8	
D. Nana×WLH			622.0	56.2	26.6	
D. Nana×Fayoumi			710.0	54.3	25.3	
Significant level (CRD)			*	*	**	

D. Nana=Indigenous naked neck, D. nana=Indigenous full feathered, RIR=Rhode Island Red, WLH=White Leghorn, FM=Floor Management, CRD=Completely randomized design, *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$ (Significance level is shown column wise for comparing among the genotypes of individual reference), S=Season, G=Genetic group.

with RIR or Fayoumi may be the most suitable combination to have improved fertility and hatchability.

Meat Yield Traits

Research work on meat yield traits is scanty (Table 5). The highest total meat yield (37.3%) is found in D. Nana followed by Redbro × D. Nana (33.5%) and Redbro × Redbro (32.0%) crossbred (Islam *et al.*, 2002a). Crossbreds from D. Nana with WLH or Fayoumi resulted in improved dressed and total meat yield in comparison with exotic or D. nana chicken (Table 5). Azharul *et al.* (2005) found the higher breast, dark and total meat yield in crossbred of RIR × Fayoumi (*Sonali*) compared with Fayoumi breed. D. Nana yielded higher dressing and total meat (%) than that of D. nana counterparts (Islam and Nishibori, 2009). Paul *et al.* (1990) found that D. nana hens were higher than broiler chickens at 6.90% dressed carcass, 11.42% total meat, 3.56% breast and 7.65% dark meat. Crossbreds of D. Nana cocks with RIR, WLH or

Fayoumi hens improve the percentage of dressing and total meat compared with exotic pure breeds at 84 days of age (Table 5). So, D. Nana with RIR, WLH or Fayoumi may be the worthy combinations for yielding improved meat.

Conclusions

From the present review, it is concluded that crossbreds may be useful for poultry production under semi-intensive or scavenging rearing systems in tropical climates because of their adaptability and resistance to disease. Some crosses such as RIR × Fayoumi, RIR × WLH, Fayoumi × RIR, D. Nana × RIR or WLH, and Redbro × D. Nana were found to be the most suitable combination for their better growth, egg production, fertility, hatchability and meat yield traits compared to the pure exotic chickens. D. Nana is superior to D. nana chicken in terms of better productive adaptability in a tropical climate. However,

crossbreds of D. Nana with RIR, WLH or Fayoumi are found to have improved production and reproduction under scavenging or semi-intensive systems in a tropical climate. Therefore the present review suggests using the crossbreds of RIR with Fayoumi or indigenous naked neck with RIR, WLH or Fayoumi for prevailing better production in tropical climate.

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