GROWTH PATTERN, REPRODUCTIVE PERFORMANCE AND SEASONAL SENSITIVITY OF BOVAN NERA AND ISA BROWN PARENT-STOCK CHICKENS IN IBADAN NIGERIA

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- A complete set of Technical data on Growth, Maturity Characteristics, Hen Day Production, Persistency of egg production, Egg Weight, Egg Fertility, Egg Hatchability, Pullet day-old chicks production, and Hatching Rejects generated was elucidated to serve as guide for Parent-Stock layer breeders' management in South-West Nigeria.
- Genotype x Season interaction was established in the breeding of Bovan Nera and ISA Brown. This resulted in various degrees of performance depression indices in Growth, Hen Day Production, Egg Weight, Egg Fertility and Egg Hatchability.
- Genotype sensitivity indices for seasons were determined for Body Weight, Hen Day Production, Egg Weight, Egg Fertility, Egg Hatchability and Pullet day-old chicks hatched for the region.

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Fly leaf

GROWTH PATTERN, REPRODUCTIVE PERFORMANCE AND SEASONAL SENSITIVITY OF BOVAN NERA AND ISA BROWN PARENT-STOCK CHICKENS IN IBADAN NIGERIA

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ABSTRACT

Parent stocks (PS) of exotic hybrids have contributed immensely to commercial poultry production in Nigeria. Their continued optimal utilization depends on their performance test. Information on performance indices of PS layer breeds in South-West Nigeria is however limited. The growth, reproductive performance and seasonal sensitivity of Bovan Nera (BN) and Isa Brown (IB) hybrids were evaluated.

Secondary data on 24 batches of PS of each of BN and IB kept over a period of 10 years (1999-2008) in Ajanla Farms, Ibadan were used. Average batch population was 3896 pullets and 600 cockerels at point-of-lay. Records on Body Weight (BW), Age, Hen-Day-Production (HDP), Egg Weight (EWt), Egg fertility (EF), Egg Hatchability (EH), Pullet Day-Old Chicks produced (PDOC) and Hatching Rejects (HR) in four seasons: Early-Wet (EW, April-July); Late-Wet (LW, August-October); Early-Dry (ED, November-January) and Late-Dry (LD, February-March) were obtained. Data were standardized and analysed for growth, Age-at-first-egg (AFE), HDP characteristics, reproduction, seasonal sensitivity, genotype-season interaction using descriptive statistics, ANOVA, correlation and regression ($p=0.05$).

There was no significant difference in BW (g) and growth rate (g/day) between hybrids: 1724.8±562.8 and 1549.8±543.3; 1.4±2.3 and 1.1±1.6 for BN and IB hens, respectively. Effect of seasons on AFE was not significant in both hybrids, but ED and LD seasons delayed AFE. The HDP values (%) recorded for BN (63.2) and IB (72.9) in ED were significantly higher than in other seasons. There were significant differences in EF (80.8 and 88.7%), EH (69.1 and 73.6%), PDOC (32.6 and 36.1%) and EWt (56.2 and 59.9 g) for BN and IB respectively in EW season. EF (86.2 and 89.5%) and EH (73.1 and 73.9%) in LW were highest within hybrids respectively. Phenotypic correlation (r) between Age and Hen Weight, Age and EWt, Hen Weight and EWt, EF and EH, EF and PDOC, and EH and PDOC were 0.78, 0.74, 0.68, 0.73, 0.72 and 0.98 in BN; and 0.77, 0.52, 0.53, 0.69, 0.71, and 0.97 in IB respectively. The positive and significant correlation between HR and EWt ($r = 0.14$ and 0.13), for BN and IB respectively, indicated increase in HR as EWt increased. The environmental performance in body weight of both hybrids was significantly depressed before 10 weeks in cocks and throughout the life cycle of hens, except at 10 to 16 weeks in the BN hen. Performance depression was also observed in HDP (-10.2%), EF (-6.9%) and EH (-14.4%) in IB, and EWt (-2.9 and -3.2%) in both genotypes respectively over their life-time period. Predictions of BW by

Age (R^2 = 0.85, 0.84), EWt by Age-in-production (R^2 = 0.65, 0.65), and PDOC by EH (R^2 = 0.99, 0.95) in both hybrids were significant at 25-75 weeks.

Hen day production, egg fertility, egg hatchability, pullet day-old chicks were higher in Isa Brown than Bovan Nera during the early-dry season. Body weight was higher in the cocks of both hybrids in early-dry and late-dry than in early-wet and late-wet seasons. The sensitivity of Isa Brown was lower than Bovan Nera except in hen weight.

Keywords: Bovan Nera, Chicken growth, Isa Brown.

Word count: 495

DEDICATION

To Queen, Dona, Jomion and Jesutinnami.

And

My Brothers, Sisters and Parents.

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CERTIFICATION

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DEFINITIONS

Chicks – Young and tender chicks from day-old to 8 weeks of age.

Point of lay – About to start laying eggs or at the point of dropping the first egg.

Growers – Birds between 8 weeks of age and point-of-lay.

Cockerels – Young males at point-of-lay to 20 weeks of age.

Layers – Female chickens or hens in lay.

Pullets – Young layers at first egg to 35 weeks of age.

Young cocks – Young males at 21 to 35 weeks of age.

Cocks – Adult males from 35 weeks of age and above.

Hens – Adult layers from 35 weeks of age and above.

Spiking – Replacement of weak and old breeding cocks with young ones at 25 weeks old in a flock.

ALL-IN, ALL-OUT – All birds in a batch stocked at the same time and culled at the same time, with the pen cleaned, disinfected and rested before restocking of a new batch of birds.

In-coming pullets – Pullets at 16 weeks of age and above, just approaching the start of lay or point-of-lay.

Micro-environment – The immediate environment of the chicken from the in the deep-litter or house from the floor level to the comb-height of the birds or the highest level of the lower wall in the open-sided house.

Early Sexual Maturity – This is the point at which a poultry flock drops her first egg.

Full Sexual Maturity – This is the point at which the peak of egg production (HDP) of a flock of poultry is attained.

Rearing period – This is the poultry management period from day-old to the first egg of a flock.

Production period – This is the poultry egg production and management period from first-egg to point of cull – subdivided into early sexual maturity stage (first-egg), full sexual maturity stage (Peak HDP) and Life-time period (average).

Age-in-production – This is the age of birds, in weeks, from first egg. This is also known as Age-in-lay.

Capons – These are castrated male chickens or cocks usually sold as Table birds from 25 weeks of age.

Strains – These are varieties of poultry within a breed for specific purposes such as meat, egg and game.

Hybrids – These are commercial birds formed from within particular strains eg. egg-type, through the process of hybridization.

Exotic – This means foreign or imported but usually highly improved and productive.

Genotype – This refers to the complete or sum total of heredity, that is, the genetic constitution that an animal either breed, species, strain, variety or hybrid possesses from the parents.

ABBREVIATIONS

Nera, BN	Bovan Nera hybrid or genotype
ISA, IB	ISA Brown hybrid or genotype
P.S.	Parent-stock
HDP	Hen-day production
DOC	Day-old chicks
EW	Early wet season
LW	Late wet season
ED	Early dry season
LD	Late dry season
PDOC	Pullet day-old chicks
HH	Hen-house
POL	Point-of-lay

Chapter One

INTRODUCTION

Poultry products are contributing greatly to ameliorating animal protein deficiency in Nigeria, although available data over the years indicate decline in the growth of the industry. In 1979, Akinwumi *et al.* (1979) identified a demand-supply gap in protein requirement of Nigerians. They therefore suggested that the fastest means of increasing supply of poultry meat and egg is the commercial production of exotic breeds and hybrids of poultry. This recommendation was made to government. They also recommended the establishment of grand parent stock farms at three or four locations across Nigeria, to ensure a steady supply of parent stock chicks, commercial day-old chicks and poultry products; and the provision of additional hatcheries. Exotic pure breeds of chicken could be bred with native chicken but adaptability may become problematic.

In the absence of improved local strains of chicken in commercial quantity, commercial breeders continue to rely on exotic breeds for their farm stock. These hybrids are reportedly produced from carefully selected, bred and tested lines starting from the Pure (unselected) lines, Great-grand parent lines, Grand parent lines, and the Parent lines. The method of crossing (hybridization) has been well developed, improved and made commercially viable for the multiplication of lines that produce the desired traits (nick) in their progeny. As production and development of new lines continue in various primary breeder companies, and competition stiffens among them, these strains are never able to become breeds due to continuous research and testing of new lines which may perform better than, and therefore replace the existing hybrids in the market. The best lines in terms of performance indices are constantly being pushed into the market.

Commercial poultry breeders and farmers in Nigeria rely on exotic chickens because of their higher productivity above local strains. This has led to the continued importation of exotic strains, hybrids, hatchable eggs and day-old chicks. As a result, various hybrids of questionable origin and quality are being imported into the country. This problem has been compounded by the absence of national and state poultry test stations to set standards and verify such for hybrids being imported into the country. Furthermore, there is neither a recognized chicken research institute to develop local strains of chicken, nor is there government political will to commit resources, manpower and facility to such research.

In Ibadan, Nigeria, the two most popular layer strains among parent-stock breeding-farmers are Bovan Nera (BN) and ISA Brown (IB). These two genotypes are therefore of interest as both have been accepted by many Parent -stock farmers in Nigeria, and they travel to Ibadan to purchase the day-old chicks of these genotypes for their commercial egg production.

Most contemporary studies focus on broilers and recently local chicken. However, the contribution of exotic layers to national protein supply is enormous and this necessitates the study into the productivity of Bovan Nera and ISA Brown parent-stock chickens. Presently, there is paucity of information on parent-stock chicken performance in humid tropical Africa, although Babiker and Musharaf (2008) have reported the effects of season on hatchability and fertility of egg-type parent-stock Bovans in Sudan. In view of the numerous parent-stock layer genotypes available in the country, it is necessary to characterize and differentiate among them, and especially between Bovan Nera and ISA Brown in growth, production, reproduction and sensitivity to seasons. Since performance depression has been associated with the introduction of exotic breeds into tropical environments, it is also important to examine the extent, if any, of interaction between genotype and season.

Justification

1. There are insufficient improved local strains of chicken in Nigeria.
2. There is total dependence of commercial poultry breeders on exotic breeds of chicken, leading to the importation of all sorts of untested and uncertified hybrids into the country.
3. Importation of exotic poultry may never end because of political, economic and commercial relations with producing countries. As such, control and standardization may be the right choice for government to pursue.
4. Adequate information data bank on the growth and reproductive characteristics of Parent-stock chickens in Nigeria is lacking. Such information from this study may serve as reference guide for parent stock farmers in the humid tropical environment.
5. There is absence of a functional Chicken Research Institute for development of local strains, and the control and standardization of poultry strains and hybrids imported into the country.

6. There is paucity of information on the effect of humid tropical seasons on exotic chicken performance.

These various challenges suggest that the tropical environment requires chickens with outstanding genetic quality. Thus we must ensure the availability of poultry genotypes of excellent genetic potential for commercial poultry breeders and farmers.

Main objective

The main objective of this study was to evaluate the growth pattern, reproductive performance, genotype - environment interaction and seasonal sensitivity of Bovan Nera and ISA Brown parent stock chickens in Ibadan, Nigeria.

Specific objectives

The specific objectives of this study were to:

- assess and compare the effect of seasons on growth pattern and reproductive performance of Bovan Nera and ISA Brown.
- estimate and compare the genotype sensitivity of Bovan Nera and ISA Brown to seasons in the environment.
- investigate and compare environmental performance in body weight and reproductive parameters for both genotypes in the region.
- estimate the relationships among growth, productive and reproductive parameters in each genotype.
- predict growth, productive and reproductive parameters in Bovan Nera and ISA Brown.

Chapter Two

LITERATURE REVIEW

2.1 Definition and background

Poultry includes any bird that is reared or hunted for a useful purpose (Oluyemi and Roberts, 2000). Domesticated chickens are known as domestic fowl. Commercial poultry industry began in Nigeria in 1961 (Taiwo, 1972). This was led by the Western Region government of Nigeria under the Premiership of Chief Obafemi Awolowo. The regional government imported pure breeds of chicken for commercial production and stocked them at Fasola Farms, Oyo. As a result of this bold action, rapid development of the industry took place later between 1963 and 1977 in Nigeria (Taiwo, 1981).

2.2 National poultry population

In 1977, the population of poultry in the country was estimated as 179, 281, 209 (Akinwumi *et al.;* 1979). Their analysis showed that domestic chicken population was 123, 898, 265 (69.10%); exotic layer population was 6, 215, 033 (3.47%); exotic broiler population was 3, 390, 892 (1.89%); guinea fowl population was 43, 739, 942 (24.40%) while other poultry constituted 2, 037, 077 (1.14%). In 1978, total hatchery incubator capacity in Nigeria was 2, 270, 000 eggs and this produced 885, 500 (39%) day-old chicks monthly. Most of the hatcheries were located in the Western States. In 1994, total chicken population was estimated as 82, 400, 000 while chicken in intensive, commercial poultry accounted for about 10, 000, 000 (11 %), but other poultry (Guinea fowl, Turkey, Ducks and Pigeons) was estimated as 31, 900, 000 (WAR/RMZ 78; 1994/1). Therefore total poultry population was 114, 300, 000. In 1997, the total population of improved and unimproved chicken was estimated as 117, 832, 000 in Nigeria (Shaib *et al.*, 1997). In 2006, total poultry population rose slightly to 140, 000, 000 according to Aphca (http://www.aphca.org/news/news_records/news_2006). This report showed the breakdown of poultry population in Nigeria as 84, 000, 000 (60%) in the backyard local poultry, 35, 000, 000 (25%) in the commercial poultry industry and 21, 000, 000 (15%) in the semi-commercial industry. These estimates thus showed a decline in the growth of the poultry industry between 1977 and 2006. There was a boom in intensive chicken production in the early 1980s. The government subsidized the price of day-old chicks and feed ingredients. With the withdrawal of subsidies, both extensive and intensive production tended to decline especially in urban areas, despite the continued high demand for chicken meat and eggs (WAR/RMZ 78; 1994/1). Poultry are mostly maintained under the traditional, low-input, free-range system of management. However, substantial number is reared intensively on commercial basis especially in the Southern States. Available data, however showed a steady growth of exotic chicken population from 9.6 million to 10 million (1994) and 35 million (2006), with an annual growth rate of 8.82 % as at 2006.

2.3.0 Bovan Nera and ISA Brown strains

2.3.1 Origin and popularity

Chicken was probably domesticated in Asia in 2500 BC and this formed the main source of modern stocks (Rose, 1997). The single-comb White leghorn breed was recognized and used in the 1950s by commercial breeders as a highly productive white-egg layer, while the brown-egg laying strains were developed by crossing Rhode Island Red with White Leghorn and other minor breeds in the 1960s. However the number of primary breeding companies of commercial poultry decreased rapidly after the 1950s when it was realized that each company must support a large breeding programme. Therefore, they must rely on large, world-wide sales of their strains to recoup the costs of their investments. Presently, there are fewer than 12 large multi-national companies involved in primary egg-laying and meat-type chicken stocks. This is a result of multi-national merging and re-organisations in the industry to cope with economic and management reality.

ISA/Hendrix Genetics Company is a global, multi-national, multi-species, animal genetics company that emerged out of the revolutional re-organisation which took place in the industry in 2005 (ISA Research and Development, 2011). The company with production and grand-parent stock (GPS) breeding centres in France, Holland, Brazil, Mexico, South Africa, India, Canada etc; is involved in the commercial distribution of egg-type layer breeder (grand-parent stock, parent stock) strains worldwide. This company distributes Bovan, ISA, Hisex, Shaver, Dekalb and Babcock layer birds. Other commercial strains being developed and distributed by other breeders include Harco, Olympia, Ross, Lohmann, Hy-line, Prelux-R etc. The breeding programme of ISA consists of individual pure-line breeding and pedigreed crossbred daughter group field testing (Recurrent Tests). Based on well defined breeding goals the best individuals of the pure lines are selected based on breeding values estimated using Best Linear Unbiased Prediction (BLUP) technology and the new genomic selection technigue (ISA Breeding Programme, 2011). The genetic origin and breeding programme details (secretes) of these genotypes are kept secrete by top technical management partners of these breeding concerns and never divulged to the public to guide against competition from rivals. Bovan Nera and ISA Brown are popularly distributed in Nigeria by CHI (Ajanla Farms) limited, Ibadan among others. These genotypes are widely accepted among farmers throughout Nigeria.

2.4.0 Growth

Growth in animals was described as increase in size and changes in functional capabilities of various tissues and organs of animals that occurs from conception to maturity (Peters, *et al.*, 2005). However, Newth (1970) reviewed growth as the increase in length, volume, mass, cell numbers and amount of a particular class of molecule within an organism. A decline in a chosen parameter is also regarded as negative growth. He also stated that in the study of animal growth, if change in size is not accompanied by change in shape, then a simple relationship would hold between equivalent linear dimensions, areas and volumes. Thus a crude data of change in size with time is usually presented as a curve of growth. The growth curve reflects life-time interrelationship between an animal's inherent impulses to grow and mature in all body parts (genotype), and the environment in which the impulses are expressed (Peters *et al.;* 2005). This stretched S-shaped curve implies an early phase of low growth rate followed by a period of high but nearly constant growth rate. The derivative of the curve of growth is the curve of growth acceleration. Since growth in living systems is a process in which every part is simultaneously involved, what is added by growth can itself grow, the rules of compound interest applies. So as livestock breeders we are interested in:

1. size and its rate of change
2. growth behaviour of unit mass of the biological system

As biologists we should also be interested in expressions that give the mean growth activity of the system rather than the overall change in size. These are:

1. Curve of specific growth
2. Curve of specific growth rate

- Growth = weight / time
- Growth acceleration = dW / dt (first derivative)
- Specific growth = log Weight / time
- Specific growth rate = d log W / dt

2.4.1 Growth of body parts

The body parts of a chicken grow at different rates indicating that growth is more or less rapid in one part of the organism than the other. This is referred to as differential growth. Thus, the weight of body parts increase as a proportion of body weight during growth. This shows that each body part has its own characteristic growth curve and equation (model). When differential growth occurs in individual animals, change in shape will usually result (Newth, 1970). Growth in body parts are usually described using allometric growth ratios, since the relative growth of all the different body parts are coordinated. So organs growing at high rates and the growth of the rest of the body are often related in a simple way thus:

$$y = a X^{b}$$

where y = weight of a part of the body

a = constant

X = weight of the whole body

b = constant

If $b > 1$, growth of y is faster than the rest of the body

If $b = 1$, growth of y is proportional to the rest of the body

If $b < 1$, growth of y is slower than the rest of the body

However, the above function can be turned to a linear function by logarithmic transformation on data. That is:

$$\text{Log } y = \log a + b \log X$$

where:

y = weight of body part (kg)

a = constant

b = allometric growth ratio (slope)

X = weight of whole body (kg)

This shows that the specific growth rates of x and y remain in a constant proportion and growth. Relationships which obey this rule are known as Allometric. Thus growth in whole animals and their parts are rigidly controlled and co-ordinated with equal effectiveness in all tissues. Nutrition, endocrine system and genetics of living animals have controlling influence on their growth (Newth, 1970) but different genotypes and strains within a species may have different allometric ratios (Rose, 1997).

2.2.2 Growth models

Various models have been used to describe growth pattern in animals over the ages. These include:

- The logistic model (Pearl and Reed, 1923)
- The Gompertz model (Windsor, 1932)
- The Mono-molecular model (Brody, 1945)
- The Richards model (Richards, 1959)

However the Gompertz growth model has become popular for describing growth and comparing different genotypes of chicken. Peters *et al.* (2005) tested three of these models above by fitting body weight – age data on chicken to them in order to describe growth and characterize the form of growth in seven chicken genotypes. They reported that monomolecular and Richards models overestimated early-life body weight, but both and the Gompertz model underestimated asymptotic (mature) weight. They also reported that the Gompertz model gave a better asymptotic (mature) weight than the other two functions. It describes the body weight – age data.

$$W = M \times 2.718^{-2.718^{(-a \times (Age - Agemax))}}$$

Where W = Weight (gm) at any age (weeks)

M = mean mature body weight for the breed (kg)

Age_{max} = age when maximum rate of weight gain is attained (days)

Coefficient a = ((maximum rate of live weight gain in kg/day) x 2.718) / M

Or

$$W_t = A_e^{-bekt}$$

where W_t = Weight (gm) at age t (weeks)

A = Asymptotic weight (average weight at maturity)

$_e$ = base of natural logarithm

b = constant of integration that expresses the rate at which a logarithmic function changes with time.

k = rate of maturing (the larger the value of K, the earlier the animal matures)

Peters *et al.* (2005) suggested that the same model may not be appropriate to describe different traits in a particular animal or genotype. Rose (1997) reported that poultry strains exhibit sexual dimorphism within and differing rates of growth without; and that the maximum rate of growth occurs when the bird is at 1/4 to 1/2 way of its mature weight while the age at which this maximum growth rate is reached is a variable describing the shape of the growth curve. Thakur *et al.* (2006) also reported sexual dimorphism in Kadaknath chicken that the rate of increase in body weight from 6 to 52 weeks was higher in males than females.

2.4.3 Growth performance in chicken

The body weight of the newly-hatched chick is about 66-68 % of the incubated egg weight having had about 12 % weight loss due to water loss during incubation [1]. However, once hatched the layer chick increases in hatching weight about 10 times within the first 6 weeks of life (Ayorinde *et al.,* 1999). He also reported a body weight increase from 32.88 gm to 1445.45 gm between day-old and 20 weeks of age, while another unpublished result gave a body weight of 2102 gm at peak egg lay (310 days) in Shika Brown commercial stock. Thakur *et al.* (2006) reported growth in Kadaknath breed of chicken in India as in Table 2.1. Weight at first egg in Fayoumi chicken was reported as 1253.53gm at 163.63 days (Khan *et al.,* 2006), while the laying test of German Democratic Republic (1986) for commercial hybrids put the body weight of white-egg layers as 1.33 kg; brown-egg layers as 1.59 kg and others as 1.32 kg at 19 weeks of

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[1] Cob hatchery management guide (1996). The cobb breeding company limited. United kingdom.

age. Petrash (1987) reported a body weight of 1395-1408 gm for 150-day (21 weeks, 6 days) old chickens in a trial to control cannibalism. Lozhkina (1987) reported that the best overall performance (in bodyweight at 40 weeks; age at first egg; egg production; survival rate; egg mass to 40 weeks) was obtained in white leghorn hens weighing 1.80 kg at 20 weeks.

However, Chineke (2001) reported an average body weight of 1726.25 ± 6.28 gm for mature Olympian Black pullets. By using a quadratic model of the form $Y = a + bX + cX^2$ to fit a predictive equation for egg traits (Y) and substituting body weight ($X_{max} = b/2c$), Chineke (2001) was able to determine the optimum body weight-range that yields the maximum egg weight and other egg traits in Olympian Black pullets. Therefore he recommended the maintenance of an optimum body weight range of 1.72 to 1.80 kg for optimum egg traits performance in Olympian black pullets. He also reported that the association between body weight and selected egg traits (egg length, egg breadth, egg index, egg weight, albumen weight, yolk weight, shell weight, shell thickness, hen-day production) was non-linear.

Handy and Ali (1986) reported weight gain at weeks 1 and 2 in Alexandria fowls as 79.7 and 129.9 gm and in Fayoumi fowls as 48.7 and 75.0 gm respectively. Also Azharul *et al.* (2005) reported weight gain in Sonali Cockerels as 209 gm at 9-11 weeks, 434 gm at 12-14 weeks and 542 gm at 9-14 weeks respectively. However, body weight was reported as significantly higher in White Leghorn birds than in Nigerian birds up to 10 weeks of age after which the differences were no more significant, and that the overall performance of the exotic strain was reported better than that of the local breeds (Makinde *et al.*, 1987). In a related study of phenotypic characteristics of Nigerian local chicken by Ajayi and Agaviezor (2009), it was reported that the mean mature body weight was 1504 ± 0.006 and 1289 ± 0.004 gm / bird for cocks and hens respectively. Similarly, the average body weight of the Fulani ecotype chicken in Nigeria was reported as 1099.28 ± 196 gm at 20 weeks and mean day-old weight of 30.45 ± 1.24 gm/chick by Sola-Ojo and Ayorinde (2009), with highest body weight gain (170.85 gm) recorded between 16 and 18 weeks while the village chicken in Tanzania was reported with mean body weight of 1948 gm / cock and 1348 gm / hen by Goromela *et al.* (2009).

Table 2.1. Growth performance of Kadaknath chicken breed in India.

Traits	Period	Mean (gm)
Body weight	0-4 weeks	28-111
	6-20 weeks	168-868
	6-7 months	1000
	6-12 months	1003-1534
	12 months	1500
Weight gain	0-4 weeks	21.0
	4-20 weeks	48.0
	20-52 weeks	22.0

Source: Thakur *et al.*, 2006.

2.5 Stocking density and behavioural pattern

Gibson et al. (1988) placed ISA Brown layers at different densities in naturally ventilated covered and strawyard, and recommended a maximum stocking density of 4 birds / metre^2 and a flock size of not more than 1000 birds for optimal performance under the straw-yard system. Gibson, Dun and Hughes reported that the birds displayed a wide range of behavioural pattern such as feeding (40 %), "comfort" behaviour (19 %), standing and perching (40 %), nesting (7 %) and foraging (7 %). Incidences of cannibalism tended to increase with age (3 years) and higher stocking density in flocks, not beak-trimmed and on deep litter system (Apple *et al.*, 1988 and Gibson *et al.*, 1988).

Pens of 7 – 8 metres width has been recommended for optimum production in the tropics while Bogosavljevic-Boskovic (1991) reported a higher mortality and low body weight at 18 weeks for birds kept at stocking density higher than 8 birds / metres ^{2}. Egg production was lowest in flocks at higher stocking density. Lee and Moss (1995) also reported that birds at higher population density had the lowest percent hen day egg production and feed efficiency. Both concluded that increasing population density decreased laying performance of birds; while Farooq *et al.* (2002) concluded that better egg production was obtained in large-sized than small-sized flocks maintained at optimal density of 5-6 birds / metres^2 under better hygiene. Appleby, *et al.* (1988) had recommended that birds in the deep-litter should be kept at low densities between 2.4 – 10.7 birds / metres^2 .

2.6 Deep litter system and chicken performance

Atmospheric dust and ammonia were reported as problems in deep-litter system and deep-pit cages while more dirty eggs were also observed in the litter system. The severity of feather loss and damage was positively corresponding with stocking density. The body weight was lower and had less fat deposition compared to caged birds (Appleby *et al.*, 1988). Also Ayorinde *et al.* (1999) reported higher egg production and egg weight in caged compared to littered birds.

2.7 Management operations in chicken breeding

Skeletal extremities include beak, spur and toes in birds. Birds in deep-litter develop behavioural vices such as feather pecking, vent pecking, cannibalism, cock fighting, over-riding. These vices lead to injuries, bleeding and death. The removal of these extremities seem the best and long-term solution to reducing these vices. Reduction in light intensity and exchange of breeding males within the farm may also be effective.

Despuring is the removal of the spur to reduce injuries to cocks during fighting and hens possibly during mounting. This is conducted in the hatchery at day-old for parent stock chicks.

Debeaking or beak trimming or beak tipping is the removal of 1/4 - 1/3 portion of the upper beak of chicks at day-old or at 8 – 10 days or at 7 – 10 weeks and possibly repeated at 12 weeks. This operation is conducted also to discourage feed wastage by birds. Adequate nutrition along with ad-libitum feed must be offered immediately post –trimming to discourage excessive bleeding.

Declawing or toe clipping is the removal of the claws on the toe at day-old in the hatchery for parent-stock chicks. These extremities grow back up to a normal length but the nerves and sense receptors in them do not penetrate the scar tissue at the end. These operations cause temporary pain, and bleeding; and then growth is affected temporarily through reduction in feed intake.

Inexperience and lack of expertise may lead to improperly conducted trimmings causing open wounds and eventual infection of these wounds (salmonellosis). This infection causes heavy mortality in infected flocks. Carey and Lassiter (1995) reported that feed consumption was significantly reduced within 14 days period after beak trimming at 63 and 84 days (9 - 11 weeks); the first trimming being done at 10 days.

2.8 Feed uptake and feeding

Rose (1997) reported that poultry eat a daily amount of feed approximately 5 % of their body weight. A prediction equation has been developed based on their daily metabolizable energy requirement. However offering palletized feed may increase intake to 8 % of body weight. Feed restriction is not practised in rearing of layer chickens while ad-libitum feeding is practiced in the first week of life before gap-feeding is established. Sometimes full-feeding is practiced till production phase. However in production, daily gap-feeding (40 / 60 %) is commercially favoured for many reasons because:

- Chickens feed mostly in the cool hours of the day – early morning and late evening in the tropics.
- It is also employed to curb feed wastage

- It is used to ensure that adequate amount of feed is available for birds at night when egg formation is taking place.
- It is used to encourage uptake of micronutrients that are in the feed dust that is left behind after selecting the larger feed particles in the feed offered.
- It is also utilized to encourage empty trough in the afternoon hours when feed uptake is low and therefore stimulate hunger for feed at late evening hours.

Phase feeding is practiced to adjust to the decreasing nutritional requirement of the hen body, with increasing age and decreasing production levels, for optimum production.

Water is important for feed metabolism in the body. Most dry poultry feeds contain 10 – 15 % water, in addition, birds will consume about twice (temperate) (Rose, 1997) and 5 times (tropics) of the weight of feed consumed.

2.9 Sexual maturity

The age at which a bird drops her first egg signifies early sexual maturity age while the age at peak production signifies full sexual maturity age. Early maturity could be achieved at 16 weeks or 112 days (Mussawar *et al.*, 2004). In black Olympian pullets, 151 and 175 days were obtained by Ayorinde and Oke (1995); while 132 days and 210 days (30 weeks) were reported for Shika brown commercial strain developed by NAPRI (Ayorinde *et al.*, 1999) and reared on deep litter. Khan *et al.*, (2006), reported early maturity at 163.63 ± 11.17 days in Fayoumi chicken with average body weight of 1253.53 ± 16.42 gm and first-egg weighing 45.79 gm under intensive management. However, full maturity was achieved earlier at 196 days (28 weeks) in caged Shika Brown birds. Analysis of results presented by Akanni *et al.* (2008) indicated that the Black Nera pullets achieved sexual maturity at 188 days at a body weight of 1421.59 gm/bird while the improved local B-Alpha pullets matured sexually at 199 days with a body weight of 1315 gm/bird. Leghorn hybrid pullets under temperate conditions attained sexual maturity at 167 – 199 days as reported by Horst and Petersen (1981). They both reported that the introduction of dwarf genes into chicken is capable of reducing both the body weight by 29.3 – 31.7 % and increasing age-at-sexual maturity by 12.6 – 17.2 % in hot environment. They also reported higher egg production in normal as against dwarf birds under the influence of long term heat stress (32^0 C, 45% R. H.) at 56 and 76 weeks; and retardation of sexual maturity in dwarf birds through the dwarf genes. This fact was also confirmed by Ayorinde and Oke (1995) that birds with lower body weight mature late by a week as against those with higher body weight , while those on *ad-libitum* feeding matured sexually 3 weeks before those on restricted feeding. Belgium (1986) however reported contrary to above information that dwarf birds began laying 14 days earlier on the average than normal birds. Re-analysis of results presented by Akanni *et al.* (2008) revealed that among improved genotypes (Indian-bred Giriraja, Nera Black, Improved local B-Alpha and White Leghorn pullets); an inverse relationship was observed between body weight and age at early sexual maturity. As the body weight of pullets at sexual maturity decreases (2063.3; 1421.6; 1315.0; 1214.3 gm), the age at sexual maturity increases (162; 188; 199; 202 days) respectively; the situation was however different compared to the normal feathered Nigerian local hens with light body weight (1208.64 gm) and early maturity age (183 days). Although the age at sexual maturity depends on species, strain, feeding and day-length, it can be estimated using the non-linear relationship:

Age at Sexual Maturity = General Average for the strain – $1.61P + 0.0006P^2 + 0.001918P^3$

Where P = constant day-length (photoperiod) used.

Thus, the age at sexual maturity can be manipulated forward or backward by management by changing the day-length during rearing (Rose, 1997). The information above emphasizes the need to photo stimulate (give extra light hours to 17 hours) birds at the right bodyweight and age combined. The domestic fowl exhibit relative photo refractoriness. Growers will reach sexual maturity even if they are kept on short day length. Grower breeders may have their sexual maturity delayed only by a combination of short day length; and feed restriction as reported by Sodhi and Sharma (1992) in which he was able to delay sexual maturity through feed restriction by 8 – 15 days in White Leghorn chickens, fed *ad-libitum* with high fibre basal diet and sawdust (4:1). The length of delay depended on the duration of restriction imposed. On the other hand, chicken kept at their critical or marginal day length reach sexual maturity earlier if increased day-lengths are applied. Early photo-stimulation of birds with low weight is highly undesirable with several consequences such as:

- Immature body and skeletal frame to cope with the stress of egg production.
- Low egg weight
- Insufficient fat pad and consequent difficulty in ovi-positioning.

It was reported by Hays (1952a) that very early maturing pullets remained significantly smaller than medium or late-maturing birds up to 12 months of age, but this difference in weight disappeared at 14 months when all age-groups showed about the same weight. Age at sexual maturity was also found to have consistent and considerable effect on egg weight (the lower the age, the lower the egg weight); while very early-maturing pullets average significantly greater number of eggs than the late maturing pullets (Beker and Banerjee, 1993; Hays, 1952a).

2.10 Photo-stimulation

Azharul *et al.* (2005) reported that egg production will normally start 14 – 18 days after onset of photo stimulation while Yakubovskii et al. (1991) reported that egg fertility of hens mated to cocks was increased by 1.7 – 2.0 % by providing artificial light during the last 3.5 – 4.0 hours of natural daylight from lamps.

2.11 Egg traits in poultry

These include egg number, egg weight, egg length, egg width, egg index, shell weight, shell thickness, age at sexual maturity, internal egg quality - haugh unit, albumin height, albumen weight, yolk colour, yolk diameter, yolk weight, yolk height, yolk index (Fayeye and Adeshiyan, 2008; and Ojedapo *et al.*, 2008).

2.12 Egg production cycle

Rose (1997) described the characteristics of an egg production curve of a flock of laying hens. He noted that the curve has 5 stages, A to E, as described in Figure 2.1. These are:

- Stage A – Early sexual maturity (1^{st} egg) point. Individuals vary.
- Stage B – 50 % egg production. This is a more reliable measure of sexual maturity.
- Stage C – Peak egg production. Point of inflection and slow decline in egg production. Rate of decline is usually constant but the slope depends on species, strain, management and biosecurity (health factors).
- Stage D – Rapid decline in egg production. This decline may further be accelerated by decreasing day length, reduced feed supply, sharp increase in number of broody birds, poor management, nutritional and other stress conditions.
- Stage E – Moulting. This is when there is rapid deterioration in egg production and shell strength. Laying soon ceases altogether. The oviduct and the ovary regress, feathers are shed

as the feather papillae are stimulated to produce new ones that push the old ones out. Moulting is a result of the complex interaction between gonadotrophic hormones. Thyroxin and prolactin also interact with gonadotrophic hormones. At this period, the birds rest from egg production and tissue regeneration (oviduct) takes place.

- Seasonal variation, heat stress, disease challenge are factors able to change the shape of the laying curve except in controlled environment.

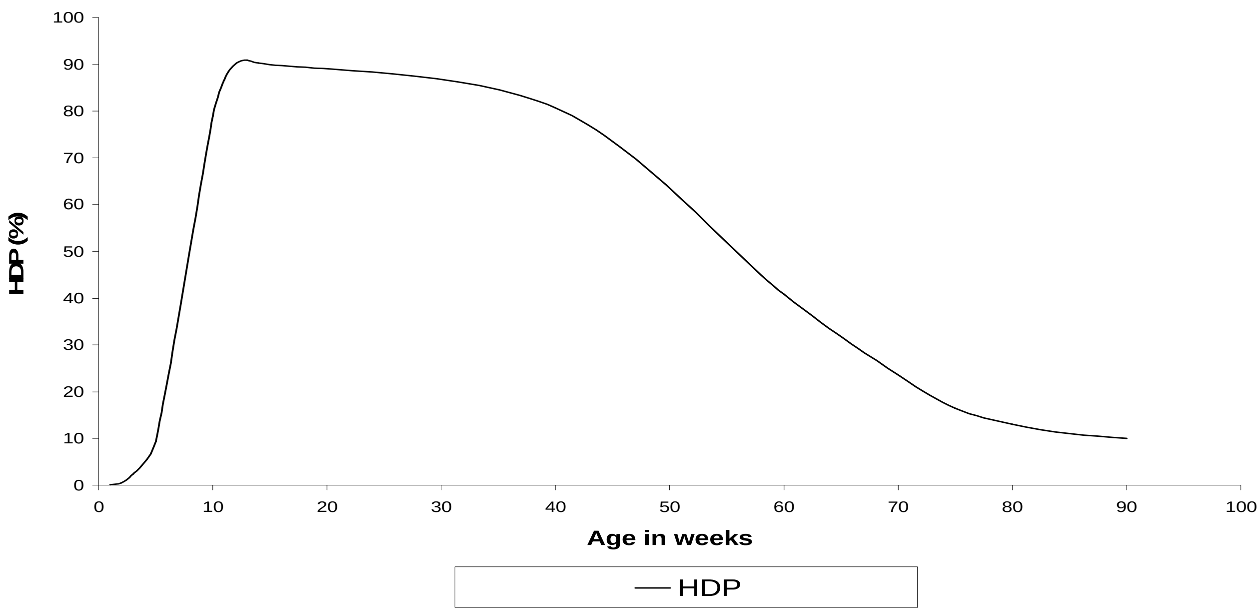
Rose (1997) and Oluyemi and Roberts (2000) also reported that the egg production curve of the domestic chicken can be divided into 3 main phases, 1 to 3, which ends with moulting as illustrated in Figure 2.1

Phase 1: This is the time from the first egg laid to the time when nearly all birds in a flock are laying continuously (peak production). It is very short because individuals are exposed to same environmental and nutritional regime. This phase ends in peak production.

Phase 2: This is the main laying period. However there is a continuous but gradual decline in HDP due to lengthening egg formation time. There is also a slow and continuous reduction in the rate of egg-yolk deposition as birds get older. This means birds are not able to form ova of the correct size quickly enough to allow long sequences of eggs (clutches) to be formed. This period lasts for various lengths of time depending on species, strain, environment and management.

Phase 3: This is the time when the number of shed ova declines rapidly. Incidence of internal laying also increases sharply. This condition is due to a number of factors such as Broodiness, moulting, changes in nutrient intake, changes in body composition, stress factors such as sharp noise, regular disturbances and fright; all these conditions accelerate end of lay and onset of moulting.

Essien (1989) reported that maximum rate of egg production occurred in shaver in the first 12 weeks of production, then declined gradually after 12 weeks and markedly decreased during 25 - 48 weeks of lay.



Source: Rose, 1997.

Figure 2.1. A typical hen-day production curve of the domestic chicken showing the stages, A to E, and the phases, 1 to 4, of egg production performance during the pullet year

2.11 Egg production

Egg production of 55.8 % was reported in Rhode Island Red (RIR) chicken reared under intensive system producing 133 eggs during 16 – 50 weeks (Sazzad, 1992). Although egg production of 240 eggs/hen/year was reported in a strain of RIR chicken; however, a bird laying 180 – 200 eggs/year in the tropics is considered a good layer (Atteh, 2004).

Layer farms in Pakistan produced 68.0 % HDP and 203 eggs HH annually (Mussawar *et al.*, 2004). Shika Brown produced 70.06, 67.43 and 54.06 % at 33 – 46, 47 – 59 and 60 – 72 weeks respectively; while the black Olympian pullets produced 55.2 % HH eggs (Ayorinde and Oke, 1995) and 69.33±0.09 % hen-day production (Chineke, 2001). Chineke (2001) also reported a significant quadratic relationship between total hen-day production and body weight at sexual maturity in white leghorn layers, as observed by Du plessis and Erasmus (1972). Essien (1989) reported that maximum rate of egg production occurred in Shaver fowls during the first 12 weeks of production. The effect of season on egg production of chicken was investigated by Khan *et. al.* (2006) among local chicken in Bangladesh. They reported that highest egg production was observed in winter season (52.78%), followed by summer, spring and late autumn respectively.

Percent egg production can be predicted for domestic chicken with the equation by Rose (1997).

$$Y = 100\ ((1 / (1+ (a \times b^{x}))) – (C \times X) + d)$$

where; Y = % HDP (number of eggs laid / day /100 birds)

a and b = constants describing increase in egg number from start to peak production (a = 39.6 and b = 0.30)

c = constants describing rate of decline in % production from peak (0.0035)

d = constants describing % production at peak (- 0.03)

X = number of weeks from first egg laid by flock

Oni *et al.* (2001) also studied egg production in a strain of Rhode Island breeder hens using six mathematical models namely exponential, parabolic exponential, woods gamma, modified gamma, inverse polynomial and linear model. They fitted 28-day periodic egg production data to models starting from first-egg. Comparison between these functions indicated that the modified gamma model by Mc Nally (1971) gave the best fit to data but they concluded that one model may not necessarily be best in all circumstances or with all data; and suggested that properties of models and data should be examined before choosing an appropriate model. The modified gamma function was:

$$Y = a X^{b} e^{(- c. x + d . x \uparrow 1/2)}$$

where Y = Number of eggs laid by an individual bird or hen-day production of the group

a = Peak egg production achievable by a strain

x = Time period

b = Rate of increase of hen-day egg production

c = Rate of decline of hen-day egg production

d = Individual rate of decline in egg production

2.14 Persistency in egg production

This is described as the ability of a flock of poultry to continue in lay (% HDP) within a range of 5 % variation in hen-day egg production, within a particular time interval (weeks) while laying eggs of uniform weight. To the average farmer, persistency is simply the number of weeks in which a flock of birds will lay eggs of uniform weight, usually at or above 70 % HDP. For comparative purpose however, the product of mean production (% HDP) and the time interval (persistency) could be very important. The CV of % HDP at this period could also be a pointer to the laying stability of a flock during the persistency period and therefore useful for strain comparison.

This phenomenon is observed in the second phase of production between peak egg lay (C) and the point of rapid decline in egg production (D). Petersen (1987) also reported that laying persistency was higher when daily photoperiod was increased by greater or equal to 1 hour /week than when increased by 0.5 hours / week, while the hy-line research programme expressed the expectation for persistency to improve along with sexual maturity with each successive generation. Persistency in lay is usually observed at 30 – 35 weeks at 90 % lay while about 66 % of the flock should perform above average between 40 – 66 weeks of age.

During late production period, persistency must be maintained through good flock management. A deficiency of amino acids at 50 weeks of age immediately reduces egg weight and then persistency around 4 – 5 weeks later. Hendrix genetics believes that a reduction of the oil content (%) and energy level is a sure way to stabilize egg weight at this period. So while considering persistency in lay, individual variability of birds in the flock, and average egg weight, the requirement for amino acids must be stable throughout the laying period.[2]

2.15 Factors affecting egg production in deep-litter flocks

These factors were reviewed by Jacob *et al.* (1998) as Age, Nutrition, Omission of ingredients in feed such as salt, calcium, vitamin D, Protein and fat; Toxicoses- salt, phosphorus, vitamin D; Mycotoxins, Anticoccidials, Management errors - feeding, watering, inadequate day-length, high house temperature; Ectoparasites – lice, mites, fleas; Endoparasites - nematodes, tapeworms; Diseases – fowl pox, coccidioses, infectious bronchitis (IBH), newcastle (ND), avian influenza (AI), avian encephalomyelitis (AE), mycoplasma galinarium (MG), Fowl cholera, Infectious coryza; Predators, Cannibalism – feather pecking, egg eating, excessive egg breakage, hidden eggs at corners.

2.16.0 Negative influences on egg production

Physiological conditions which influence egg production negatively include photo-refractoriness, brooding and moulting.

2.16.1 Photo-refractoriness

Rose (1997) reported that changes in day-lengths are used to synchronize seasonal breeding patterns. As decreasing day lengths result in decreased leutenising hormone secretion by birds and the ceasing of egg production. However, the stimulatory effect of lighting both in controlled and open-sided environments diminish over time and birds eventually stop laying eggs. The loss of photo stimulation in birds is referred to as photo-refractoriness.

2.16.2 Broodiness

Rose (1997) also reported on broodiness in chicken. This is the condition in which the hen after completing the clutch size that is characteristic of her species and strain, sits on her eggs to incubate them. This period from start of incubation to the end of chick brooding is the broody

[2] **Hendrix genetics (2006). Primary breeder of ISA brown and Bovan Nera parent stocks.**

period. During this period, egg-laying stops and their ovaries regress. Abdominal feathers are lost and the abdomen eventually forms a bare brood patch when they start incubating their eggs. During broodiness, the levels of circulating prolactin increase and may reach a threshold level that starts overt behaviour. There are also changes in the circulating leutenizing, progesterone and other gonadotrophic hormones at this period. He noted that domestication and selection have reduced this trait in egg-strain chickens. The author also noted that in practice in large poultry systems, fertile eggs are promptly removed from the nest boxes, incubated and reared separately from parents. High incidences of broodiness result in large drop in production in flocks. Remedies that have been employed in practice over time include:

- Timely collection of fertile eggs (5 times /day).
- Filling the lay-nests with adequate, clean and dry litter regularly
- Providing perches in the pen
- Identifying early stages of broodiness in individuals and separating them to an uncomfortable broody pen.

2.16.3 Moulting

Rose (1997) reported that egg production declines once a moult is begun and ceases completely after 10 days. The oviduct and ovary regresses and reduce in weight to about 1/10 and 1/20 of previous weight respectively. The weight loss in both cases may account for about 25 % of total weight loss by the hen during a moult. Liver weight and body fat store are also reduced. Feather loss starts 15 days into moulting.

2.17 Egg weight

In Nigeria, unpublished results of Shika brown commercial pullets gave an egg weight of 64.9 and 66.3 gm at 33 and 59 weeks respectively while Black Olympian pullet eggs weighed an average of 54.56 gm (Ayorinde and Oke, 1995) at 21 - 32 weeks. Ojedapo *et al.* (2008) reported mean egg weight in Brown Shaver commercial layers as 56.15±4.85 gm with a range of 43.70 – 81.30 gm. Chineke (2001) reported an average egg weight of 63.06±0.19 gm, a maximum weight of 66.15 gm and a direct relationship between egg weight and body weight in Black Olympian layers. It has been reported that the weight of the egg increased between 2 to 7 months of lay by

Cunningham *et al.* (1960) while that of Shika increased between 20 – 44 weeks (Ayorinde *et al.*, 1999). The average weight of the egg is determined by age and consequently the size (growth rate) of the magnum (Austic and Nesheim, 1990; In: Ayorinde *et al.*, 1999). Average egg weight among Fayoumi chicken was reported as 45.79 gm (Khan *et al.*, 2006) while that of the Nigerian light Eastern ecotype layer was reported as 38.99 ± 0.37 gm (Oleforuh *et al.*, 2008). The egg weight of the frizzle-feathered Nigerian local hen, ff, was reported as 51.07 ± 0.77 gm (Peters *et al.*, 2007). Beker and Banerjee (1993) reported data which showed that the higher the age at first-egg, the higher the egg weight within the first 20 weeks of lay. Akanni *et al.*, (2008) also presented results which indicated that the higher the body weight of the hen at first egg, the higher the weight of the first egg. This indicates that it is possible to manipulate the body weight of the hen through management to obtain higher egg weight at first egg. The effect of genotype was also reported significant on egg weight.

As laying flock ages, the egg weight increases due to body weight gain and declining egg production after peak. Increased breeder egg weight over the productive life-time has significant benefits on performance. Bigger eggs hatch bigger chicks which are of better quality with more residual yolk, lower susceptibility to dehydration and heat loss. However, Flemming (2005) reported that excessive increase in egg weight during late production has negative implications for egg quality and handling. Bigger eggs tend to have a poorer hatchability, poorer shell quality and increased number of cracks. So, it is important to manage egg size in late production to achieve a balance between layer performance and egg quality. This can be achieved through management of persistency of lay, body weight and nutrition. Tandron *et al.*, (1987) reported data showing that eggs bigger in weight lose more moisture during 1- 4 days of storage, leading to lower percent hatchability and lower percent chick weight.

However, Unal and Ozcan (1989) reported data which showed that the higher the weight of eggs set in the incubator (without storage), the lower the hatchability, the higher the chick weight and chick survival to eight (8) weeks. In 1986, the German Democratic Republic laying-test conducted on 6 white-egg strains and 5 brown-egg strains of fowls showed that the weight of the brown-egg strain (63.5 gm) was higher than that of the white-egg strain (60.2 gm) fowls. However, the weight of chicken egg can be predicted by an equation by Rose (1997) describing the asymptotic relationship between age and egg weight:

$$Y = a - (b \cdot r^{x})$$

where, Y = egg weight (gm)

a = a constant describing the maximum egg weight (62.0)

b = a constant describing the rate of increase in egg weight (18)

r = 0.9 for all poultry species.

x = number of weeks in lay, not age

This asymptotic relationship describes the rapid increase in egg weight which later move slowly towards a constant weight as they get older. Fayeye and Adesiyan (2008) also investigated thirteen egg quality traits using multiple regression analysis to identify the determinant of egg weight. They concluded that albumen weight was the most important determinant of egg weight probably due to the fact that it constitutes the largest portion of the egg. They reported that the linear function gave the best fit for the regression of egg weight on other egg quality traits.

2.18 Factors affecting egg size

The author noted from field observations that the egg weight may be influenced by factors such as:

- Maturity weight – the lower the age at first-egg, the lower the egg weight.
- Age of flock – older birds in second or third year of production produce eggs with higher average weight than the previous year
- Mature body weight – the heavier the weight of the hen, the heavier the egg weight.
- Breed and strain (genotype) of flock
- Flock body weight uniformity
- Nutrition and level of feeding
- Diseases

2.19 Nutrition and egg weight

The egg weight during the early stages of egg production cycle can be increased by increasing the protein level from 17 to 21 % or by adding 4 % fat to the conventional layer diet (Keshavarz and Nakajima, 1995). They also concluded that the beneficial effect of fat on egg weight is independent of its energy effect. However, Keshavarz (1995) reported that methionine effect on egg weight was significant during early stages of egg production and that most traits were increased by addition of 4 % fat to high protein (21%) diet. However, in late production period, reduction in the oil content (%) and energy level to stabilize the egg weight must also ensure that the amino acid profile of the feed is not affected (Flemming, 2005).

2.20 Egg sorting

Smith, (2000) and Cobb (1996) summarized the characteristics for eggs that are required for setting in the incubator. These eggs are usually selected to achieve high level of hatchability and include eggs with uniform weight and size (55 gm ±10 %). Eggs below this range contain very small yolk which provides insufficient nutrients while eggs above the range usually contain double-yolk which may be infertile or produce deformed or fused chicks. Pullets in early-lay period (1 – 4th week) are likely to produce double-yolked eggs. Unracked eggs should be selected for setting, picking out the cracked ones. Cracked eggs usually become desiccated before end of incubation and fail to hatch. Those eggs that do not contain blood and meat spots should be selected also. Blood and meat spots are heritable characteristics. Eggs with thick shell are usually selected. Thin, chalky and discoloured shells are discarded. Eggs with clean shells are also picked. Those eggs with the characteristic oval shage and those with smooth shell surfaces are selected for setting also.

2.21 Storage of hatchable fertile eggs

It has been recommended that fertile, hatchable and sorted eggs should not be stored for more than 7 days before setting in the incubator. Eggs should be stored broad-end up. The average room temperature should be 10 – 14^0 C and 75 – 85% relative humidity (Ross, 1997, and Smith, 2000). Fertility of eggs set in the incubator tends to decline by 1% per day after 4 days of storage and 2 % per day after 10 days. Other effects of egg storage include the prolongation of incubation time, as each day's storage of eggs adds 1 hour to the incubation time. Hatchability is also depressed after the initial 5-day period of storage, losses in hatchability of 0.5 - 1.0% per day has been observed. Tandron, *et al.* (1987) reported data showing that eggs 48 - 53 gm stored for 4 days pre-incubation recorded the highest hatchability of 90 - 98 %, losing the least amount of moisture (0.05 gm) and having the highest percent chick weight (72.67 %). Unal and Ozcan (1989) also reported that eggs weighing 58.1 gm recorded a hatchability of 92.0 %. A close study of these reports inform one that the optimum weight of hatchable eggs for best hatchability result could be maintained between 54 and 59 gm.

2.22 Fertility of incubated chicken eggs

Fertility was reported among the Deshi breed of chicken as 83% (Bhuiyan *et al.*, 2005) while Jayarajan (1992) reported that egg fertility was highest for white leghorn and Rhode Island Red breeds during the cold and summer seasons respectively. This means that hatchability of eggs is influenced by breed and season among other factors.

2.21 Hatchability of chicken eggs

Hatchability is the number of first quality chicks obtained, expressed as a percentage of all eggs set in the incubator. Hays (1952b) reported a linear increase in sex ratio as hatchability declines. He further re-instated the hypothesis that "embryos of the heterogametic sex are much more likely to die than those of the homogametic sex" and "hens with very high hatching records will generally be expected to give normal proportions of male and female chicks".

The effect of egg cleaning on hatchability of eggs was reported by Milosevic, *et al.* (1992) that hatchability was significantly reduced in dirty eggs washed with disinfectant and in unwashed control eggs. The worst hatchability was obtained in eggs washed with water. They further stated the disadvantages of mechanical cleaning of eggs as its slowness and possibility of contamination of the incubator and other eggs by soiled eggs. Hatchability is influenced both by breed and season (Jayarajan, 1992); and other factors which are broadly categorized into farm management and hatchery management factors.[3]

1. Farm management factors include nutrition, diseases, infertility, egg damage and egg hygiene.
2. Hatchery management factors include egg storage, egg damage, hygiene, management of incubation, and egg handling.

Levin (1989) reported data which showed that hatchability of eggs declined as the weight of eggs set in the incubator exceeded 59 gm. Hatchability reported by Bhuiyan *et al.* (2005) among the Deshi breed of chicken (52%) was low. Failure of eggs to hatch could be traced to egg storage

[3] **Cob hatchery management guide (1996). The cobb breeding company limited. United kingdom.**

(25%), true infertility due to flock age (20%), bacteria and mould contamination (12%), egg faults and shell damage (10%), breeder nutrition (10%), diseases (10%), genetics (8%) and incubation faults (5%).[4]

2.24 Day-old chick body weight

The day-old chick weight is normally about 66 - 68 % of the egg weight. Individual chick weight normally were between 34 and 46 gm/bird at hatching.[5] The time interval between hatching, take-off and delivery of chicks significantly affects the final weight at the point of delivery.

2.25 Hatchery wastes and disposal

With 80 % hatchability on fertile eggs, 20 % of eggs set will either be infertile or contain dead embryo. Egg shells constitute a substantial portion of hatchery wastes. Incorporation of hatchery wastes into by-products meal may increase the risk of the spread of pathogenic organisms. In large concerns, unhatched eggs, pipped eggs, cull chicks are macerated and destroyed using carbon dioxide.[6] Locally, these are sold without separation to catfish farmers to incorporate into feed for their fish stock. These wastes could also be disposed by dumping in a landfill site or processed and spread on farm site as manure.

2.26 Environment and chicken reproduction

Bordas *et al.* (1993) reported that hens kept in cages, from 18 weeks of age, at 31^{0}C, of normal plumage group (na+ na+ genotype) had significantly lower egg production, egg fertility, egg hatchability and mortality than those heterozygous or homozygous for naked neck (Na na+ and Na Na) and lower than those kept at 21^{0}C. Horst (1981) reported differences between locations in poultry performance during production. In a comparison of related genotypes between temperate and tropical environment, environmental depressions of about 20% were observed in growth and egg production. Feed consumption and egg weight at 60 - 64 weeks also experienced depressions of 5 and 9 % respectively. He also reported that genetic improvement results in the tropics

[4] Cob hatchery management guide (1996). The cobb breeding company limited. United kingdom.
[5] Ibid
[6] Cob hatchery management guide (1996). The cobb breeding company limited. United kingdom.

showed an antagonism (negative relationship) between growth and adaptability in highly selected populations. However, Horst and Petersen (1981) reported that hens with smaller body weight compared with heavier groups are superior under heat stress, and so confirmed earlier findings that smaller genotypes react less sharply to stress than larger ones. Jayarajan (1992) also investigated the effect of seasons on egg set, fertile eggs and hatchability of fertile eggs. He reported that hatchability was highest during the monsoon season (September – November; mean temperature, 29.75^{0}C; mean rainfall, 1250 mm[7]) compared to the cold winter season (December – March; mean temperature, 21^{0}C) and summer (March – June; mean temperature range, 35 – 40^{0}C).

2.27 Breeder hen selection and age

Hays (1951) reported that birds in their second or third year of laying were less efficient breeders than the same individuals in their first year as they layed fewer eggs, and had lower fertility and lower hatchability. However, if the desire is to breed for high fecundity, greater progress may be made by using partially-tested yearlings as compared with pullets. Yearling hens produce greater chick size and higher chick viability, while Lerner and Gunns (1952) reported that the reproductive fitness of birds laying eggs of intermediate weight (49.6-56.6 gm) was greater than those laying smaller or larger eggs.

2.28 Hen testing and comparison parameters

These include bodyweight at first-egg, peak production, 4, 16, 20, 45, 60 and 70 weeks; feed consumption at first egg, peak, 4, 16, 20, 45, 60 and 70 weeks; age at first-egg and peak production; Mortality at rearing, production, first egg, peak, 4, 16, 20, 45, 60 and 70 weeks; egg production at peak production, 45, 60 and 70 weeks; Egg weight at first-egg, peak, 21, 45, 60 and 70 weeks; feed conversion at peak, 4, 16, 20, 45, 60 and 70 weeks; total egg laying period; egg fertility at peak, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70 weeks; egg hatchability at peak, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70 weeks and adaptability.

[7] **Redmond, W. A. 2008. Monsoon. Microsoft Encarta 2009 DVD. Microsoft corporation. Retrieved in December 2009.**

2.29 Correlation among morphological traits

Kunev (1987) reported that the duration of the egg laying cycle was significantly correlated with egg production (0.69), egg weight (0.22), body weight (0.50) and age at first-egg (0.69); while Halaj and Konan (1986) reported that egg weight was correlated with egg fertility (-0.66), with hatchability of egg set (-0.92) and with hatchability of fertile eggs (-0.87). However, Tserveni-Gousi (1987) reported significant correlation between egg weight and day-old chicks weight (R^2 = 0.32), between age of dam and chick weight (R^2 = 0.86), and that chick weight was adequately predicted by the use of age as a single independent variable. Mishra *et al.* (1987) reported on age at first-egg in five strains of white leghorn hens. The average was 180.84 ± 0.30 days while the heritability was 0.14 ± 0.03. This heritability was genetically and significantly correlated with egg fertility (0.11 ± 0.09); hatchability of fertile eggs (-0.14 ± 0.09); egg production (-0.94 ± 0.02) and egg weight (0.23 ± 0.10). Also, Lozhkina (1987) reported significant correlation between body weight (20 weeks) and egg mass (to 40 weeks) as 0.19; egg mass (at 40 weeks) and rate of increase in egg weight as 0.18 and between body weight (at 20 weeks) and egg production as 0.11.

2.30 Evaluation of chicken flock

The quality of a flock of pullets at point-of-lay may be measured using:

- body weight
- age
- feed intake capacity
- beak trimming quality
- body weight uniformity
- health status

While in production however, a flock may be evaluated using:

- Peak egg production
- Persistency in lay (HDP and length of time)
- Percent fertility (mean and peak)
- Maximum hatching eggs / HH / week
- Optimum egg weight and shell quality

- Body weight uniformity of flock (>85 %)
- Livability (high!)
- Attainment of target body weight for genotype.

2.31 Genotype sensitivity

Graphically, the slope of the phenotypic values (y) of a genotype, G, against the environmental values of all the genotypes (x) in the environment will give the environmental sensitivity coefficient, b, of the genotype in the environment.

- Sensitivity of G = (b) = $\Delta y / \Delta x$

So, Sensitivity = Phenotypic values of a genotype in an environment / Mean of all Genotypic values in the environment.

But statistically, environmental sensitivity is the regression of a genotype's phenotypic values on the phenotypic mean values of all genotypes in that environment (environmental values) (Falconer and Mackay, 1996). If the environment chosen is different seasons of the year, then, by the simple regression procedure of most softwares,

$$Y = a + \underline{b} X$$

Where Y = genotype's response in season

a = intercept or genotypic constant for the season

b = sensitivity / power / slope / response coefficient

X = Mean value of all genotypes, from all seasons, in the environment.

Thus, the amount of variance due to sensitivity to season is obtainable from the heterogeneity of regression slopes, that is, the slope of the regression line measures the seasonal sensitivity of a genotype. Large differences in sensitivity among genotypes in various environments may lead to a reversal of the order of merit (Falconer and Mackay, 1996) among the genotypes. Part of the genotype – environment interaction variance can be ascribed to differences in sensitivity of different genotypes to different environments (Falconer and Mackay, 1996; Horst, 1981). Khan, *et al.* (2006) showed a classical case of seasonal sensitivity in which they reported that the local chicken strains of Bangladesh recorded highest egg production of 52.78 % in winter, followed by summer, spring and late autumn productions respectively.

Therefore, seasonal sensitivity is a component of the genotype by environment interaction (G-E); and the variance due to sensitivity can be estimated by regression and mathematical procedures. Sensitivity indices help breeders to rank genotypes according to its magnitude, and also to decide which genotype shall be selected. Environmental sensitivity helps to understand responses of genotypes to selection in different environments, since a low genetic correlation means that all genotypes react differently and have regression lines with different slopes, that is, individuals have different environmental sensitivities.

According to Falconer and Mackay (1996), when an environment increases character or trait, it is termed ‘good’ but when it decreases character, it is termed ‘bad’. In this regard, the humid tropical region of South-West Nigeria may be classified as a bad environment because of its endemic nature and its depressive climate. In good environments, high sensitivity brings high performance while in bad environments, low sensitivity brings about high performance. Therefore in this ‘bad’ region, upward selection will be most appropriate rather than downward selection. In selecting upward, individuals with low sensitivity are selected. This type of selection in which selection and the environment act in opposite directions - upward selection in a bad environment is referred to as antagonistic selection as against synergistic selection. Therefore sensitivity is reduced by antagonistic selection and this produces the best overall performance in genotypes.

2.32 Genotype - environment interaction

Genotype – environment interaction (G-E) has been defined as a change in the relative performance of a character of two or more genotypes measured in two or more environments (Bowman, 1974). When a genotype is reared under two specific environments, for example temperate and tropical, its response (body weight) may differ in the two environments. The differences could be due to management, feeding, crowding, weather, equipment, farms, nutrition, season, or geographical locations etc. This means that each environment has a specific effect on members of the same genotype and different genotypes. If the effects on a genotype are the same in several environments, there is no genotype – environment interaction; but if different and large, then genotype – environment interaction may be implicated. The phenotypic value of an individual in the genotype then becomes: $P = G + (E + I_{G.E.})$

Since a single genotype is a genetically uniform group, the variance observed will be due entirely to environmental differences among individuals within the genotype. This means that, the variance depends on the way in which the particular genotype responds to the environmental differences (particular environments). It is usually observed that, one genotype may be more sensitive than the other to environmental differences; that is, a specific difference of environment may have a greater effect on one genotype than the other (Falconer and Mackay, 1996).

Interaction may involve:

- A greater effect of an environment on some genotypes than on others, leading to differences in genotype sensitivity to the environment.
- Changes in Rank order for genotypes between environments. The environments have to differ considerably for rank order changes to be important (significant).
- Changes in absolute and relative magnitude of the genetic, environmental and phenotypic variances between environments, so changing heritability.

The variance due to interaction can be estimated by factorial ANOVA procedure of most statistical softwares. Therefore the existence of G-E interaction is a pointer to the adaptability potential of a new genotype or an exotic strain to the local condition. When there is no interaction, the best genotype in an environment will be the best in all. The presence of much interaction means that particular genotypes must be sought for particular environments (Falconer and Mackay,1996).

Chapter Three

MATERIALS AND METHODS

3.1 Location

The research was conducted at Ajanla Farms, Ibadan; situated in the rain forest zone of Nigeria. It is located on latitude 07^{o} 26’N, longitude 03^{o} 54’E and on an altitude of 227.08 metres above mean sea level (MSL). For experimental purpose, the climate was divided according to natural seasons namely early wet (16th April-July); late wet (August-October); early dry (November-January) and ate dry (February-15th April) respectively.

3.2 Research materials

Bovan Nera (BN) is an autosex hybrid (hybrids in which barring-allele for pigmentation in the plumage has been introduced and so the sexes are easily separated at day-old in the hatchery by utilizing plumage (feather) pattern and or colour. The female chick has a complete dark head. Approximately 30% of the female chicks have reddish colouration around their eyes. Commercial male chicks have a white spot on their heads at day-old. Sexing is achieved by the use of plumage pattern. Bovan hybrids that are not autosex are separated by the use of secondary feathers as the female day-old chicks possessed the fast-feathering gene which could still be identified in the parent-stock chicks a few hours after hatching. As they grow, the female chicks evolve their full plumage which is mottled black and white. The male chicks which are produced from the male line, separated through vent-sexing and brown coloured at day-old, evolve their full reddish-brown plumage as they mature.

ISA Brown parent-stock chick (ISA) is not an autosex hybrid. The day-old chicks are white in plumage while sexing is accomplished by the Japanese vent method. The day-old female commercial chicks are white while the male chicks are reddish-brown in plumage. Both parent -stock hybrids are identified by their respective plumage (colour) and pattern.

3.3 Housing and population

Each hybrid was stocked in an open-sided pen measuring 84 x 12 metres, with gable roof-type opening to the geographic north to allow thorough ventilation. Each hybrid consisted of about 3896 pullets and 600 cockerels at point-of-lay. Batches of each hybrid were reared on all-in, all-out, deep litter system for a minimum life-time of 75 weeks. Stocking density of 5-6 pullets per metre squared were adopted at point of lay.

3.4 Farm bio-security

Biosecurity includes a series of practices observed to prevent pathogens from coming in contact with the resident birds on the farm. To the farmer, it means breaking loose from the chains of possible infection, in order to ensure the security of their livestock and own lives. Programmes put in place included:

1 Adequate cleaning and disinfection programme
2 Complete vaccination programme
3 Effective medication when necessary
4 Quarantine (isolation) programme
5 Adequate personnel hygiene procedures
6 Adequate pest control programme
7 Adequate farm environmental sanitation procedures.
8 Strict traffic control procedures
9 Water quality programme
10 Management discipline

3.5 Management operations

Weighing was conducted weekly, while feeding was ad-libitum during rearing and gap-feeding was employed (40-60 %) during production. Both sexes were reared together. The male to female ratio in the population was reduced to 1:9 at 20 weeks by leaving the best cockerels in the flock and further reduced to 1:10 at 30 weeks to prevent over-riding of the females and consequent mortality. Weak males were removed at this stage for tender loving care and steaming-up in a male reserve pen. When reared separately the males were introduced at 14 weeks latest. Perches were introduced at early life (8 weeks) to allow birds learn to jump and develop their flight instincts and muscles. Lay-nests were introduced at 12 weeks to train birds to use them. Dummy eggs were placed in laynests to attract birds to the lay-nests and to induce them to lay eggs in them. Rodent control programme was put in place. Debeaking was conducted early at 8 -10 days-old. Full vaccination programmes were put in place based on serology analyses. Both genotypes were managed in batches containing an average population of about 4496 per Pen for 75 weeks life-time. Stocking sex ratio was 1 male to 7 females (1:7) but was gradually reduced to I male to 10 females (1:10) at full sexual maturity (30 weeks) period.

The reduction in population ratio to 1:10 was achieved through routine weekly culling during rearing and that done during pre and early production periods (weeks 21-35) to maintain the genetic quality of strains. Males remaining after the population ratio had been achieved were placed in a Reserve-pen for use later (45> weeks) either as replacement stock, or for cock exchange or sold. Batches were stocked and culled for sales at old age (75 weeks >) following the popular ALL-IN, ALL-OUT system of management.

3.6 Seasonal weather conditions of the research field

Table 3.1. Mean seasonal weather parameters of Ibadan, South-West Nigeria from 1999 to 2008

Parameter	Early Wet	Late Wet	Early dry	Late dry	Mean
Months	April – July	August – October	November – January	February – March	All-year
Rainfall (cm)	174.08±11.29^{a}	174.43±16.38^{a}	11.01±3.26^{b}	41.29±8.75^{b}	111.27±8.96
Sunshine (hours)	8.95±1.17^{a}	6.17±1.07^{b}	8.27±1.19^{ab}	10.41±1.69^{a}	8.33±0.63
Wind speed (Km/hr)	2.78±0.20^{b}	2.10±0.20^{c}	2.26±0.21^{bc}	3.57±0.26^{a}	2.61±0.11
Temperature (^{o}C)	26.37±0.21^{c}	25.24±0.14^{d}	26.99±0.14^{b}	28.70±0.16^{a}	26.63±0.14
Relative Humidity (%)	79.53±0.68^{a}	82.00±0.68^{a}	66.37±1.36^{b}	65.45±1.47^{b}	74.51±0.83
Rainy days	12^{b}	14^{a}	1^{d}	4^{c}	31

Means across rows with different superscripts are significantly (P<0.05) different.

Table 3.2. Mean wet and dry season parameters of Ibadan, South-West Nigeria from 1999 to 2008

Parameter	Wet Seasons	Dry Seasons	Mean
Months	April-October	November- March	All-year
Rainfall (cm)	174.25±13.84[a]	23.12±6.01[b]	111.27±8.96
Sunshine (hours)	7.56±1.12	9.13±1.44	8.33±0.63
Wind speed (Km/hrs)	2.44±0.20	2.92±0.24	2.61±0.11
Temperature (^oC)	25.81±0.18[b]	27.67±0.15[a]	26.63±0.14
Relative humidity (%)	80.76±0.68[a]	66.00±1.42[b]	74.51±0.83
Rainy days	26[a]	5[b]	31

Means across rows with different superscripts are significantly ($P<0.05$) different

3.7 Data collection

Data collection commenced at day-old on arrival of each batch of chicks. Data were collected on 24 batches of each genotype covering a period of 10 years (1999 - 2008). Information collected on weekly flock averages from day-old to 75 weeks included: population, live weight (LW; gm), feed intake (FI; gm), mortality (M), cull (C), number of eggs laid (NEL), average egg weight (AEW; gm), number of eggs set (NES), number of fertile eggs (NFE), number of eggs hatched (NEH), number of good chicks (NGC), number of good pullet day-old chicks (NPDOC), number of reject chicks (NRC), number of unhatched eggs (NUE). A total of 25, 536 data set were collected on each hybrid.

3.8 Experimental design

Randomised complete block design in factorial.

3.9 Statistical model

$$Y_{ij\kappa l} = \mu + \alpha_i + \beta_j + C_k + \alpha\beta_{ij} + \alpha C_{ik} + \beta C_{jk} + \alpha\beta C_{ijk} + e_{ij\kappa l}$$

where; i = Hybrid, (1, 2)

and j = Season, (1,…,4)

and k = Batches or replicates (1,…., 24)

$Y_{ij\kappa l}$ = Weekly flock mean taken in ith hybrid, jth season, kth batch and lth measurement.

μ = Overall mean, fixed and unknown.

α_i = Mean effect of ith hybrid, where a = (1, 2) .

β_j = Mean effect of jth season, where b = (1,…., 4).

C_k = Mean effect of Kth batch, where c = (1,.....,24)

$\alpha\beta_{ij}$ = Interaction effect between hybrid and season

αC_{ik} = Interaction effect between hybrid and batch

βC_{jk} = Interaction effect between season and batch

$\alpha\beta C_{ijk}$ = Interaction effect between hybrid, season and batch

$e_{ij\kappa l}$ = Random error ~ NID (0, $\sigma^2 e$) in the ith hybrid, jth season, kth batch and lth measurement.

3.10 Regression models for growth and egg weight

$Y_{ijk} = a X^{b} + e_{ijk}$

Where,

Y_{ijk} = body weight and egg weight (gm)

a = intercept or constant

b = regression coefficient or allometric growth ratio

X= age of birds or age-in-production from first-egg (weeks)

e_{ijk}= random error term

$Y_{ijk} = a + bX + e_{ijk}$

Where,

Y_{ijk} = weekly growth rate (gm/day)

a = intercept or constant

b = regression coefficient

X = weekly weight gain (gm/week)

e_{ijk}= random error term

3.11 Seasonal response model

$Y = a + \underline{b}X$

where Y = genotypes's response in season

a = constant for genotype

$\underline{b}$ = sensitivity of genotype to season

X = Mean of all genotypes, from all seasons, in the environment.

3.12 Estimation of parameters

Body weight was determined once a week on the due day by weighing with a metric hanging scale.

Growth rate was determined using the relation:

Growth rate (gm/day) = (body weight (week 2 – week 1) / 7)

Egg weight was determined by weighing 5% of every collection on the 3rd and the last day of the week. The weights were then pooled together to obtain the mean value.

Day-old body weight (gm) of chicks was determined by weighing 5% of chicks received in suitable media and calculating the mean.

Age at first-egg (weeks or days) is the age of the flock from hatch to the time when the first egg was dropped, provided the next egg was laid within the next 10 days (Haque and Ukil, 1994).

Body weight at first-egg (gm) was taken as the mean weight of pullets in each batch when the first egg was dropped.

Flock production performance was measured according to the method of Rendel and Marple (1986) by using the relationship: egg mass at full maturity divided by the mean body weight, that is :

Flock production performance = Egg mass / Mean body weight at full maturity x 100

= (HDP % x Egg weight) / Mean body weight at full maturity x 100.

Body weight gain at first egg was calculated according to the method of Rendel and Marple (1986) as: body weight at first egg minus bodyweight at 10 weeks, all divided by body weight at early maturity.

Early maturity age (age at first-egg) was attained and measured at the age (weeks or days) at which the first egg was dropped;

Full maturity age (weeks or days) was measured at the peak HDP of the flock.

Hen-day production was calculated as number of eggs layed by a flock divided by the number of birds in the flock divided again by the number of days in lay multiplied by 100. That is:

Mean hen-day production (%)

= (number of eggs layed / (number of birds in flock x number of days in lay)) x 100.

Hen-day production is also referred to as laying intensity and production intensity.

Persistency of egg production (weeks) was expressed in terms of number of weeks in which the egg production was stable within a 5 % fluctuation range and at 70 % HDP and above.

Percentage of Eggs set was taken as total egg set divided by the total number of hatchable eggs sorted, all multiplied by 100.

Eggs set (%) = (Total egg set / total number of hatchable eggs sorted) x 100.

Fertility of eggs set (Percentage of egg fertility) was taken as total number of fertile eggs on candling divided by the number of eggs set into the incubator, all multiplied by 100.

Fertility of egg set (%) =

(Total number of fertile eggs on candling / total number of eggs set in the incubator) x 100.

Hatchability of eggs set was calculated as total number of good quality chicks divided by the number of eggs set, multiplied by 100.

Hatchability of egg set (%) =

(Total number of good quality chicks / total number of eggs set) x 100.

Total rejects was taken as the totality of all wastes from egg setting to hatching and unsold chicks destroyed.

3.13 Derived functions

Genotype-season interaction was examined using the factorial ANOVA procedures of SAS/STAT (1999).

Environmental performance value was taken as the response of a parameter in the temperate minus response in the tropics, divided by the response in the temperate, all multiplied by 100.

Environmental performance value (%) =

((temperate response – tropical response) / temperate response) x 100.

Seasonal sensitivity was according to the method of Falconer and Mackay (1996) as the regression of phenotypic values on the phenotypic mean values of all genotypes, from all seasons, in the environment. Thus in a simple regression $Y = a + b X$,

$b = \Delta Y/\Delta X$ = genotype's sensitivity to the season.

Y = Observed seasonal response

X = Mean of all genotypes, from all seasons, in the environment.

The separation of rejects from eggs layed was as in table 3.3:

Table 3.3. Reject details from the farm to end of hatching operation as separated from eggs layed by hens

Stage	Reject details
Eggs received from the farm	cracks, broken, dirty, mis-shaped, thin shell, chalky shell, discoloured shell, rough shell, small egg, double-yolked egg
Egg setting	broken, cracks.
Candling	dead-in-shell (bangers), infertile eggs, cracks, broken.
Hatching	unhatched eggs, dead chicks, weak chicks, deformed chicks.
Hatching rejects	all rejects from setting to hatching
Total rejects	totality of all rejects from the pen to hatching plus unsold chicks destroyed

3.14 Statistical analysis

The means, analyses of variance (ANOVA, $p < 0.05$), t- test, Duncan multiple range test (DMRT), Pearson's correlations and regression analyses were all based on the procedures of statistical analytical systems, version 8, SAS/STAT (1999) and statistical package for social sciences, version 10.0, (SPSS, 2001). Curves and charts were based on the procedures of Excel (2007) while sensitivity analyses and predictive equations were based on regression procedures.

3.15 Hypotheses

$H_o : \sum \alpha_i = 0$ for $i = 1, 2$

- There are no significant differences between genotypes within season in growth, production, reproduction and sensitivity.

$H_o : \sum \beta_j = 0$ for $j = 1, \ldots, 4$

- There are no significant differences between seasons within genotype.

$H_o : \sum \alpha\beta_{ij} = 0$ for $i = 1, 2; j = 1, \ldots, 4$

- There is no significant interaction between seasons and genotypes.

3.16 Test of Hypotheses

Tests were conducted to differentiate between the two genotypes using the student t-test procedures, the seasons were differentiated using Duncan multiple range test while interaction was examined using the analysis of variance procedures.

Chapter Four

RESULTS

4.1.0 Growth performance

4.1.1 Body weight of breeder cocks

Table 4.1 shows the mean and seasonal growth performance of breeder cocks by genotypes. Analysis of variance showed significant difference ($P < 0.05$) between Bovan Nera and ISA Brown in body weight during early: 2115.09 vs 2543.66 gm/bird, and late: 2451.72 vs 2098.98 gm/bird, dry seasons. Within the wet seasons, there was no significant ($P > 0.05$) difference between the body weight of both strains. Within genotypes, BN showed a significant ($P < 0.05$) difference between late dry season body weight: 2451.72 gm/bird and the other seasons; while IB had significant difference between early dry: 2543.66 gm/bird and other seasons. The mean body weight between genotypes was slightly higher but not significantly ($P > 0.05$) different : 2226.63 vs 2214.14 gm/bird between IB and BN cocks respectively.

4.1.2 Growth pattern of breeder cocks

Table 4.1 further indicates no significant ($P > 0.05$) difference in mean growth: 5.51 vs 5.68 gm/day, growth in rearing stage: 13.76 vs 14.97 gm/day and growth in production stage: 2.46 vs 2.14 gm/day, between BN and ISA cocks respectively. Late wet season produced the best early-growth (4.19 gm/day during Rearing) in BN cocks but early dry season gave the best early-growth (16.12 gm/day) in IB cocks. Table 4.2 gives the trend of growth in both strains on 4-weekly period. This indicates that the greatest growth in cocks occurred during rearing between weeks 9 and 12: 28.28 vs 30.07 gm/week and during production period between 21 and 24 weeks: 13.86 vs 11.45 gm/week. The least growth occurred between 65 and 68 weeks in Nera: 1.40 gm/week and between 73 and 75 weeks: 1.22 gm/week in ISA cocks. There were no significant ($P > 0.05$) differences in these growth rates between the two genotypes.

Table 4.1. Influence of season on 75-week growth performance in Bovan Nera and ISA Brown breeder cocks

	Genotype	Body weight (gm/bird)	Mean growth (gm/day)	Rearing (gm/day)	Production (gm/day)
Early wet	Nera	2176.83 ± 854.90^{j}	5.50±6.37	14.16±4.70	2.29±3.04
	ISA	2221.87 ± 852.09^{y}	5.69±8.23	15.92±9.42	1.67±1.70
Late Wet	Nera	2162.93 ± 859.02^{j}	5.47±6.70	14.19±6.03	2.30±3.22
	ISA	2112.91 ± 830.27^{y}	5.37±6.57	14.13±6.16	2.19±2.65
Early Dry	Nera	2115.09 ± 854.24^{bj}	5.62±6.76	13.63±6.74	2.71±3.78
	ISA	2543.66 ± 391.82^{ax}	5.69±6.87	16.12±3.61	1.90±2.26
Late Dry	Nera	2451.72 ± 439.73^{ai}	5.46±5.89	13.06±2.81	2.54±3.75
	ISA	2098.98 ± 886.74^{by}	6. 01±7.25	13.73±8.66	2.86±3.13
Genotypic	**Nera**	**2214.14±793.56**	**5.51±6.41**	**13.76±5.20**	**2.46±3.44**
Mean	**ISA**	**2226.63±798.13**	**5.68±7.21**	**14.97±7.26**	**2.14±2.50**

Means with different superscripts (ab, ij, xy) along the same column, within season are significantly ($P<0.05$) different.
± means Standard deviation

Table 4.2. Mean growth (gm/week) of breeder cocks classified by 4-weekly period

Age	Body weight gain (gm)		Growth rate (gm/week)	
(weeks)	Bovan Nera	ISA Brown	Bovan Nera	ISA Brown
1 – 4	54.12	49.68	13.53	12.42
5 – 8	95.40	98.21	23.85	24.55
9 -12	120.26	113.13	30.07	28.28
13 – 16	117.92	111.71	29.48	27.93
17 – 20	93.57	96.33	23.39	24.08
21 – 24	55.45	45.80	13.86	11.45
25 – 28	38.43	27.48	9.61	6.87
29 – 32	29.92	23.00	7.48	5.75
33 – 36	16.99	18.54	4.25	4.64
37 – 40	12.16	14.44	3.04	3.61
41 – 44	11.25	11.88	2.81	2.97
45 – 48	9.05	8.28	2.26	2.07
49 – 52	8.40	7.93	2.10	1.98
53 – 56	9.48	6.89	2.37	1.72
57 – 60	7.84	6.27	1.96	1.57
61 – 64	6.59	6.38	1.65	1.59
65 – 68	5.59	5.40	1.40	1.35
69 – 72	6.51	5.99	1.63	1.50
73 – 75	4.77	3.66	1.59	1.22

4.1.3 Body weight of breeder hens

Table 4.3 shows the growth performance in BN and ISA breeder hens. Test of difference between two means showed significant ($P < 0.05$) difference in body weight: 1923.11 vs 1514.67 gm/bird, between BN and ISA hens in late dry season. Within seasons Nera had higher but not significant body weight. Within genotype, BN had significantly ($P < 0.05$) higher body weight in late dry season: 1923.11 gm/bird, than other seasons: ≤1677.74 gm/bird. The mean live weight showed no significant difference between the two genotypes but was superior in Nera than ISA: 1724.81 and 1549.83 gm/bird respectively.

4.1.4 Growth pattern of breeder hens

Table 4.3 shows that the growth rate of BN hen was not significantly ($P > 0.05$) higher than that of ISA: 4.12 vs 3.80 gm/day. There was no significant ($P > 0.05$) difference in growth during rearing: 11.35 vs 11.08 gm/day and production: 1.40 vs 1.12 gm/day, periods between genotypes, and also within seasons; although BN hens exhibited slightly higher rate for growth. Therefore between and within genotypes, between and within seasons, growth rate was similar. Table 4.4 shows the mean growth of breeder hens classified by a 4-weekly interval. This reveals the trend of growth in both genotypes. The mean weight gain observed in pullet growers was 85.26 and 89.30 gm respectively between 5 and 20 weeks. Highest rate of growth was attained between 9 and 12 weeks: 24.43 vs 22.67 gm/week, of age within genotypes and this declined till 75 weeks, but Bovan hens still maintained a slightly higher growth rate than ISA hen.

4.2 Influence of genotype on growth performance

Table 4.5 shows growth classified by genotype and sex. This table showed that ISA cock exhibited higher growth rate: 5.68 gm/day, than BN cock: 5.51 gm/day while BN hen had higher growth rate: 4.12 gm/day, than IB hen: 3.80 gm/day. These results indicate that in body weight, ISA Brown cock was superior while Bovan Nera hen had higher mean weight in life-time. These body weight differences were not significantly ($P > 0.05$) different between breeds but it dictated the trend of mean growth, both in rearing and in reproduction within both genotypes. Growth was more pronounced during rearing than production.

Table 4.3. Influence of season on 75-week growth performance in Bovan Nera and ISA Brown breeder hens

Season	Genotype	Body weight (gm)	Mean growth (gm/day)	Rearing (gm/day)	Production (gm/day)
Early wet	Nera	1671.02±601.76^{y}	4.18±6.48	11.37±7.92	1.36±2.49
	ISA	1590.67±519.27	3.74±5.56	12.15±4.01	0.62±0.57
Late Wet	Nera	1677.74±608.74^{y}	4.10±5.47	11.38±4.15	1.40±2.75
	ISA	1596.93±569.90	3.99±5.12	11.31±3.41	1.24±1.93
Early Dry	Nera	1669.11±609.71^{y}	4.22±5.46	11.29±5.46	1.55±1.97
	ISA	1497.56±543.67	3.75±4.57	10.41±2.91	1.32±1.79
Late Dry	Nera	1923.11±293.75^{ax}	3.9±84.86	11.37±1.52	1.29±1.99
	ISA	1514.67±542.40^{b}	3.72±5.04	10.47±4.99	1.27±1.73
Genotypic Mean	**Nera**	**1724.81±562.80**	**4.12±5.56**	**11.35±5.19**	**1.40±2.31**
	ISA	**1549.83±543.29**	**3.80±5.06**	**11.08±3.89**	**1.12±1.62**

Means with different superscripts (ab, xy) within column, within season differ (P<0.05) significantly.

± means Standard deviation

Table 4.4. Mean growth (gm/day) of breeder hens classified by 4 - weekly period

Age	Body weight gain (gm)		Growth rate (gm/week)	
(weeks)	Bovan Nera	ISA Brown	Bovan Nera	ISA Brown
1 – 4	56.35	52.02	14.09	13.00
5 – 8	87.28	89.28	21.82	22.32
9 -12	97.70	90.68	24.43	22.67
13 – 16	89.55	78.89	22.39	19.72
17 – 20	66.51	73.74	16.63	18.45
21 – 24	49.80	31.06	12.45	7.77
25 – 28	21.91	8.95	5.48	2.24
29 – 32	11.95	7.36	2.99	1.84
33 – 36	7.10	7.44	1.78	1.86
37 – 40	7.12	6.79	1.78	1.70
41 – 44	6.67	6.46	1.67	1.62
45 – 48	5.61	6.51	1.40	1.63
49 – 52	4.96	6.04	1.24	1.51
53 – 56	4.17	5.01	1.04	1.25
57 – 60	3.92	4.28	0.98	1.07
61 – 64	1.72	3.87	0.43	0.97
65 – 68	5.35	3.59	1.34	0.90
69 – 72	6.81	3.26	1.70	0.82
73 – 75	5.9	2.92	2.22	0.74

Table 4.5. Influence of genotype on 75-week growth performance in Bovan Nera and ISA Brown

Traits	Type	Bovan Nera	ISA Brown
Body weight (gm)	Cocks	2214.14 ± 793.15	2226.63 ± 798.13
	Hens	1724.81 ± 562.80	1549.83 ± 543.29
Mean growth (gm/day)	Cocks	5.51 ± 6.41	5.68 ± 7.21
	Hens	4.12 ± 5.56	3.80 ± 5.06
Growth during Rearing (gm/day)	Cocks	13.76 ± 5.20	14.97± 7.26
	Hens	11.35 ± 5.19	11.08 ± 3.89
Growth during Production (gm/day)	Cocks	2.46 ± 3.44	2.14 ± 2.5
	Hens	1.40 ± 2.31	1.12 ± 1.62

NOTE: There are no significant differences (P > 0.05) between values within rows.

4.3 Sexual dimorphism in body weight

Figure 4.1 shows the trend of growth in both strains as influenced by genotypes. Sexual dimorphism in body weight in both Bovan Nera and ISA Brown genotypes was observed. This is a phenomenon in which the males separate themselves from the females in body weight as they express their higher genetic potential for growth over the females. The phenomenon began within genotypes and between sexes about the 10th week of life in growers. This period was about 1/3 of the mean full maturity age: 29 weeks, in both genotypes.

4.4.0 Phenotypic correlation among growth parameters

4.4.1 Relationship among the growth parameters for cocks

Table 4.6 shows the correlation matrix obtained on breeder cocks. Results indicated highly significant ($P < 0.01$) correlation between the pairs of weight gain and growth rate: r =1.00 and; between Age and cock weight: r = 0.832 and 0.823, for BN and ISA cocks respectively. Other paired parameters namely age and weight gain; age and growth rate, cock weight and weight gain, and cock weight and growth rate were low and negative.

4.4.2 Relationship among the growth parameters for hens

Table 4.7 shows the negative correlation matrix among breeder hen parameters. It indicates significant ($P < 0.05$) and strong correlation between the pairs of weight gain and growth rate: r = 1.00, and Age and hen weight: r = 0.781 and 0.770, for Nera and ISA breeder hens respectively. The correlations between age and weight gain, age and growth rate, hen weight and weight gain, and hen weight and growth rate, were all low.

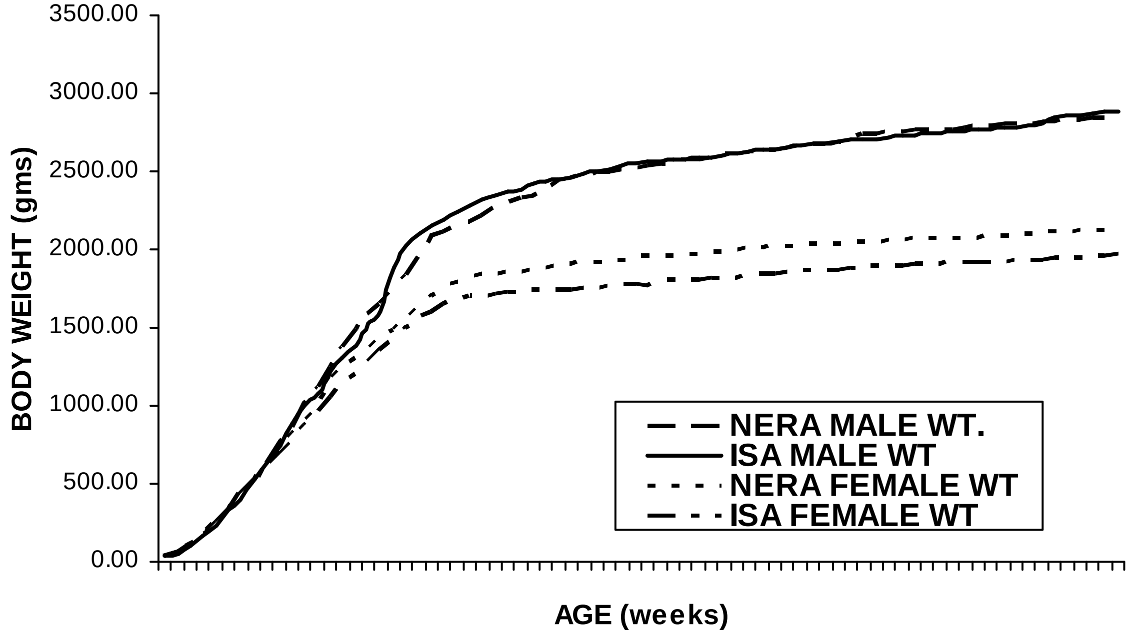


Figure 4.1. Influence of genotype on 75-week body weight curves of Bovan Nera and ISA Brown

Table 4.6. Correlation matrix for growth parameters of Bovan Nera and ISA Brown cocks

		BOVAN NERA			
	TRAITS	Age	Cock weight	Weight gain	Growth rate
ISA BROWN	Age		0.832**	0.143**	- 0.143**
	Cock weight	0.823**		- 0.102*	- 0.102*
	Weight gain	- 0.307**	- 0.274**		1.000**
	Growth rate	- 0.307**	- 0.274**	1.000**	

Note: * = p<0.05; ** = p<0.01

Table 4.7. Correlation matrix for growth parameters of Bovan Nera and ISA Brown hens.

		BOVAN NERA			
	TRAITS	Age	Hen weight	Weight gain	Growth rate
	Age		0.781*	- 0.148*	- 0.148*
ISA	Hen weight	0.77*		0.133*	- 0.133*
BROWN	Weight gain	- 0.391*	0.336*		1.000*
	Growth rate	- 0.391*	- 0.336*	1.000*	

Note: * = P< 0.05

4.5 Growth models

Table 4.8 shows the regression models for body weight in both breeder cocks and hens. By linear transformation of the power model to rectify and linearise it to its log form: log Y = log a + b log X; the equations were obtained. Equations obtained for cock weight in both genotypes could be differentiated by the diferrence in the values of their intercepts which differ by 10. The values of b, standard error, SE; and R^2 of respective equations were very close. In the hen, there were differences in the values of the intercept, a and the power, b; while the SE and R^2 were very close. The growth rate in both genotypes was predicted with the simple linear model. The predictive linear equations in table 4.9 were obtained. This shows that equations for growth rate in cocks of both hybrids were only differentiated by their intercepts, while their slopes, b; R^2 and P–values were the same. The same trend was obtained in equations for growth rate in the hens of both genotypes.

4.6.0 Influence of season on early sexual maturity characteristics

Table 4.10 shows the early maturity characteristics of both strains as influenced by seasons and genotype. Parameters studied include age at fist egg and body weight at first-egg, both in pullets and cockerels. These trends are presented on figures 4.2 – 4.4.

4.6.1 Age at first-egg

Figure 4.2 shows multiple bar charts and the trend of the influence of season on age at early maturity in hens of both strains. Effect of season on this parameter in BN was a polynomial, producing higher ages of 124 days in the late wet and early dry seasons than in early wet and late dry seasons: 120 days. In the IB however seasonal effect increased age at first-egg from 118 days in early wet to 125 days in late dry season, producing a linear trend. Analysis of variance showed that there was no significant ($P > 0.05$) difference between genotypes, and between seasons. The influence of these seasons on early sexual maturity of pullets within genotypes is depicted by the curves for the genotypes in figure 4.2.

Table 4.8: Predictive models for body weight in Bovan Nera and ISA Brown breeder cocks and hens

Model		Log Y = log a + b log X		
Sex	Genotype	Body weight equations	SE	Model R^2
Cocks	Bovan Nera	Y = -173.65+703.57 In X	± 326.59	0.852
	ISA Brown	Y = -163.40+703.07 In X	± 338.72	0.843
Hens	Bovan Nera	Y = -17.92+503.17 In X	± 227.15	0.859
	ISA Brown	Y = -43.93+457.11 In X	± 204.29	0.862

Key: Y = Body weight (gm); X = age (weeks), SE = Standard Error
R^2 = Coefficient of multiple determination

Table 4.9: Predictive models for growth rate in Bovan Nera and ISA Brown breeder cocks and hens

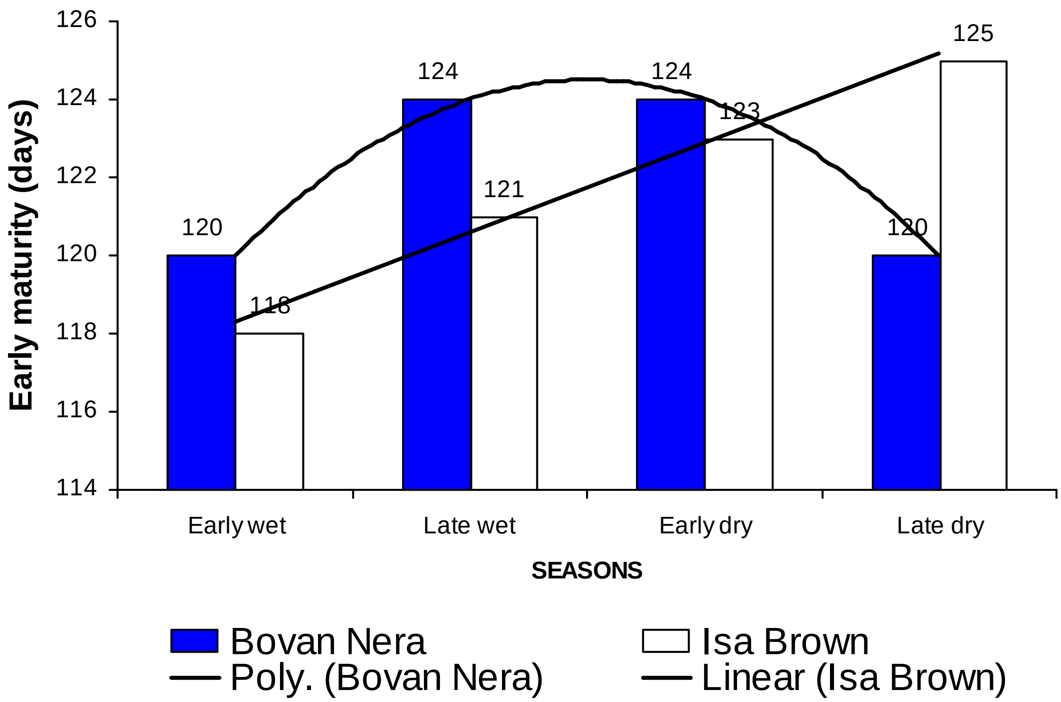
Model		$Y = a + bX$	
Sex	Genotype	Growth rate equations	Model R^2
Cocks	Bovan Nera	$Y = 0.00002 + 0.143 X$	1.00
	ISA Brown	$Y = 0.0004 + 0.143 X$	1.00
Hens	Bovan Nera	$Y = 0.00003 + 0.143 X$	1.00
	ISA Brown	$Y = 0.0004 + 0.143 X$	1.00

Key: Y = weekly growth rate (gm/day); X = weekly weight gain (gm/weeks). Model Significant for all equations (P-value) = < 0.01

Table 4.10. Influence of season on early maturity characteristics of bovan Nera and Isa Brown hybrids

Parameter	Type	Genotype	Eearly wet	Late wet	Early dry	Late dry
Age at first -egg (days)	Pullets	Nera	120 ± 8	124 ± 8	124 ± 8	120 ± 10
		ISA	118 ± 4	121 ± 8	123 ± 5	125 ± 2
Body weight at first-egg (gm ± SE)	Pullets	Nera	1527.71 ± 59.60	1494.06 ± 27.4^{i}	1456.02 ± 20.25^{i}	1436.00 ± 30.75
		ISA	1489.02 ± 20.15^{a}	1374.8 ± 23.5^{bj}	1339.00 ± 7.00^{bj}	1389.00 ± 42.3^{ab}
Body weight at first-egg (gm ± SE)	Cockerels	Nera	1720.60 ± 96.20^{a}	1757.10 ± 24.3^{a}	1695.60 ± 32.20^{abj}	1566.60 ± 60.55^{b}
		ISA	1937.50 ± 50.66^{a}	1670.16 ± 49.40^{b}	2008.00 ± 7.00^{ai}	1662.00 ± 85.10^{b}

Means in the same rows with different superscripts are significantly ($P < 0.05$) different.
ij superscripts compare hybrids within season season while ab superscripts compare hybrids between seasons



NOTE: Poly. means Polynomial

Figure 4.2. Influence of season on age at first-egg in Bovan Nera and ISA Brown pullets.

4.6.2 Body weight of breeder pullets at first-egg

On Table 4.10, the influence of season on early maturity characteristics in Bovan Nera and ISA Brown genotypes are observed. ANOVA showed that no significant ($P > 0.05$) difference was obtained between seasons within BN although birds in early wet season gave the highest body weight: 1527.7 gm/bird, at sexual maturity; but significant differences ($P < 0.05$) were observed between seasons within ISA Brown pullets. The body weight of ISA pullets in early wet season: 1489.0 gm/bird, was significantly higher than in late dry season: 1389.0 gm/bird, which was next in rank. Body weight in late wet: 1374.8 gm/bird, and early dry: 1339.0 gm/bird, seasons were lower respectively. Figure 4.3 is the bar-chart showing the influence of season on body weight of breeder pullets at early sexual maturity. This indicates that the highest body weight in pullets was obtained in early wet season: 1527.70 and 1489.0 gm/bird, within both genotypes. Comparison between genotypes revealed that BN hens exhibited significantly ($P < 0.05$) higher body weight than ISA hens in late wet: 1494.1 vs 1374.8 gm/bird, and early dry: 1456.0 vs 1339.0 gm/bird, seasons respectively. These two periods fall within the middle of the year in the South-West. The curve describing the influence of season on BN is exponential while it is linear in IB, both decreasing in magnitude from early wet to late dry season (Figure 4.3).

4.6.3 Body weight of breeder cockerels at first-egg

Table 4.10 shows there was significant ($P < 0.05$) difference in the body weight of young breeder cocks within genotypes between seasons. In BN, the body weight in early and late wet seasons: 1720.56 and 1757.11 gm/bird, were higher than that in early and late dry seasons: 1695.56 and 1566.60 gm/bird. In IB however, body weight in early wet and early dry seasons: 1937.50 and 2008.00 gm/bird, were higher than in the late wet and late dry seasons: 1670.16 and 1662.00 gm/bird, respectively. Results also reveal that within season between hybrids, IB cocks had slightly higher body weight than BN cocks at first-egg except in late wet season. Further analysis showed that ISA cocks were slightly heavier in the dry season: 1835.00 gm/bird, than in the wet season: 1803.83 gm/bird. Figure 4.4 shows the influence of seasons on body weight of cockerels at early maturity in genotypes. This is linear in BN and polynomial in IB.

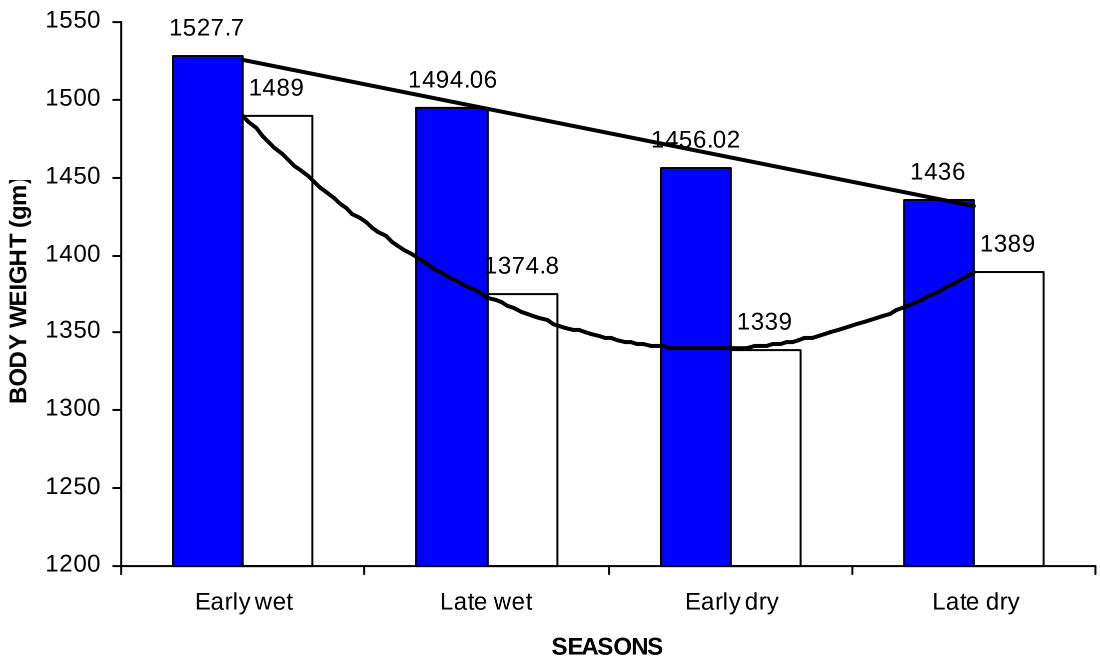
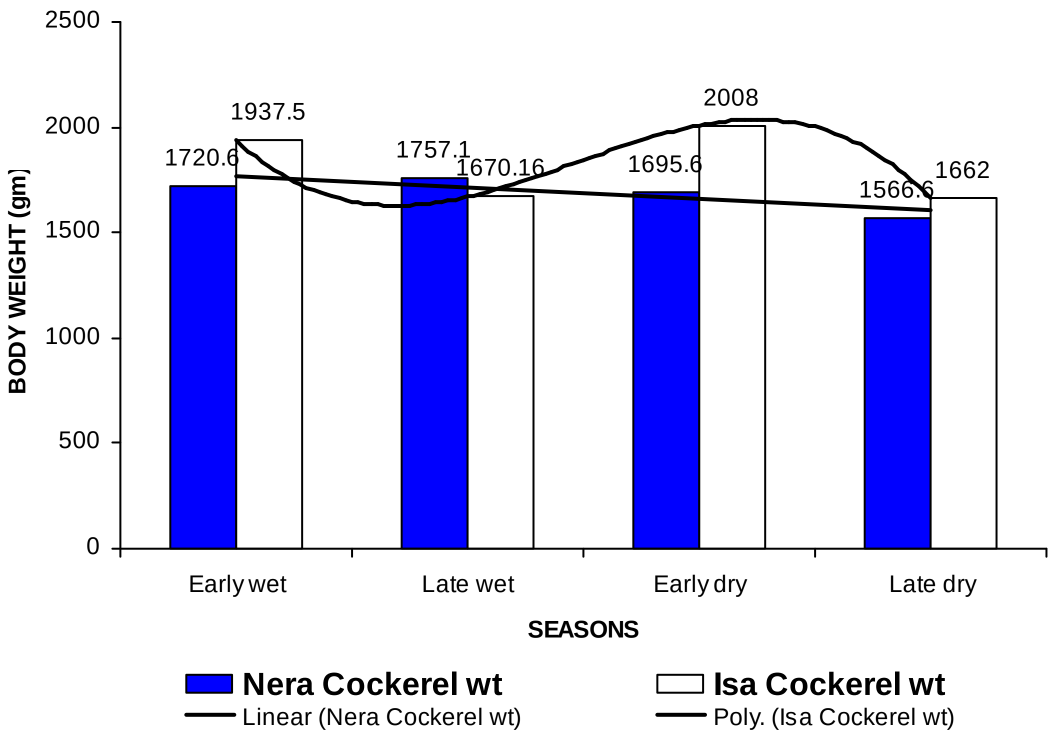


Figure 4.3. Influence of season on body weight at first-egg in Bovan Nera and ISA Brown pullet breeders



NOTE: Poly. means Polynomial

Figure 4.4. Influence of season on body weight of young breeder cocks at first -egg in Bovan Nera and ISA Brown

4.7 Influence of genotype on early sexual maturity characteristics

Table 4.11 shows the influence of genotype on early maturity characteristics within both strains. Sexual maturity occurred late by 2 days: 123 days, in BN hen while maturity occurred early: 121 days, in ISA pullets. It also showed that Bovan Nera had significantly ($P < 0.05$) higher hen weight than ISA: 1485.4 vs 1377.7 gm/bird, and a slightly higher cock weight: 1765.4 vs 1744.06 gm/bird, at sexual maturity.

Table 4.11. Influence of genotype on early maturity characteristics in Bovan Nera and ISA Brown pullets

Parameter	Bovan Nera (mean + s.e.)	ISA brown (mean + s.e.)
Age at first-egg (days)	123 ± 8	121 ± 7
Cock weight (gm)	1765.35 ± 23.2	1744.06 ± 46.4
Hen weight (gm)	1485.38 ± 28.2[a]	1377.70 ± 17.0[b]

Means in the same row with different superscripts differ significantly ($P < 0.05$)

4.8.0 Influence of season on full sexual maturity characteristics

Table 4.12 shows the influence of seasons at the peak of production (full sexual maturity) on selected characteristics of both genotypes.

4.8.1 Age at full sexual maturity

Table 4.12 indicates that at full sexual maturity, there were no significant (P > 0.05) differences in age at full sexual maturity, (the age at which a poultry flock attains the peak hen day production, HDP), between seasons within genotypes. Also there was no significant (P > 0.05) difference between genotypes within season. Figure 4.5 showed that age at full sexual maturity in Bovan Nera was highest in early wet season: 226 days, but decreased to 200 days in early dry season and rises to 217 days in late dry season depicting a quadratic curve. In ISA Brown, age at full sexual maturity was highest in early wet season at 224 days and decreased to 196 days in late dry season, giving a linear curve for the hybrid.

4.8.2 Cock body weight at full sexual maturity

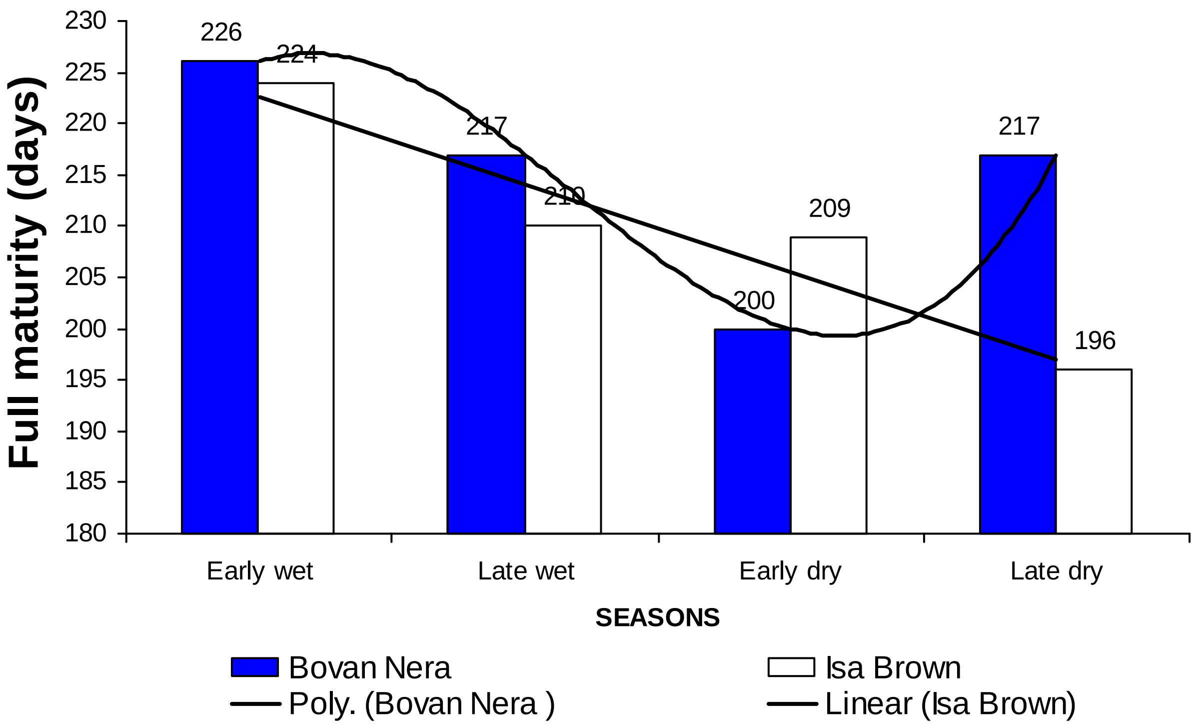
Table 4.12 showed no significant (P > 0.05) differences in the body weight of mature breeder cocks at full maturity between seasons between hybrids. Also there was no significant (P > 0.05) difference between hybrids within seasons. Both BN and IB cocks recorded highest body weights: 2460.17 gm/bird and 2472.00 gm/bird, respectively in early wet season. Body weight in BN was lowest in the early dry season: 2299.93 gm/bird, while that of IB was lowest in late dry season: 2390.07 gm/bird. While body weight was higher in both genotypes in early wet season than other seasons, IB cocks were also heavier than BN cocks within seasons at full maturity. Results showed that between hybrids the curve of body weight in IB was higher than that of BN (Figure 4.6).

Table 4.12. Influence of season on full sexual maturity characteristics in Bovan Nera and ISA Brown genotypes

Parameter	Genotype	Early wet	Late wet	Early dry	Late dry
		(mean + s.e.)	(mean + s.e.)	(mean + s.e.)	(mean + s.e.)
Age (days)	Nera	226±29	217±35	200±33	217±36
	ISA	224±23	210±32	209±23	196±10
Cock weight (gm)	Nera	2460.17±77.26	2396.76±53.73	2299.93±56.01	2387.00±60.58
	ISA	2472.00±70.12	2399.40±37.40	2393.83±34.98	2390.07±99.95
Hen weight (gm)	Nera	1992.38±32.55	1922.81±28.16	1864.42±45.83^{i}	1876.00±38.42
	ISA	1915.00±35.21^{a}	1863.47±21.50^{ab}	1679.92±43.05^{jc}	1713.43±55.79^{bc}
HDP (%)	Nera	83.40±1.10	85.55±1.20^{j}	84.19±1.74	82.97±1.35
	ISA	88.13±2.50	92.02±0.92^{i}	90.26±2.31	87.92±2.63
Egg weight (gm)	Nera	57.40±1.90	55.98±1.20	53.50±1.45	56.0±1.62
	ISA	62.40±2.06^{a}	56.99±0.62^{ab}	56.82±5.51^{ab}	54.01±0.92^{b}
Egg set (%)	Nera	99.68±0.04	99.30±0.20	93.37±6.32	99.62±1.50
	ISA	99.48±3.46	99.95±3.25	93.13±3.99	93.55±3.59
Egg fertility (%)	Nera	83.18±5.40	89.48±2.04	77.99±2.27	91.18±5.31
	ISA	93.19±3.67	91.12±1.08	79.80±5.77	86.82±2.65
Egg hatch. (%)	Nera	78.89±5.67	77.36±3.69	61.64±3.52^{j}	81.15±5.22
	ISA	85.03±3.16^{a}	79.63±1.35^{ab}	72.99±1.2^{ibc}	71.30±3.63^{c}
Pullet DOC (%)	Nera	35.54±2.70	36.94±1.71	29.00±1.76^{j}	38.80±2.46
	ISA	41.89±1.55^{a}	39.11±0.63^{ab}	35.99±0.70^{ibc}	34.15±1.25^{c}
Hatching rejects (%)	Nera	9.19±0.96^{b}	13.19±1.89^{ab}	17.07±2.16^{a}	10.87±2.35^{ab}
	ISA	8.37±1.65^{b}	12.07±1.29^{ab}	15.08±1.6^{ab}	17.02±1.83^{a}

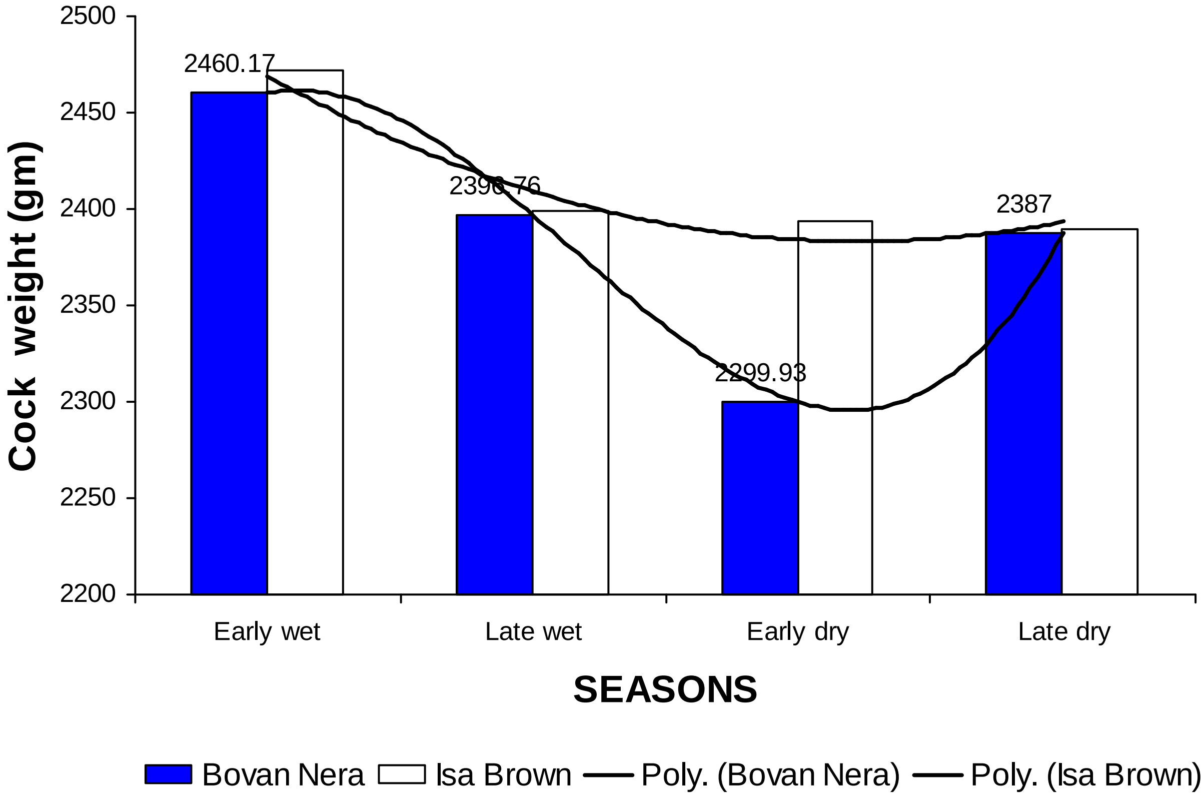
Means with ij superscripts within seasons differ significantly ($P<0.05$)

Means with abc superscripts along the same rows differ significantly ($P<0.05$)



NOTE: Poly. means Polynomial

Figure 4.5: Influence of season on age at full sexual maturity in Bovan Nera and ISA Brown hens



NOTE: Poly. means Polynomial

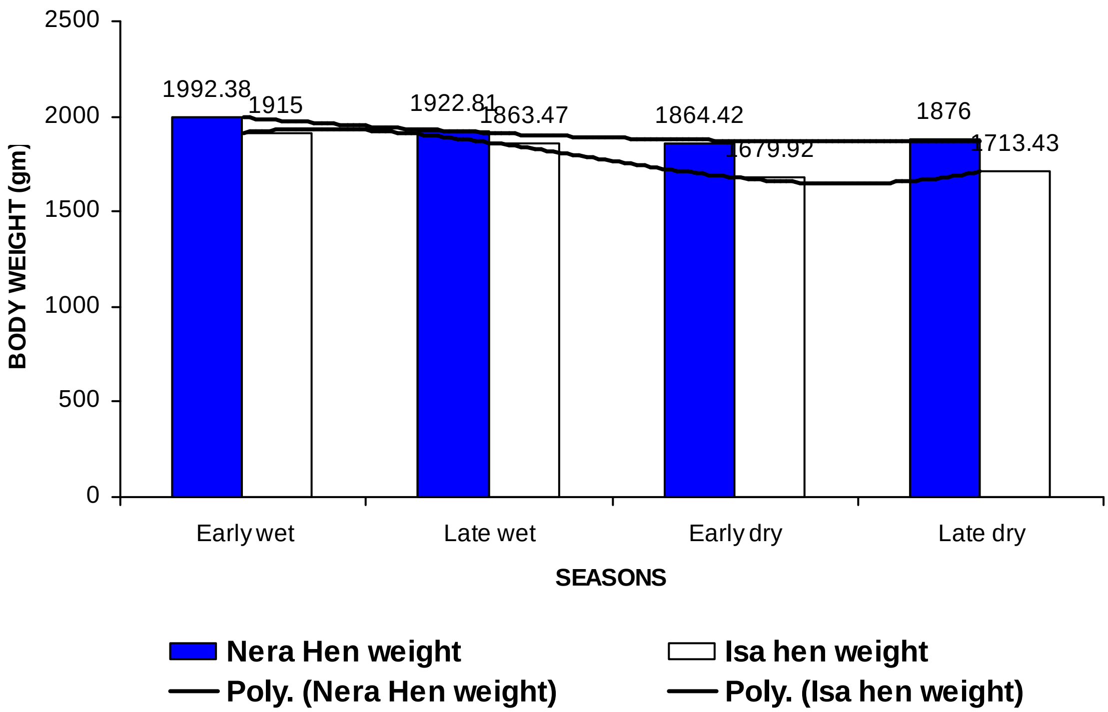
Figure 4.6. Influence of season on cock weight at full sexual maturity in Bovan Nera and ISA Brown

4.8.3 Pullet body weight at full sexual maturity

In Nera, no significant (P > 0.05) difference was observed between seasons in pullet body weight at full maturity. In ISA body weight, significant (P < 0.05) differences were observed between seasons at full maturity. Results showed that early wet season produced highest body weights: 1992.38 vs 1915.00 gm/bird; this was closely followed by late wet: 1922.81 vs 1863.47 gm/bird, early dry: 1864.42 vs 1679.92 gm/bird, and late dry: 1876.0 vs 1713.43 gm/bird, seasons in Nera and ISA respectively. Within early wet, late wet and late dry seasons, there were no significant (P > 0.05) differences between strains, however there was a significant (P < 0.05) difference between strains: 1864.42 vs 1679.92 gm/bird, in early wet season in favour of Nera. It was observed that within seasons BN pullets had higher weight. It was also observed that pullet body weight were higher in the wet seasons: 1957.60 vs 1889.24 gm/bird, than in the dry seasons: 1870.21 vs 1696.68 gm/bird, seasons respectively. The influence of season on body weight of the strains at peak production is shown in Figure 4.7.

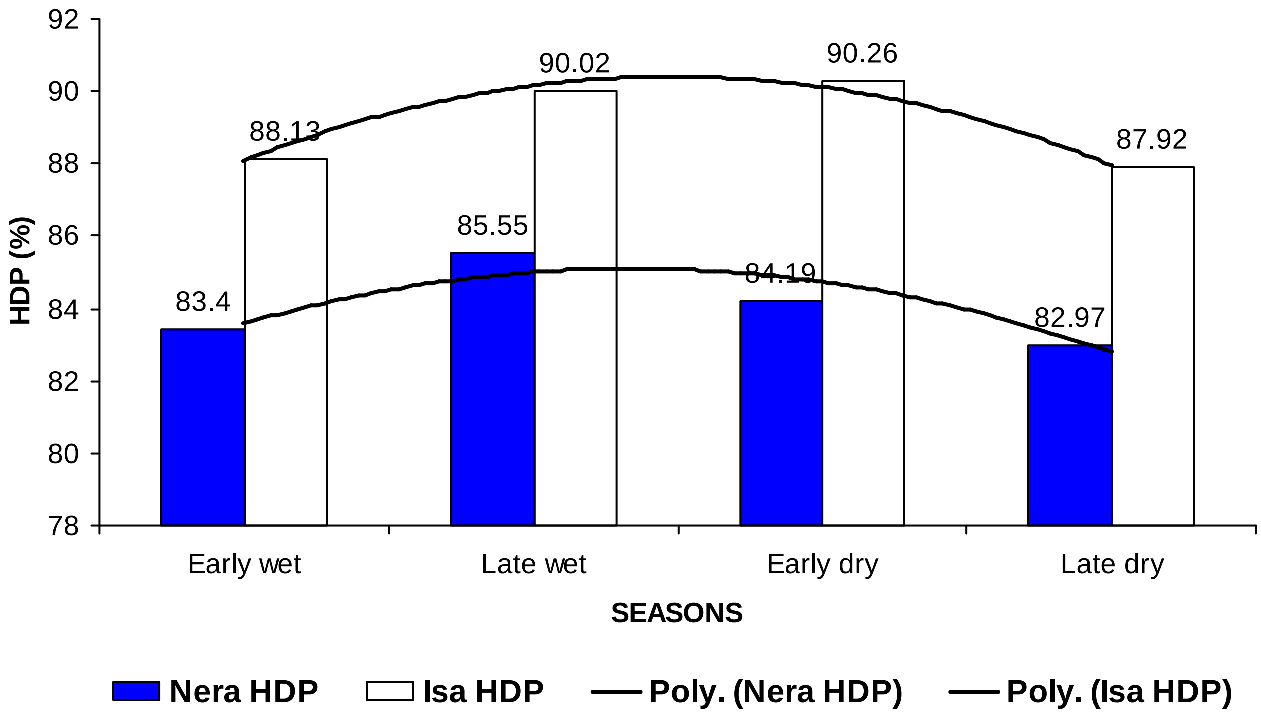
4.8.4 Hen-day production at full sexual maturity

Table 4.12 reveals that there was no significant (P > 0.05) difference between seasons within genotypes in hen-day production at full maturity. Comparison between genotypes within seasons indicated that there was significant (P < 0.05) difference in HDP in late wet season: 85.55 vs 92.02 %, in favour of ISA pullets, although all seasons showed higher HDP in ISA mature pullets (Figure 4.8). The highest difference of 7.68 % in HDP between the two genotypes was observed in late wet season. Figure 4.8 shows the curves of production of genotypes between seasons in which ISA shows superiority over Nera.



NOTE : Poly. means Polynomial

Figure 4.7. Influence of season on body weight at full maturity in Bovan Nera and ISA Brown pullet breeders



NOTE : Poly. means Polynomial

Figure 4.8. Influence of season on HDP of pullet breeders at full sexual maturity in Bovan Nera and ISA Brown

4.8.5 Egg weight at full sexual maturity

Results on Table 4.12 revealed that between seasons, there was no significant ($P < 0.05$) difference in egg weight of BN pullets while significant ($P < 0.05$) differences were observed in the egg weight of ISA pullets at full maturity. Early wet season (16 April – July) yielded highest egg weight within both genotypes: 57.40 vs 62.40 gm, for BN and ISA respectively, while late wet and early dry seasons followed in descending order of magnitude within genotypes.

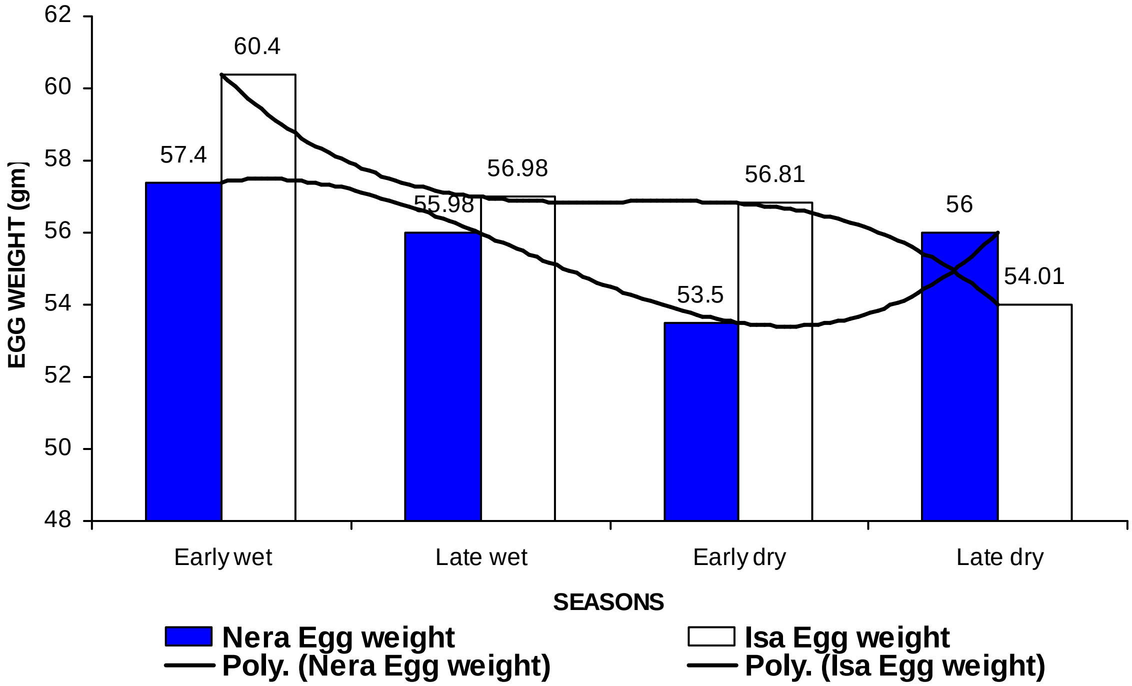
Further analysis revealed that heavier egg weight was obtained in wet seasons: 56.69 vs 59.69 gm, as against the dry seasons: 54.75 vs 55.41 gm, respectively in BN and ISA pullets at full maturity. The influence of season on egg weight was not significant ($P > 0.05$) in Bovan Nera mature pullet but was significant ($P < 0.05$) in ISA pullets at full maturity. Figure 4.9 shows that ISA Brown pullets were superior to Bovan Nera pullets in egg weight in all seasons except late dry.

4.8.6 Egg-set at full sexual maturity

Table 4.12 shows the result of the influence of seasons on eggs set of pullet breeders at full maturity in Bovan Nera and ISA Brown. There was no significant ($P > 0.05$) difference between seasons within genotypes and, between genotypes within seasons in percent egg set of the two strains. However the wet seasons recorded higher ($P > 0.05$) percent eggs set: 99.49 vs 99.72, as against the dry seasons: 96.50 vs 93.34, for the two genotypes respectively. There was a large difference: 6.07 %, between eggs set of both hybrids in late dry season in favour of BN hens. Both genotypes exhibited same polynomial pattern in egg production as depicted in Figure 4.10.

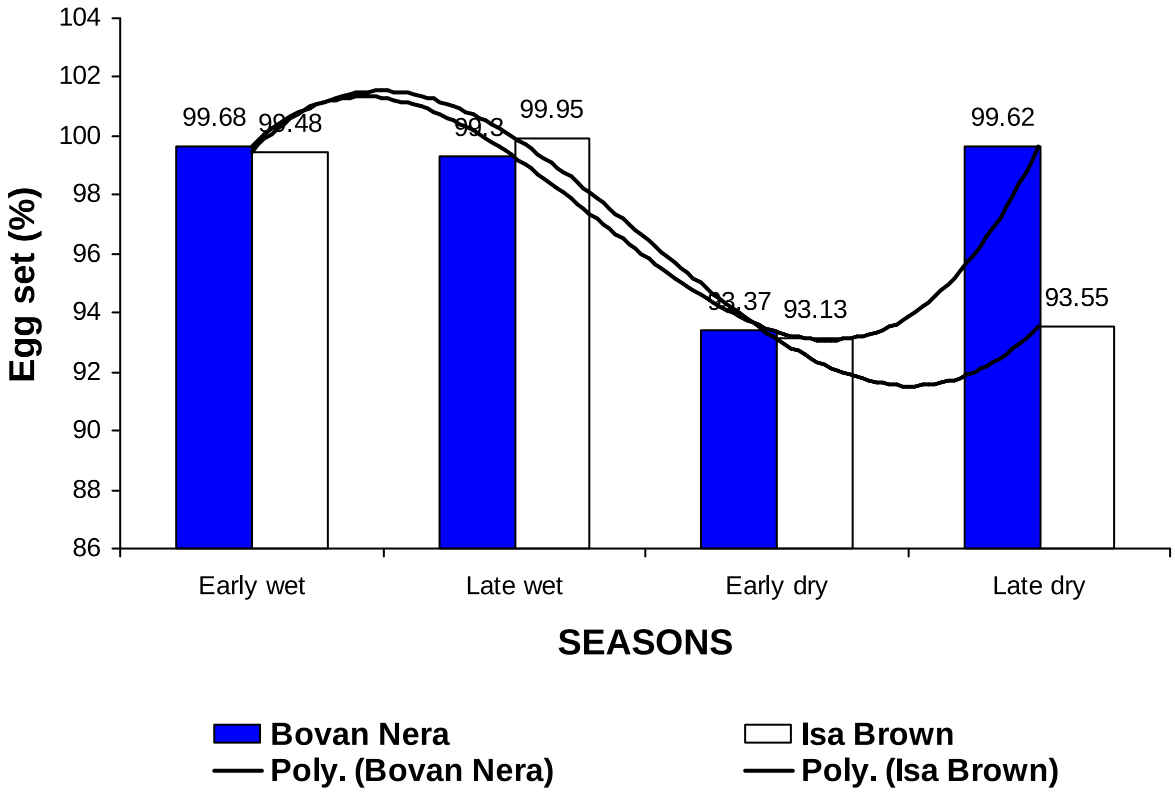
4.8.7 Egg fertility at full sexual maturity

Results on Table 4.12 showed no significant ($P > 0.05$) difference between seasons within genotypes, and between genotypes within seasons, in percent egg fertility. However, higher percent fertility was observed in the wet: 86.33 vs 92.16, seasons (16 April – October) as against the dry: 84.59 vs 83.31, seasons (November -15 April) within BN and ISA genotypes respectively. Figure 4.11 shows the influence of season on egg fertility in both genotypes, which prooduces similar pattern in both hybrids.



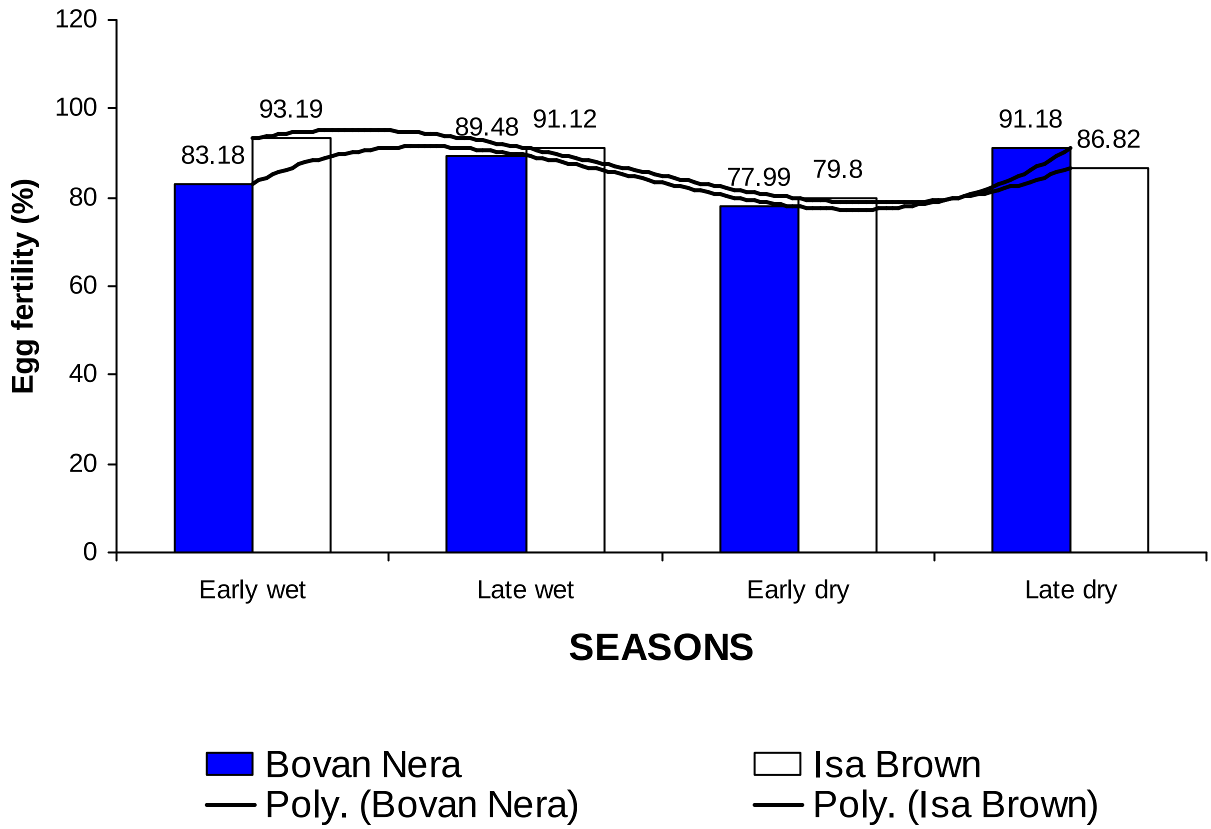
NOTE : Poly. means Polynomial

Figure 4.9. Influence of season on egg weight of pullet breeders at full maturity in Bovan Nera and ISA Brown



NOTE: Poly. means Polynomial

Figure 4.10. Influence of season on eggs set of pullet breeders at full sexual maturity in Bovan Nera and ISA Brown



NOTE: Poly. means Polynomial

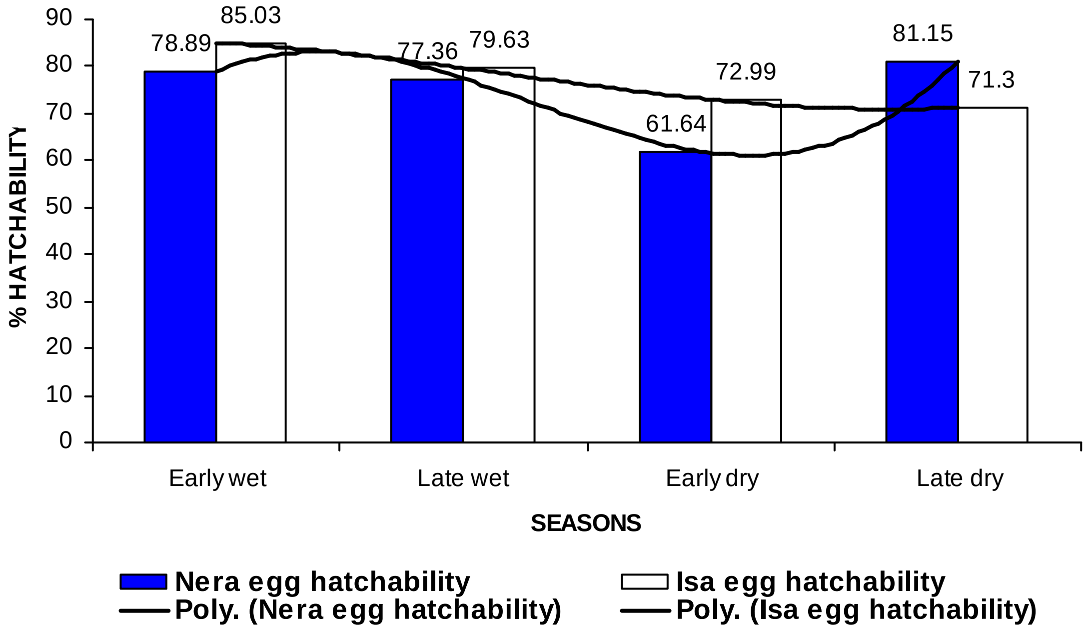
Figure 4.11. Influence of season on egg fertility of pullet breeders at full maturity in Bovan Nera and ISA Brown

4.8.8 Egg hatchability at full sexual maturity

There was no significant (P > 0.05) difference in egg hatchability between seasons within BN, however significant (P < 0.05) differences were observed between seasons within ISA pullets at full sexual maturity (Table 4.12). Highest percent egg hatchability: 85.03, was observed in ISA in early wet (16 April - July) followed by late wet, early dry and late dry seasons in order of descending magnitude. Highest egg hatchability in BN was recorded in late dry season. Figure 4.12 shows the pattern of hatchability as influenced by seasons within genotypes. This pattern differs in both strains.

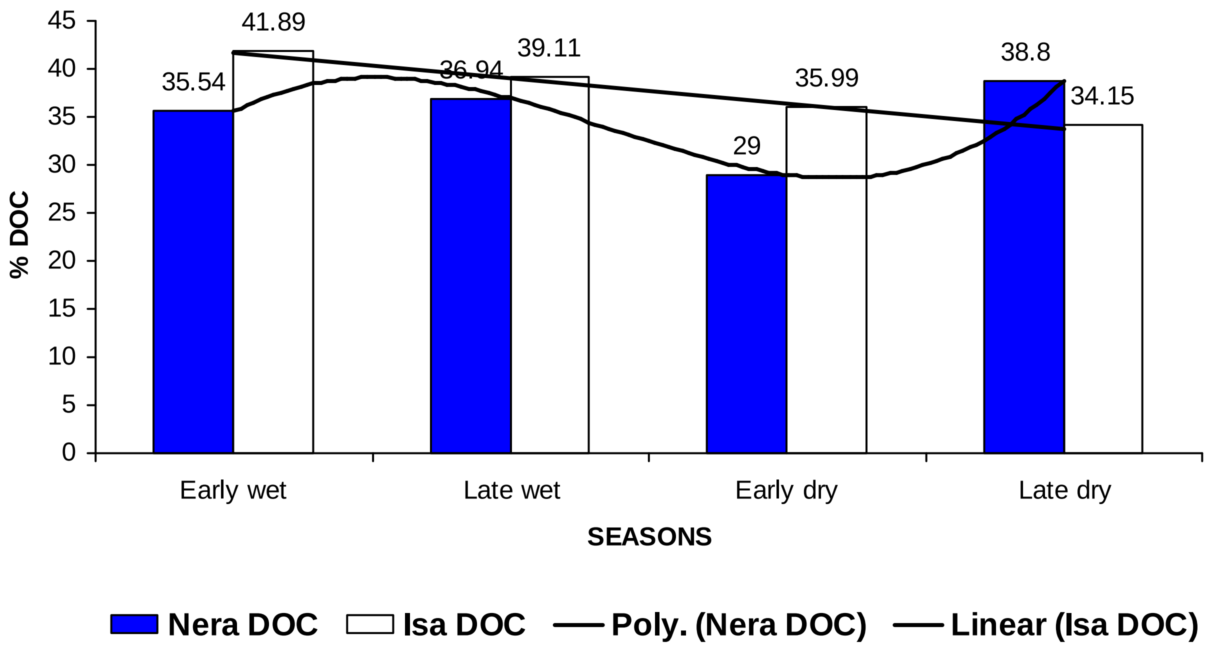
4.8.9 Pullet day-old chicks hatched at full sexual maturity

Results showed that within genotypes between seasons, no significant (P > 0.05) difference was observed in percent pullet DOC produced by Nera hens, but significant (P < 0.05) differences were observed between seasons in pullet DOC hatched by ISA hens. While the highest percent pullet chicks: 38.80 %, was observed in late dry season (February – 15 April) within BN, the highest pullet DOC: 41.89 %, was observed in early wet season (April - July) within ISA. Other seasons (LW, ED and LD) followed in pullet DOC production: 39.11, 35.99 and 34.15 %, in descending order of magnitude within ISA respectively. Comparison between genotypes within seasons indicated significant (P < 0.05) differences in percent pullet DOC hatched in early dry season at full maturity. ISA produced higher percent Pullet DOC than Nera: 29.00 vs 35.99 %. Both genotypes had higher values in wet seasons: 36.24 vs 40.50 %, than in dry seasons: 33.9 vs 35.07 % respectively. The curve showing the influence of season on DOC production is shown in Figure 4.13. The curve of production in BN was a polynomial with high body weights in early wet and late dry seasons. Pullet chicks’ production decreased gradually in ISA from early wet season maximum: 41.09 %, to late dry season minimum: 34.15 %, presenting a linear curve.



NOTE: Poly. means Polynomial

Figure 4.12. Influence of season on egg hatchability of Pullet breeders at full maturity in Bovan Nera and ISA Brown



NOTE: Poly. means Polynomial

Figure 4.13. Influence of season on pullet day-old chicks hatched at full maturity in Bovan Nera and ISA Brown

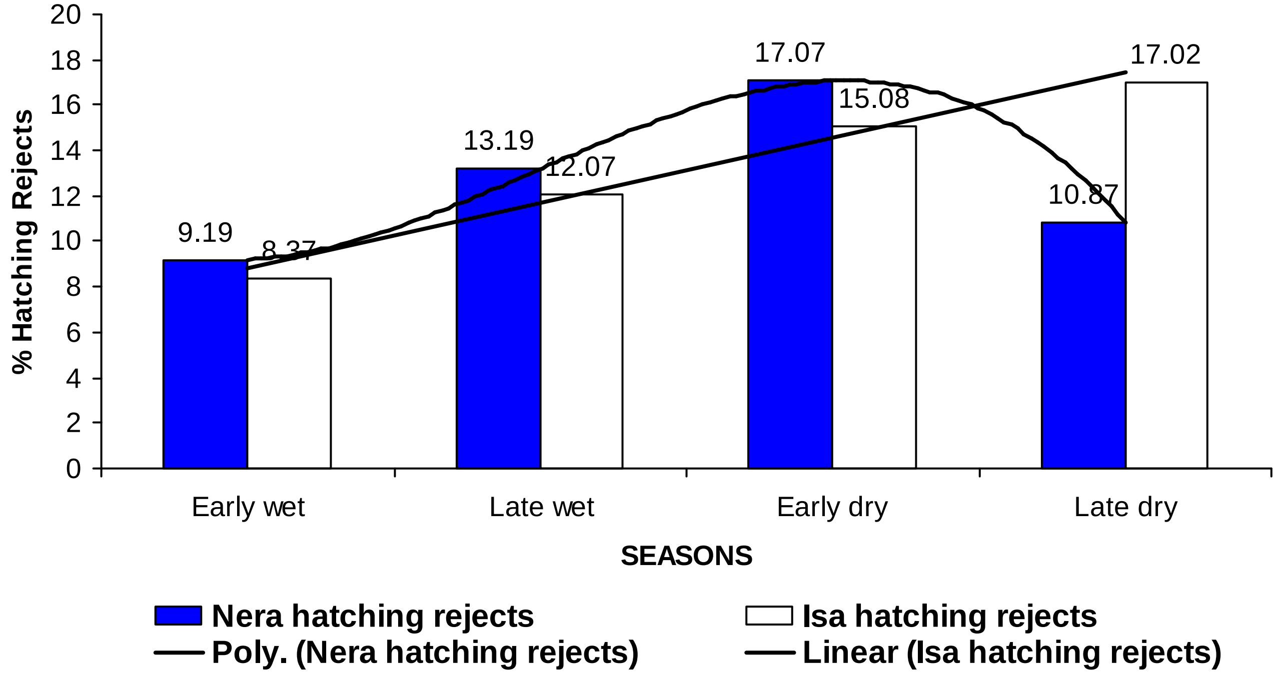
4.8.10 Hatching rejects at full sexual maturity

Table 4.12 shows the influence of seasons on hatching rejects produced during hatching activities in the hatchery. Anova indicated significant ($P < 0.05$) differences between seasons within BN and IB in hatching rejects respectively. Highest hatching rejects: 17.07 vs 17.02 %, were observed in BN at early dry season and in ISA at late dry season. Least hatching rejects occurred in early wet season: 9.19 vs 8.37 %, within strains. Within seasons, no significant ($P > 0.05$) differences were observed in hatching rejects between genotypes. Figure 4.14 shows the curve of hatching rejects produced in both genotypes. This reveals a progressive increase in hatching rejects generated as the seasons progressed from early wet to late dry. The curve of BN was quadratic ($a > 0$) while that of IB was linear with minimum and maximum values in early wet and late dry seasons respectively.

4.9 Influence of genotype on body weight and egg characteristics at full sexual maturity

Table 4.13 shows the results of the influence of genotype on full maturity characteristics of pullet breeders. This revealed significant ($P < 0.05$) difference between BN and ISA in hen weight: 1916.08 vs 1792.20 gm/bird, hen-day production: 84.39 vs 90.57 %, and pullet day-old chicks: 33.37 vs 37.29 %, hatched. There was no significant difference ($P > 0.05$) between genotypes in other characteristics, although ISA had heavier cock weight: 2374.98 vs 2390.10 gm, heavier egg weight: 55.45 vs 56.56 gm, higher egg fertility: 82.99 vs 87.13 %, higher egg hatchability: 71.56 vs 76.23 %, and higher hatching rejects: 13.47 vs 13.80 %. Results also showed that, BN pullets attained full sexual maturity later: 214 days, at a heavier body weight: 1916.08 gm/bird, ($P < 0.05$); and had higher amount of eggs set: 96.99 %, ($P > 0.05$), but exhibited significantly lower HDP, % Pullet DOC and lower hatching rejects. ISA brown pullets attained full sexual maturity earlier: 208 days, with significantly lower body weight: 1792.20 gm/bird and lower egg set: 94.38 %, but with higher HDP, pullet DOC (both at $P < 0.05$) and hatching rejects ($P > 0.05$). There appears to be, an inverse relationship between pullet body weight and hen day production in chicken between genotypes (Table 4.13) and within genotypes (Table 4.12) at full maturity. One may approximate the relationship as:

Hen Body weight = 1 / HDP



NOTE: Poly. means Polynomial

Figure 4.14. Influence of season on hatching rejects of pullet breeders at full maturity in Bovan Nera and ISA Brown

Table 4.13. Influence of genotype on body weight and egg characteristics at full sexual maturity in Bovan Nera and ISA Brown pullets

Parameter	Bovan Nera (mean + s.e.)	ISA Brown (mean + s.e.)
Age (days)	214 ± 32	208 ± 26
Cock weight (gm)	2374.98 ± 35.13	2390.10±30.73
Hen weight (gm)	1916.08 ± 23.41[a]	1792.20±27.35 [b]
HDP (%)	84.39 ± 0.80[b]	90.57 ± 0.92[a]
Egg weight (gm)	55.45 ± 0.70	56.56 ± 0.82
Egg set (%)	96.99 ± 2.60	94.38 ± 1.99
Egg fertility (%)	82.99 ± 2.15	87.13 ± 2.02
Egg hatchability (%)	71.56 ± 3.04	76.23 ± 1.32
Pullet DOC (%)	33.37 ± 1.42[b]	37.29 ± 0.69[a]
Hatching rejects (%)	13.47 ± 1.28	13.80 ± 0.97

Means in the same row with different superscripts differ significantly (P < 0.05)

4.10.0 Life-time (first-egg to 75 weeks) productive performance.

Table 4.14 shows the mean 75-week productive performance of hen breeders classified by genotype and season.

4.10.1 Hen-day production

Table 4.14 shows the influence of season on productive performance in Bovan Nera and ISA Brown breeder hens from first-egg to 75 weeks. This shows significant ($P < 0.05$) difference between BN and ISA genotypes in early dry: 63.23 vs 72.92 % season but no significant ($P > 0.05$) difference was observed between genotypic means: 62.73 vs 69.08 %, although ISA had higher HDP than Bovan Nera. It was also observed that within seasons ISA Brown layed higher percent eggs (HDP). Within genotypes BN layed the highest HDP in late wet: 65.57 %, while IB layed the highest HDP in early dry: 72.29 %, season. The table reveals that both genotypes layed more eggs within late wet and early dry seasons, with ISA hens laying more eggs than Bovan hens.

Figure 4.15 also illustrates the mean curve of HDP in both genotypes over their productive life without season with IB having the better curve.

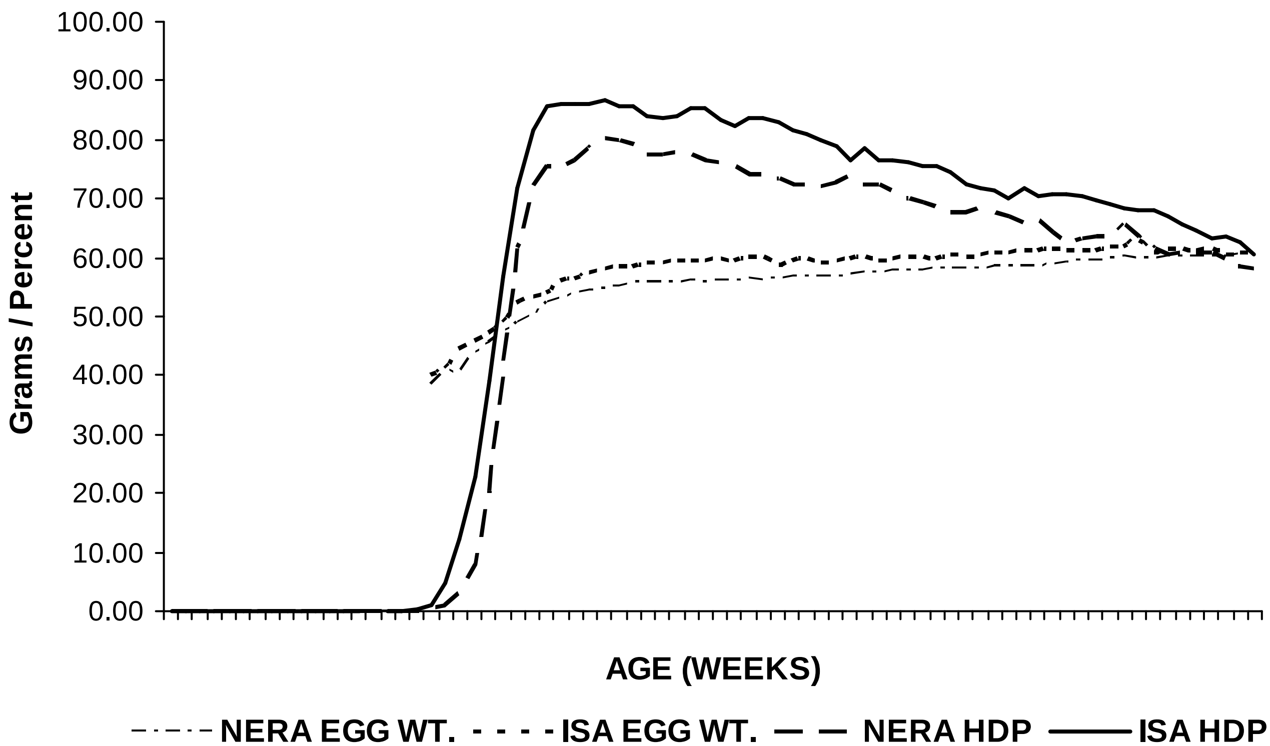
4.10.2 Egg weight

Table 4.14 shows the influence of season on life-time egg weight in Bovan Nera and ISA Brown breeder hens from first-egg to 75 weeks. There was significant ($P < 0.05$) difference between BN and ISA breeder hens within early wet season: 56.20 vs 59.99 gm, late dry season: 54.71 vs 56.88 gm, and between genotypic means: 56.05 vs 58.23 gm, in egg weight. All seasonal and genotypic mean results were higher in ISA than in Nera. Late dry season egg weight was the lowest in both strains. Figure 4.15 also shows the influence of genotype on the curve of egg weight in Bovan Nera and ISA Brown breeder hens over their productive life-time. The curve of IB was higher than that of BN in egg weight but with similar shape as ISA hen with lower body weight had higher egg weight than BN hen with higher body weight.

Table 4.14. Influence of season on productive performance in Bovan Nera and ISA Brown Breeder Hens at first-egg to 75 weeks

Season	Genotype	Body weight (gm)	Mean growth (gm/day)	HDP (%)	Egg weight (gm)	Persiste-ncy (weeks)	Cumm. Production
Early wet	Nera	1671.02^{j}	4.18	60.79±20.49	56.20±5.06^{b}	18	1474
	ISA	1590.67	3.74	66.74± 20.99	59.99±4.96^{a}	31	1647
Late wet	Nera	1677.74^{j}	4.10	65.57± 21.82	56.68± 4.72	42	1808
	ISA	1596.93	3.99	69.38± 24.07	57.97± 5.04	31	1968
Early dry	Nera	1669.11^{j}	4.22	63.23±21.02^{b}	56.66± 4.64	37	2708
	ISA	1497.56	3.75	72.92±18.71^{a}	58.12± 5.18	43	2795
Late dry	Nera	1923.11^{ai}	3.98	61.35± 21.27	54.71±4.93^{b}	27	1339
	ISA	1514.67^{b}	3.72	67.34± 22.16	56.88±5.16^{a}	33	2187
Genotypic mean	**Nera**	**1724.81**	**4.12**	**62.73± 21.10**	**56.05±4.88^{b}**	**28**	**2097**
	ISA	**1549.83**	**3.80**	**69.08± 21.60**	**58.23±5.18^{a}**	**40**	**2489**

Means along the same column with different superscripts differ (P<0.05) significantly.
ab superscripts compare genotypes within seasons while ij superscripts compare between seasons within genotype.
± means Standard deviation; Persistency: ≥ 70%; Cumm. means cummulative.



NOTE: Poly. means Polynomial

Figure 4.15. Influence of genotype on mean HDP and egg weight (First-egg to 75 weeks) curves in Bovan Nera and ISA Brown breeder hens

4.10.3 Persistency of egg production

Table 4.14 showed that Bovan Nera persisted longer than ISA Brown in hen-day production (HDP) above 70 % level in late wet season: 42 vs 31 weeks, while ISA Brown persisted longer in average HDP within early wet season: 18 vs 31 weeks, early dry season: 37 vs 43 weeks, and late dry: 27 vs 33 weeks, season. Results also revealed that BN recorded highest persistency: 42 weeks, of production when it layed highest average HDP: 65.57%. The mean genotypic persistency was 31 weeks for BN hens and 35 weeks for ISA breeder hens. Results also showed that early wet season recorded the least production persistency: 18 vs 31 weeks, within both genotypes. Further study revealed that HDP persistency was observed at 30 -56 weeks in both genotypes. The cumulative egg production was taken as the product of persistency and HDP. Table 4.14 shows that BN produced less eggs cumulatively than ISA: 2097 vs 2489; but early dry (November - January) season produced highest cumulative eggs: 2708 and 2795, within Nera and ISA flocks respectively. It is also observed in Figure 4.16 that, the trends of production in both strains were similar.

4.11 Influence of genotype on life-time (first-egg to75 weeks) production

Table 4.15 shows the influence of genotype on hen weight, hen-day production, egg weight, egg production persistency of Bovan Nera and ISA Brown. Egg weight: 56.06 gm, in BN was lower ($P < 0.05$) than that: 58.23 gm, in ISA. There was also a significant difference ($P < 0.05$) in HDP: 62.70 vs 69.10 %, between both genotypes in favour of ISA. Average egg production persistency and cumulative production during this period were higher in ISA: 35 weeks, 2489; than in Nera: 31 weeks, 2097.

4.12 Phenotypic correlation among productive parameters

Table 4.16 shows the correlation matrix for egg production parameters in breeder hens of both genotypes. Within genotypes, highly significant ($P < 0.0001$) correlation was observed between age and egg weight: $r = 0.735$ vs 0.522, hen weight and egg weight: $r = 0.682$ vs 0.529, in Bovan and ISA hens respectively. Correlation between hen weight and HDP was also highly significant ($P < 0.0001$) in ISA breeder hens: $r = 0.582$, while other pairs of parameters (HDP and egg weight, growth and HDP, growth and egg weight, and age and HDP) were weak: 0.419 to -0.091.

4.13 Regression equation models for egg weight

The model: $Y = a X^{b}$ was used to fit egg weight – age data.

Where Y= egg weight (gm)

X = Number of weeks in lay from first egg (weeks)

By log transformation to linear form:

In Y = In a + b In X, the predictive equations below were obtained.

BN: Y = 39.347 + 0.110 In X ± 0.307; R^2 = 0.654

ISA: Y = 40.399 + 0.109 In X ± 0.540; R^2 = 0.654

But by using the asymptotic model of Rose (1997): $Y = a – b C^{X}$ to fit same data by trial and error method;

Where Y = egg weight (gm)

a = maximum egg weight for genotype (gm)

b = rate of increase in egg weight (18)

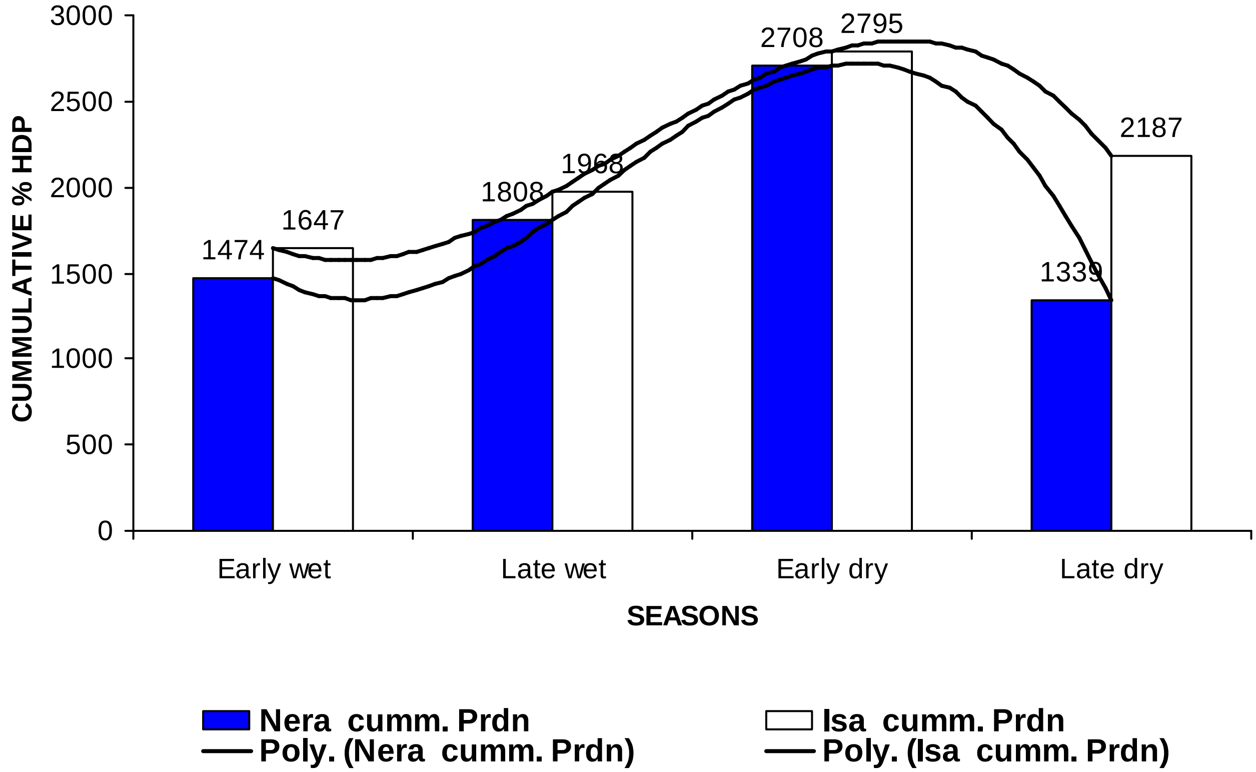
X = Number of weeks in lay from first egg (weeks)

And $a \geq Y_{maximum}$ for genotype

The relationship below were obtained for Bovan Nera and ISA Brown hens

Bovan Nera: $Y = 64 – 18 (0.9)^{X}$

ISA Brown: $Y = 63.7 – 18 (0.9)^{X}$



NOTES: Poly. means Polynomial

Cumm. Prodn means Cummulative Production

Figure 4.16. Influence of season on cumulative egg production during persistency period

Table 4.15. Influence of genotype on the production of Bovan Nera and ISA Brown breeder hens at first egg to 75 weeks

TRAITS	Bovan Nera	ISA Brown
HDP (%)	62.73 ± 21.10^{b}	69.08 ± 21.60^{a}
Egg weight (gm)	56.05 ± 4.88^{b}	58.23 ± 5.18^{a}
Persistency at ≥ 70% HDP (weeks)	31	35
Cummulative production	2097^{b}	2489^{a}
Hen weight (gm)	1724.81 ± 562.80	1549.83 ± 543.29

HDP means hen-day production

Means in the same row with different superscripts are significantly different ($P < 0.05$)

Table 4.16. Correlation Matrix for egg production parameters of breeder hens

		Bovan Nera				
	Parameter	Age	Hen weight	Growth rate	HDP	Egg weight
	Age		-	-	0.046 NS	0.735***
ISA	Hen weight	-		-	0.267***	0.682***
Brown	Growth rate	-	-		-0.109**	-0.091*
	HDP	0.173***	0.528***	0.307***		0.234***
	Egg weight	0.522***	0.529***	0.215***	0.419***	

* :p< 0.01; **: p<0.001; ***: p<0.0001; NS – Not significant

4.14.0 Life-time reproductive performance (25 to75 weeks)

Table 4.17 shows the results of reproductive performance in Bovan Nera and ISA Brown breeder hens classified by seasons. ANOVA study revealed that there were no significant (P > 0.05) differences between hybrids between seasons in all reproductive traits.

4.14.1 Life-time percent of eggs set

Table 4.17 shows no significant (P > 0.05) difference was observed etween genotypes between seasons in percent eggs set of Bovan Nera and ISA Brown throughout their reproductive life. Mean quantity of eggs set between genotypes, and within seasons were between 96.91 and 98.92 %. The pattern of eggs set in BN was a normal curve (Figure 4.17) with late wet and early dry seasons which gave the highest percentages: 98.92 and 97.57% respectively. However the pattern was a polynomial in IB although there was an all-time high percent eggs set in ISA: 97.77 – 98.74 %.

4.14.2 Life-time fertility of eggsset

Table 4.17 also shows the results on reproductive performance of breeder hens at 25 to 75 weeks; while Figure 4.18 shows the results on mean egg fertility in BN and ISA breeder hens classified by season. Anova indicates that the differences observed between egg fertility of BN and IB genotypes within seasons were significant (P < 0.05). These differences were in the early wet: 80.82 vs 88.72%, and late wet: 86.23 vs 89.45%, seasons respectively, with ISA having the higher values. Both strains showed highest performance in egg fertility: 86.23 and 89.45 %, in the late wet season. but showed their lowest performance in different seasons of the year. Egg fertility was lowest: 80.82 %, in early wet season in BN hens but it was lowest: 84.20 %, in late dry season in IB hens. Mean fertility was higher in ISA hens in the wet seasons than in the dry seasons. Figure 4.18 shows the mean life trend of egg fertility in both genotypes. Similar shapes were observed for both strains.

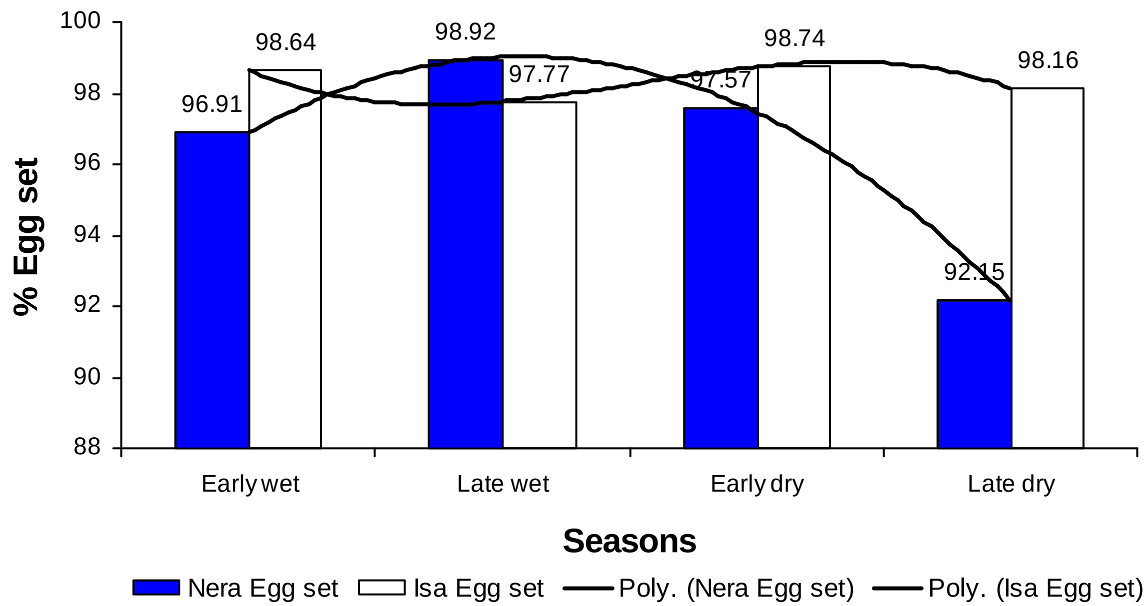
4.14.3 Relationship between cock weight and fertility of eggs set

Study indicates a positive and highly significant (p = 0.0001) correlation between cock weight and egg fertility in BN: r = 0.267 and ISA: r = -0.314. Table 4.18 shows the association between cock weight and egg fertility in both genotypes, while Figures 4.19 and 4.20 show the curves of cock weight against egg fertility in BN and ISA genotypes respectively. These reveal that the highest egg fertility: 84–90%, was obtained between 2600 – 2650 gm body weight ranges corresponding to 44-48 weeks of age in Bovan Nera hen, while the highest egg fertility: 90%, was achieved at a lower cock weight range of 2482 to 2537 gm at a lower age range of 33–36 weeks in ISA. From the two curves above, it is observed that as cock weight increases, the egg fertility increases to a maximum and then begins to decrease. The regression of egg fertility on cock weight yielded a quadratic and a cubic model with R^2 of 0.126 and 0.133 respectively for Bovan Nera and a quadratic model with R^2 of 0.091 for ISA hens. The Table also reveals that optimum egg fertility was attained earlier: 33 to 36 weeks, in IB hybrid with the lower body weight han BN: 44 to 48 weeks, with the higher body weight.

Table 4.17. Life-time reproductive performance of breeder hens at 25 to 75 weeks classified by season

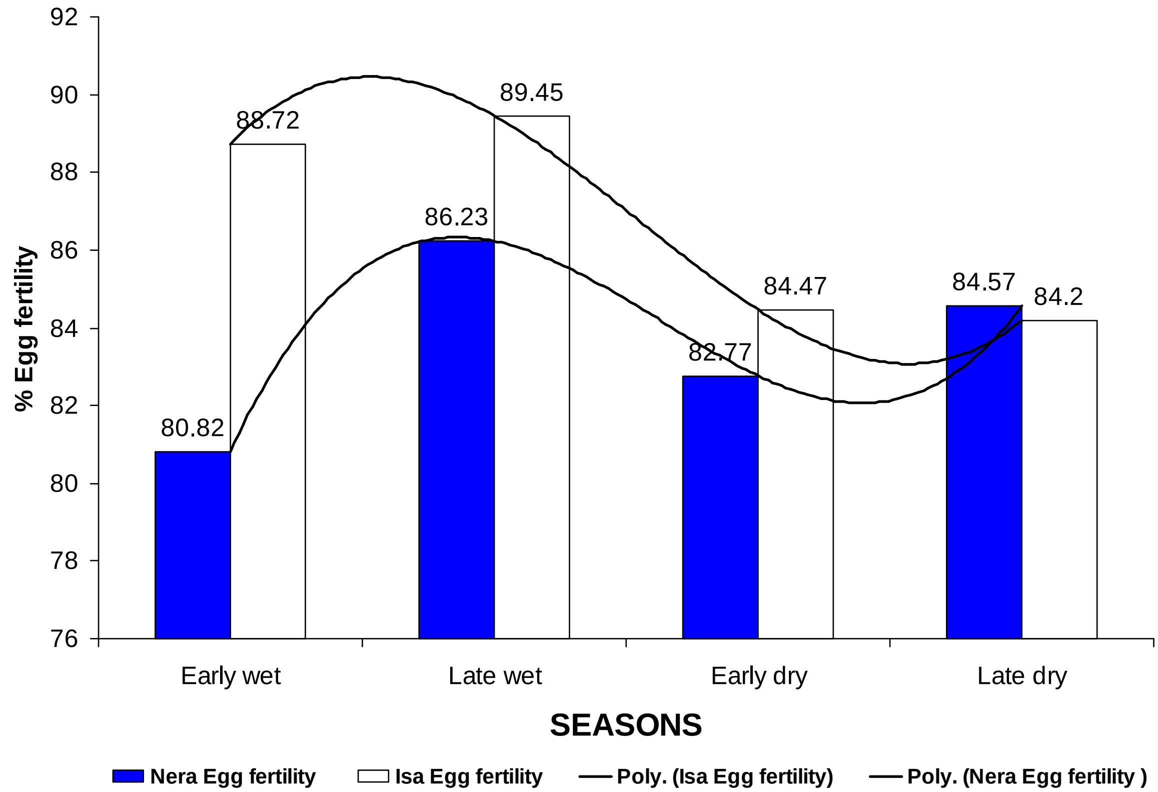
Seasons	Genotype	Egg set (%)	Egg fertility (%)	Egg Hatchability(%)	Pullet DOC (%)	Hatching rejects (%)
Early wet	BN	96.91±5.72	80.82±5.01^{b}	69.08±6.07^{b}	32.58±3.18^{b}	13.12±3.15^{b}
	IB	98.64±4.21	88.72±2.99^{a}	73.59±7.60^{a}	36.06±3.98^{a}	15.51±5.88^{a}
Late wet	BN	98.92±1.81	86.23±6.16^{b}	73.12±8.12	34.56±4.40	14.04±4.60^{b}
	IB	97.77±3.91	89.45±3.15^{a}	73.88±5.12	35.74±2.69	16.33±4.55^{a}
Early dry	BN	97.57±4.07	82.77±5.86	68.85±7.21	32.46±3.57	17.66±5.41
	IB	98.74±2.74	84.47±3.09	68.32±7.19	33.25±3.80	17.41±7.20
Late dry	BN	97.70±9.63	84.57±5.77	70.36±11.86	33.02±6.33	15.89±9.99
	IB	98.16±9.63	84.20±6.73	67.73±13.49	32.44±7.15	18.79±7.12
Strain	**BN**	**97.78±6.02**	**83.61±6.02^{b}**	**70.35±74.58**	**33.1±64.58**	**15.19±6.53**
Mean	**IB**	**98.33±3.85**	**86.70±4.90^{a}**	**70.86±4.94**	**34.36±4.94**	**17.02±6.36**

Means in same column within season with different superscripts are significantly ($P < 0.05$) different. BN = Bovan Nera, IB = ISA Brown



NOTE: Poly. means Polynomial

Figure 4.17. Life-time percent eggs set in Bovan Nera and ISA Brown breeder hens at 25 to 75 weeks of age classified by season.



NOTE: Poly. means Polynomial

Figure 4.18. Life-time fertility of eggs set in Bovan Nera and ISA Brown breeder hens at 25-75 weeks of age classified by season

Table 4.18. Relationship between cock weight and fertility of egg-set in Bovan Nera and ISA Brown genotypes

Genotype	Optimum Egg Fertility (%)	Cock weight (gm)	Age (weeks)
Bovan Nera	84 – 90	2600 – 2650	44 – 48
ISA Brown	90	2482 – 2537	33 – 36

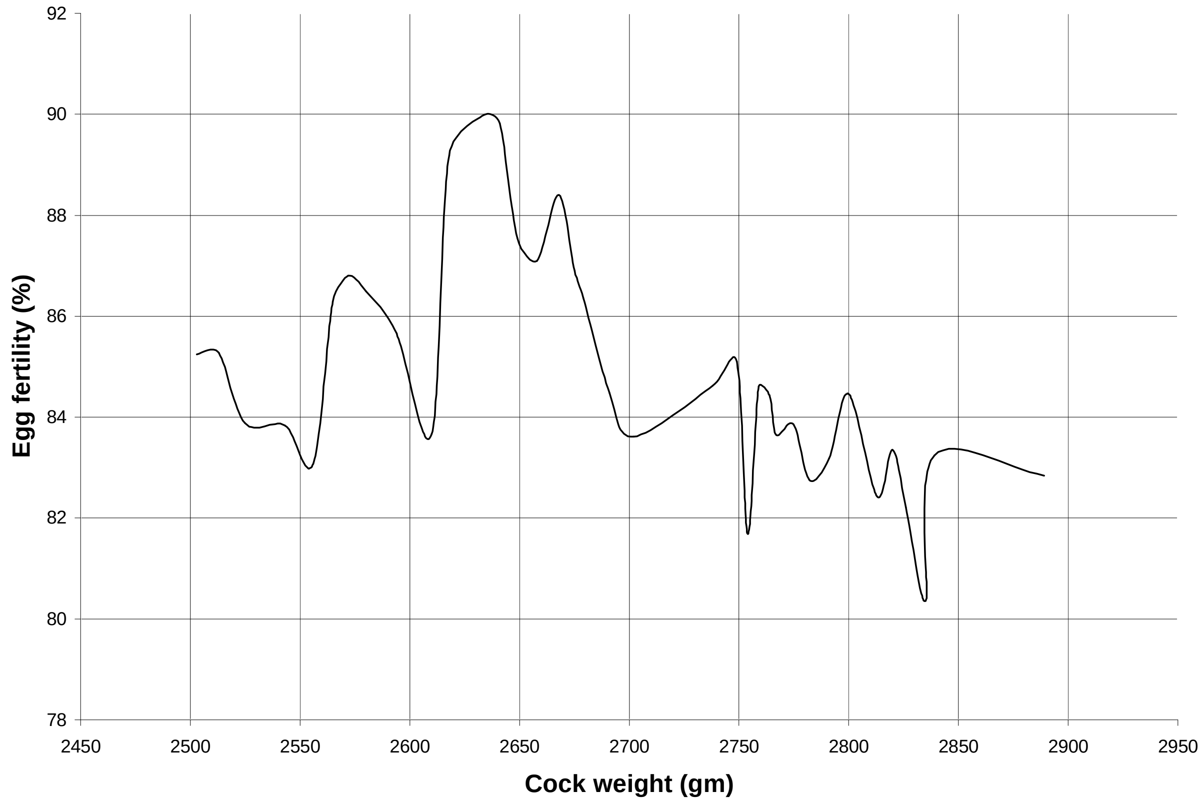


Figure 4.19. Curve of cock weight against fertility of egg-set in Bovan Nera hens

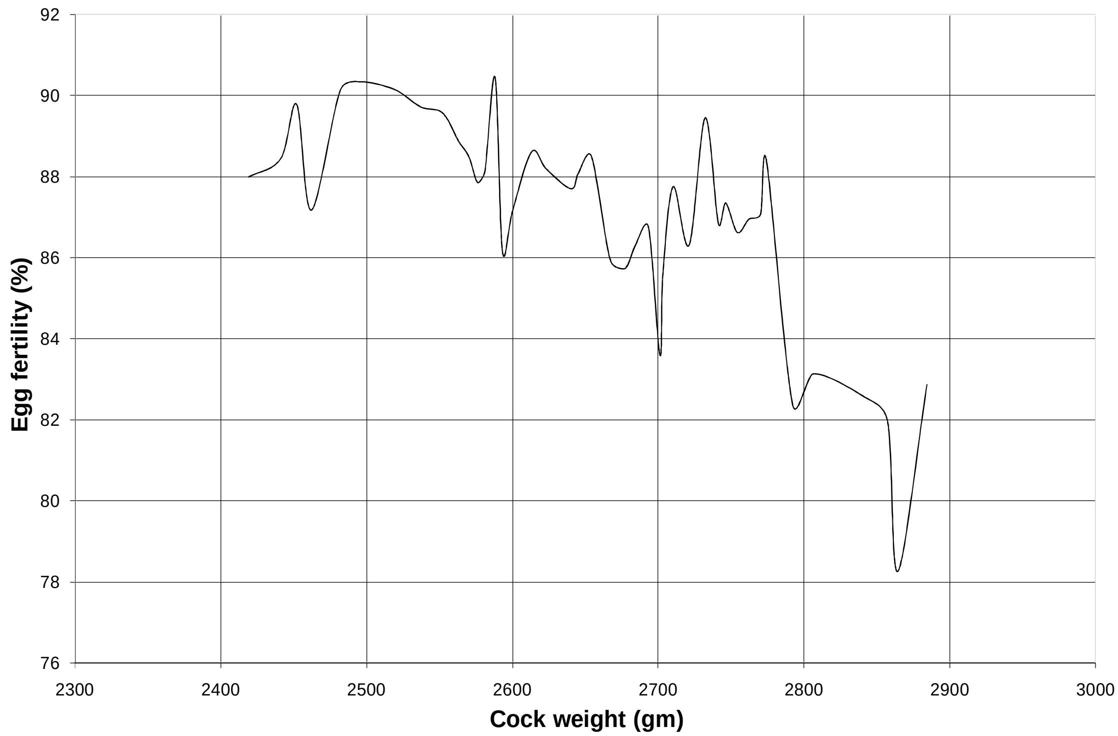


Figure 4.20. Curve of cock weight against fertility of egg-set in ISA Brown hens

4.14.4 Life-time hatchability of eggs set

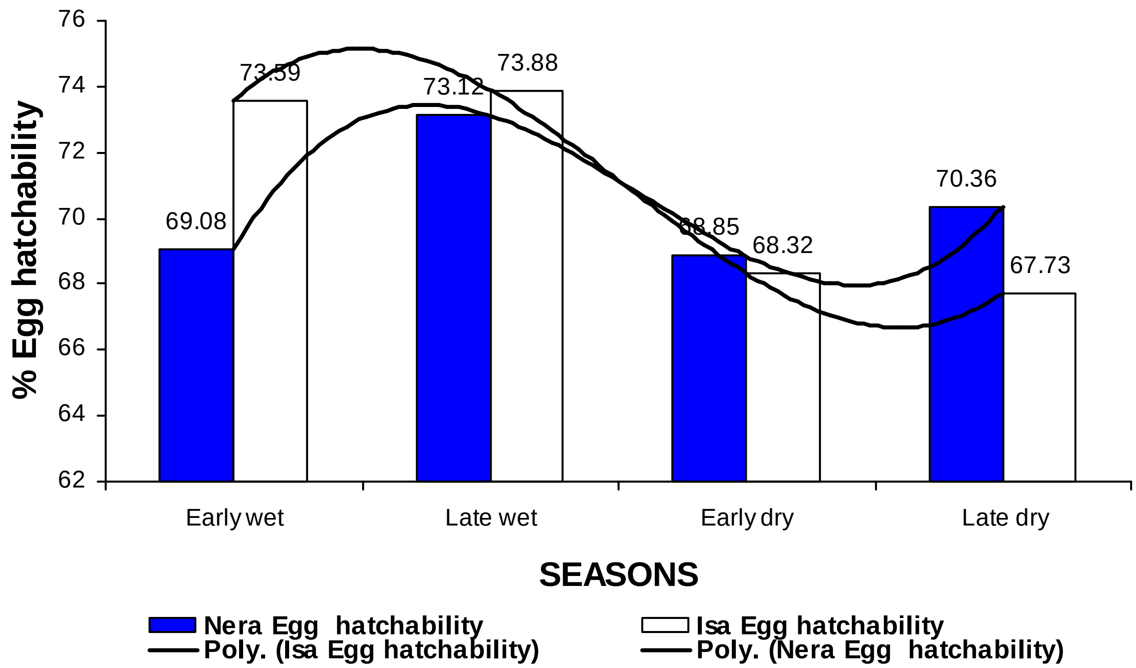
Table 4.17 shows that there was significant ($P < 0.05$) difference in egg hatchability during early wet season: 69.08 vs 73.59% in favour of ISA. Other seasons did not produce any significant ($P > 0.05$) difference in egg hatchability. Figure 4.21 shows the results on egg hatchability in both strains classified by season. It also reveals that both Bovan Nera and ISA Brown recorded higher hatchability within the wet (early and late) seasons as against the dry seasons. Both table 4.15 and Figure 4.19 show that IB was better in the wet seasons while BN was better in the dry seasons. This demonstrated clearly that there was an interaction between genotype and season and a reversal of the order of merit between ISA hens in the wet seasons, and Bovan hens in the dry seasons of South-West Nigeria.

4.14.5 Relationship between egg weight and hatchability of eggs set

Significant correlation was observed between egg weight and hatchability of egg set in BN ($r = 0.216$; $P > 0.005$) but non-significant and negative correlation ($r = - 0.009$) was observed in ISA.

Table 4.19 shows the influence of egg weight on mean hatchability of fertile Nera and ISA eggs set in the hatcher; while Figures 4.22 and 4.23 show the curve of egg weight against egg hatchability of BN and ISA breeder hens respectively. Table 4.19 shows that at egg weight range of 56.5 – 59.5 gm, hatchability of more than 70% could be obtained but as the egg weight increases beyond this range, hatchability dropped. This is also observed on the curve of egg weight against hatchability in Figure 4.22.

In ISA brown, egg hatchability of more than 70 % was obtained between the egg weight ranges of 54.0 - 61.0 gm at 26 to 60 weeks of age. The curve of egg weight against hatchability in Figure 4.23 shows, it is possible to obtain 80 % hatchability of egg set between 58.0 – 59.0 gm at 30 – 33 weeks of age in hens. From Figures 4.22 and 4.23, it is observed that from 64 weeks in BN and 60 weeks in ISA hens, higher egg weight resulted to a reduced egg hatchability and hence number of day-old pullet chicks obtained. The regression of egg hatchability on egg weight in both genotypes yielded a cubic model with R^2 of 0.113 for Bovan and a quadratic model with R^2 of 0.010 for ISA hens. Manipulation of nutrition has been suggested as the practical means to control egg weight in layer breeders.



NOTE: Poly. means Polynomial

Figure 4.21. Life-time hatchability of eggs set in Bovan Nera and ISA Brown breeder hens at 25 to75 weeks of age classified by season

Table 4.19. Relationship between egg weight and hatchability of egg-set in Bovan Nera and ISA Brown genotypes

Genotype	Optimum Hatchability (%)	Egg weight (gm)	Age (weeks)
Bovan Nera	≥70	56.5 - 59.5	40 – 64
ISA Brown	≥70	54.0 - 61.0	26 – 60
	80	58.0 - 59.0	30 – 33

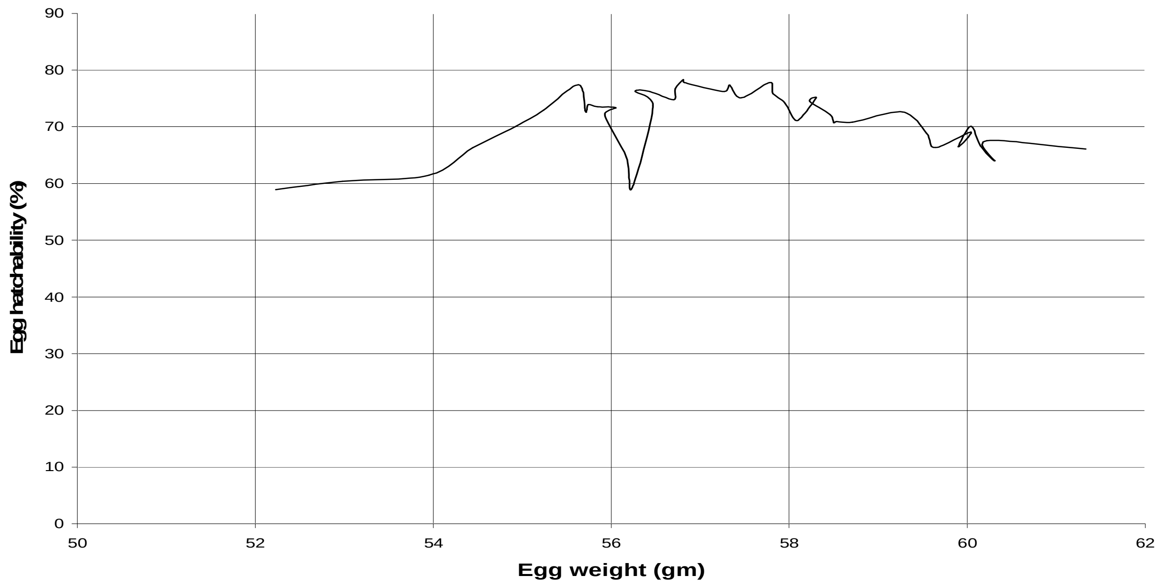


Figure 4.22. Life-time curve of egg weight against hatchability of egg-set in Bovan Nera hens

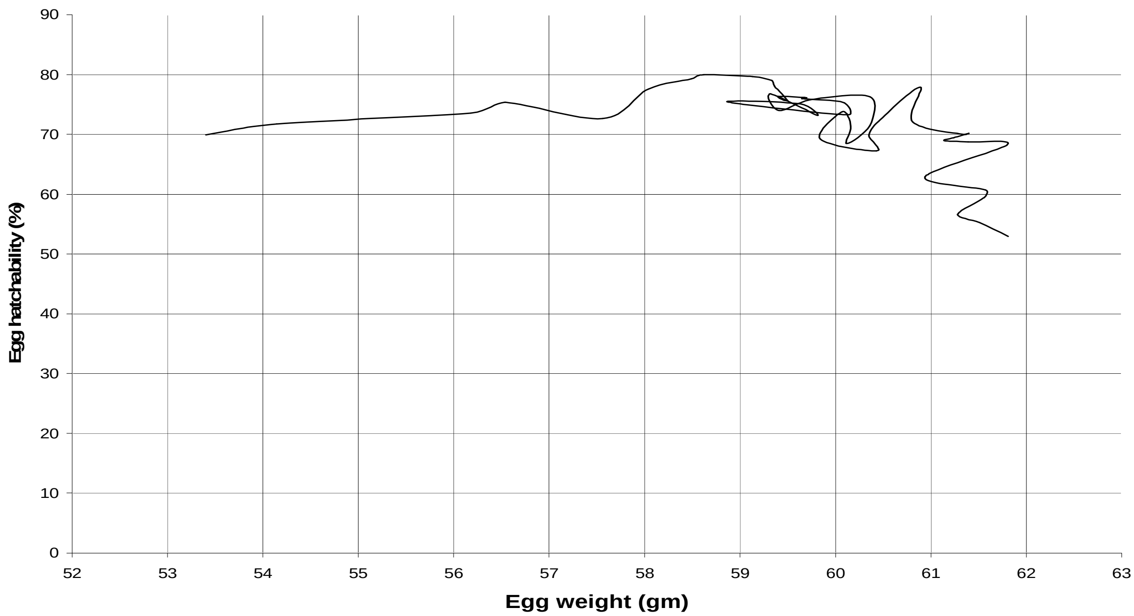


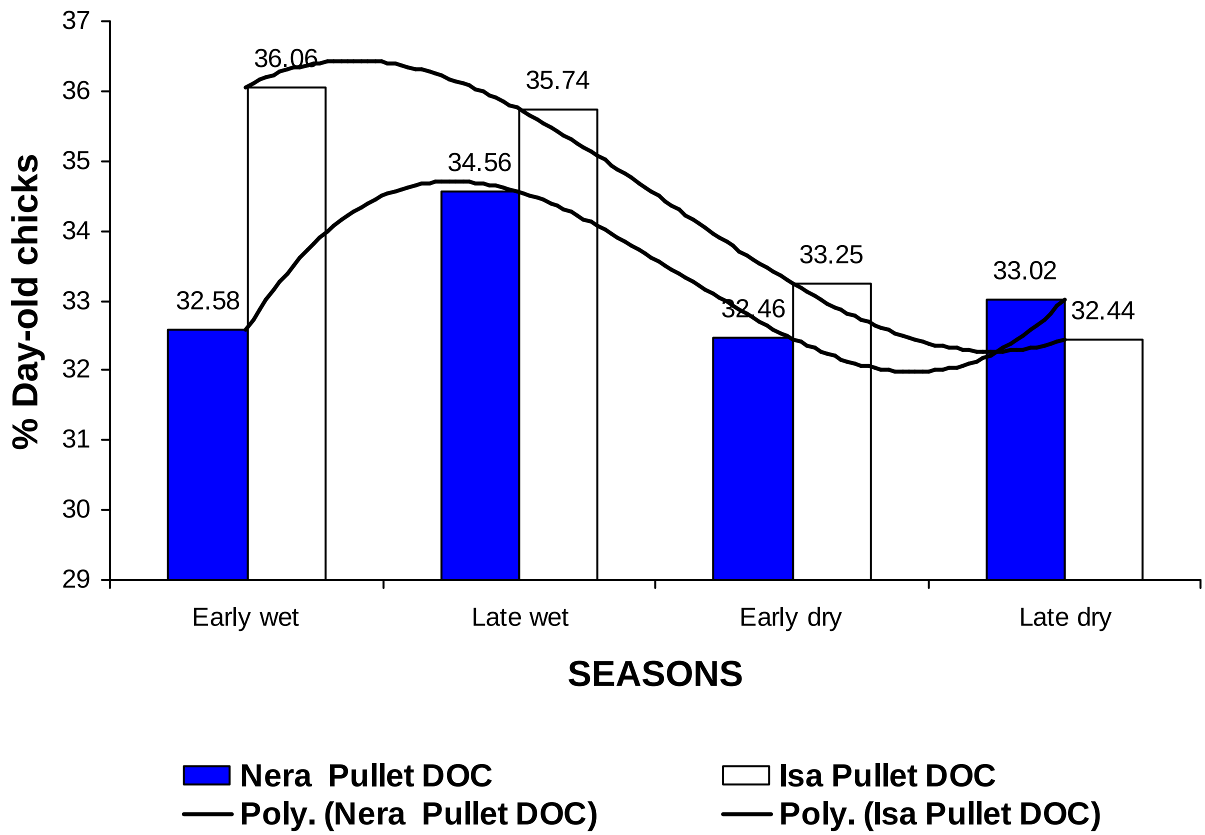
Figure 4.23. Life-time curve of egg weight against hatchability of egg-set in ISA Brown hens

4.14.6 Life-time pullet day-old chicks hatched

There was significant ($P < 0.05$) difference in the pullet day-old chicks hatched in early wet season: 32.58 vs 36.06, between BN and IB hens respectively. No significant ($P > 0.05$) differences were observed between genotypes within other seasons. Between seasons, percent pullet DOC hatched in BN was highest: 34.56 %, in late wet season while that of IB was highest: 36.06 %, in early wet season. Both genotypes exhibited higher hatching percentage in the wet seasons as against the dry seasons. Results also showed that there was progressive decrease: 36.06 – 32.44 %, in the percent pullet day-old chicks obtained from ISA flock as the seasons progressed from early wet to late dry. The percent pullet DOC obtained from BN fluctuated between seasons: as it moved from 32.58% in EW season to 34.56%, then back to 32.46% and up to 33.02% in LD season. Figure 4.24 shows the Pullet day-old chicks hatched in both genotypes classified by season and their interaction.

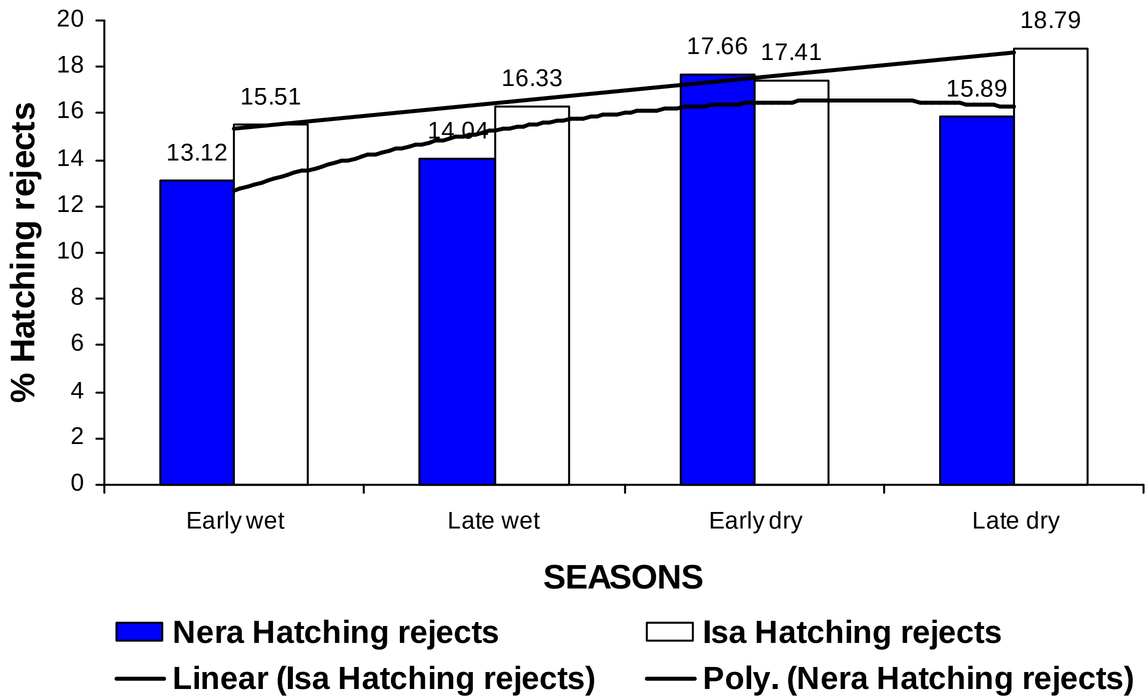
4.14.7 Life-time hatching rejects

Significant ($P < 0.05$) differences were observed in mean hatching rejects generated in the hatchery in early wet: 13.12 vs 15.51 %, late wet: 14.04 vs 16.33 %, and late dry: 15.89 vs 18.79 % seasons for BN and IB respectively in favour of IB. It was also observed that both genotypes generated increasingly higher rejects as the seasons progressed from early wet: 13.12 vs 15.51 %, to late dry: 15.89 vs 18.79 %, in the strains respectively. Figure 4.25 shows the hatching rejects over the life time of breeder hens in both genotypes, and this is similar to the pattern of hatchability in Figure 4.21.



NOTE: Poly. means Polynomial

Figure 4.24. Life-time pullet day-old chicks hatched in Bovan Nera and ISA Brown breeder hens at 25 to 75 weeks of age classified by season



NOTE: Poly. means Polynomial

Figure 4.25. Life-time hatching rejects in Bovan Nera and ISA Brown breeder hens at 25 to 75 weeks of age classified by season

4.15 Influence of genotype on life-time reproductive performance

Table 4.20 shows that there was significant ($P < 0.05$) difference in the mean egg fertility of BN and IB genotypes throughout their life time, while IB also showed higher but not significant ($P > 0.05$) values for percent egg set, egg hatchability, pullet DOC and hatching rejects. Although there was no significant ($P > 0.05$) difference between genotypes in mean hatchability, mean pullet day-old chicks hatched, mean hatching rejects and in mean genotypic performance; ISA Brown hens still produced more (17.02%) rejects than Bovan Nera (15.19%). Table 4.21 shows that while the mean egg fertility of Bovan Nera increased from 82.99 % at full maturity to 83.61% life-time average, the mean egg fertility in ISA Brown decreased from 87.13 % at full maturity to 86.70 % mean life-time value. Figure 4.26 shows the life-time results on mean reproductive performance as classified by genotype.

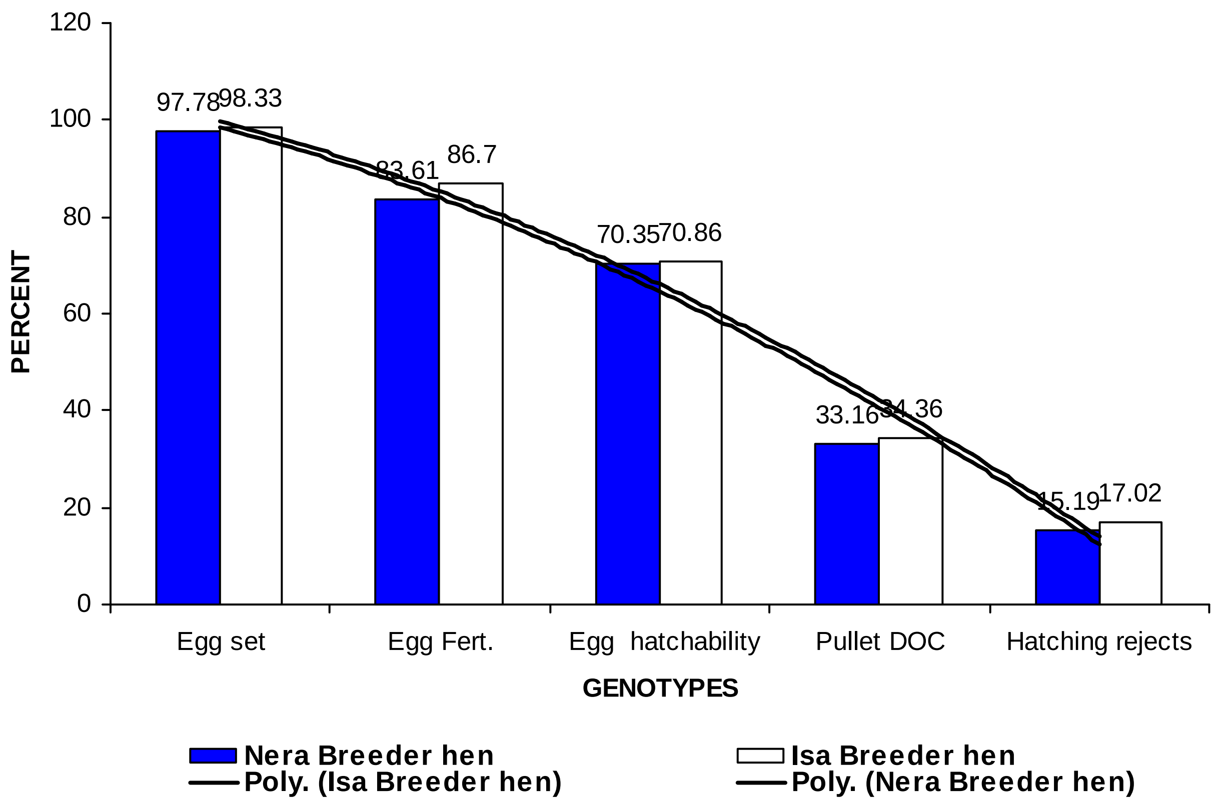
Table 4.20. Influence of genotype on reproductive performance of Bovan Nera and ISA Brown breeder hens at 25 to 75 weeks

Traits	Bovan Nera (n=24)	ISA Brown (n=24)
Egg set (%)	97.78 ± 6.02	98.33 ± 3.85
Egg fertility (%)	83.61 ± 6.02^{b}	86.70 ± 4.90^{a}
Egg hatchability (%)	70.35 ± 4.58	70.86 ± 4.94
Pullet day-old chicks	33.16 ± 4.58	34.36 ± 4.94
Hatching rejects (%)	15.19 ± 15.19	17.02 ± 6.36
Mean performance (%)	**60.02 ± 7.28**	**61.45 ± 4.99**

Table 4.21. Egg fertility in Bovan Nera and ISA Brown at full sexual maturity and mean (25 to 75 week) life-time (n=24)

Season	Genotype	Full maturity	Mean life-time
Early wet	Bovan Nera	83.18 ± 5.40	80.82 ± 5.01[b]
	ISA Brown	93.19 ± 3.67	88.72 ± 2.99[a]
Late wet	Bovan Nera	89.48 ± 2.04	86.23 ± 6.16[b]
	ISA Brown	91.12 ± 1.08	89.45 ± 3.15[a]
Early dry	Bovan Nera	77.99 ± 2.27	82.77 ± 5.86
	ISA Brown	79.80 ± 5.77	84.47 ± 3.09
Late dry	Bovan Nera	91.18 ± 5.31	84.57 ± 5.77
	ISA Brown	86.82 ± 2.65	84.20 ± 6.73
Mean	**Bovan Nera**	**82.99 ± 3.76**	**83.61 ± 6.02[b]**
	ISA Brown	**87.13 ± 3.29**	**86.70 ± 4.90[a]**

NOTE: Means with different superscripts in the same row within same season are significantly ($P < 0.05$) different.



NOTE: Poly. means Polynomial

Figure 4.26. Life-time egg-set, fertility, hatchability of egg-set, pullet day-old chicks and hatching rejects of Bovan Nera and ISA Brown breeder hens at 25 to75 weeks of age

4.16 Phenotypic correlation among reproductive parameters

Tables 4.22 and 4.23 show the correlation matrix for pairs of body, productive and reproductive parameters, in BN and ISA parent stock chickens. These two tables reveal that correlation values (r) between pairs of parameters such as egg weight and egg fertility: 0.326 vs 0.087, egg weight and egg hatchability: 0.216 vs 0.009, egg weight and pullet DOC: 0.221 vs 0.009, and egg weight and hatching rejects: 0.141 vs 0.129, were weak in BN. Similarly, the correlation values between HDP and egg fertility: 0.288 vs 0.385, HDP and egg hatchability: 0.337 vs 0.577, HDP and pullet DOC: 0.369 vs 0.583, and, HDP and hatching rejects: 0.284 vs - 0.660, were comparatively lower in BN than in ISA hens. However, high correlation values were observed between pairs of reproductive parameters of egg fertility and egg hatchability: 0.732 vs 0.691, egg fertility and pullet day-old chicks: 0.724 vs 0.707, egg hatchability and pullet day-old chicks: 0.982 vs 0.968 and, pullet day-old chicks and hatching rejects: - 0.622 vs - 0.792 respectively in both genotypes. Hatching rejects exhibited negative correlation with each of the reproductive parameters but a positive correlation: 0.141 vs 0.129, with egg weight in both genotypes respectively.

Table 4.22. Correlation matrix for body, productive and reproductive parameters of Bovan Nera and ISA Brown breeders.

Genotype		BOVAN NERA			
	Traits	Cock Weight	Hen Weight	Egg Weight	HDP
	Cock weight		0.992**	0.939**	0.626**
	Hen weight	0.986**		0.940**	0.667**
	Egg Weight	0.872**	0.795**		0.669**
ISA	HDP	0.575**	0.561**	0.697**	
BROWN	Egg Set	0.046^{NS}	0.031^{NS}	0.154*	-0.034^{NS}
	Egg Fertility	-0.314**	-0.085^{NS}	0.087^{NS}	0.385**
	Egg Hatchability	-0.457**	-0.33**	-0.009^{NS}	0.577**
	Day-old chicks	-0.494**	-0.374**	-0.04^{NS}	0.583**
	Hatching Rejects	0.586**	0.52**	0.129^{NS}	-0.66**

Note: * P< 0.05; ** P< 0.01; NS = Not significant

Table 4.23. Correlation matrix for body, productive and reproductive parameters of Bovan Nera and ISA Brown breeders

Genotype		Bovan Nera				
	Traits	Egg Set	Egg Fertility	Egg Hatchability	Day old chicks	Hatching Rejects
	Cock weight	0.060^{NS}	0.267**	0.198**	0.197**	0.086^{NS}
	Hen weight	0.059^{NS}	0.241**	0.138*	0.133**	0.186**
	Egg Weight	0.025^{NS}	0.326**	0.216**	0.221**	0.141*
	HDP	0.010^{NS}	0.288**	0.337**	0.369**	0.284**
ISA	Egg Set		0.012^{NS}	0.031^{NS}	0.033^{NS}	-0.031^{NS}
	Egg Fertility	0.039^{NS}		0.732**	0.724**	-0.173**
Brown	Egg Hatchability	0.025^{NS}	0.691**		0.982**	-0.622**
	Day-old chicks	0.013^{NS}	0.707**	0.968**		-0.622**
	Hatching Rejects	-0.089^{NS}	-0.454^{NS}	-0.454^{NS}	-0.792**	

Note: * *P*< 0.05; ** *P*≤0.01; NS = Not Significant

4.17 Predictive models for fertility and hatchability of egg-set

Table 4.24 shows the models for reproduction using the cubic model: $\mathbf{Y = a + b X + c X^2 + d X^3 \pm S.E.}$ Using the above model to fit Age in lay – egg fertility data in which Y= egg fertility (%) and X = age-in-lay from first egg (weeks); the regression of egg fertility on age-in-lay in both genotypes were significant although the R^2 were low: 0.27 and 0.17, for BN and IB respectively. The standard error (S.E.) was lower in ISA; while the cubic and quadratic models obtained for BN and ISA hens respectively were significant. To obtain equations to predict egg hatchability, the egg weight-hatchability data were fitted into the above model to obtain three sets of equations. The first set of equations, Where X_1 = Egg weight at-lay on the farm (gm) and Y = Egg hatchability in the hatchery (%), were cubic models. Regressing hatchability on egg weight produced the poorest coefficients of determination (R^2 = 0.10 and 0.01) but by regressing hatchability on both age-in-lay and egg weight, the equations obtained improved the value of the R^2 to 0.13 and 0.45 for the genotypes. The third set of regression equations relating hatchability with fertility produced the highest R^2 of 0.55 and 0.47 for Bovan and ISA hens respectively.

The quadratic model in Table 4.25 gave high R^2 for the regression of pullet day-old chicks (PDOC) either on egg fertility or egg hatchability. While the regression on fertility produced R^2 of 0.53 and 0.50; the regression on hatchability gave the highest R^2 of 0.97 and 0.94 for BN and IB hens respectively. All equations for hatchability were significant ($p < 0.05$), except the regression of hatchability on egg weight in ISA Brown hens.

Table 4.24: Predictive equations for fertility and hatchability of eggs set for Bovan Nera and ISA Brown breeder hens

Model $Y = a + bX + cX^2 + dX^3 \pm$ S. E.

Trait	Genotype	Equation	S.E.	R^2	Model Sig. (*p*)
Fertility on egg set	Nera	$y = -11.29 + 5.60X - 0.10X^2 + 0.0006X^3$	15.23	0.268	0.0001
	ISA	$y = 78.33 + 0.50X - 0.006X^2$	4.47	0.170	0.0001
Hatchability On egg set	Nera	$y = -402.62 + 12.19X_1 – 0.001X_1^{3}$	8.18	0.102	0.0001
	ISA	$y = 58.33 + 0.34X_1 – 0.0004X_1^{3}$	9.37	0.01	>0.05
	Nera	$y = -43.68 – 0.35X + 2.29X_1$	20.70	0.129	0.0001
	ISA	$y = -19.99 – 0.54X + 1.97X_1$	14.10	0.445	0.0001
	Nera	$y = 164.84 – 3.46F + 0.03F^2$	50.61	0.548	0.0001
	ISA	$y = -111.13 + 2.96F – 0.01F^2$	80.63	0.474	0.0001

X= Age-in-lay from first-egg (weeks); X_1 = Egg weight at-lay on the farm (gm); F= Egg fertility on eggs set (%)

Table 4.25: Predictive equations for pullet day-old chicks hatched by Bovan Nera and ISA Brown breeder hens

Model		$Y = a + bX + cX^2 \pm S.E.$			
Trait	Genotype	Equation	S. E.	R^2	Model Sig.
PDOC	Nera	$y = 79.56 - 1.73F + 0.01F^2$	26.85	0.531	0.0001
	ISA	$y = -87.64 + 2.17F + 0.009F^2$	42.12	0.501	0.0001
	Nera	$y = -2.68 + 0.51H + 0.00004H^2$	1.72	0.969	0.0001
	ISA	$y = -4.96 + 0.61H - 0.0007H^2$	2.44	0.938	0.0001

F = Fertility on eggs set (%); H = Hatchability on eggs set (%); PDOC (y) = Saleable pullet day-old chicks hatched (%)

4.18 Genotype by season interaction

The result of factorial ANOVA indicated no significant ($P > 0.05$) interaction between genotypes and seasons among traits at full sexual maturity. However significant ($P < 0.05$) interaction was observed in early maturity weight, life-time mean cock weight and egg production (HDP) persistency in breeder hens. Therefore at early maturity period, BN possessed higher cock weight: 1566.60 gm, in late dry season while IB gave higher weight of 2008.00 gm in early dry season. Bovan Nera exhibited higher mean cock weight: 2451.72 gm, in late dry season; ISA Brown cock indicated higher weight: 2543.66 gm, in early dry season as observed on Table 4.26. Table 4.27 shows the effect of interaction in HDP persistency on the reproductive parameters of the breeder hens in both genotypes. In egg production persistency, BN hens recorded longer period of 42 weeks of stable production at ≥70 % in late wet season while persistency of HDP was 43 weeks in ISA at early dry season, thus BN performed better in late wet while ISA hens performed better in early dry season (Table 4.27). It was also observed on Table 4.21 that while there was a decline in Bovan Nera egg fertility; there was a corresponding increase in ISA Brown's fertility of incubated eggs from 89.48 and 79.80 % at full maturity to 86.23 and 84.47 % at 25 – 75 weeks life-time average respectively.

There was also a reversal in the order of ranking of the two genotypes in hatchability between seasons in which egg hatchability was superior in ISA hen in the wet seasons as against the dry seasons in BN hens, as seen in Figure 4.21. Table 4.28 also shows the effect of interaction in mean egg hatchability on the performance of both genotypes. This indicated that BN performed better in the dry seasons while IB did better in the wet seasons: 69.61 vs 73.74 %. This also caused significant ($P < 0.05$) difference in the mean pullet DOC hatched between genotypes as BN recorded the lower value of 32.74 % in the dry seasons while IB hens recorded the higher value of 35.90 % in the wet seasons.

Table 4.26. Effect of Interaction in cock weight on Bovan Nera and ISA Brown (75-week) performance and order of merit

Traits	Bovan Nera	ISA Brown
Best season	Late dry	Early dry
Early maturity weight (gm)	1566.60 ± 60.55	2008.0 ± 07.00
Full maturity weight (gm)	2387.00 ± 60.58	2393.83 ± 34.98
Mean Cock weight (gm)	2451.72 ± 439.73	2543.66 ± 391.2
Mean egg fertility (%)	84.57 ± 5.77	84.47 ± 3.09
Mean egg hatchability (%)	70.36 ± 11.86	68.32 ± 7.19
Mean DOC (%)	33.02 ± 6.33	33.25 ± 3.80

Table 4.27. Effect of Interaction in HDP (≥ 70%) Persistency on Bovan Nera and ISA Brown (25 to75 week) performance and order of merit.

Traits	Bovan Nera	ISA Brown
Best Season	Late wet	Early Dry
Persistency (weeks)	42	43
Age @ early maturity (days)	124 ± 8	123 ± 5
Age @ full maturity (days)	217 ± 35	209 ± 23
HDP @ full maturity (%)	85.55 ± 1.20	90.26 ± 2.31
Mean HDP (%)	65.57 ± 21.82	72.92 ± 18.71
Egg weight @ full maturity (gm)	55.98 ± 1.20	56.81 ± 5.51
Mean egg weight (gm)	56.68 ± 4.72	58.12 ± 5.18
Egg fertility @ full maturity (%)	89.48 ± 2.04	79.8 ± 5.77
Mean Egg fertility (%)	86.23 ± 6.16	84.47 ± 3.09
Egg hatchability @ full maturity (%)	77.36 ± 3.69	72.99 ± 1.21
Mean egg hatchability (%)	73.12 ± 8.12	68.32 ± 7.19
DOC @ full maturity (%)	36.94 ± 1.71	35.99 ± 0.70
Mean DOC (%)	34.56 ± 4.40	33.25 ± 3.80
Hen weight @ early maturity (gm)	1494.1 ± 27.41	1339 ± 7.0
Hen weight @ full maturity (gm)	1922.81 ± 28.16	1679.92 ± 43.05
Mean hen weight (gm)	1677.74 ± 608.74	1497.56 ± 543.67

Table 4.28. Effect of Interaction in egg hatchability on Bovan Nera and ISA Brown (25 to 75 week) performance and merit order.

Traits	Bovan Nera	ISA Brown
Best Seasons	DRY (Early and Late)	WET (Early and Late)
Hatchability @ full maturity	71.4 ± 4.37	82.33 ± 2.26
Mean Hatchability	69.61 ± 9.54	73.74 ± 6.36
Mean egg set	97.64 ± 6.85	98.21 ± 4.06
Mean egg fertility	83.67 ± 5.82	89.09 ± 3.07
Mean Pullet DOC	32.74 ± 4.95[b]	35.90 ± 3.34[a]
Mean hatching rejects	16.78 ± 7.70	15.92 ± 5.22
Mean egg weight	56.67 ± 4.68	58.98 ± 5.00
Mean HDP	62.29 ± 21.15	68.06 ± 22.53
Mean hen weight	1796.11 ± 451.73	1593.80 ± 544.59
Mean cock weight	2283.41 ± 646.99	2167.39 ± 841.18

4.19.0 Genotype sensitivity

The seasonal sensitivity of a genotype will be the regression of the genotype's phenotypic values on the phenotypic mean values of all genotypes, for all seasons, in the environment (Falconer and Mackay, 1996). In a typical response equation: $Y = a + b X$; the value of b will be the sensitivity of the genotype for the trait of interest.

4.19.1 Within-season sensitivity

Table 4.29 indicates the sensitivity indices of body, productive and reproductive traits within-season for BN and ISA hens in Ibadan, Nigeria. T-test showed no significant differences ($P > 0.05$) between genotypic values within-season, in body weights and productive traits, but significant differences ($p < 0.05$) were observed between sensitivity values of BN and ISA breeder hens in reproductive traits. In egg fertility, egg hatchability and PDOC, the lowest sensitivities in BN and ISA were 0.90, 0.86, 0.85 and 0.54, 0.62, 0.63 while the highest sensitivity were 1.46, 1.38, 1.37 and 1.10, 1.14, 1.15 respectively. These lowest values were observed in LD, EW, EW and LW, LW, LW while the highest values were recorded in LW, LW, LW and LD, EW, EW seasons respectively as seen on Table 4.30. within season, the genotype with the lower sensitivity values recorded the higher values respectively in ¾ of all cases.

Within genotype, the relationship between hen weight and all other productive and reproductive traits was studied, an inverse relationship was observed. That is, as the sensitivity for body weight increased, the sensitivity for each of the other traits namely: HDP, Egg weight, Egg fertility, Egg hatchability and Pullet day-old chicks decreased. This is of the form:

Hen weight = 1/ HDP, Egg weight, Egg hatchability and PDOC.

It was also revealed through graphical analysis that a direct and proportional linear relationship was demonstrated between hen weight sensitivity and egg fertility sensitivity indices in both genotypes. In LW season, the sensitivity of the reproductive traits in BN hens were higher than that of her body weight and also higher than that of counterpart reproductive traits in ISA Brown hens.

4.19.2 Between-seasons sensitivity

Table 4.31 shows the effect of seasons on the sensitivity of body, productive and reproductive traits of Bovan Nera and ISA Brown breeder hens, while Table 4.32 shows the seasonal sensitivities classified by traits, seasons and magnitude, showing the highest and lowest sensitivities respectively. No significant differences (P > 0.05) were observed between seasons within genotype but significant differences (P < 0.05) were observed between genotypes within season in egg hatchability and pullet day-old chicks sensitivities in Early dry season.Figures 4.27 and 4.29 show the plots of seasonal sensitivities for cock weight and hen weight for Bovan Nera and ISA Brown respectively, obtained from the seasonal sensitivity regression lines in Figures 4.28 and 4.30 respectively.

In cock weight, Bovan Nera recorded the higher indices in Early wet, Late wet and Early dry seasons while ISA Brown was higher in Late dry season. The highest indices: 1.48 and 1.22 for Bovan Nera and ISA Brown respectively and the largest difference between indices: 0.26 were observed in Early dry season in favour of Bovan Nera as observed in Figure 4.27. It also shows interaction between season and genotype in cock weight. In hen weight, Bovan Nera exhibited higher sensitivity indices in all four seasons. Figure 4.29 shows no interaction between season and genotype in hen weight, but indicates that the largest difference of 0.38 in sensitivity was observed between Bovan Nera and ISA Brown in Early wet season, in favour of Bovan Nera.

In productive traits, hen-day production and egg weight, seasonal sensitivity results show that there was interaction between genotype and season as observed in Figures 4.31 and 4.33. In HDP, Bovan Nera hens showed superiority in Early wet and Late dry seasons while ISA Brown demonstrated higer values in Late wet and Early dry seasons. The largest difference in sensitivity: 0.034, in favour of Bovan Nera hen was recorded in Late dry season. In egg weight, interaction was also observed between genotype and season. The differences between both genotypes in egg weight sensitivity were distinct in Early wet and Late wet seasons in favour of ISA Brown and Bovan Nera respectively. The largest difference in sensitivity of 0.10 was observed in the Late wet season in favour of Bovan Nera.

In reproductive traits, interaction was implicated between genotype and season in egg fertility and egg hatchability, but not in pullet day-old chicks as in Figures 4.35, 4.37 and 4.39. In egg fertility, Nera hen was superior in sensitivity in Early wet, Late wet and Late dry while ISA hen was higher in Early dry season with the highest difference being obtained as 0.57 in Late wet season in favour of Nera. In egg hatchability also, Nera recorded higher sensitivity values only in Late wet while ISA hens had the upper values in Early wet, Early dry and Late dry respectively. The largest difference in sensitivity between both genotypes: 0.76, was obtained in favour of ISA hen in Early dry season. In pullet day-old chicks, sensitivity indices were higher in ISA Brown hens in all four seasons thus eliminating the occurrence of interaction between genotype and season. As in egg hatchability, Early dry season produced the largest difference of 1.40 between Bovan Nera and ISA Brown genotypes in favour of the later. Between-seasons and between-genotypes, an inverse relationship was observed between hen body weight sensitivity and that of each of the sensitivities of Hen-day production, Egg weight, Fertility of Egg-set, Hatchability of Egg-set and Pullet day-old chicks.

Table 4.29. Within-season relative sensitivity of Bovan Nera and ISA Brown genotypes classified by traits.

Parameters	Genotype	E-Wet	L-Wet	E-Dry	L-Dry
Cock body	Nera	1.00	1.02	1.16	0.97
Weight	ISA	0.99	0.98	0.84	1.03
Hen body	Nera	1.05	1.03	1.06	1.01
Weight	ISA	0.95	0.97	0.94	0.99
HDP	Nera	0.99	1.03	1.02	0.98
	ISA	1.01	0.97	0.98	1.02
Egg	Nera	0.96	1.11	1.04	0.98
Weight	ISA	1.04	0.89	0.96	1.02
Fertility of	Nera	1.40^{a}	1.46^{a}	1.36^{a}	0.90
Eggs set	ISA	0.60^{b}	0.54^{b}	0.64^{b}	1.10
Hatchability	Nera	0.86^{b}	1.38^{a}	0.97	0.91
Of Eggs set	ISA	1.14^{a}	0.62^{b}	1.03	1.09
Pullet	Nera	0.85^{b}	1.37^{a}	0.92	0.91
DOCs	ISA	1.15^{a}	0.63^{b}	1.08	1.09

NOTE: Values along the same row with different superscripts are significantly ($P < 0.05$) different

Table 4.30. Within-season sensitivity for traits classified by genotype, season and magnitude

	Season and Highest sensitivity		Season and Lowest sensitivity	
PARAMETERS	**BOVAN NERA**	**ISA BROWN**	**Bovan Nera**	**ISA Brown**
Cock weight	ED / 1.16	LD / 1.03	EW/1.00	ED/0.84
Hen weight	ED / 1.06	LD/ 0.99	LD/1.01	ED/0.94
HDP	LW / 1.03	LD / 1.02	LD/0.98	LW/0.97
Egg weight	LW / 1.11	EW / 1.04	EW/0.96	LW/0.89
Egg fertility	LW / 1.46	LD / 1.10	LD/0.90	LW/0.54
Egg hatchability	LW / 1.38	EW / 1.14	EW/0.86	LW/0.62
Day old Chicks	LW / 1.37	EW / 1.15	EW/0.85	LW/0.63

Table 4.31. Influence of season on the relative sensitivity of Bovan Nera and ISA Brown genotypes classified by traits.

Parameters	Genotype	E-Wet	L-Wet	E-Dry	L-Dry
Cock body	Nera	0.938	1.054	1.478	1.118
Weight	ISA	0.798	0.908	1.218	1.185
Hen body	Nera	0.995	1.058	1.211	1.103
Weight	ISA	0.617	0.894	1.036	1.082
HDP	Nera	0.980	1.006	0.986	1.026
	ISA	0.975	1.037	0.994	0.992
Egg	Nera	1.436	1.946	1.933	0.931
Weight	ISA	1.511	1.849	1.930	0.971
Fertility of	Nera	2.629	3.285	2.627	1.665
Egg-set	ISA	2.371	2.714	2.634	1.242
Hatchability	Nera	1.083	1.314	0.839^{b}	1.589
Of Egg-set	ISA	1.528	1.091	1.596^{a}	1.835
Pullet	Nera	1.028	0.906	0.156^{b}	1.613
DOCs	ISA	1.414	0.969	1.560^{a}	1.925

NOTE:Values with different superscripts along the same rows are significantly (P<0.05) different.

Table 4.32. Between-Season sensitivity for traits classified by genotype, season and magnitude

	Season and Highest sensitivity		Season and Lowest sensitivity	
PARAMETERS	**BOVAN NERA**	**ISA BROWN**	**Bovan Nera**	**ISA Brown**
Cock weight	ED/1.478	ED/1.218	EW/0.938	EW/0.798
Hen weight	ED/1.211	LD/1.082	EW/0.995	EW/0.617
HDP	LD/1.026	LW/1.037	EW/0.980	EW/0.975
Egg weight	LW/1.946	EW/1.930	LD/0.931	LD/0.971
Egg fertility	LW/3.285	LW/2.714	LD/1.665	LD/1.242
Egg hatchability	LD/1.589	LD/1.835	ED/0.839	LW/1.091
Day old Chicks	LD/1.613	LD/1.925	LW/0.160	LW/0.969

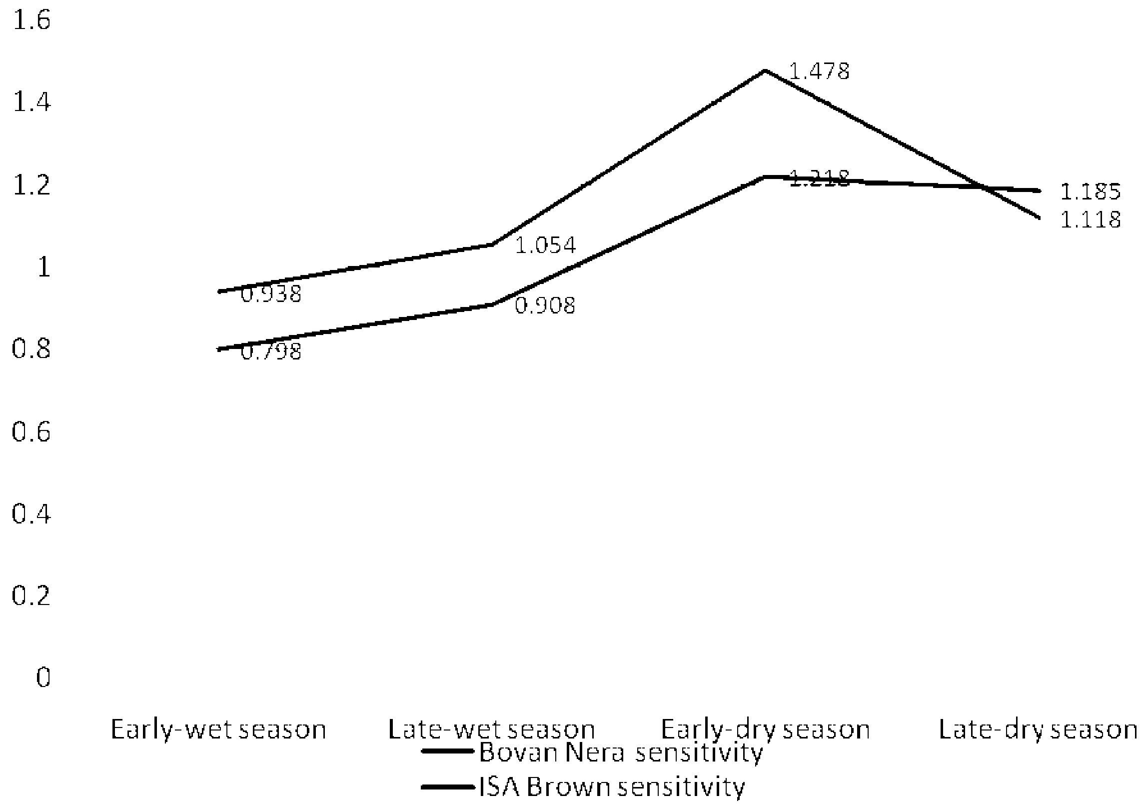


Figure 4.27: Seasonal sensitivity trends for cock body weight for Bovan Nera and ISA Brown genotypes in Ibadan Nigeria.

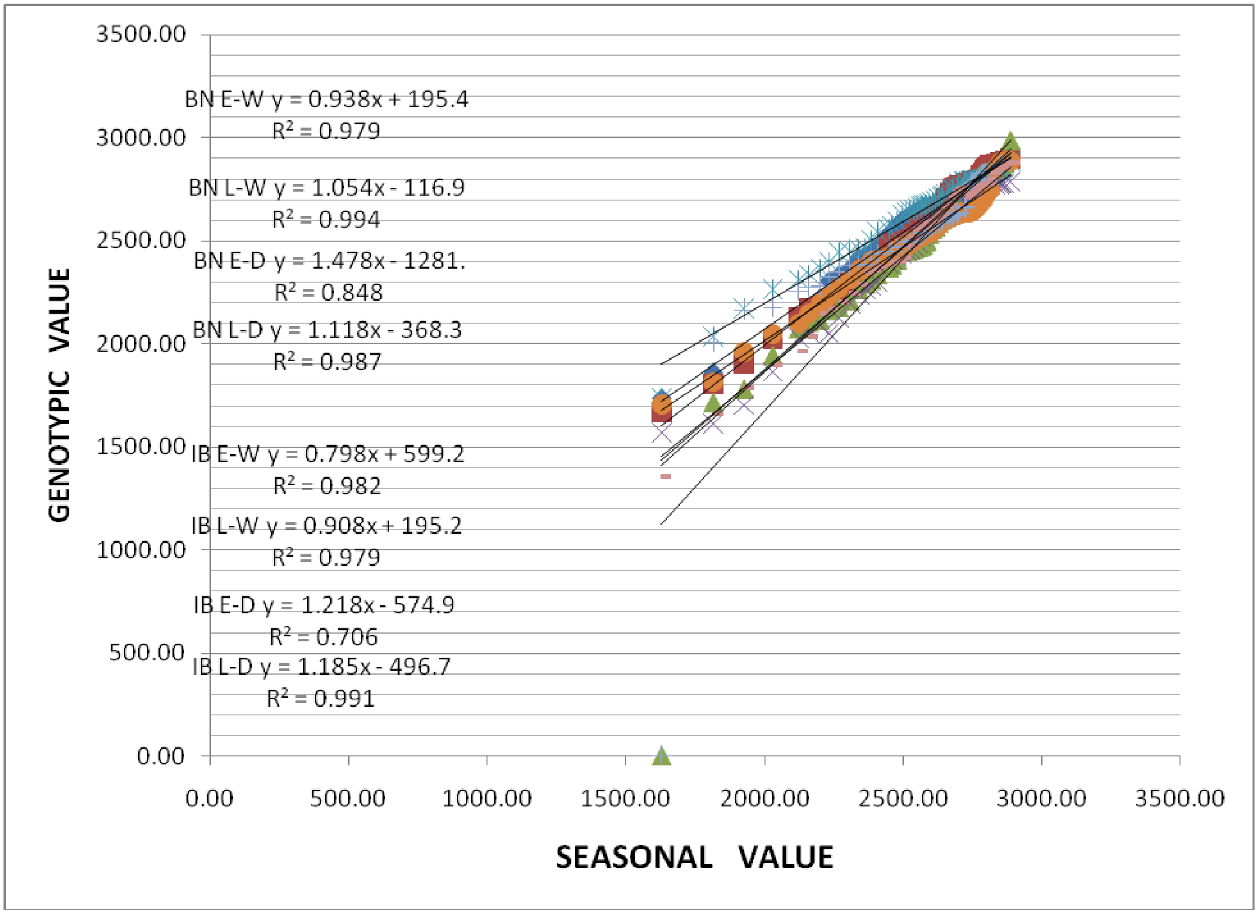


Figure 4.28: Seasonal sensitivity regression lines for cock body weight for Bovan Nera and ISA Brown genotypes showing respective sensitivity indices in Ibadan Nigeria.

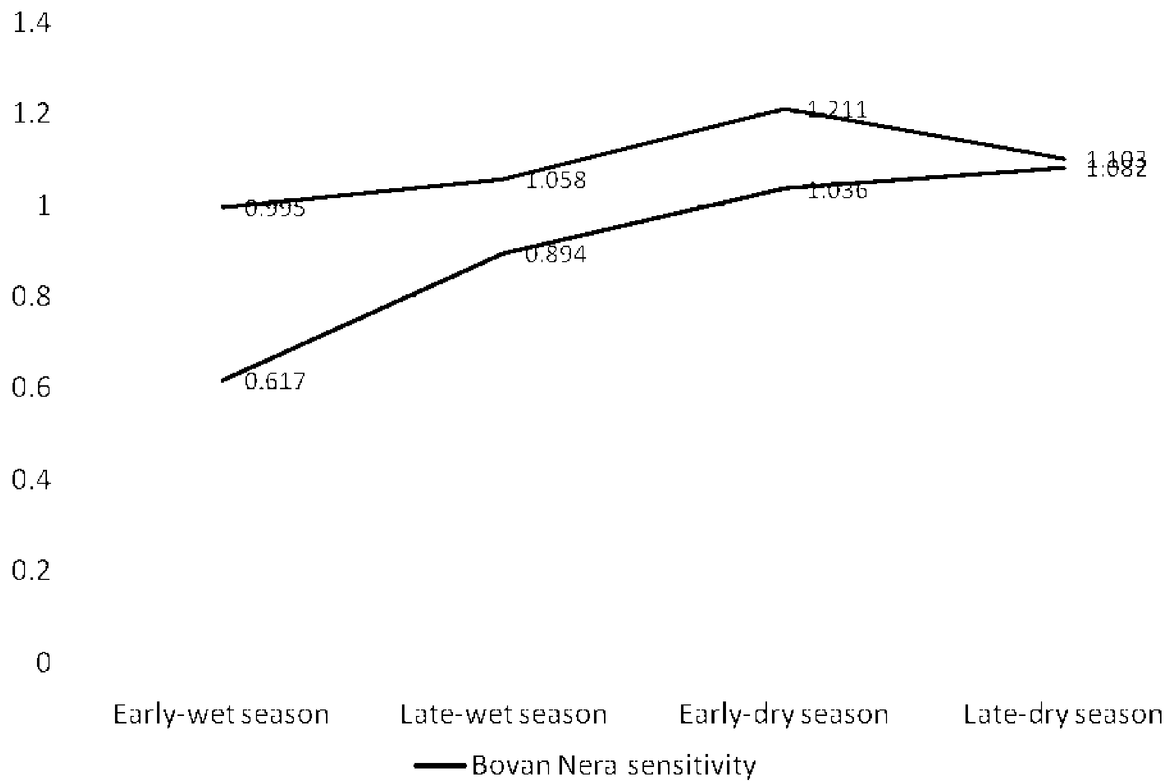


Figure 4.29: Seasonal sensitivity trends for hen body weight for Bovan Nera and ISA Brown genotypes in Ibadan Nigeria.

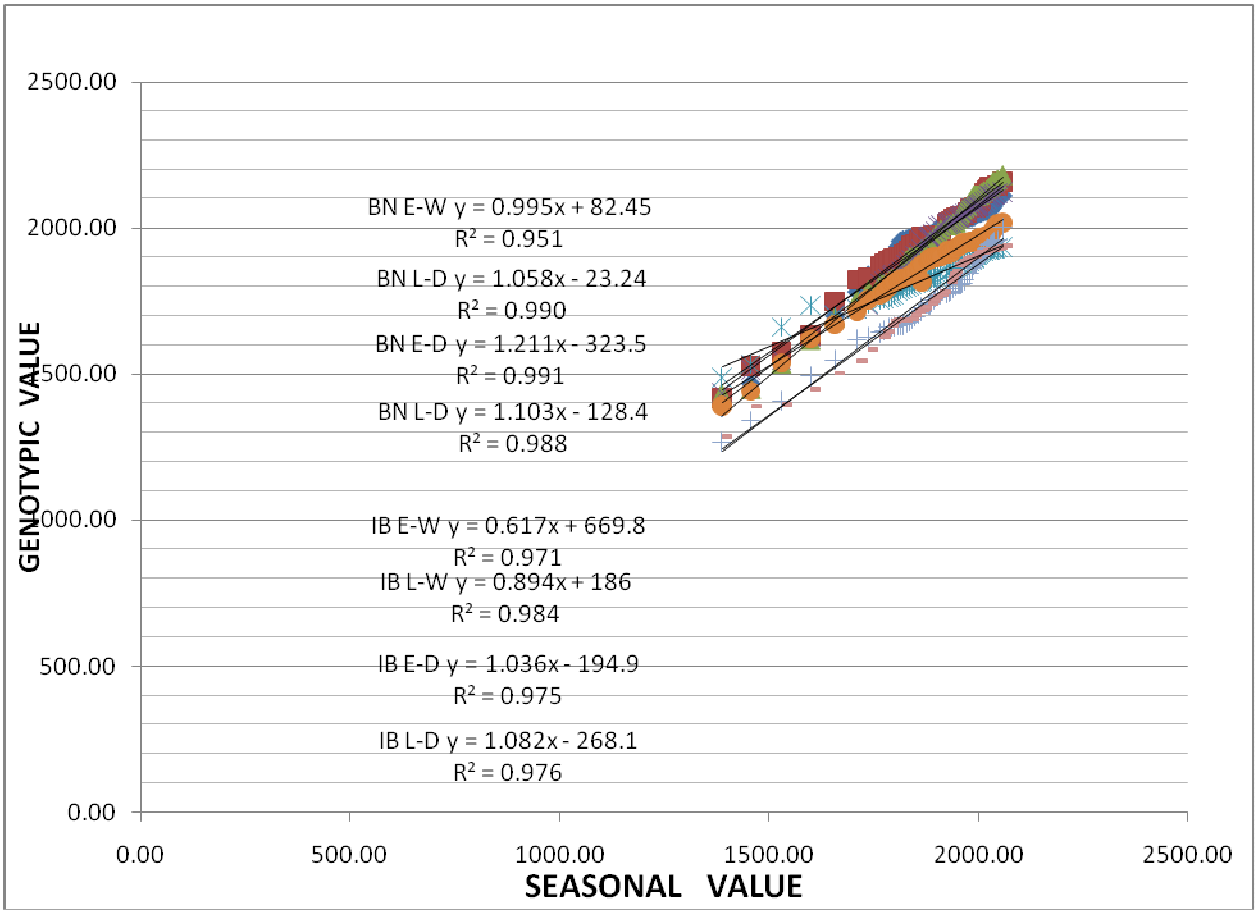


Figure 4.30: Seasonal sensitivity regression lines for hen body weight for Bovan Nera and ISA Brown genotypes showing respective sensitivity indices in Ibadan Nigeria.

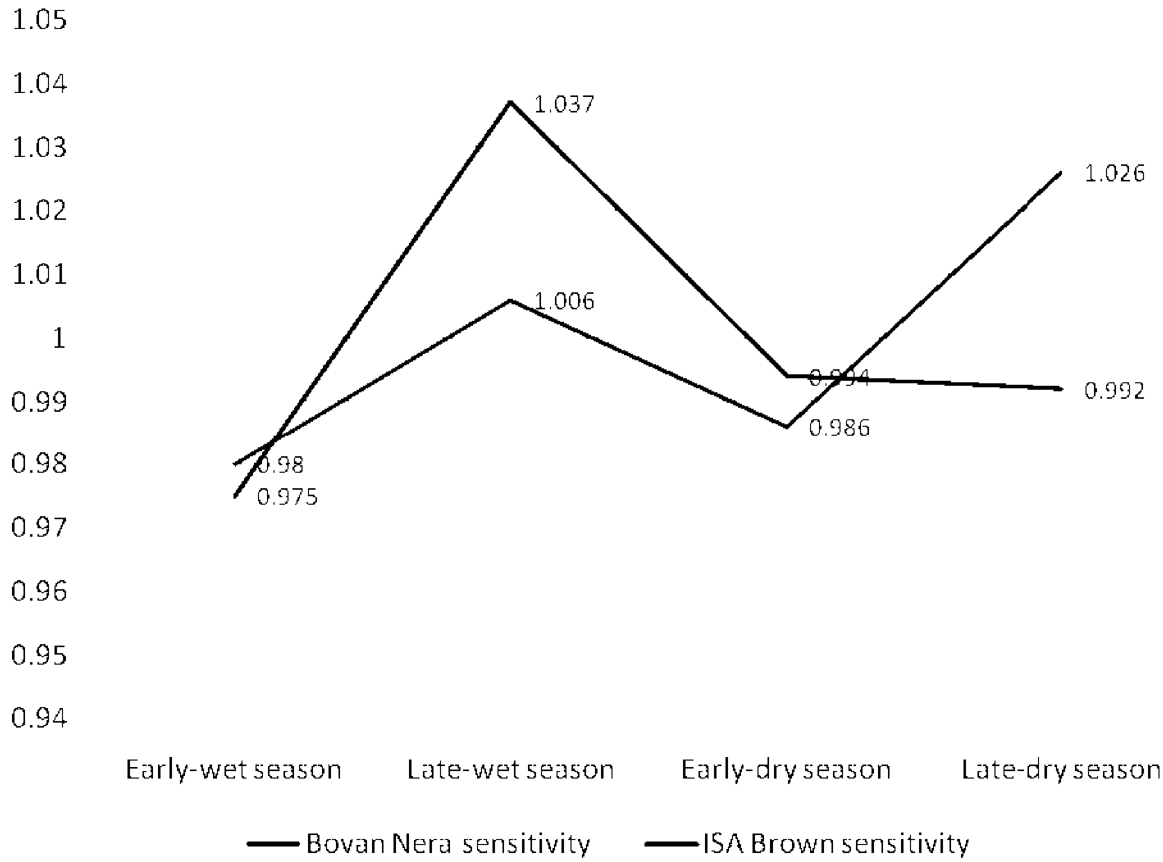


Figure 4.31: Seasonal sensitivity trends for hen-day production hatched for Bovan Nera and ISA Brown genotypes in Ibadan Nigeria.

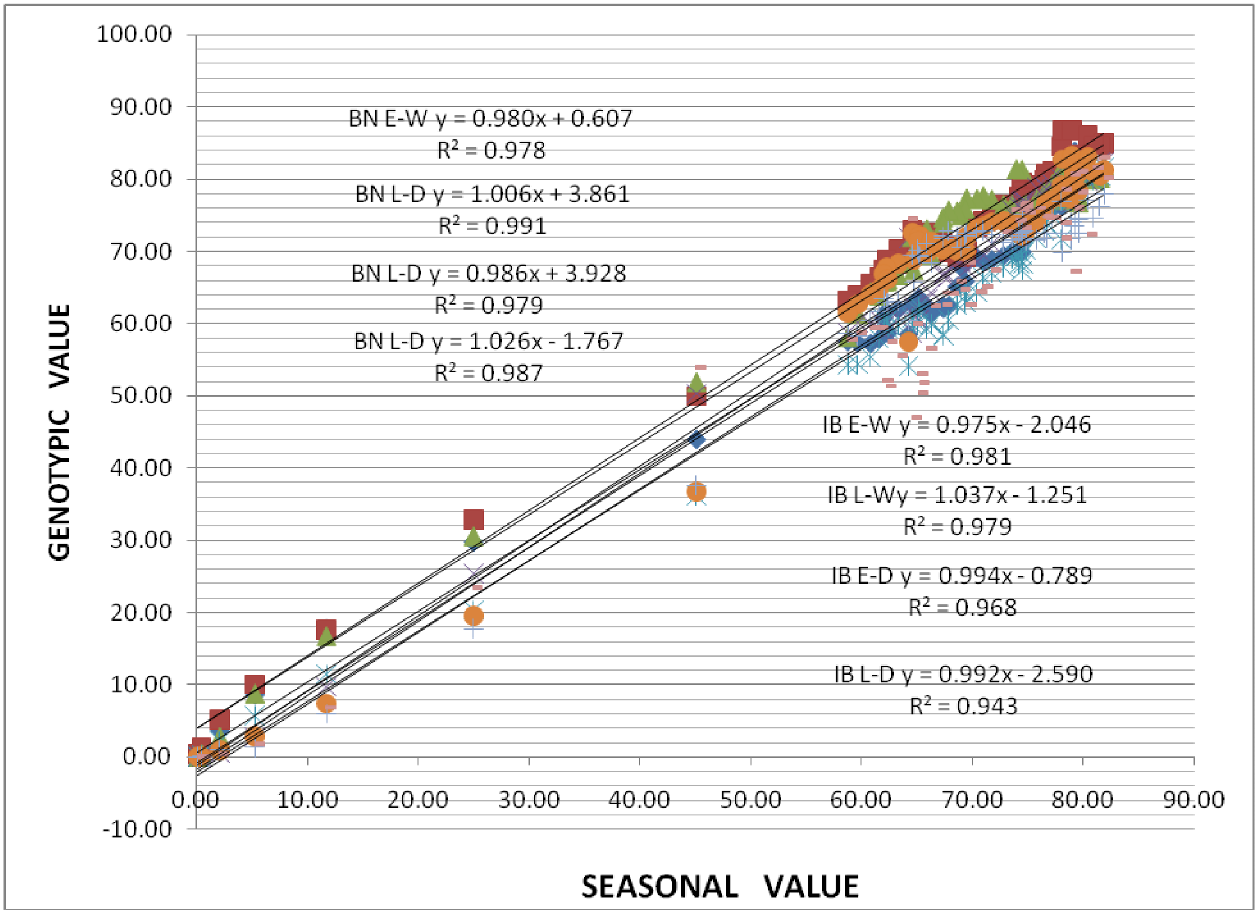


Figure 4.32: Seasonal sensitivity regression lines for hen-day production for Bovan Nera and ISA Brown genotypes showing respective sensitivity indices in Ibadan Nigeria.

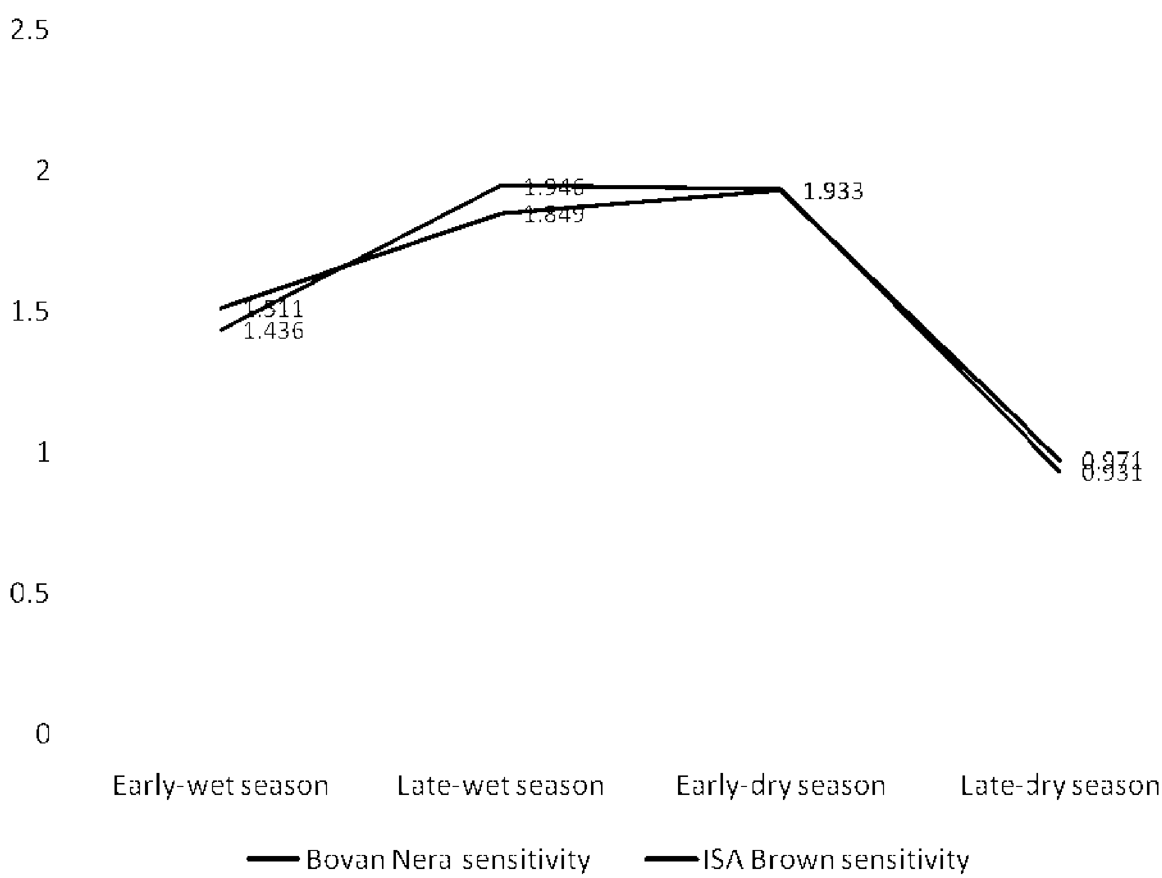


Figure 4.33: Seasonal sensitivity trends for egg weight for Bovan Nera and ISA Brown genotypes in Ibadan Nigeria.

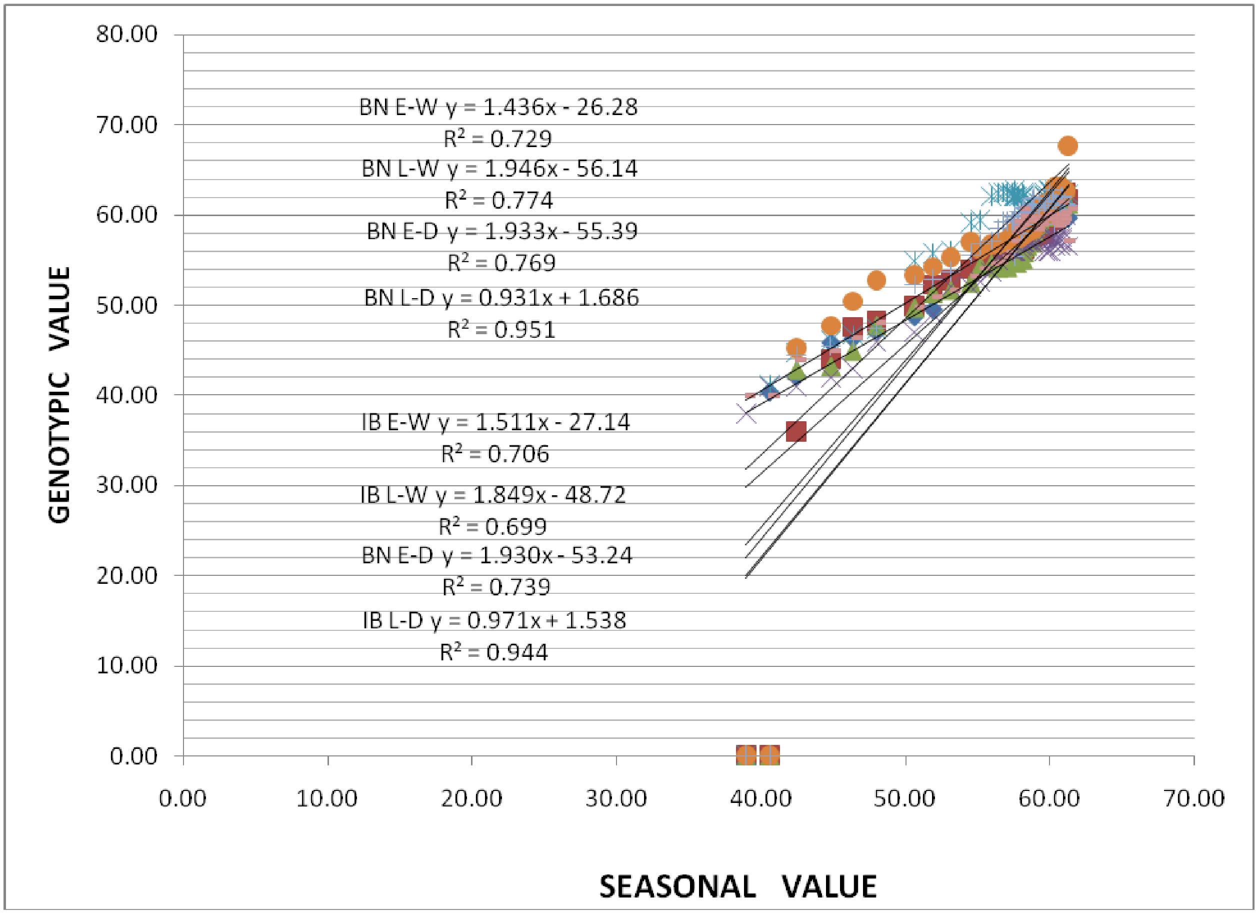


Figure 4.34: Seasonal sensitivity regression lines for egg weight for Bovan Nera and ISA Brown genotypes showing respective sensitivity indices in Ibadan Nigeria.

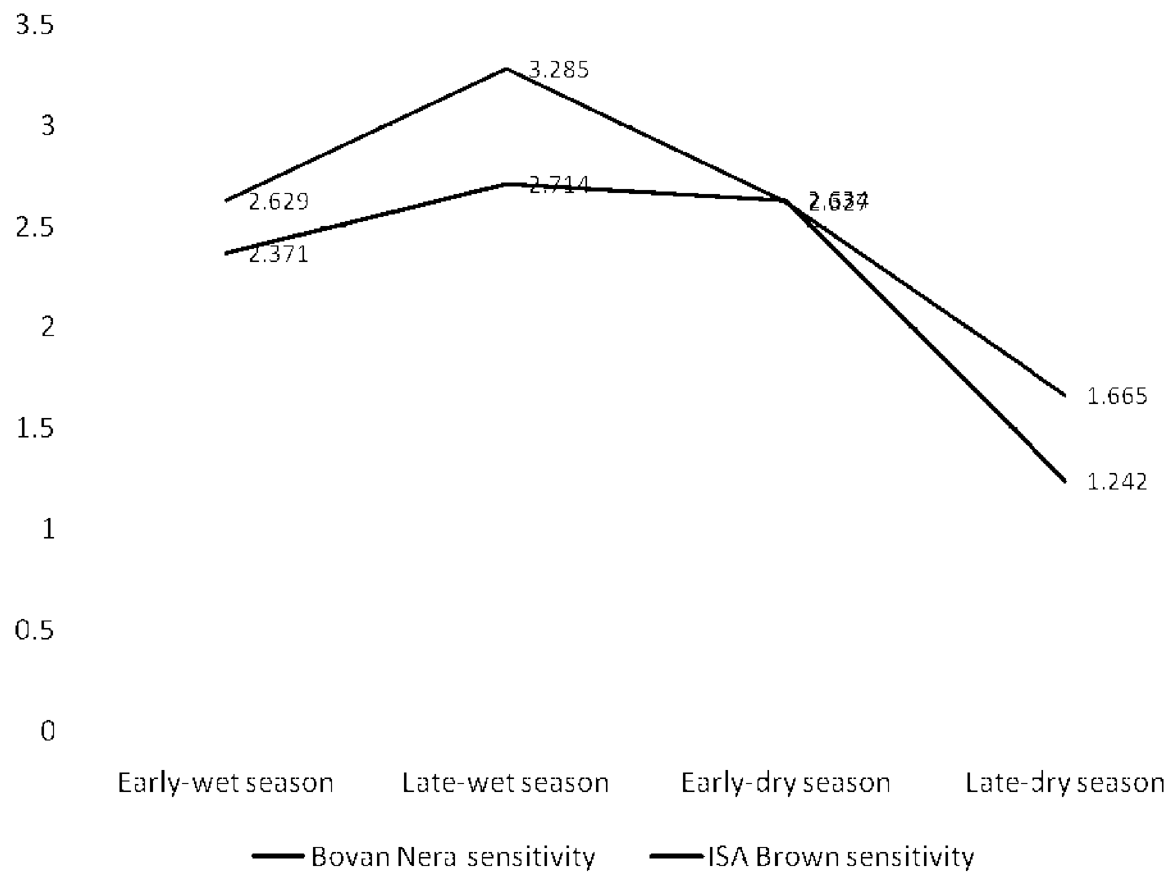


Figure 4.35: Seasonal sensitivity trends for fertility of eggs set for Bovan Nera and ISA Brown genotypes in Ibadan Nigeria.

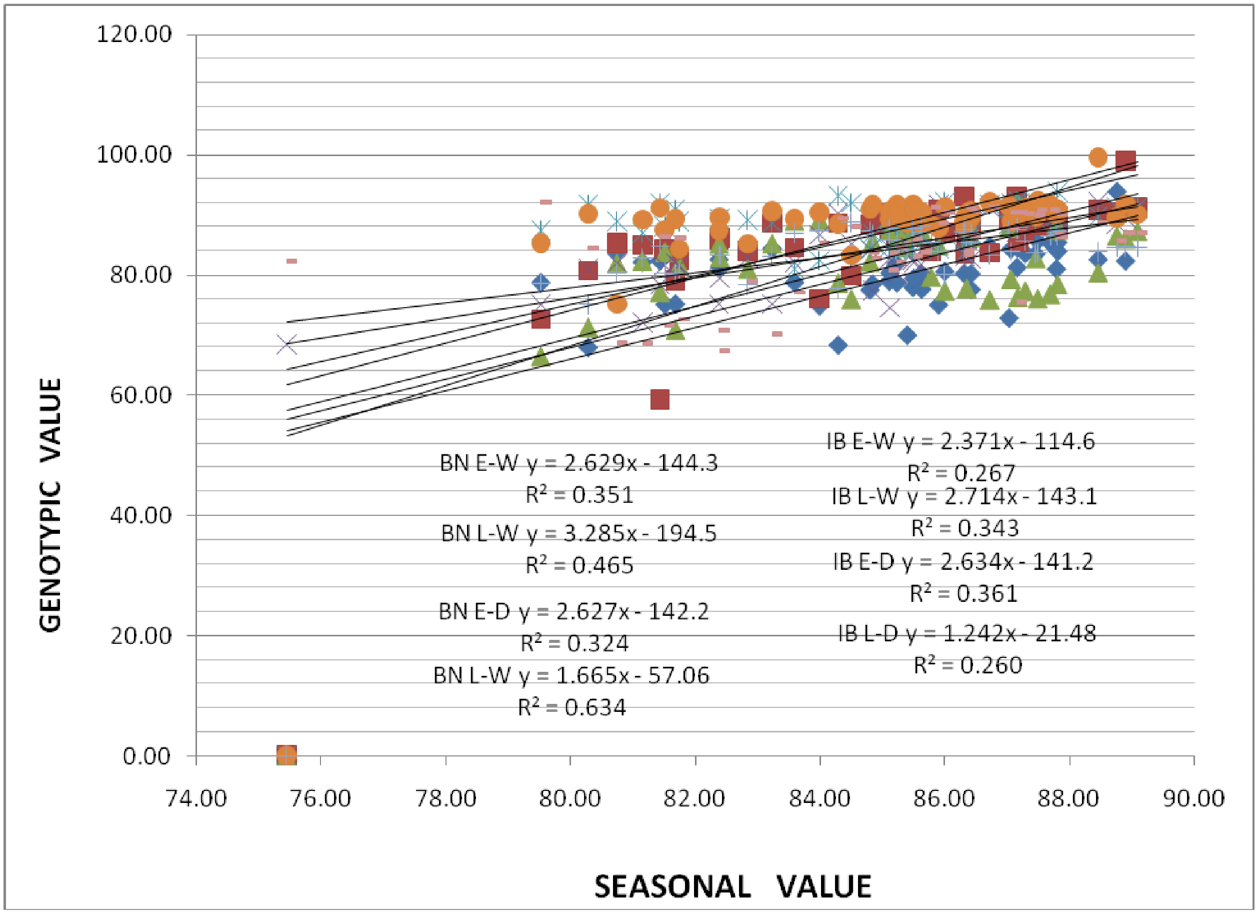


Figure 4.36: Seasonal sensitivity regression lines for fertility of eggs set for Bovan Nera and ISA Brown genotypes showing respective sensitivity indices in Ibadan Nigeria.

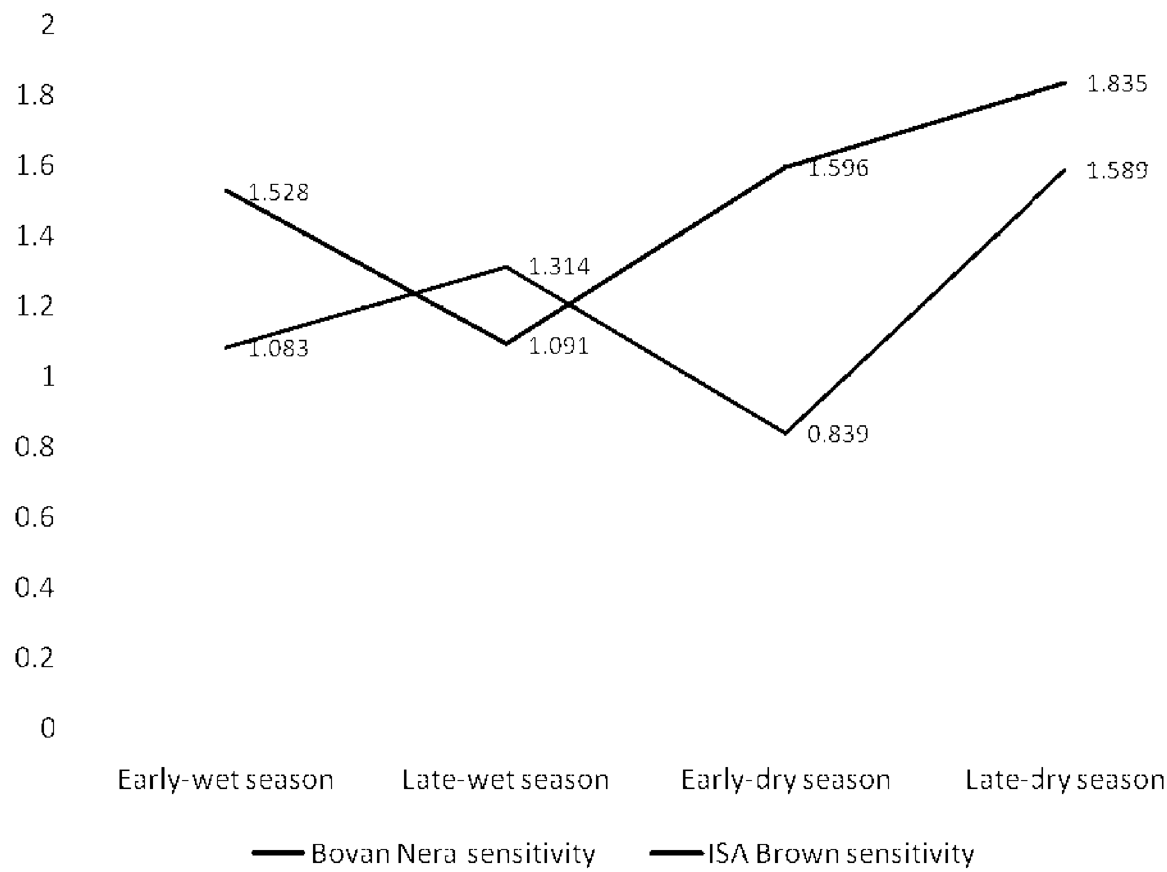


Figure 4.37: Seasonal sensitivity trends for hatchability of eggs set for Bovan Nera and ISA Brown genotypes in Ibadan Nigeria.

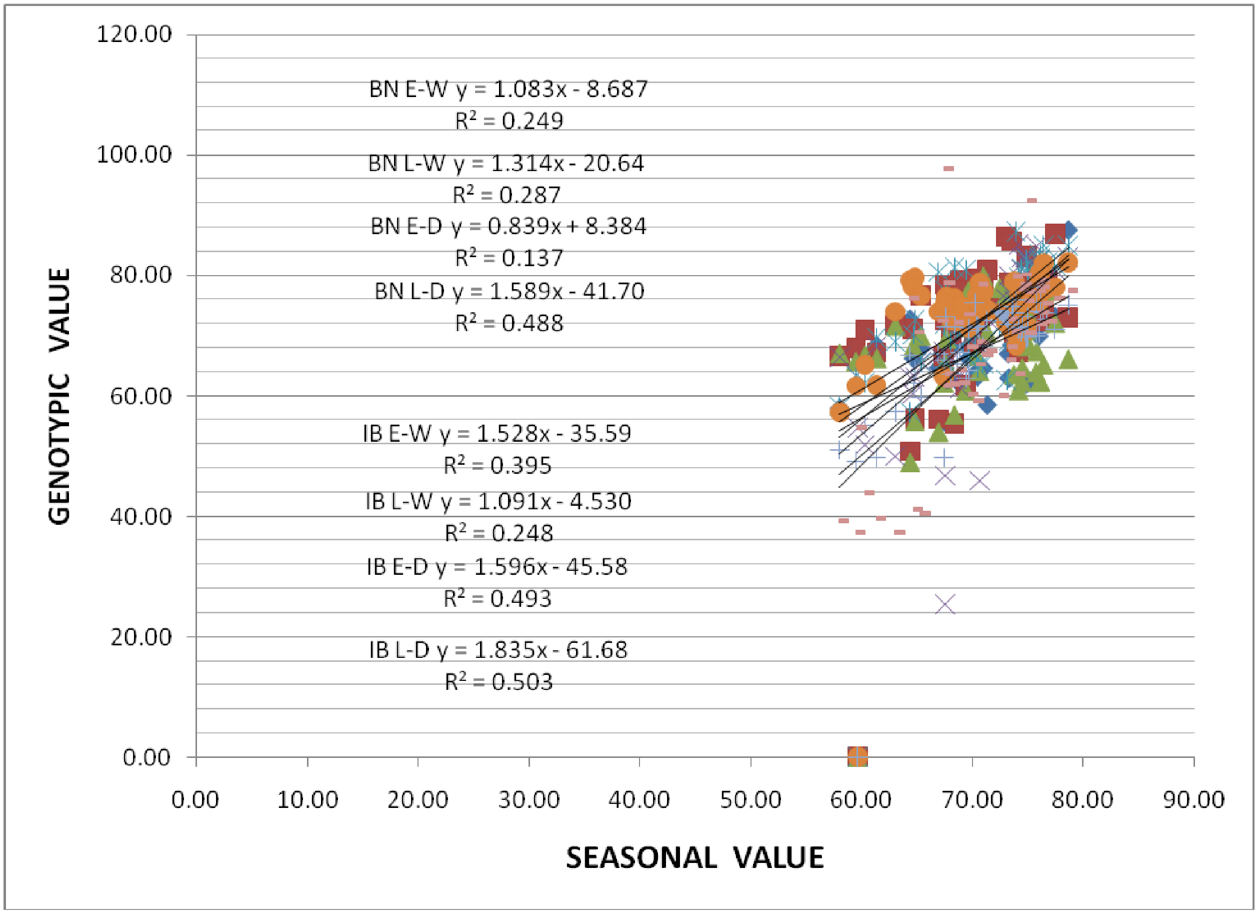


Figure 4.38: Seasonal sensitivity regression lines for hatchability of eggs set for Bovan Nera and ISA Brown genotypes showing respective seasonal sensitivity indices in Ibadan Nigeria.

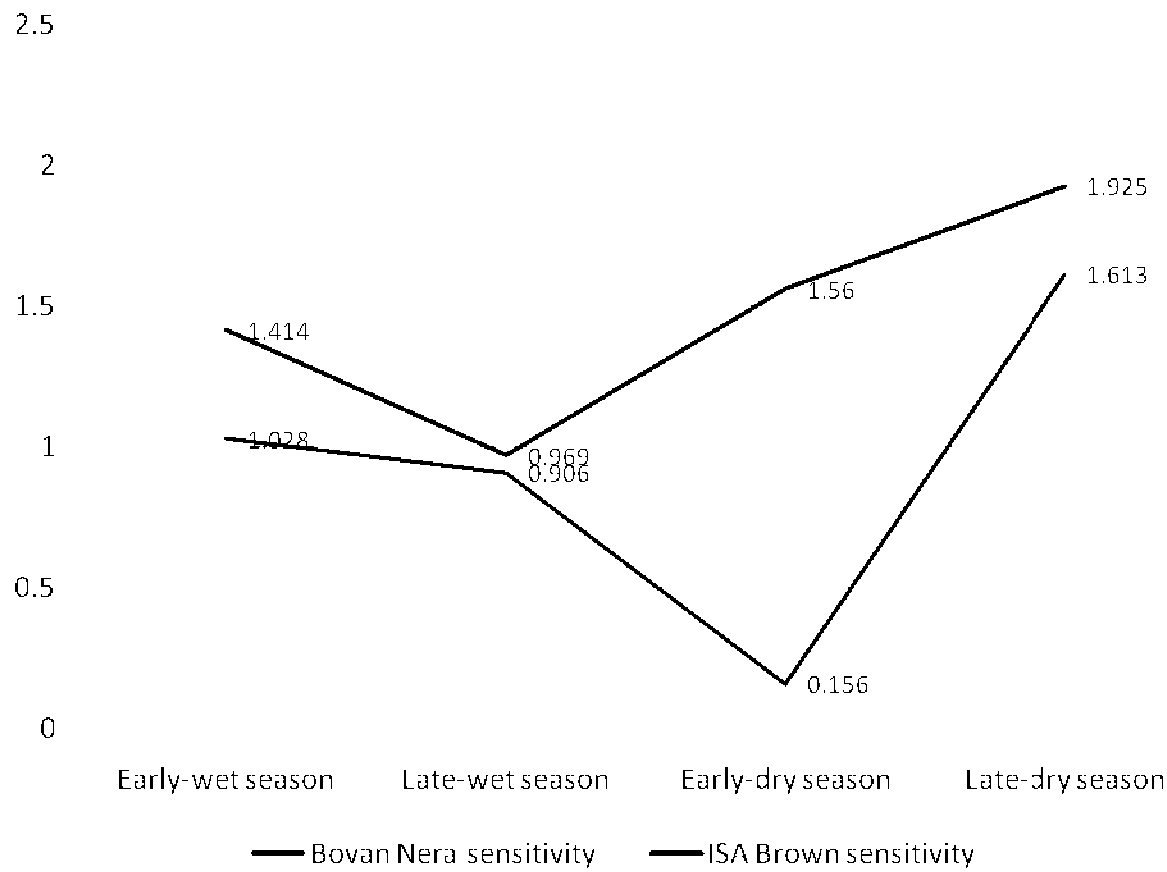


Figure 4.39: Seasonal sensitivity trends for pullet day-old chicks hatched for Bovan Nera and ISA Brown genotypes in Ibadan Nigeria.

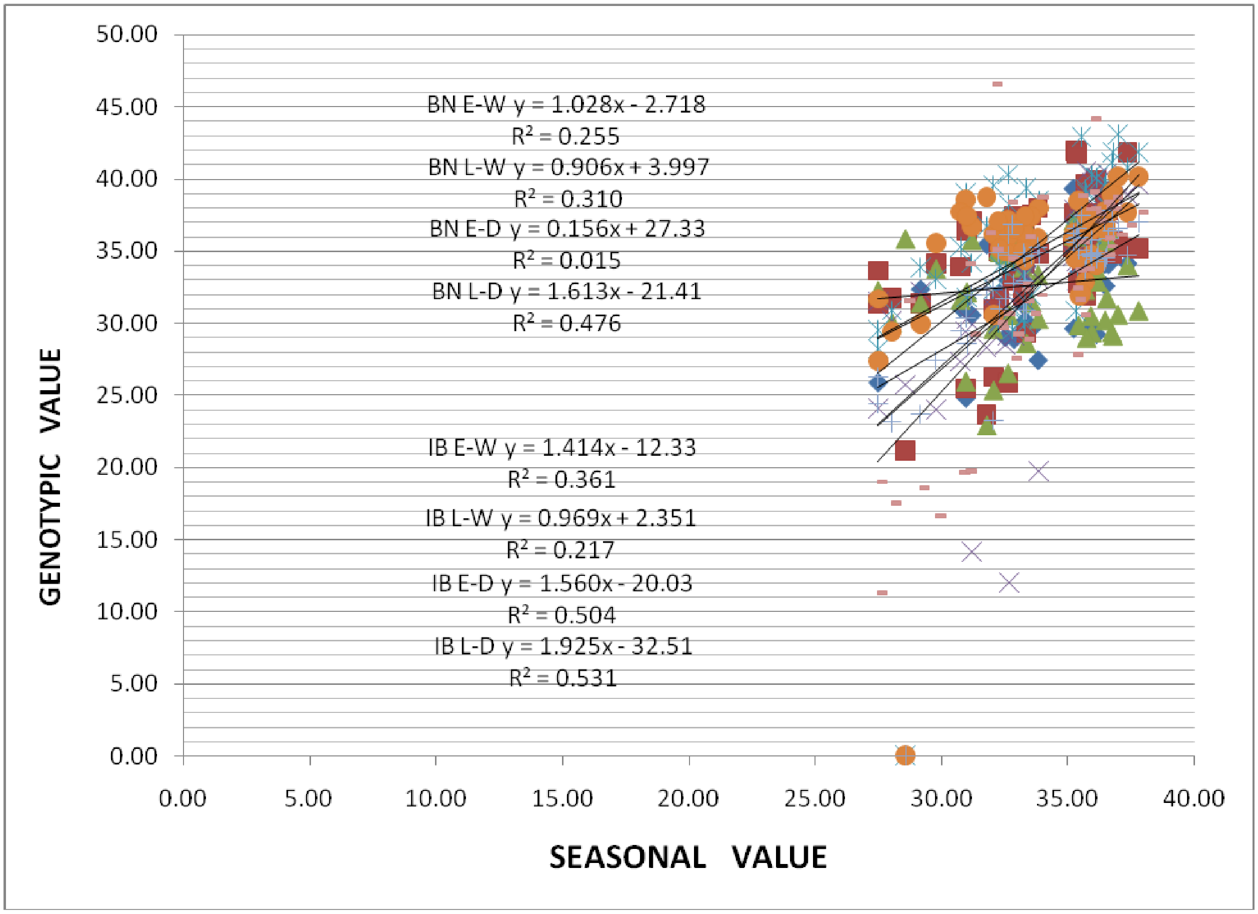


Figure 4.40: Seasonal sensitivity regression lines for pullet day-old chicks hatched for Bovan Nera and ISA Brown genotypes showing respective sensitivity indices in Ibadan Nigeria.

4.20.0 Environmental performance values

Both strains were evaluated in Ibadan, South-West environment and compared to their sources of origin to ascertain their relative performance in the environment. Depression was observed in their performances. Performance depression is the inability or failure of a genotype to attain its genetic potential or known performance standard or target, as a result of being reared and managed in an environment different from its natural origin. In this study, the performances of both genotypes in humid Ibadan Nigeria, were compared with the recommended standards of the respective primary breeders in the temperate environment. Results indicated that both genotypes manifested various degrees of performance depression as in Table 4.33 and in Figures 4.41 - 4.43.

4.20.1 Performance depression

Figure 4.41 illustrates the life-time curves of performance of cocks and hens in body weight in the environment. This trend shows that cocks experienced depression in body weight mainly early in life before the age of 10 weeks. Both genotypes manifested this depressions during brooding stage from day-old to about 8 weeks, but the lowest depressions of -15.96 and -27.66 % were observed in the first month of life (0 – 4 weeks) for Bovan Nera and ISA Brown cocks respectively (Appendix 7.2.1). Bovan Nera cocks also exhibited depression in body weight at early stage of production (21-25 weeks). The mean life-time cock weight performance value was 2.09 and 1.39 % for Bovan Nera and ISA Brown respectively. In the Hen breeders, both genotypes demonstrated depressions in body weight almost throughout the 75-week management period except between weeks 8 and 16 in Bovan Nera, and between weeks 16 and 24 (50% production) in ISA Brown. These recoveries were transitional as they did not persist beyond the periods. The lowest depression in hen weight was observed in the first month of life at day-old to 4 weeks both in Bovan Nera: -12.99 %, and ISA Brown: -15.39 %; while the magnitude of depression suffered throughout life ranged from 2.14 to -12.99 % and from 1.50 to -15.39 % for BN and IB hens respectively (Appendix 7.2.2). The mean performance value between weeks 4 and 75 in both genotypes was - 4.94 and - 4.39 % respectively indicating depression. Figure 4.42

shows the life-time curve of performance in hen-day production (HDP) and egg weight of both genotypes. While egg production in BN was not depressed before 25 weeks and after 55 weeks of age, IB experienced depression in egg production almost throughout life-time. At 21 weeks, HDP appreciated by 13.57 % in BN but this trait exhibited depression of -23.73 % in IB hens. A depression of 7.65 and 9.44 % respectively was also observed between weeks 25 and 55 but the life-time performance value was 0.14 and -10.20 % for both genotypes respectively.

In egg weight, an appreciation in performance was observed around peak production period (28 weeks) in both genotypes and this did not persist beyond 35 weeks in IB hens. Age at peak production did not suffer depression but rather suffered delay, and thus peak production was attained late in both genotypes by 7.14 and 7.41 % compared with their temperate counterparts for BN and IB respectively (Appendix 7.2.3). Figure 4.43 shows the life-time curve of egg fertility and hatchability of Bovan Nera breeders. This indicates a life-time depression in egg fertility and hatchability ranging from -3.07 to -11.77 % and -6.80 to -20.39 % respectively (Appendix 7.2.4). However the lowest depressions in egg fertility and egg hatchability were observed between 20 and 25 weeks of age as -11.77 % and -20.39 % respectively. These values appreciated till 45 weeks of age to -3.12 % and -6.80 % respectively but began to fall again. The mean performance value in egg fertility and hatchability observed was -6.88 % and -14.41 % respectively in Bovan Nera. It was also observed that the magnitude of the depression decreased gradually as the genotypes advanced in age (Appendix 7.2.4).

Table 4.33. Mean 75-week environmental performance values (%) classified by traits

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Traits	Bovan Nera	ISA Brown
Cock weight	2.09	1.39
Hen weight	-4.94	-4.39
Age @ Peak production	7.14	7.41
Egg production	0.14	-10.2
Egg weight	-2.89	-3.19
Egg fertility	-6.88	N. A.
Egg hatchability	-14.41	N. A.
Pullet DOC	N. A.	N. A.

NOTE: N. A. means Not available

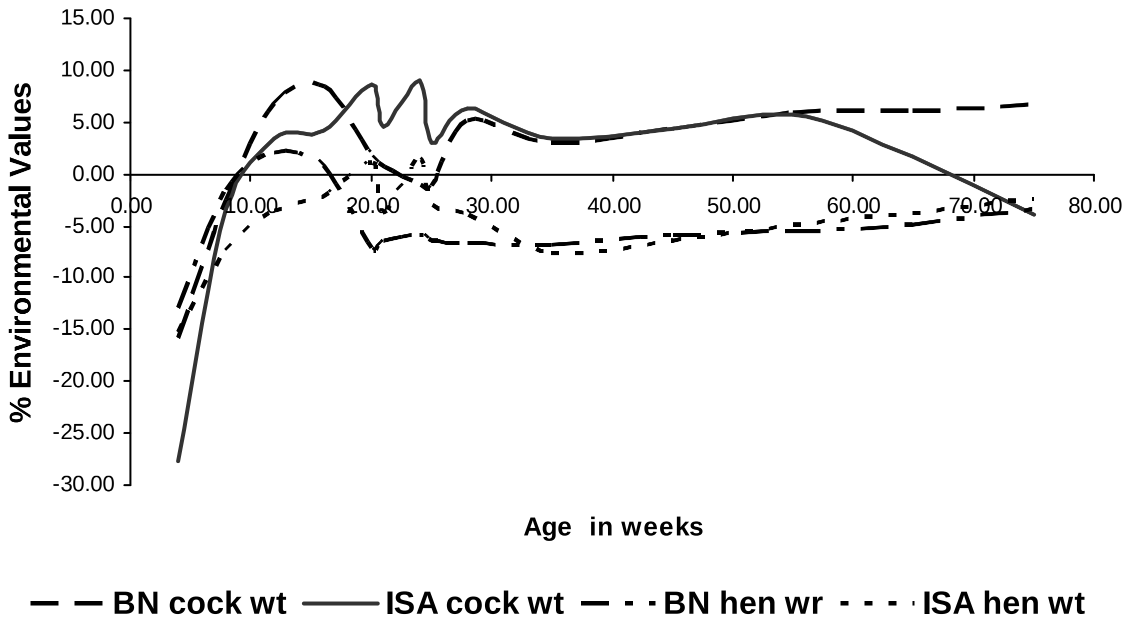

Figure 4.41. Life-time environmental curve of body weight of Bovan Nera and ISA Brown breeders

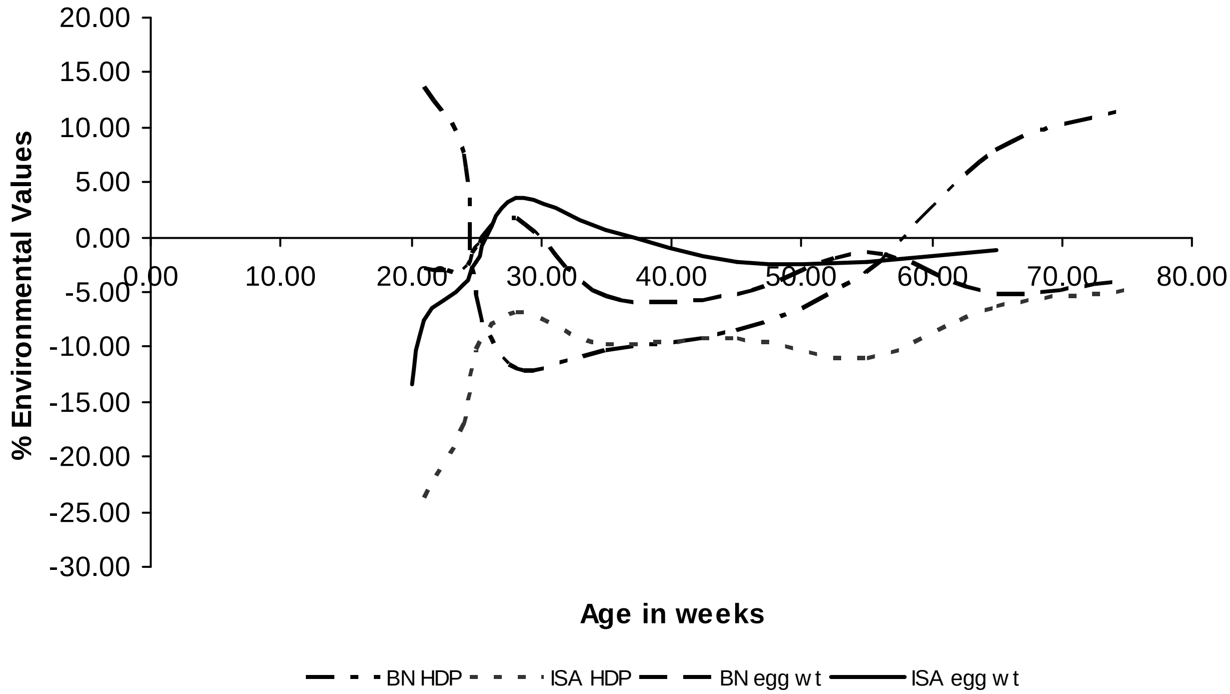

Figure 4.42. Life-time environmental curve of hen-day production and egg weight of Bovan Nera and ISA Brown breeders

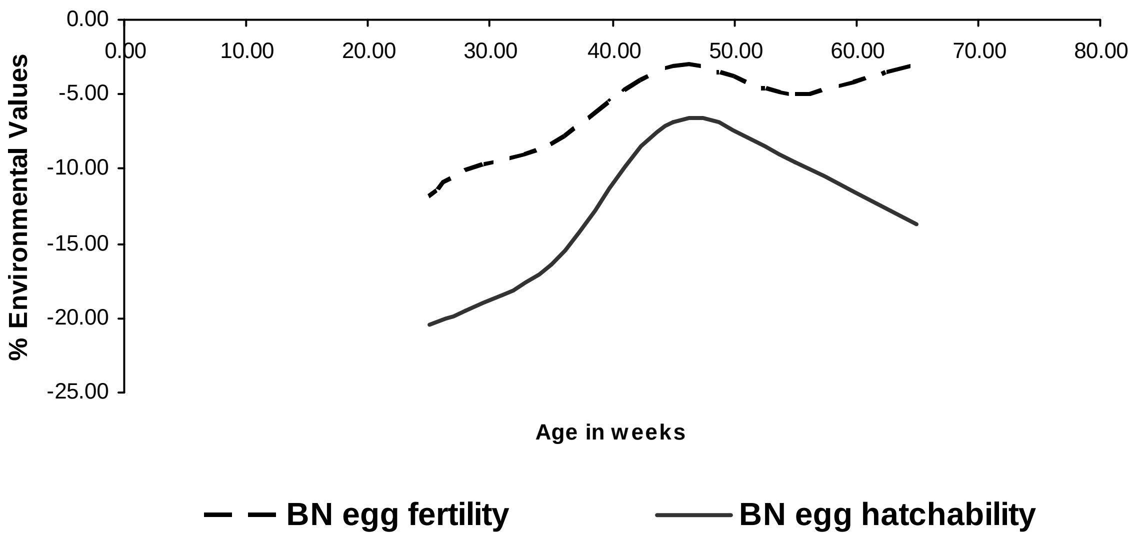

Figure 4.43. Life-time environmental curve of egg fertility and hatchability of Bovan Nera

Chapter Five

DISCUSSION

5.1.0 Influence of season on 75-week growth performance

5.1.1 Body weight of breeder cocks

The reversal of the body weight merit between Bovan Nera and ISA Brown, at late dry and early dry seasons; suggested that ISA Brown cock with higher body weight in early dry season responded better to dry conditions (rainfall = 100.1 mm, sunshine hours = 8.27, temperature = 26.99 ^{o}C and relative humidity = 66.37 %) and was able to perform better; while Bovan Nera which indicated higher body weight in the late dry season was able to perform better under hotter condition (rainfall = 412.9 mm, sunshine hours = 10.41, temperature = 28.70 ^{o}C and relative humidity = 65.45 %) of the year. This suggested that ISA cocks probably required a slightly dry weather as it recorded the lowest body weight in the late dry season while Bovan Nera cocks required a slightly humid-hot weather condition for optimum performance. Both were heavier than Tanzanian village chickens reported with mean adult body weight of 1948 gm by Goromela *et al.* (2009). However, the slightly higher mean weight of ISA cocks probably indicates higher genetic potential for body weight over Nera cocks. The higher average body weight of both genotypes in the dry season than wet seasons also implied that drier weather conditions were better for their growth and development.

5.1.2 Growth pattern of breeder cocks

This study showed that the rate of growth during rearing (day-old to first-egg), production (first-egg to 75 weeks) and mean life-time (day-old to 75 weeks) in cocks of both genotypes was similar. Since growth was most rapid during rearing and occurred slightly during early production period, efforts aimed at improving growth could be done during puberty, and before on-set of production. It can be inferred that while ISA cocks possessed higher overall genetic potential for growth, BN cocks possessed a higher genetic potential for late growth during production stage from 21 to 75 weeks. The sharp reduction observed in growth about the 24th week of life in cocks coincides with the period of adjustment to sexual activity in the flock. The weight gain of cocks in both genotypes at 9 - 16 weeks of age was lower than that reported for Sonali cockerels (≤ 120 vs 542 gm) by Azarul *et al.* (2005). This large difference in gain may be due to management control of growth in research genotypes which was done to retard the rate of maturity in the cocks which is known to be faster than that in the hens. The early-life (1 – 20 weeks) growth (13.76 vs 14.97 gm/day) obtained during rearing for BN and ISA respectively, was comparable to the recommendation (13.9 gm/day) of the primary breeders. To improve growth, post-hatch uniformity and efficiency in growing chicks, grading of day-old chicks could be done using hatching size and egg sorting could also be done by weight-range before setting the eggs into the incubator (Wilson, 1991).

5.1.3 Body weight of breeder hens

The significant difference in hen weight between Bovan Nera and ISA Brown in favour of Nera hen in Late dry season, could mean that the slightly higher weather indices of the season (rainfall = 412.9 mm, sunshine hours = 10.41, mean temperature = 28.70 ^{o}C and relative humidity = 65.45 %) favoured growth and development better in BN. Season did not seem to have much impact ($P > 0.05$) on body weight development in ISA hen. The mean weight obtained in BN (1724.81 gm/bird) was comparable to 1.80 kg recommended for best performance in layers by Lozhkina (1987) and 1726.25 gm reported on mature Black Olympia pullets by Chineke (2001); while the body weight of ISA hen (1549.83 gm/bird) was also comparable with 1.59 kg mature weight obtained on brown-egg layers in the German Democratic Republic (1986) but heavier than the local Bayelsa hen (1289 gm) reported by Ajayi and Agaviezor (2009).

5.1.4 Growth pattern of breeder hens

Growth rate (gm/day) and pattern of growth was similar in both genotypes as it occurred mainly during rearing period. Growth observed during production phase (1.38 vs 1.14 gm/day) exceeded the recommendation of the primary breeder (0.8 gm/day). Comparison between hens of both strains showed that Bovan Nera hen maintained a consistent rate of growth higher than ISA which indicated a higher potential for growth. The mean life-time weight gain (85.26 vs 89.30 gm) observed in pullet growers during the rearing (5 - 20 weeks) period in both strains respectively was higher than 48.0 gm obtained by Thakur *et al.* (2006) on Kadaknath chicken. However the weight gain obtained at 1 – 4 weeks (56.35 vs 52.02 gm) was lower than 82.5 gm in Kadaknath chicken as was reported by Mishra (1983) but higher than 21 gm reported by Thakur *et al.* (2006). The lower growth rate obtained during rearing (11.36 vs 11.87 gm/day) compared favourably with the primary breeder's recommendation of 12.5 gm/day, and this probably indicated performance depression arising from the effect of the hot humid environment of the farm location.

5.2 Influence of genotype on growth performance

ISA Brown cock was found to be superior in body weight while Bovan Nera hen had higher mean body weight over life-time. This may mean that BN hen probably grew faster than IB hen while IB cock grew faster than BN cocks. Growth was more pronounced during rearing than production probably due to the demand of production on dietary energy and body nutritional reserve in the laying hens.

5.3 Sexual dimorphism in body weight

Sexual dimorphism is a phenomenon in which natural, phenotypic, morphological and physiological differentiation (usually with the appearance of sex gonads) that is easily distinguishable, takes place between males and females in animals and birds. This enables early separation or sorting of chicken on the basis of sex. It could be through the use of wing coverts used in separating sexes of chicks at day-old, the use of tail-length in separating growers at 10 days old (Hays, 1952c), or the use of body weight and conformation from 10 weeks. Body weight was used to examine sexual dimorphism in both genotypes and this was observed within and between genotypes about the 10th week of life. This period was about 1/3 of the mean age at full maturity (29 weeks) in both genotypes and therefore confirms the findings of Rose (1997). The phenomenon occurred during the period (9 – 12 weeks) of most active growth in both genotypes. Sexual dimorphism is important to breeders as it enables:

1. The separation of pullets from cockerels during rearing.
2. The culling of runts and undesirable pullets and cockerels from the population based on body development and conformation.

3. The reduction of the cost of rearing and labour.

This phenomenon has been attributed to differences in the hormonal levels in the body of the male and female chicken by Ajayi and Agaviezor (2009). It has also been reported by Rose (1997) that poultry strains exhibit sexual dimorphism within and differing rates of growth without, while Thakur *et al.* (2006) reported that the rate of increase in body weight from 6 – 52 weeks was higher in males than females of Kadaknath chicken. During selection and improvement operations which could commence at 10 weeks in growers, the good males and females that exhibited the typical body conformation and the required body weight range are selected. The rest are either discarded or given more space and ad-libitum feed to see if they could catch-up before point of lay.

5.4 Phenotypic correlation among growth parameters

The highly significant relationships between weight gain and growth rate, age and body weight implied that these correlated parameters could be utilized in breeding to:

1. Estimate each other.
2. Predict particular trait of interest
3. Cull, grade, and or select for desired traits.

This means that weight gain could be utilized to estimate growth rate while age could estimate body weight in both genotypes. The correlation between weight and age in the sexes of both genotypes corroborate the results of Tserveni-Gousi (1987) who reported significant correlation between chick weight and age, and concluded that chick weight was adequately predicted by the use of age as a single independent variable. Therefore from this investigation, age seems the best parameter, for estimating body weight, while weight gain seems to be the best parameter for estimating growth rate, within and between genotypes.

5.5 Prediction of body weight and growth pattern

While the power model fitted the body weight – age data ($R^2 \geq 0.843$), the simple linear model fitted the growth rate – weight gain data ($R^2 = 1.00$) adequately. The transformation of the power model to its log form was done to rectify and linearize the model. From the predictive equations for body weight, the difference in the intercept observed in cock weight equations indicate the genetic differences in basal growth between genotypes, but the value of b in the growth equations was almost the same ($P > 0.05$). In equations for hen weight, the differences obtained in the intercept (log a) and the power (b) indicated the significant ($P < 0.05$) differences in their basal and late growth between genotypesrespectively. This confirmed the differing growth rates observed between genotypes and the superiority of Bovan hens over ISA hens in body weight and growth.

Comparison between growth rate equations in both genotypes indicated differences in their intercept, a, between sexes. These differences indicated that genotype was probably the most important factor responsible for the difference in their rate of growth, as both had been raised under the same environment. The high values of R^2 obtained indicated that the equations for growth rate in both genotypes and sexes were highly predictable. This meant one could utilize either equation within sex to estimate for both genotypes. The R^2 obtained from this study was superior to 0.667 obtained on chick weight – egg weight data by Caglayan *et al.* (2009) in their study on rock partridges, but was comparable to 0.986 obtained from egg weight – hatchling weight data of quails (Kucukyilmaz *et al.*, 2001).

5.6.0 Influence of season on early sexual maturity characteristics

5.6.1 Age at first-egg

As seasonal weather became drier, hotter and the day-length (sunshine hours) increased, the age at which onset of sexual maturity in pullets occurred increased, (except in BN pullets at late dry season). Within genotypes, the humid and cooler seasons of the year accelerated on-set of sexual maturity by reducing age at first-egg while the dry and hotter seasons increased age at sexual maturity. The mean annual temperatue and rainfall in the research location were 25^oC and ≥1500 mm of rain guage respectively. Mishra *et al.* (1987) reported age at first-egg in five strains of White Leghorn hens. The average was 180.84 ± 0.30 days. Bhuiyan *et al.* (2005) also reported age at first egg as 175 days in Deshi breed of Bangladesh (mean temperature, $19\ ^0C$ and annual rainfall, ≥ 1400 mm). These values were obtained in colder environments than south -west Nigeria. The results of this study further confirmed that cold environments accelerated onset of sexual maturity by reducing age at first-egg, while hot humid environments delayed onset by increasing age at sexual maturity.

5.6.2 Body weight of breeder pullets at first-egg

Seasons did not seem to have any significant effect on body weight at first-egg in Bovan Nera but did ($P < 0.05$) in ISA Brown pullets. The highest body weight was recorded in early wet season in both genotypes while the lowest was observed in early dry and late dry seasons in ISA Brown and Bovan Nera pullets respectively. Comparatively, the better body weight of Nera over ISA pullets in late wet and early dry seasons indicated superior genetic potential and that it could adjust better than ISA hens to these seasons. Figure 4.3 shows from the curve of both genotypes that, while body weights in Bovan Nera decreased from late wet to late dry, body weight in ISA hens decreased from the late wet season towards the end of the year but rose again in the late dry season. It also suggested that to obtain high body weight at sexual maturity in growing pullets, chick stocking could be planned so that birds would attain early sexual maturity in early wet season.

The late maturity date (124 days) of BN and IB pullet flocks with low body weight in early dry season (1456.0 gm/bird) confirmed findings that body weight of pullets lower than genetic potential retarded sexual maturity age and therefore resulted in lateness in attaining maturity as observed in the reports of Horst and Petersen (1981); Ayorinde and Oke (1995) and Belgium (1986). It could be inferred therefore that the potential genetically induced body weight of BN and IB pullet breeders in the environment was close to that attained in the early wet season. This means that the combination of the right body weight, the right age and the right timing of photo-stimulation or the photoperiod (hours/day) would most effectively influence the point-of-lay of in-coming pullets; and these conditions were probably closer to that attained and supported by the early wet season in both genotypes. Nutrient manipulation, feed restriction or temporary feed shortage could be used to delay on-set of lay whenever the average flock body weight is excessively high. Technical expertise is therefore required for success in management of in-coming pullets to obtain the right body weight at the desired age, in order to obtain good egg weight at point of lay.

5.6.3 Body weight of breeder cockerels at first-egg

The effect of season on breeder cocks at first-egg was clearly indicated by the significant difference obtained by ANOVA test. The exhibition of greater body weight by ISA cocks at first-egg, in all seasons except late wet suggested that highly humid conditions were probably detrimental to growth and production of ISA cocks as against Bovan Nera cocks, whereas, cocks maturing in early and late wet seasons in Bovan Nera indicated the highest body weights within genotype between seasons.

The wet seasons encouraged heavier weights in cockerels of both genotypes especially the early wet season. This implied that the early wet season was most suitable for attainment of good body weight and conformation at first-egg in cockerels, while the late dry season seemed to be the least conducive season for their development. The body weight of cockerels at first-egg that would most likely complement reproduction in pullets was that obtained in the early wet season.

5.7 Influence of genotype on early sexual maturity characteristics

This study strongly revealed the influence of genotype on body weight at first-egg. ISA hens with lower body weight matured early while Bovan Nera with higher body weight matured late in the humid Ibadan environment. Under the same conditions, exotic hybrids with lower body weight could mature earlier than those with higher body weight. This observation was also observed in the report of Akanni *et al.* (2008).

The mean age at first-egg obtained in this study (123 and 121 days) for BN and ISA genotypes respectively were lower than 151 days in Black Olympia pullets reported by Ayorinde and Oke (1995), 132 days in Shika Brown commercial pullets obtained by Ayorinde *et al.* (1999) and 126 days for Pakistan layers by Farooq *et al.* (2002). However, Horst and Petersen (1981) reported 167 – 199 days in Leghorn hybrid pullets raised under temperate conditions. The report of Horst and Petersen (1981), and the results of this study confirmed that birds raised under tropical conditions generally attained sexual maturity earlier than those raised under temperate conditions Other factors having effect on age at sexual maturity include body weight uniformity, feeding method – full or restricted (Ayorinde and Oke, 1995), timing of photo-simulation (Rose, 1997), health status of flock and feed intake capacity pre-maturity (ISA, 2005).

5.8.0 Influence of season on full sexual maturity characteristics

5.8.1 Age at peak hen-day production

The influence of season on age of Bovan Nera pullets at full sexual maturity was polynomial (Figure 4.5), and thus was different from the maximum quadratic curve at early sexual maturity period in Figure 4.2. Therefore, the influence of season on age at the peak of egg production in Nera hen was not similar to that at first-egg (early maturity period). This indicated lack of relationship between the two stages of maturity in both strains. Generally, while wet seasons seemed to accelerate on-set of sexual maturity, they however delayed attainment of full maturity in both hybrids. Results also revealed that dry seasons increased age at first-egg in ISA Brown from early wet to late dry and decreased age at full maturity from early wet to late dry season. This trend indicated that dry seasons delayed on-set of sexual maturity in in-coming pullets, and accelerated full sexual maturity in the same flock by reducing age at which birds attained peak hen-day production. Therefore, ISA hen flocks which arrived at sexual maturity late due to the effect of late dry season still achieved full sexual maturity earlier, while flocks in the early wet season which attained the point-of-lay early arrived at full maturity very late. Comparison between genotypes (Figure 4.5) at full sexual maturity showed that in both hybrids, full sexual maturity was delayed by wet seasons, while it was accelerated by the dry seasons.

5.8.2 Cock body weight at peak hen-day production

The ability of Bovan Nera cocks to reduce the large differences in body weight between it and ISA at first-egg to minimal values at full maturity within and between seasons indicated the rapid growth rate of BN cocks over ISA within the period. The effect of season on the body weight of both genotypes at full maturity was not strong enough to cause significant differences in body weight between them within and between seasons. However, body weight was highest in both genotypes in early wet season than other seasons, and so it can be deduced that early wet season favoured fast development of cocks of both genotypes, and therefore early and late dry seasons could not provide the best conditions for the development of body weight in both strains. Figure 4.6 also revealed that between genotypes, the curve of IB was higher than that of BN depicting that IB was more productive within seasons than BN cocks.

5.8.3 Body weight of pullets at peak hen-day production

There was a lack of similarity in the effect of seasons on pullet body weight at early and full maturity stages and this suggested that seasons probably exacted different magnitude of effect on body weight of BN pullets at both stages of life. In ISA, seasons exacted significant ($P < 0.05$)

influence on pullet body weight at full maturity. This influence decreased from EW to LD, and thus was similar to that observed at early maturity, and further revealed that the effect of seasons on hen body weight within genotypes at both stages of life were different in trend and magnitude. The higher pullet weight in the wet seasons than dry seasons implied that wet seasons (16 April - October), especially early wet, was more suitable for body weight development and growth in both genotypes. The further differentiation in pullet weight between genotypes in favour of Bovan Nera between first-egg and peak production within seasons, indicated the higher ability for fast growth in BN. It could be concluded that early wet season supported high body weight development in both genotypes at full maturity.

5.8.4 Hen-day production at the peak of production

Season had no appreciable influence on hen-day production within genotypes. Figure 4.8 shows that the curves of production between seasons within genotypes were similar and normal, yielding a quadratic curve. ISA brown pullet breeders however showed an all-season genetic superiority over BN pullets. The chart implied that late wet (85.55 vs 92.02 %) and early dry (84.19 vs 90.26 %) seasons stimulated higher egg production in both genotypes (August - October and November - January) but the significant difference between genotypes was only captured in the LW season at this period in favour of ISA pullets.

5.8.5 Egg weight at peak hen-day production

The influence of season on egg weight at this stage of life in both genotypes followed different polynomial patterns (Figure 4.9). Results revealed that heavier egg weights (56.69 vs 59.59 gm) were obtained in the wet seasons than in the dry seasons (54.75 vs 55.41 gm) in Bovan Nera and ISA Brown respectively. Since EW season produced the highest egg weight in both genotypes, this indicates that the season supported high egg weight in poultry production. Both Figure 4.9 and Table 4.12 reveal the superiority of ISA pullets over Bovan pullets in egg weight between and within seasons. The lack of significant influence of season on egg weight of BN indicated that this trait was not easily subject to seasonal variations and so BN hen could perform to its genetic potential between seasons.

5.8.6 Eggs set at peak hen-day production

The lack of significant (P > 0.05) difference between seasons and between genotypes in percent eggs set in the hatchery incubator means that season did not exact any significant influence on percent eggs set. However during the wet seasons, higher (P > 0.05) percent eggs were set (99.49 vs 99.72) as against the dry seasons (96.50 vs 93.34) within BN and IB respectively. Both genotypes exhibited similar patterns in percent eggs set at full sexual maturity across seasons. Percent eggs set also depended on the egg production pattern of both genotypes, handling of eggs on the farm and in the hatchery.

5.8.7 Fertility of eggs set at peak hen-day production

The lack of significant (P > 0.05) difference beween seasons and genotypes in percent egg fertility of both genotypes meant that season did not influence percent egg fertility significantly, although within seasons, ISA pullets recorded higher fertility than Bovan pullets. However, higher percent fertility were obtained in the wet (86.33 vs 92.16) seasons (16 April – October) than dry (84.59 vs 83.31) seasons (November -15 April) within Nera and ISA genotypes respectively. The trend of fertility and influence of seasons on egg fertility within genotypes were similar. These results on percent eggs set and egg fertility could prove that wet seasons (16 April – October) favoured high egg production (P > 0.05) and high fertility (P > 0.05) of pullet eggs at full sexual maturity.

5.8.8 Hatchability of egg-set at peak hen-day production

The highest percent egg hatchability (85.03) obtained in ISA at early wet (16th April - July) probably implied that this season (rainfall = 1740.8 mm, temperature = 26.37 ^{o}C, and relative humidity = 79.53 %) favoured egg hatchability most as the atmospheric humidity was close to that required by the incubator (Setter = 37.7 ^{o}C, 52-55 % R H and Hatcher = 36.7 ^{o}C, 70 -75 % R. H.) for optimum hatchability of light-breed chicken eggs.

Within BN however, the highest hatchability (81.15 %) that was obtained in late dry season (February – 15 April) was unexpected, in the light of above findings and the prevailing dry weather conditions at this season of the year (rainfall = 412.9 mm, temperature = 28.7 ^{o}C, and relative humidity = 65.45 %) which was considered inclement for hatching operations. Contrary to expectation, BN pullet eggs seemed to tolerate better the dry environmental conditions to yield high egg hatchability. Breeders could plan stocking of chicks so that they could obtain first-egg in late dry season (February – 15th April) or early wet season in Bovan Nera, and early wet season (16 April - July) in ISA Brown, for optimum hatchability. Figure 4.12 shows that the effect of seasons on egg hatchability in BN fluctuated more with seasons than in ISA.

5.8.9 Pullet day-old chicks hatched at peak hen-day production

The seasonal pattern of percent pullet day-old chicks (PDOC) that was hatched in Nera was different from that in ISA. This pattern was a polynomial in BN but a straight line from early wet to late dry season in IB. The observed pattern in BN was similar to that observed earlier in fertility and hatchability, while that observed in ISA was similar to that observed during hatchability within same genotype. This implied that fertility and especially hatchability influences PDOC hatched in the hatchery. Therefore late dry to early wet season (February - July) for BN and early wet to late wet season (April - October) in for IB seemed most suitable for production of optimum quantity of pullet chicks respectively. Between genotypes, ISA had higher curve (Figure 4.13) indicating better performance and higher potential. As in other full maturity traits, both genotypes performed better under humid conditions (36.24 vs 40.50 %) than under dry (33.9 vs 35.07 %) weather conditions. Figure 4.13 showing the influence of seasons on PDOC production revealed that, percent pullet day-old chicks hatched fluctuated more between seasons in Nera than in ISA.

5.8.10 Hatching rejects at peak hen-day production

Since breeders and hatchery managers prefer low quantity of hatching rejects to maximize PDOC production, the least hatching rejects (9.19 vs 8.37 %) was obtained in early wet season in both genotypes, and this implied that early wet season was probably best for hatching operations in the environment. While the pattern of hatching rejects was polynomial in BN, it followed a straight line in IB with the least in EW and the highest in LD season. The curve showing the influence of seasons on hatching rejects that were generated in both genotypes, revealed that there was progressive increase in hatching rejects as the seasons progressed from early wet season to late dry season in both genotypes, except late dry season in Bovan Nera. Hatching rejects obtained in BN at early dry (17.07 %) and in ISA at late dry (17.02 %), indicated that dry seasons increase the quantity of rejects from hatching operations. This means that chicken Farmer-breeders could stock their birds so as to commence production and hatching operation in Early wet season (16th April - July) to reduce the amount of hatching wastes and rejects for more pullet chicks.

5.9 Influence of genotype on body weight and egg characteristics at full sexual maturity

Results further indicated that BN pullets were late maturing (214 days) with significantly higher body weight (1916.08 gm/bird; $P < 0.05$) than ISA brown pullets which were early maturing (208 days) with significantly lower body weight (1792.20 gm/bird). The influence of genotype was observed on hen weight, HDP and PDOC production. Other traits exhibited marginal differences between genotypes, although IB had higher values except in percent eggs set. The higher productivity of ISA pullet compared with BN pullet was believed to be linked to its smaller size and lower response to seasonal variations. BN had lower values in HDP compared to IB but the percent eggs set was higher than that of IB, which might be due to higher egg loss (breakages) during transport, sorting and grading of ISA eggs in the hatchery. These loses probably translated to lower egg-shell quality in IB eggs than in BN eggs. The exact relationship between body weight and egg production in chicken was not investigated but the results showed an inverse relationship between the two parameters, both within and between genotypes, at full sexual maturity. These finding confirmed previous reports on the influence of genotype on body weight ($P < 0.05$) and egg weight ($P > 0.05$) by Oguike and Onyekweodiri (2000), and Wang *et al.* (1992). Although percent eggs set was superior in BN, the genetic ability for fertility and hatchability in IB was superior, translating to the higher percent pullet day-old chicks from ISA Brown eggs.

5.10.0 Influence of season on Life-time (first-egg to75 weeks) productive performance.

5.10.1 Life-time hen-day production

Results of this study showed that BN was less productive within season and therefore probably more sensitive to seasonal variations in HDP than IB hens, although both genotypes layed more eggs within late wet and early dry seasons. This could indicate that the weather conditions in these seasons were conducive for high percent egg production in chicken, although ISA hens layed more eggs than Bovan hens. The pattern of HDP at full sexual maturity was also similar to this. Early dry season produced the largest difference in egg production intensity between genotypes and the second largest value for BN hen.

Comparing both body weight and HDP between genotypes within seasons, showed that BN hens with higher body weight and growth rate (4.12 gm/day) produced fewer eggs (HDP) while ISA hens with lower body weight and growth rate (3.80 gm/day) produced more eggs (Figure 4.15). This suggested that BN hens probably channelled less energy to egg production and more of its energy to growth and maintenance activities, while the reverse seemed to be the case in ISA hens. This seemed to be the most notable physiological difference between the two genotypes in this study. Therefore, it was recommended that early dry and late wet seasons should be considered for high egg production in IB and BN hens. This result confirmed the report of Khan *et al.* (2006) that highest egg production among local chickens of Bangladesh was observed in winter, followed by summer, spring and late autumn.

5.10.2 Life-time egg weight

Result of this study indicated the superiority of ISA over BN breeder hens in egg weight as seasonal and genotypic means were higher in ISA than in Nera hen, although significant ($P<0.05$) differences were only observed between strains in early wet (56.20 vs 59.99 gm) and late dry (54.71 vs 56.88 gm) seasons.

In contrast to the above results, late wet and early dry seasons seemed favourable for the production of heavy eggs in BN hens. Egg weight was least in late dry season in both strains implying that the season was least favourable for expressing high egg weight, as it was very dry and hot.

The curves of egg weight (Figure 4.15) of both genotypes over the productive life-time indicate the superiority of ISA over BN breeder hens in this trait. ISA hens with lower body weight produced heavier eggs than BN with heavier body weight. This could imply a genetic potential for higher egg weight in ISA hens.

5.10.3 Persistency of egg production

Egg production persistency as a trait is the ability of a chicken to lay eggs consistently within a particular period of her life time at a specific range of production. Persistency of production becomes a focal management target in chicken production and breeding after 28 weeks of age, along with the maintenance of high livability and good shell quality. This trait is greatly influenced by the growth achieved within genotype before 25 weeks of age and the mean flock body weight uniformity (ISA, 2000).

In this study, the chosen production target for estimating and comparing persistency was ≥ 70 % HDP. Bovan Nera persisted longer than ISA Brown in hen day production (HDP) above 70 % in late wet season (42 vs 31 weeks) while ISA Brown persisted longer in average HDP in early wet (18 vs 31 weeks), early dry (37 vs 43 weeks) and late dry (27 vs 33 weeks) seasons. Also late wet and early dry seasons favoured high production persistency in Nera (42 and 37 weeks) while early dry season favoured high persistency in ISA (43 weeks). BN recorded highest persistency (42 weeks) of production in LW season in which it laid highest average HDP (65.57%, August-October); This meant that the weather conditions (rainfall = 1744.3 mm; sunshine = 6.17 hours/day; temperature = 25.24 ^{o}C and relative humidity = 82.00 %) supported high egg production and persistency in Bovan Nera hens. However, early dry season (November - January) was more favourable (rainfall = 110.1 mm; sunshine = 8.27 hours/day; temperature = 26.99 ^{o}C; relative humidity = 66.37 %) for ISA as it recorded the highest egg production (72.92 %) and persistency (43 weeks) therein. The mean genotypic persistency was 31 weeks for BN hens and 35 weeks for ISA breeder hens, indicating the superiority of ISA over Nera in the trait.

The results from this study therefore showed that there was both synergy and interaction among persistency of egg production (week), level of production (HDP) and season which could boost or reduce cumulative egg production in poultry. For both genotypes under study, the co-action of these three factors boosted cumulative production in late wet and early dry seasons in Nera and ISA hens respectively. Results also indicated that ISA hens recorded highest HDP (92.02%) in late wet season at full maturity but dropped in mean persistency in the same season, probably due to the high humid condition (RH = 82%) and the endemic nature of the environment but persisted better in early dry season. The early wet season recorded the least production persistency (18 vs 31 weeks) within both genotypes indicating that it might not be a good season for expression of this trait in poultry; probably due to the unfavourable interaction between weather parameters of the season (sunshine hours = 8.95, wind speed = 2.78 km/hour, environmental temperature = 26.37 ^{o}C, relative humidity = 79.53 %) compared to late wet season. Persistency occured at 30-56 weeks in both genotypes and this period was longer than 30-35 weeks reported by Hendrix Genetics (2006) although the level of production was unknown. They however suggested a stable amino acid requirement, reduction of oil and energy level of feed during late production stage to stabilize egg weight and production persistency. Feeding level could also be in line with the level of egg production of the flock at this stage to control feed intake and avoid accumulation of excess fat which destroys persistency. Oluyemi and Roberts (2000) had recommended a 2% increase in feed offered to poultry with every 1% increase in egg production of the flock.

The cumulative egg production was the product of persistency and HDP. Comparatively BN produced less cumulative eggs to ISA (2097 vs 2489) while early dry (November - January) season produced highest cumulative eggs (2708 and 2795) within both flocks respectively. Fleming (2005) reported that the pre-lay high body weight, high body-weight uniformity of flock, adequate post-peak nutrition, feeding level and skilled management are important to maintaining high persistency of egg production (which is a combination of high HDP (≥ 70 %), low (5 %) variation in level of HDP within genotype, long period of production and uniform egg weight with low CV). It was inferred that given BN and ISA hens to manage for commercial production of eggs, ISA would probably be the farmers' choice based on its higher mean HDP, egg weight and persistency of egg production.

5.11 Influence of genotype on life-time (first-egg to 75 weeks) production

The significant difference ($P < 0.05$) obtained in egg weight implied the effect of genotype on this trait. These egg weights were lower than that of Shika Brown commercial pullets (65.07 gm/egg) raised on deep litter (unpublished data) but higher than figures (54.60 gm/egg) claimed by Janda and Jandova (1974) and 53.2 gm/egg reported by Sazzad (1992) on Black Plymouth rock chicken. Shika Brown strain has been adapted to the tropical environment for several generations with continuous selection for high productive performance.

The significant difference ($P < 0.05$) in HDP (62.70 vs 69.10 %) that was obtained between the genotypes in favour of ISA brown hybrid probably implied the genetic superiority of ISA. Results obtained in HDP in BN and IB strains were higher than 55.80 % reported for Rhode Island Red (RIR) chicken by Sazzad (1992), Shika Brown layers unpublished results (52.62 %), Black Olympia pullets (55.2 %) published by Ayorinde and Oke (1995), but comparable with 69.30 % reported by Farooq *et al.* (2002) and 68.0 % reported for Pakistan layers by Mussawar *et al.* (2004). Crossed Japanese quails however recorded higher percent HDP of 74.15 % compared to the two hybrids above (Yerturk *et al.,* 2008).

Average egg production persistency and cumulative production were higher in ISA (35 weeks, 2489) than in Nera (31 weeks, 2097) hen. These results comfirmed that BN had mean lower productive ability compared to IB in HDP, egg weight, persistency of production and cumulative egg production during the period of persistency. This ability was probably due to the genetic constitution and potential conferred on smaller genotypes for egg production in chicken. This finding was in line with that of Horst (1981) in which he observed a systematic increase of productive adaptability, accompanying a decrease of the genetically determined body size in layers. The report of the German Federal Republic Test-Station (1986) also showed that genotypes with smaller body weight tend to perform better in egg production.

5.12 Phenotypic correlation among productive parameters

The result on phenotypic correlation among productive parameters within genotypes revealed highly significant ($P<0.0001$) relationship between age and egg weight ($r = 0.735$ vs 0.522), hen weight and egg weight ($r = 0.682$ vs 0.529) in Bovan and ISA hens respectively. This probably implied a strong relationship between these paired parameters, which meant that both age and hen weight could be utilized independently to estimate egg weight in laying hens. Tserveni-Gousi (1987) had reported significant correlation between egg weight and day-old chicks weight ($R^2 = 0.32$) although his focus was slightly different from that in this study. Ayorinde *et al.* (1988) also reported positive correlation between body weight and egg weight ($r = 0.77$), and between body weight and hen day production. They submitted that the relationship between body weight and HDP could be negative as a result of fat deposition in large-bodied hens. Correlation between hen weight and HDP was also significant ($P < 0.0001$) in both Bovan Nera and ISA breeder hens ($r = 0.267$ vs 0.582), indicating that hen weight might be a good estimator of hen-day production in both strains respectively. Other pairs of parameters (HDP/egg weight, growth rate/HDP, growth rate/egg weight and age/HDP) submitted low coefficients in both genotypes.

5.13 Prediction of egg weight and hen-day production

Two models were used to predict and compare egg weight between strains. They were the linearized power model and the asymptotic model which produced the equations reported in section 4.13. Comparison between strains using the linearized equations revealed little differences in their intercepts (hybrid constants) and standard errors but none in their R^2. The asymptotic equations produced no significant difference between hybrids in their constants, a; and this showed similarity in the rate of increase in the weight of eggs layed by both genotypes. The only difference between the genotypes was in their potential for maximum egg weight, which was higher in Nera than ISA in old age. This work differed from that of Fayeye and Adesiyan (2008) who utilized the linear function to regress egg weight on other egg quality traits, and selected equations with the best fit using R^2, F-ratio, power of the explanatory coefficients and significance of the regression model.

Rose (1997) reported the model: $Y = 100 ((1/(1 + (ab^X))) – ((CX) + d)$ for hen-day production in the temperate environment,where:

100 = Maximum possible egg production by any genotype (%)

a = Minimum egg weight (39.6 gm)

b = Rate of increase in HDP to peak (0.3)

c = Rate of decline in HDP from the peak (0.0035)

d = constant for percent HDP at peak (0.03)

x = Number of weeks in lay from first egg.

But by trial and error method, the equation above was modified to fit the age - HDP data from Bovan and ISA hens for predictive purpose to obtain the equations below:

Bovan Nera : $Y = 100 ((1 / (1 + (39.6 \times 0.3^X))) – (0.48 x – 0.03)$

ISA Brown : $Y = 100 ((1 / (1 + (39.6 \times 0.3^X))) – (0.32 x – 0.03)$

It was observed that within the research environment, maximum recorded hen-day production for both genotypes was (91 and 93 %) while the observed rate of decline in HDP from the peak was 0.480 and 0.315 for Bovan Nera and ISA Brown respectively. The modification of the equation given by Rose (1997) to fit egg production pattern of both hybrids in the humid environment of Ibadan gave adequate description of the pattern of HDP throughout their productive life-time, as each equation predicted figures close to the actual values observed. Therefore by plotting the age-in-production or number of weeks-in-lay into the modified equations, an estimate of egg production (%) can be made for either strain. However, Ayorinde *et al.* (1988) had observed a significant quadratic relationship between total egg production and body weight at full sexual maturity in the White leghorn hen; while Oni *et al*. (2001) in their work on egg production curve of the Rhode Island Red chicken reported that the best R^2 was obtained from the Gamma type function by McNally, followed by the parabolic exponential function. The predictive ability of the models obtained were compared by Oni and Abubakar (2001), and they reported that the McNally model had highest R^2 (0.946), smaller error and close agreement between estimated and actual values.

5.14.0 Influence of season on reproductive (25 to 75 weeks) performance.

5.14.1 Mean Life-time percent of eggs set

The influence of season on percent eggs set into the incubator of BN was a normal curve (Figure 4.17) with late wet and early dry seasons giving the highest percentages (98.92 and 97.57%). These high values might be due to the favourable weather in these seasons which complemented the high level of management, both on the farm and in the hatchery. The higher percent eggs set of BN over IB in the late wet season further confirmed the relative difference between both genotypes in their HDP potential in hot humid weather. There was an all-time high percent eggs set in ISA, except in late wet season, and this was not influenced by season as no significant difference was observed between seasonal results. This outcome revealed that percent eggs set could be strongly influenced by genotype and handling than season.

5.14.2 Life-time fertility of eggs set

The differences observed ($P < 0.05$) in mean seasonal egg fertility in the early wet (80.82 vs 88.72 %) and late wet (86.23 vs 89.45 %) seasons in BN and ISA hens respectively showed that ISA Brown was better in egg fertility in these seasons. This was also confirmed by Agapova *et al.* (1992) on local chicken while Caglayan *et al.* (2009) reported a lower average fertility of 81.11% on rock partridges. However, Babiker and Musharaf (2008) reported no significant effect of season on percent egg fertility of Bovan Nera. This might be because data used covered only two years of production while the data employed in this work spanned over 10 years. The highest egg fertility was obtained in both genotypes in the late wet (25.24 ^{0}C, 1744.3 mm and 82 % RH) season of the year (August - October), and this confirmed the findings of Jayarajan (1992) in which he reported highest egg fertility from White Leghorn and White Plymouth Rock during cold season (December - February) but highest egg fertility from Rhode Island Red ocurred during summer (March - May). The supremacy of ISA in egg fertility in late wet and early dry seasons supported the report of Jayarajan (1992) that highest egg fertility occurred during the warm, wet monsoon season (September - November) at 29.75 ^oC mean environmental temperature and torrential rains of 1250 mm of rain guage.

The higher egg fertility of ISA hens further suggested that its origin might probably include Rhode Island Red , White Leghorn and White Plymouth Rock; having distinguished itself in egg fertility; both in the cool wet seasons (25.81 ^oC and 80.76 % R.H) and in the warm dry seasons (27.67 ^oC; 66.00 % R H); over Bovan Nera. This result probably confirmed the superior ability of IB cocks to mount and copulate with hens than BN cocks, or ISA Brown male sperm was probably more potent than that of Bovan Nera cock in *in-vivo* egg fertilization.

5.14.3 Relationship between cock weight and fertility of egg-set

The positive and significant correlation figures obtained between cock weight and egg fertility, though low, signify that cock weight has a remote association with egg fertility. This is because the weight of the cock may either aid or hinder its ability to mount the hen. Since the highest fertility range was obtained between 2600 and 2650 gm in BN and between 2482 and 2537 gm in ISA hen; these body weight ranges could be critical for high egg fertility. Therefore, the ages at which these body weights were attained 44 and 36 weeks in BN and IB hens respectively could be made the target period to begin critical hen weight management in both genotypes for optimum fertility in both genotypes. While low weight does not give the cock the desired balance on the big hens, excessively high body weight suppresses libido and hinders mounting by the cock. However, the age of the hen at which the highest egg fertility occured will probably be influenced by genotype, cock weight, nutrition and management.

This result implied that management of cock weight is important and could be maintained at these weight ranges to assist mating by cocks for optimum fertility, starting from peak hen-day production age.

The low value of the R^2 obtained from the regression of egg fertility on cock weight means that cock weight alone cannot account adequately for the total variability involved in the prediction of egg fertility; but Figure 4.19 and 4.20 further shows that as cock weight increases, the egg fertility increases to a maximum and then begins to decrease probably because of deposition of excess body fat as weight and inability of the cocks to mount the hen properly. The decrease in egg fertility can also be caused by factors such as excessive body weight, loss of agility, dwindling libido, old age, disease conditions such as leg weakness or sore legs, infection, poor nutrition of the cocks and inadequate level of feeding. In deep-litter system, litter reconditioning programme must be in place and be strictly followed by turning at regular intervals and keeping to the replacement schedule for the litter at the right ages. This reduces contact of birds with droppings and reduce rapid spread of infectious pathogens. Wet litter must be removed promptly to avoid spread of disease infections such as coccidioses. Total replacement of the litter at 18 to 20, and 45 weeks upwards is recommended. Further management of cocks for optimum egg fertility during the productive life of the flock will include replacement of old cocks exhibiting dwindling libido or exchange of cocks between flocks of same age and strain, under the same management; to improve mounting in the flock through competition among cocks. The feeding of ground limestone - 2 % of current level of feeding thrice a week - to ameliorate any calcium deficiency which usually develops, helps to correct leg weaknesses in cocks as from 45 weeks upward, and improves egg shell strength.

5.14.4 Life-time hatchability of eggs set

The observed difference in egg hatchability in early wet season in favour of ISA could be attributed to the difference in the fertility of both genotypes within the season, and the mean weight of eggs set in the incubator (Table 4.14). The interaction between genotype and season, and the change in the order of merit between genotypes in wet and dry seasons had implications for breeders' management in the study environment. It was also observed that wet seasons recorded higher hatchability values than dry seasons implying that wet seasons were more suitable for the expression of hatchability trait in chickens. Both results above meant that breeding and hatching operations could be programmed to commence in late wet season while improvement programmes could be planned to fall within early and late wet seasons to take advantage of the high hatchability and the conducive weather condition.

The above results supported the report of Jayarajan (1992) that mean egg hatchability was highest during the warm, wet monsoon (September - November) season with torrential rains

(29.75 ^{o}C and 1250 mm) for all eggs set[8]. Babiker and Musharaf (2008) found no significant effect of seasons on egg hatchability of Bovan P.S. hens in Sudan, probably because the information used were collected over 2 years only instead of a 10-year data utilized for in study. However, Agapova *et al.* (1992) has attributed high egg hatchability partly to aggressive social behaviour of cocks. Egg weight (Table 4.14) has also been found to influence hatchability of eggs set significantly (Tandron *et al.*, 1987; Markovskaya, 1988; and Unal and Ozcan, 1989), while egg shell thickness was also an important factor influencing egg hatchability.

4.14.5 Relationship between egg weight and hatchability of eggs set

The correlation observed between egg weight and hatchability of eggs set in BN showed a strong relationship between both traits, but the low R^2 obtained from the regression of egg hatchability on egg weight in both genotypes meant that egg weight alone could not explain most of the variability involved in predicting the hatchability of eggs set. Also at the egg weight range of 56.5 and 59.5 gm, hatchability of more than 70% could be obtained in BN but as the weight increased beyond this range, hatchability dropped. This was also observed on the curve of egg weight against hatchability (Figure 4.22). Thus it was possible to obtain above 70% hatchability by skillful egg weight management between 56.0 and 60.0 gm in the Bovan Nera hens. In ISA brown, egg hatchability of more than 70 % was obtained between 54.0 and 61.0 gm. The curve of egg weight against hatchability (Figure 4.23) showed, it was possible to obtain 80 % hatchability of eggs set between 58.0 and 59.0 gm in ISA hens. This meant an optimum egg weight range of 58.0 – 59.0 gm could yield highest possible hatchability on eggs set of ISA breeder hens. The results obtained thus demonstrated an inverse relationship between egg weight and egg hatchability.

To maintain highest possible hatchability on egg set and percent pullet chicks obtainable, egg weight could be controlled and made as uniform as possible from week 40 in BN and week 30 in ISA hens through the management of nutrition and body weight uniformity. Nutrition management could involve manipulation of the linoleic acid, protein and some specific amino acid content (Fleming, 2005) of the feed. These amino acids include methionine+cystein, methionine, lysine, tryptophan and threonine. The use of body weight uniformity of a flock of hens to control egg weight uniformity demands weekly body weight measurements of the flock

[8] Redmond, W. A. Monsoon. Microsoft Encarta DVD. 2009. Retrieved in December 2009.

(5 %) and the determination of the flock weight uniformity. This will inform the manager on the level of feeding needed to encourage uniform body weight, better egg-lay and overall health status of the flock. The use of grills on feed troughs, also encourage undisturbed individual *ad-libitum* feeding and so promotes flock uniformity. It has been established that there is positive and significant relationship between egg weight and shell thickness (r = 0.26, Stadelman, 1986), egg weight and shell weight (r = 0.35), and egg weight and egg length (r = 0.48) by Ojedapo *et al.* (2008). This meant that these correlating traits with egg weight would be influenced positively by skilled egg weight management of flock which in turn influences hatchability. The positive relationship between shell thickness, shell weight, egg length and egg weight meant that these parameters will increase hatchability as the egg weight increase. Their influence could however be optimized through the maintenance of a stable egg weight range of 58-60 gm/egg and body weight uniformity of hen flock.

5.14.6 Life-time pullet day-old chicks hatched

The difference observed in percent pullet DOC produced within genotypes at early wet season could be attributed to the differences in their fertility and hatchability, enhanced by the season. The progressive decrease (36.06 – 32.44 %) in the percent pullet day-old chicks obtained from ISA flock as seasons progressed from early wet to late dry could be the effect of the progressively dry and hot seasonal weather conditions. The percent pullet DOC obtained from BN fluctuated between 32.46 and 34.56 % between seasons, but was higher than percent pullet chicks from ISA in late dry season. This could mean that BN fertile eggs had lower hatchability potential between early wet and early dry seasons of the year compared to ISA fertile eggs. It was therefore concluded that:

1. Wet seasons (especially late wet) were more favourable to chick hatching in both genotypes.
2. Bovan Nera eggs hatched more eggs than ISA in the hot, late dry season.
3. ISA Brown produced more pullet chicks than Bovan Nera within seasons, except in late dry, and probably possessed a higher genetic attribute for pullet production.

5.14.7 Life-time hatching rejects

Results showed that egg hatchability and season were major factors that affected the volume of hatching rejects generated in this study. As hatchability increased, hatching rejects decreased and vice versa, indicating an inverse relationship between both traits within and between seasons. It could also be concluded that the similarity in pattern observed between hatchability and hatching rejects in both genotypes within season implied an influence of the former on the later. Also, the pattern of hatching rejects generated within early wet (13.12 vs 15.15 %) and late wet (14.04 vs 16.33 %) seasons were similar to that on egg fertility between genotypes within seasons. Both genotypes also generated higher percent rejects as the seasons became drier and hotter except in LD in BN. This behaviour showed that the wet seasons produced least rejects while the dry seasons resulted in more rejects. The wet seasons were considered more conducive for hatching for farmers to obtain more chicks from hatching operations. It was also observed that the quantity of rejects obtained in ISA was more than that in BN. This clearly implied the peculiar ability of ISA eggs to produce more rejects probably because the embryos were probably weaker than those of BN, and thus had lower genetic ability to break through the egg shell and hatch properly at this stage.

5.15 Influence of genotype on life-time reproductive performance

From results obtained from this study, genotype showed significant influence on egg fertility in the wet seasons. It was also observed that IB had an early and higher egg fertility that decreased with age, while the early and low egg fertility of BN improved over life-time. Thus, egg fertility improved in Bovan Nera while it decreased in ISA Brown with age. This implied that BN cocks probably perform better in sexual activity with age. The fertility result obtained from this study was superior to 78.5 – 79.0 % reported by Markovskaya (1988) in Hybro 6 cross chicken and 81.11% reported by Caglayan *et al.* (2009) on rock partridges, but lower than 94.8 0 % reported for eggs weighing 52 – 64 gm by Halaj and Konan (1986); and 95.7 % for Shaver Starcross hen eggs weighing 56 – 58 gm stored for 5 days before setting in the incubator. The results were however comparable with 83 % obtained from crossed Japanese quail (Yerturk *et al.*, 2008) and 83.9 % fertility reported by Halaj (1986) for eggs weighing 56 – 58 gm and stored for 10 days before setting.

The mean hatchability of eggs set in this study (> 70.35 vs 70.86 %) was also lower than 86.5 % obtained on crossed Japanese quail by Yerturk *et al*, (2008) and 74.70 % reported by Halaj

(1986) for 56 -58 gm eggs set after 10 days of storage in the cold room, but it was higher than 69.10 % obtained from traditional African poultry keeping system reported by Wilson *et al.* (1987) and 69.30 % from rock partridges' eggs submitted by Caglayan *et al.* (2009). From the results obtained in fertility and hatchability in this work, it could be inferred that hatchable eggs in this study were stored in the hatchery cold room for minimum period of 5 to 10 days before being set in the setter compartment. The lack of significant difference between genotypes in egg hatchability, pullet day-old chicks, hatching rejects and average life-time performance implied that either genotype could substitute the other for commercial production when it was not available. The influence of genotype on mean reproductive performance was further strengthened by the outcome of this study when ISA exhibited higher values in all traits examined.

5.16 Phenotypic correlation among reproductive parameters

The results obtained on egg weight correlation with other hatching parameters negate the report of Halaj and Konan (1986) in which they reported significant correlation between egg weight and egg fertility (r = -0.66) and between egg weight and hatchability on eggs set (r = -0.92). This was because very low coefficients were obtained from this work probably due to the deep litter system of production used. Similarly, the correlation values between HDP and egg fertility, HDP and egg hatchability, HDP and pullet DOC, and between HDP and hatching rejects were medium (r = 0.284 to 0.660) and comparatively lower in BN than in ISA hens. However, the correlation values obtained between pairs of reproductive parameters of egg fertility and egg hatchability, egg fertility and pullet day-old chicks, egg hatchability and pullet day-old chicks and between pullet day-old chicks and hatching rejects within genotypes were very high. This meant that these values could be used to estimate each other to a high level of accuracy, as it is needed to forecast production and therefore engage in booking of customers for sales of expected day-old chicks. There seemed to be paucity of information on correlation among reproductive traits in chicken.

The negative correlation between hatching rejects and each reproductive parameters except egg weight (0.141 vs 0.129) within BN and IB genotypes respectively, implied decrease in those parameters as percent hatching rejects and egg weight increased in both genotypes. Unal and Ozcan (1989) presented a report which showed that the chick weight increased, as the weight of egg increased; but the hatchability and the percent chicks hatched decreased. This further underscores the need to maintain an optimum and uniform egg weight for the flock, that minimizes percent rejects at hatching, to achieve high percent day-old chicks at the end of operations.

5.17 Prediction of fertility and hatchability of eggs set

In both genotypes, the cubic and quadratic models were more accurate than other models in describing the curve of fertility of eggs set using age-in-lay from first-egg. The equations obtained within hybrids were different in the values of intercept and the coefficients of X, although the values of R^2 were low (0.27 vs 0.17) for BN and IB respectively. These signified the difference between the two genotypes in egg fertility. Despite the low values of R^2, the use of these equations for predictive purpose was recommended based on the significance of the models which this meant that by plotting age-in-lay (weeks) into the equation of respective genotype, the expected percent fertility of eggs set could be obtained. This could enable the farmer-breeder to predict the performance of cocks especially, in the flock at any future age of production and plan ahead for the necessary intervention that could be necessary.

The same models above were used to regress hatchability on egg weight at-lay, hatchability on age-in-lay and egg weight; and hatchability on fertility, all in the hatchery respectively. The first set of equations yielded low R^2 (0.10 and 0.01) whereas the second set of equations yielded higher R^2 (0.13 and 0.45) for Nera and ISA genotypes respectively. However, the use of age-in-lay and egg weight at-lay on the farm in multiple linear model, to predict hatchability only made improvement on the R^2 (0.13 and 0.45) in ISA, in the second set of equations. This second combination could be a useful alternative for the prediction of hatchability eggs while on the farm, especially in ISA. With this technique it was possible for the farmer long before receiving the hatchery report, to predict to a high level of certainty the hatchability of eggs laid by his flock based on the age of his flock in-lay and the average egg weight. Plotting the expected or actual fertility figures into the last set of equations would enable farmers to predict hatchability of each genotype at any age-in-lay of the flock, but the disadvantage of these equations lie in the fact that farmers must wait until he receives the fertility report before he could predict the hatchability of eggs from his chicken flock.

This study therefore revealed that fertility of eggs set was the most predictive parameter among those tested that could explain to a very high level, the variability responsible for egg hatchability in the hatchery, as the R^2 obtained (0.55 vs 0.47) for both genotypes were most superior. The quadratic equations obtained for the prediction of pullet day-old chicks produced in both genotypes were highly significant (P = 0.001). These would enable farmers to forecast percent pullet day-old obtainable from percent egg fertility figures after receiving the hatchery reports. But the use of hatchability-pullets data to fit the model above resulted in better R^2 (0.97 and 0.94) for Nera and ISA respectively. With the second set of more reliable equations, accurate prediction of pullet day-old chicks was expected in these genotypes in the environment.

Despite the availability of this tool, the usual delay in getting hatchery report could be frustrating to farmers, hatchery operations were also subject to uncertainty and disappointment as chicks could enter the market before the result was received. The solution to the problem would be to utilize the multiple linear technique which combined age-in-lay with egg weight to estimate hatchability; and thereafter use the hatchability value obtained to estimate percent pullet chicks obtainable while on the farm. This could be used to forecast production and make booking for sales ahead of hatching. Booking ahead of the hatching of day-old chicks is the practice worldwide in commercial hatcheries.

5.18.0 Genotype by season interaction

G-E interaction meant that a specific change in the environment would result in different responses in particular phenotypes for the entire array of genotypes (Legates and Warwick, 1990), so that any selection for improvement in one environment would not necessarily result in improved performance in another as genotypes change their ranks in different environments. Since some genotypes perform better under some conditions than others, genotype-environment interaction (G-E) was used to determine the better genotype for the best seasons in this research (Wiener, 1999). Genotype-season interaction indicated the importance of both components as one factor in poultry breeding, this was then utilized for comparing both hybrids or genotypes under similar environment for the purpose of selecting between them. Interaction between genotype and season was important in this study because each hybrid was managed and bred under the four pre-defined seasons of Ibadan in South-West Nigeria, with wet and dry seasons that were distinctly different ($P < 0.05$) from each other in rainfall (1742.5 vs 231.2 mm), relative humidity (80.76 vs 66.00 %) and number of rainy days (26 vs 5) above 100 mm of rain gauge. The significance of this phenomenon in cock weight development was that ISA cocks raised in early dry season tended to perform to its genetic potential while BN cocks raised in late dry season performed to its potential where the weather parameters were higher. To achieve high performance in body weight, appropriate stocking dates, season and good management must be ensured. Selection conducted on the two genotypes in these respective seasons could produce higher response than in other seasons, as interaction results showed that the genotypes were most adjusted to late and early dry seasons respectively. Commercial farmers could specialize in BN and ISA cock production and capons in late and early dry seasons respectively to enhance their optimum performance. The lack of significant interaction at full sexual maturity in HDP, egg weight, egg fertility, pullet DOC production and hatchability between genotypes and seasons implied that both genotypes have been well bred to tolerate varying conditions of weather.

Similarly, in HDP Persistency, BN performed better in late wet while ISA hens performed better in early dry season. Since wet seasons have been reported as highly conducive for outbreak and spread of pathogens, diseases and infections, because of the endemic nature of the humid environment; the persistency of BN hen for HDP in late wet season meant that it was probably more resistant to infections, and thus more adjusted to late wet season, than ISA hen that seemed more adjusted to the early dry season. BN hen could require more humid environment for breeding than ISA hen, although the fertility of incubated eggs declined in BN while this appreciated in ISA from peak production to point of cull, that is, 30 to 75 weeks. Graphically, interaction also occurred between genotype and season in hatchability because there was a reversal in the order of ranking of the two genotypes. BN performed better in the dry seasons while IB did better in the wet seasons, although the better performance between the two genotypes was obtained from ISA Brown. Breeding and improvement for high hatchability in both genotypes at these seasons could be appropriate, although a genotype would be expected to show close results for same trait between seasons that are not significantly different from each other.

5.18.1 Implication for egg production and pullet day-old chicks hatched

Interaction between genotype and season in persistency had implication for commercial egg production in both genotypes. It meant that rearing of both genotypes should be under skilful management which could take steps to ensure adequate care of layers of Nera and ISA in late wet and early dry seasons respectively, to optimize their productive potentials. During rearing, management should ensure attainment of point-of-lay at the right body weight (1494.10±27.41

and 1339.00±7.00 gm), at genetically-associated ages (124±8 and 123±5 days), and at the right seasons (late wet and early dry) for Bovan Nera and ISA Brown respectively. Adequate nutrition, bio-security, full vaccination cover, optimum population density (6 birds/m^2), right sex-ratio (1:8 – 1:10) and flow-through ventilation should be provided. Therefore the management goal in pullet and hen breeders from point-of-lay onward should be to achieve full sexual maturity characteristics at the right body weight (1957.60 and 1889.24 gm) and age (222 and 217 days) respectively. This goal could be achieved through nutritional and feeding-level management; assisted by weekly weight monitoring,which helps to check accumulation of excess fat in hens. This destroys uniformity in flock weight, persistency of egg production and reduces percent hen-day egg production.

Similarly, interaction between genotype and season in egg hatchability has implication for percent pullet day-old chicks hatched. If possible stocking of genotypes could be programmed so that grower hens could attain point-of-lay in late wet season (August - October) in Bovan Nera and ISA Brown flocks respectively, then selection and improvement activity could be attempted in this season to take full advantage of the genotypic potentials. In this study, the result of ANOVA test for interaction was not significant for the five reproductive parameters studied probably because the four seasons were closely interwoven with no clear demarcation between them. It also revealed that since genotypes were not products of natural adaptation but of hybridization, they had been well bred to adjust to various kinds of weather conditions.

5.19.0 Genotype sensitivity to seasons

5.19.1 Within-season sensitivity

The significant differences obtained between genotypic sensitivity values in early and late wet seasons in reproductive traits indicated the genetic differences existing between hybrids. This meant that a large gap probably existed between Bovan Nera and ISA Brown within-season, in reproductive parameters, in favour of IB with the lower sensitivity and higher production and reproduction values.

These results which indicated lack of significant differences between genotypes within seasons, in body weight and productive parameters, probably implied that the response potential of both genotypes within seasons were similar, so both were almost equally adjusted to seasons in those parameters. Although BN had a higher body weight of the two genotypes, both were still considered as light-body strains in view of the closeness of their sensitivities. ISA brown had a more definite pattern in sensitivity values as body weight sensitivity values were lowest in early dry season while other traits recorded their lowest sensitivity values in late wet season where it recorded higher productive and reproductive values. The results on HDP sensitivity within-season in Nera contradicted the production results, because seasons conferring higher sensitivity on genotype did not produce the higher number of eggs probably because of its lowere genotypic merit. Results also suggested that both genotypes could be exploited maximally for egg production in their commercial layer strains in those seasons in which they recorded their lowest sensitivities.

Without selection, the ranking of sensitivity values of both hybrids within parameters in order of magnitude, shows that BN hen had the highest index in all (Table 4.30). ISA Brown that was more productive than Nera hen had the lowest sensitivity values within parameters to the seasons. The highly significant sensitivity results in reproductive parameters displayed by BN hen in early and late wet seasons meant that Bovan hens were probably lower in their genetic merit for reproduction in those seasons compared to ISA hens. These sensitivity results buttress the inverse relationship observed between hen weight, and productive and reproductive traits within-season and within-genotype; so that, as hen weight sensitivity to season increases, productivity in HDP, egg weight, egg fertility, egg hatchability and Pullet-DOC decreases and vice versa. The results from within-season sensitivity study showed that:

- Both Bovan Nera and ISA Brown could be regarded as light-weight strains because of the closeness of their sensitivity indices for body weight.
- Genotypes with higher and significant body weight sensitivity, could be less productive except in hen weight.
- Within-season, the sensitivity of Egg fertility was higher in Bovan Nera than in ISA Brown, but the body weight sensitivity of Bovan was lower than her Egg fertility sensitivity but the resverse was the case in ISA.
- Bovan Nera was genetically superior in hen weight while IB was genetically superior in cock weight, productive – hen-day production, egg weight, and reproductive – egg fertility, egg hatchability and Pullet day-old chicks - parameters studied.
- An inverse relationship existed between hen weight, and all other parameters above, within season between genotypes.

- The productive and reproductive output of ISA Brown was higher than that of Bovan Nera in late wet season.

If selection was to be conducted between genotypes for productive and reproductive traits, ISA Brown would be the better choice based on its lower sensitivity and hiher output values. The breeder could select the genotype with the lower sensitivity value. Further selection could then proceed within season in the selected hybrid for the desired trait of interest. A selction based on genotype sensitivity will be expected to to yield maximum potential in ISA Brown. Abdou *et al.* (1977) studied seasonal sensitivity in Fayoumi chicks and reported that significant differences in hatchability was observed between lowly inbred lines in summer but not in highly inbred local chickens; but in fertility and hatchability, inbred lines were found to be more sensitive to seasonal variations than control chicks. But Abdou and Moukh-tar (1973) had noted that it was possible to get reasonable hatchability in June if fertile eggs were set the next day of laying. Highly inbred local chickens did not show any significant differences in sensitivity between seasons in their report. This is an indication of better adaptability to the environment in local than in exotic chickens. Abdou *et al.* (1977) also noted a decrease in seasonal sensitivity as chicks advanced in age and attributed this to genetic homeostasis in the local breeds, because alleles responsible for early growth were probably more sensitive to seasonal variations. In the light of above findings, ISA Brown was recommended for skilful farmers based on its low and better sensitivity to seasons while Bovan Nera was recommended to the new-entrant farmers with less experience in poultry management based on its higher sensitivity to seasons and ruggedness.

5.19.2 Between-seasons sensitivity

The lack of significant differences between seasons meant that genotypes were well adjusted to the seasons but IB with the lowest sensitivity values was better adjusted. Similarly the lack of significant differences between genotypes within and without seasons could mean that either hybrid could substitute each other at times of scarcity or when the other was not available to the farmer. Results show that in cocks, lower sensitivity resulted in higher body weight between genotypes in favour of IB while in hens higher sensitivity submitted higher body weight in favour of Bovan Nera. This indicated differences in the manner in which the male and the female genotypes for growth responded to seasonal variations.

In productive traits - hen-day production and egg weight - both lower and higher sensitivity values of ISA Brown demonstrated higher production levels above Bovan Nera in all the four seasons. This was contrary to the pattern of results obtained in body weight between sexes of genotypes above, and also contradicted the interaction between sensitivity values observed between genotype and season in both traits (Figures 4.31 and 4.33) respectively.

In reproductive traits – fertility of egg-set, hatchability of egg-set and pullet day-old chicks - interaction was only observed in hatchability of eggs set. The sensitivity values in fertility and hatchability of eggs set demonstrated lack of definite pattern with their output levels respectively. BN genotype exhibited superiority in egg fertility sensitivities except in early dry season, while IB hens had higher sensitivity values in hatchability of eggs set except in Late wet season but the production results were contrary to expectation as Isa hen demonstrated superior productivity between seasons in all parameters. The significant difference obtained between the sensitivity values of Bovan Nera and ISA Brown in hatchability of eggs set and pullet day-old chicks within early dry season was contrary to expectation but also indicated the diference in their genotypic potentials since ISA Brown had superior sensitivity and production indices in both parameters.

In pullet day-old chicks production, there was no interaction between genotypes and seasons but ISA Brown produced higher sensitivity indices and higher pullet day-old chicks than Bovan Nera. This was similar to the behaviour of BN hen genotype for body weight, which demonstrated higher sensitivity and corresponding body weight levels in all seasons. Between-season study of sensitivity revealed that:

- ISA cocks had lower sensitivity indices and higher body weight than Bovan cocks.
- The genetic difference between BN and IB cocks was accentuated by early dry season, as ISA showed significant superiority.
- Bovan hens have higher sensitivity and body weights than ISA hens.
- The genetic difference between BN and IB hens was accentuated in early wet season where BN recorded the highest body weight and difference in sensitivity index.
- Despite the interaction of sensitivity values, ISA Brown was better in HDP and Egg weight in all four seasons.
- The ‘genotype and season’ with the lowest sensitivity index for HDP: LD; 0.992, did not translate to the highest HDP: ED; 72.92%. Also the factor with the lowest sensitivity :

LD; 0.931, for Egg weight did not translate to that with the highest Egg weight, EW; 59.99 gm.

- The same trend as above was observed in Fertility of eggs set, hatchability of eggs set and Pullet day-old chicks hatched.

Between-season study of sensitivity suggested that in Ibadan environment with different climatic seasons, BN and IB strains and probably many other exotic strains will respond variously with different sensitivity levels as they interact with seasons. These levels were inconsistent with body weight, productive and reproductive expectations

Selection between hybrids may become difficult when using sensitivity indices alone in the presence of genotype - season interaction because of the inconsistency in its pattern when compared with production output. For successful selection, it could be better to select genotype based on their productivity between seasons, that is, whether the season increased or decreased a parameter – wether it is good or bad. In hen, a decrease in body weight was desired, especially in heavy strains, to improve egg production and hatching parameters. Selection in other parameters could be based on production level, so that a season could be termed ‘good’ for a parameter with high output levels (Falconer and Mackay, 1996). Since these two genotypes had been grown in all four seasons, the better hybrid in all would be that which demostrated the better mean performance in all parameters in all four seasons. However when selecting for many parameters, an appropriate selection index could also suffice to aid selection.

5.20.0 Environmental performance values

Domestic chicken are exposed to extreme diurnal temperature range in the humid tropics and have to maintain the normal chemical and physiological processes. To do this they produce metabolic heat through exercise, production, ingestion and maintenance, but the first three factors constitute heat load in the body in hot environment. Since these add to the heat stress imposed by the environment, the birds react to the situation by reducing feed intake and this action results to drop in performance and productivity. Having no sweat glands, they loose heat by radiation, convection and panting - which starts at 43 ^{o}C - to reduce endogenous heat (Horst, 1981). Thus under tropical environment, birds consume less feed, produce high metabolic heat and are subject to various degrees of performance depression compared to their temperate counterpart (Horst, 1981). This is further complemented by the endemic nature of the humid environment.

5.20.1 Performance depression

The performance depression experienced by cocks and hens early in life (day-old to 10 weeks) was probably due to environmental shock, as a result of the abrupt change in the internal environment of the egg to that of the endemic ambient environment of Ibadan in Nigeria. The adverse effect of the temperature shock and the environment could be reduced through nutrition by offering highly nutritious diet – broiler-starter feed – to the day-old chicks from the beginning. Other management strategies could include provision of the right brooding temperature, recommended chick and feeding space, adequate number of equipment and high level of ventilation, to reduce competition for feed and water, and encourage high level of *ad-libitum* self or individual-feeding as early as from day-old. The slight recovery from depression between 8 and 20 weeks in BN hens and between 16 and 24 weeks (50% production) in IB hens coincided with periods of rapid development of body frame and reproductive organs in young cockerels and pullets. But these recoveries were transitional and did not persist beyond these periods because the stresses of the environment, egg production and cock-mounting all contributed to depress the hen weight almost permanently. Bovan Nera cocks also exhibited body weight depression between early and peak production stages. This may be associated with stresses from:

- The sudden introduction of the cocks into the breeder hen flock.
- The sudden and increasing sexual activity of the cocks
- The increased physical activity of males in the flock during the period.
- The attendant energy demand on the males
- The diversion of energy for some other physiological activities to reproduction.

But these effects soon waned-out, as they adjusted to sexual activities and mating behaviour.

During the period, a transition from growth to sexual reproduction probably took place in the body of cocks while undergoing the many physiological adjustments necessary for body maintenance and continued sexual activity. The mean performance depression between weeks 4 and 75 in both genotypes was - 4.94 and - 4.39 % in hens while cock weight appreciated to 2.09 and 1.39 % for Bovan Nera and ISA Brown respectively over temperate weights. These growth depression values were minimal compared to - 20 % reported for layer chickens by Horst (1981). The implication of early-life performance depression for chick management is the need for tender loving care (TLC) through provision of standard rearing conditions and adequate nutrition to boost early growth, so that they could reduce the depressive effects of the environment from early-life

Although in production, BN was less affected by the environment at early and late egg production periods, IB experienced depression throughout life in HDP. The implication of the high influence of the environment on egg production between 25 and 55 weeks of age informed on the need for proper flock management though the provision of adequate nutrition, and the reduction of heat stress, sudden high noise and other forms of stress in poultry micro environment. The life-time performance depression in HDP was 0.14 and - 10.20 % for BN and ISA hen genotypes respectively. These figures were better than - 19 % depression in egg production reported for layer-type birds by Horst (1981). Age at peak egg production rather suffered delay, and was attained late in both genotypes by 7.14 and 7.41 % over their temperate counterparts for BN and IB hens respectively. Egg weight depression was observed almost throughout life in both genotypes except at peak production period (week 28) in both genotypes but this did not persist beyond 35 weeks in IB hens. The mean depression at 5 % level of egg production was - 13.32 % in ISA Brown while the average life-time depression for egg weight was - 2.89 and - 3.19 % for BN and ISA breeder hens respectively. This was lower in magnitude than - 9 % obtained on egg weight by Horst in 1981.

Reproductive performance indicated a life-time depression in egg fertility and hatchability ranging from - 3.07 to - 11.77 % and - 6.80 to - 20.39 % respectively. The egg fertility depression observed could be as a result of weak libido, excessive body weight causing inability of cocks to mount the hens for matting, old age, disease condition in mating cocks and hens or some other factors. Consequently, management intervention at this period could include replacement of weak cocks – Spiking – with younger cockerels at 25 weeks of age to ameliorate this condition. The depression in hatchability could be due to the increasing egg weight as a result of the increasing size of the ampulla with age. The egg weight could also have interacted with the environment to cause depression in egg hatchability.

The mean depression in egg fertility and hatchability observed was - 6.88 % and - 14.41 % respectively in Bovan Nera. Since the magnitude of performance depression decreased gradually as genotypes advanced in age, early tender loving care for DOC should be the most feasible choice of managers. The positive effect of this choice of management could only be observed later in life during reproduction. Depression in performance of exotic chickens in the tropics informed the author on the necessity to develop the genetic potentials of our ecotype-based local chickens that are already adapted to the environment, to make them highly productive and commercially viable.

These environmental performance results on BN and IB potentials in Ibadan partly contradicted the findings of Horst and Petersen (1981) in their work on laying hens with dwarf genes which concluded that hens of lighter body weight under high temperature react with smaller magnitude of performance depression. This was because the magnitude of depression obtained in egg weight and HDP in ISA Brown was more than that from Bovan Nera hens with higher body weight.

Chapter Six

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

There was no significant difference in growth rate between Bovan Nera and ISA Brown within and between seasons throughout their life-time, however the observed mean growth during production in the hens were higher than that recommended by their primary breeders. This means that with skilled management and provision of standard requirement exotic hens are capable of higher rates of growth in humid tropics than recommended although this may further impact negatively on their productivity in the region. Bovan hens probably directed more energy to growth while ISA hens appeared to mobilize more energy to egg-laying during their production periods. This was probably a major difference between the two genotypes. Age was found to be the best trait to estimate body weight, as revealed by regression equations, though the correlation indices were higher in cocks than in hens. Similarly, age and hen weight were found to be highly correlated with egg weight in both genotypes and therefore useful for estimation of egg weight. High and significant correlation was observed among egg fertility, egg hatchability, pullet day-old chicks and hatching rejects; and so could be utilized as estimators of each other to a high level of accuracy.

Early wet season reduced age while early dry season increased age at early sexual maturity (first egg-lay). Between the two, the genotype with the higher hen body weight at full maturity (peak egg-lay) produced the higher percent eggs set. This probably implied among other factors, a lower rate of breakages as a result of better egg shell quality. At full maturity ISA Brown had higher cock weight, HDP, egg weight, egg fertility, egg hatchability, pullet day-old chicks and hatching rejects while Bovan Nera was higher in hen weight and percent eggs set. After peak egg-lay in both genotypes, egg weight increased rapidly while the hen-day production (%) decreased till birds began to moult. Average egg weight was significantly higher in ISA than Nera hen. Average persistency of egg production was longer in ISA than in Nera, although while ISA persisted longer in early dry, Nera persisted longer in late wet season. Egg production persistency was observed at 30 to 60 weeks in both genotypes but the duration was generally lower in early wet season.

Early dry season produced improvement in mean egg fertility within both genotypes and in mean life-time egg fertility than at full sexual maturity stage. Within the two genotypes, an inverse relationship was established between hen weight, and productive and reproductive traits. While late wet season encouraged high percent egg fertility, egg hatchability and pullet DOC hatched, the percent rejects generated in the hatchery was lowest in early wet season. It seemed that these genotypes had been bred to adjust to varying seasonal conditions such as in Ibadan. This was shown by the lack of significant difference between Bovan Nera and ISA Brown in mean reproductive performance. Since the two genotypes are products of 4-line breeding programmes, and not completely of natural adaptation, this study has thus tested in Ibadan the suitability for the environment of the genetic combinations that produced these crosses. The results call for concerted efforts at improving local strains of chicken to the level of the productivity of these exotic ones, as it is impossible to replace them with indigenous strains presently in the humid tropics. This study had revealed that ISA brown was more productive, possessed higher hatchability and lower sensitivity than Bovan Nera which had lower productive ability, hatching ability and higher sensitivity within-seasons and between-seasons; but higher hen weight. However, under poor nutritional regime as observed among farmers in the region, Bovan Nera would produce better result than ISA Brown, since Nera seemed to tolerate rough handling and harsh treatment better than ISA.

Selection between genotypes within seasons is possible as IB hen with the lower sensitivity values was consistently higher in productivity in all seasons, although the better genotype in a season may not be the better in another since the seasonal values were regressed against the seasonal mean values and not against the environmental values. The use of seasonal sensitivity for selecting between hybrids in the presence of genotype-environment interaction made decision making a cumbersome exercise, but the best approach in such situation would be to use the average performance of both hybrids in all seasons to select between them. Body weight was depressed throughout the life-time of ISA Brown but only during early-life in Bovan Nera. Performance depression was obtained in productive and reproductive parameters throughout their life-time.

Results from this study justified the call and need for continuous testing of exotic strains and genotypes to standardize and control proliferation of the country with all sorts of crosses. This can only be attained through a systematic programme of performance testing, control of importation of chicken genetic materials, standard-setting for the growth and development of the industry and the development of local chicken genetic resources. These measures would serve to halt the gradual extinction of local poultry genetic resources, the annual loss of scarce foreign exchange through importation of exotic hybrids of poultry, and create wealth through export of our local poultry resources eventually. This is because only domestic chicken that are highly productive and also possess the high adaptive traits of the local poultry would be able to overcome the problems of the exotic poultry in the humid tropics, which is due to the depressive nature of the environment which interacts with their genotypes.

6.2 Recommendations

Chicken breeding growth-targets of 11.22 and 1.26 gm/day for hens, and; 14.37 and 2.3 gm/day for cocks was recommended at rearing and production stages of life respectively in the humid tropics.

Body weight and typical conformation traits should be utilized by breeders to monitor growth and make selection in chicken flocks in practice.

Breeding of chicken could be highly productive and profitable in the wet seasons. ISA Brown was recommended over Bovan Nera for breeding, based on its higher performance indices although both could be stocked as from mid-March.

Results on productivity, genotypes' seasonal sensitivity and performance depression on both hybrids further reinforced the need for a National Institute for Chicken Research, with Test-stations at strategic chicken entrée-ports in the country, to develop programmes for testing and set standards for all imported hybrids of chicken. This could reduce importation of zoonotic diseases and prevailence of sub-standard hybrids in Nigeria.

Efforts should be intensified in improving indigenous chicken for productive and reproductive traits to make them useful for commercial exploitation in order to overcome the problem of performance depression being experienced by exotic chicken in the tropics.

6.3 Areas for further research

This study did not consider the effect of specific seasons on environmental performance in chicken, that is, which seasons increased or reduced performance, and in what traits? Under tropical conditions, we need birds with high genetic potential to dissipate heat, reduce the adsorption of heat from the environment, and reduce basic metabolic heat in this warm environment. These traits would definitely eliminate or reduce depression in exotic chicken performance in the environment. Further studies should be conducted into appropriate and economic measures which may further reduce the negative effects of the humid-hot environment on exotic chicken performance. These could be through genomic, genetic, breeding, housing, nutrition and management approaches. It will also be interesting to study the effect of year on chicken performance over the decade in the environment.

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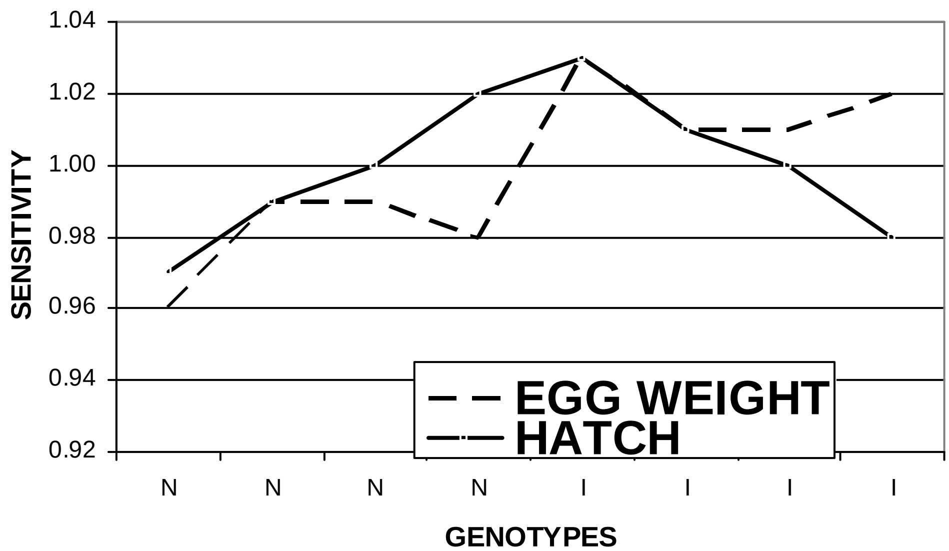
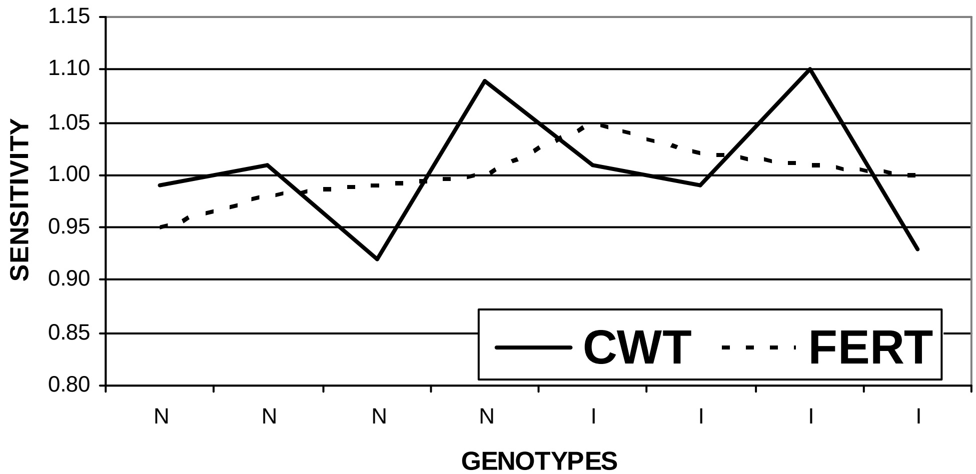
APPENDICES

7.1.0 Charts

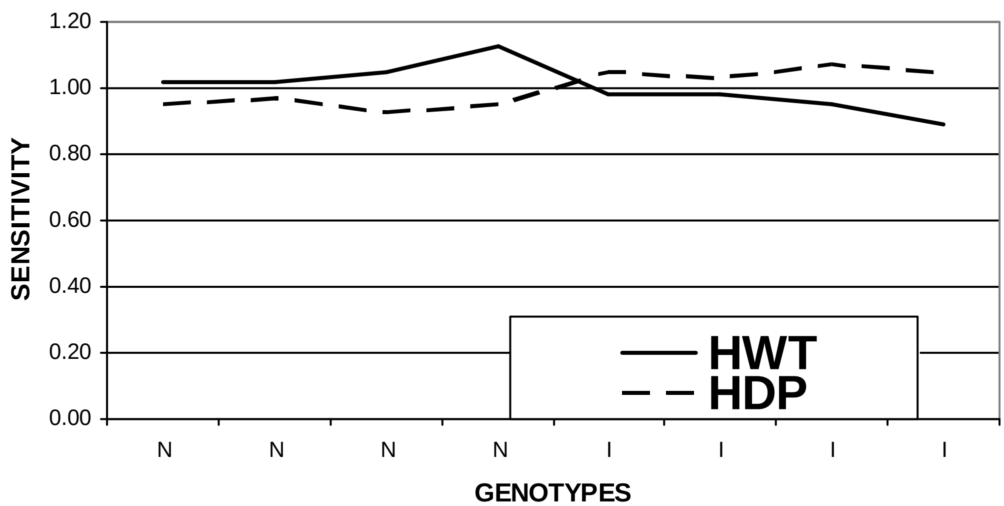
Appendix 7.1.1: Chart of sensitivity relationship between breeder egg weight and egg hatchability



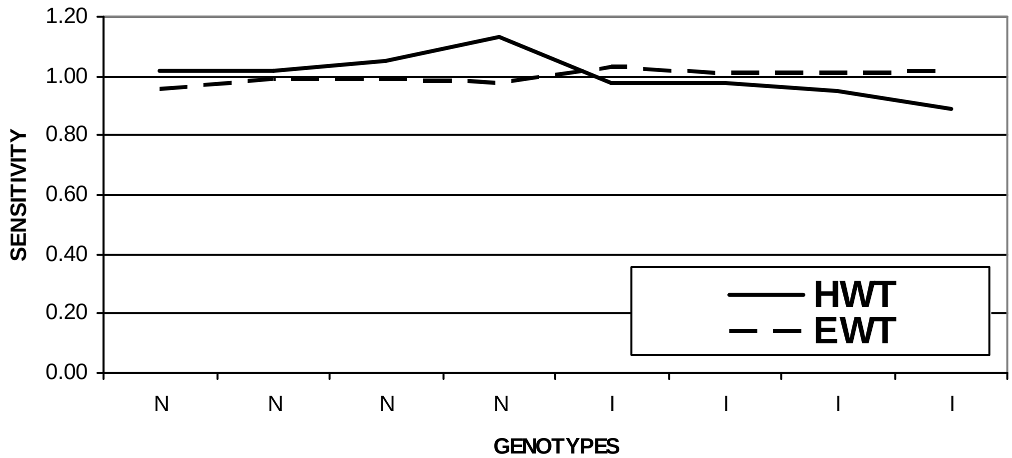
Appendix 7.1.2: Chart of sensitivity relationship between breeder cock weight and egg fertility



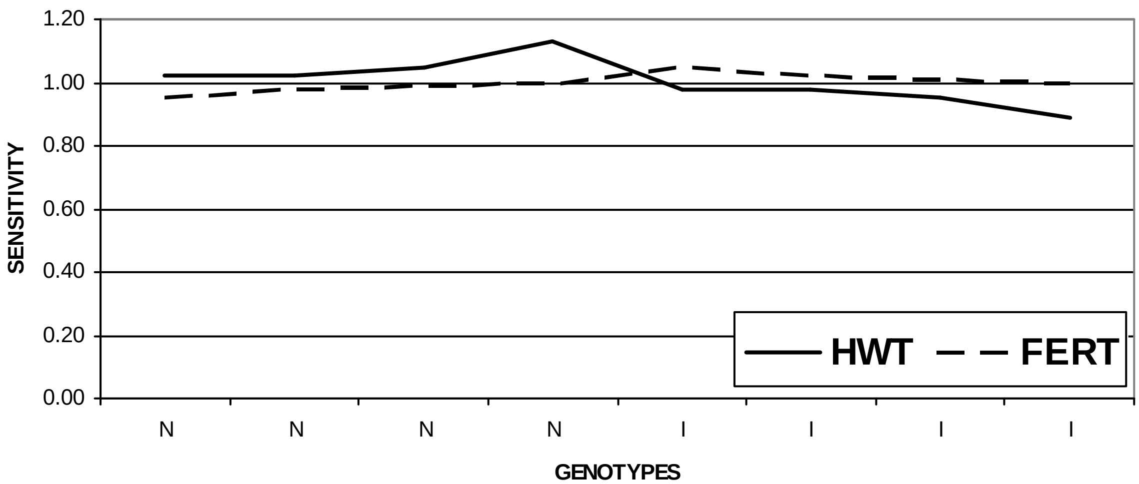
Appendix 7.1.3: Chart of sensitivity relationship between breeder hen weight and hen day production



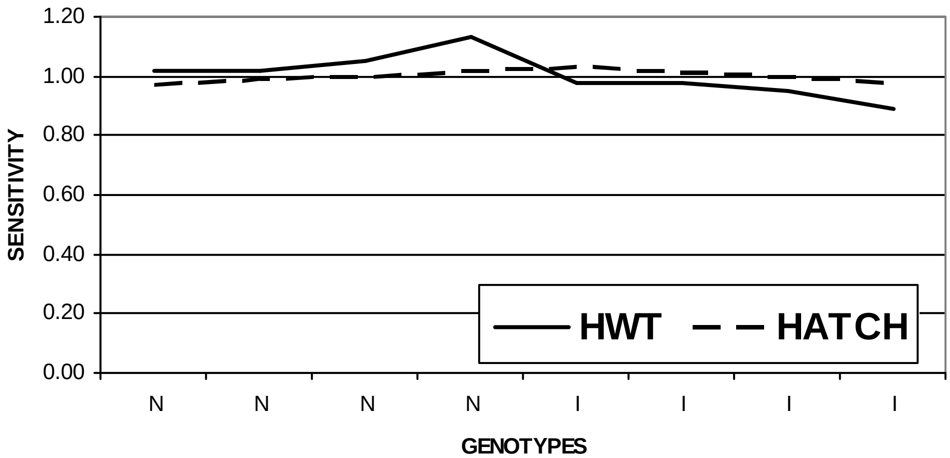
Appendix 7.1.4: Chart of sensitivity relationship between breeder hen body weight and egg weight



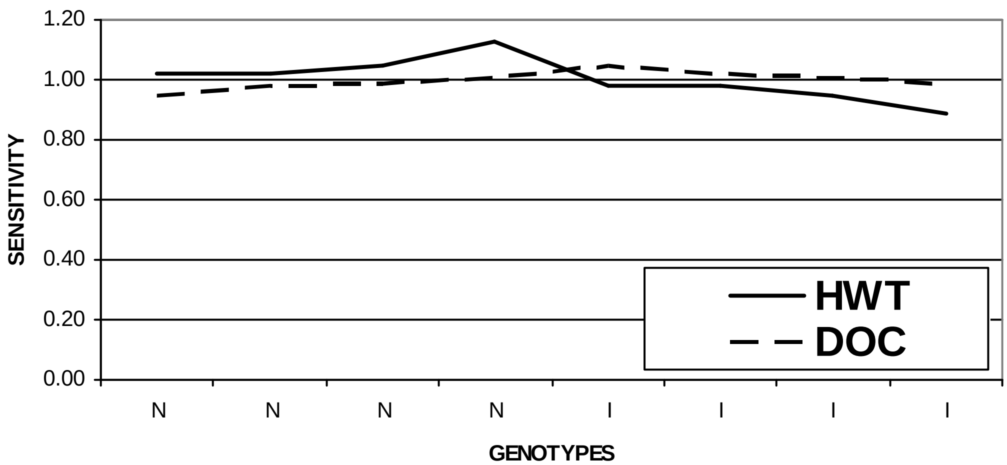
Appendix 7.1. 5: Chart of sensitivity relationship between breeder hen weight and egg fertility



Appendix 7.1.6: Chart of sensitivity relationship between breeder hen weight and egg hatchabiltiy



Appendix 7.1.7: Chart of sensitivity relationship between hen weight and day-old chicks hatched



7.2.0: Tables

Appendix 7.2.1: Cock body weight depression of Bovan Nera and ISA Brown in hot-humid Ibadan environment

Parameter	Week	Bovan Nera (%)	ISA Brown (%)
	4	-15.96	-27.66
	8	-2.51	-3.40
	12	6.77	3.39
	16	8.35	4.25
Cock	20	1.64	8.63
	5% Production	-	4.65
Weight	50 % Production	-1.12	8.94
	25	-1.19	3.01
	Peak production	5.14	6.38
	35	2.97	-
	45	4.40	4.32
	55	5.98	5.80
	65	6.03	4.63
	75	6.71	-3.96
	Life-time Mean	2.09	1.39
Environmental depression = ((Temperate - Tropical) / Temperate) x 100			

Appendix 7.2.2: Hen body weight depression of Bovan Nera and ISA Brown in hot-humid Ibadan environment

Parameter	Week	Bovan Nera (%)	ISA Brown (%)
	4	-12.99	-15.39
	8	-1.59	-7.31
	12	2.14	-3.48
	16	0.68	-2.23
Hen	20	-7.13	1.01
	5% Production	-	-3.71
Weight	50 % Production	-5.86	1.50
	25	-6.48	-2.88
	Peak production	-6.55	-3.88
	35	-6.82	-7.60
	45	-5.94	-6.49
	55	-5.47	-4.88
	65	-4.95	-3.80
	75	-3.32	-2.34
	Life-time Mean	-4.94	-4.39

Environmental depression = ((Temperate - Tropical) / Temperate) x 100

Appendix 7.2.3: Depression of age, hen-day production and egg weight of Bovan Nera and ISA Brown in hot-humid Ibadan environment

Parameter	Week	Bovan Nera (%)	ISA Brown (%)
Age of Hen	5 % Production		-5.00
	50 % Production		4.65
	Peak Production	7.14	7.41
	Mean		
Hen Day Production	21	13.57	-23.73
	25	-5.26	-10.22
	Peak production	-11.85	-6.76
	35	-10.28	-9.69
	45	-8.54	-9.15
	55	-3.20	-11.08
	65	7.91	-6.20
	75	1.65	-4.76
	Life-time Mean	0.14	-10.20
Egg Weight	5 % Production	-	-13.32
	21	-2.78	-7.63
	25	-0.96	-2.2
	50 % Production	-2.95	-4.22
	Peak production	1.70	3.64
	35	-5.34	0.61
	45	-5.22	-2.27
	55	-4.43	-2.19
	65	-5.21	-1.15
	75	-3.86	-
	Life-time Mean	-2.89	-3.19

Environmental depression = ((Temperate - Tropical) / Temperate) x 100

Appendix 7.2.4: Depression of egg fertility and hatchability of Bovan Nera and ISA Brown in the hot-humid Ibadan environment

Parameter	Week	Bovan Nera (%)	ISA Brown (%)
	25	-11.77	-
Egg	Peak production	-10.13	-
Fertility	35	-8.33	-
	45	-3.12	-
	55	-4.92	-
	65	33.01	-
	75	-	-
	Life-time Mean	-6.88	N. A.
	25	-20.39	-
	Peak production	-19.55	-
Egg	35	-16.45	-
Hatchability	45	-6.80	-
	55	-9.57	-
	65	-13.69	-
	75	-	-
	Life-time Mean	14.41	N. A.

Environmental depression = ((Temperate - Tropical) / Temperate) x 100

Appendix 7.2.5: Seasonal stocking pattern, recommended stocking dates and onset of egg-lay in genotypes

SEASONS	BOVAN NERA			ONSET OF	ISA BROWN		
	BATCHES	FREQ. %	STOCKING DATE	EGG-LAY	BATCHES	FREQ. %	STOCKING DATE
Early wet	5	20.83		April 16 - July	1	4.17	
Late wet	9	37.5	18-Mar	August - October	12	50	24-Mar
Early dry	9	37.5	18-Jun	November - January	6	25	20-Jun
Late dry	1	4.17		February - April 15	5	20.83	
Total	24	100			24	100	

Appendix 7.2.6: Mean body weight, production and reproduction data on Bovan Nera Parent-stock flock raised on deep-litter system in the humid South-West Nigeria

Age (week)	Cock weight (gm)	Hen weight (gm)	Egg weight (gm)	HDP (%)	Egg set (%)	Egg fert. (%)	Egg Hatch. (%)	pullet DOC (%)	Rejects (%)
Day-old	35.63	35.62	.	.	.	.	.	.	.
1.00	65.17	69.64	.	.	.	.	.	.	.
2.00	104.91	114.26	.	.	.	.	.	.	.
3.00	164.71	180.17	.	.	.	.	.	.	.
4.00	252.11	261.02	.	.	.	.	.	.	.
5.00	327.68	339.17	.	.	.	.	.	.	.
6.00	441.30	436.68	.	.	.	.	.	.	.
7.00	527.74	508.68	.	.	.	.	.	.	.
8.00	633.70	610.15	.	.	.	.	.	.	.
9.00	766.57	723.94	.	.	.	.	.	.	.
10.00	861.71	814.11	.	.	.	.	.	.	.
11.00	1006.97	902.10	.	.	.	.	.	.	.
12.00	1115.74	1000.95	.	.	.	.	.	.	.
13.00	1239.18	1155.86	.	.	.	.	.	.	.
14.00	1368.00	1256.06	.	.	.	.	.	.	.
15.00	1487.59	1311.97	.	.	.	.	.	.	.
16.00	1587.40	1359.15	.	.	.	.	.	.	.
17.00	1654.06	1418.03	.	0.04	.	.	.	.	.
18.00	1749.37	1489.76	38.50	0.18	.	.	.	.	.
19.00	1831.19	1559.91	40.69	1.14	.	.	.	.	.
20.00	1961.66	1625.20	40.47	2.95	.	.	.	.	.
21.00	2087.75	1711.43	43.75	7.95	.	.	.	.	.
22.00	2121.24	1771.20	45.43	20.30	.	.	.	.	.
23.00	2153.59	1798.44	47.25	41.14	99.82	72.48	56.00	24.62	20.16
24.00	2183.44	1835.41	48.83	61.65	95.26	77.59	63.11	27.58	17.70
25.00	2218.39	1842.27	50.51	72.00	95.93	73.23	58.91	27.57	15.57
26.00	2269.68	1849.65	52.23	75.44	96.67	75.23	57.93	26.41	18.64
27.00	2308.40	1857.51	52.98	75.36	89.88	76.78	60.39	28.28	17.57
28.00	2337.16	1863.04	53.95	76.49	99.11	74.30	61.45	28.61	13.55
29.00	2350.81	1879.69	54.44	78.52	96.99	81.01	66.26	31.26	15.57
30.00	2370.70	1887.63	54.92	80.22	99.33	83.58	69.99	33.11	14.51
31.00	2444.58	1898.60	55.24	80.03	98.30	84.82	72.97	34.56	12.71
32.00	2456.83	1910.83	55.63	79.23	99.10	81.43	77.44	36.43	12.20
33.00	2475.79	1918.69	55.71	77.57	99.11	84.22	72.66	34.52	12.37
34.00	2493.64	1925.42	55.74	77.66	99.44	85.20	73.91	34.98	12.16
35.00	2503.25	1931.52	55.85	78.06	98.74	85.25	73.52	34.79	12.58
36.00	2512.55	1939.24	56.05	77.59	98.61	85.27	73.36	34.98	12.60
37.00	2524.71	1945.13	55.93	76.62	99.46	83.88	72.05	34.25	12.53

38.00	2543.19	1958.04	56.17	76.34	98.68	83.84	64.62	30.17	20.51
39.00	2556.92	1966.50	56.23	75.47	99.34	83.08	59.17	28.13	24.52
40.00	2565.06	1967.73	56.47	74.26	82.43	86.29	73.76	35.21	13.27
41.00	2572.09	1969.39	56.27	74.00	98.11	86.80	76.23	36.40	11.32
42.00	2580.13	1975.03	56.43	73.37	99.50	86.49	76.25	36.28	10.98
43.00	2594.35	1982.12	56.70	72.51	98.44	85.65	74.73	35.72	11.66
44.00	2610.06	1990.40	56.72	72.33	96.93	83.66	76.77	36.48	11.54
45.00	2618.45	1998.67	56.87	72.25	99.44	87.19	78.29	37.24	11.85
46.00	2632.64	2013.75	56.82	72.94	97.87	87.99	77.81	37.10	10.87
47.00	2640.60	2017.14	57.27	73.85	97.83	89.82	76.24	36.28	10.69
48.00	2645.87	2020.85	57.33	72.35	93.62	87.55	77.33	36.52	11.01
49.00	2657.92	2023.99	57.46	72.53	95.32	87.10	75.10	36.02	12.76
50.00	2667.96	2027.64	57.78	71.49	99.57	88.40	77.80	37.42	11.36
51.00	2674.69	2032.92	57.82	70.19	68.21	84.90	75.87	36.09	20.55
52.00	2679.46	2037.87	57.95	69.47	98.49	86.36	74.17	35.37	13.23
53.00	2691.19	2042.03	58.07	68.66	95.77	84.48	71.20	33.43	12.18
54.00	2702.07	2046.55	58.16	67.82	99.49	83.61	72.15	34.31	13.35
55.00	2737.51	2049.44	58.30	67.76	99.25	84.62	75.06	36.58	10.95
56.00	2749.30	2055.33	58.23	68.44	99.33	85.10	74.44	35.29	12.08
57.00	2754.89	2063.82	58.46	67.62	99.39	81.68	72.16	33.89	10.30
58.00	2758.96	2068.10	58.50	67.04	99.40	84.61	70.70	32.58	14.34
59.00	2763.97	2072.75	58.34	65.88	99.20	83.05	66.32	31.51	18.41
60.00	2764.72	2074.99	58.53	66.28	99.77	84.43	70.88	33.46	13.27
61.00	2767.77	2076.77	58.71	64.19	99.22	83.65	70.70	33.02	15.51
62.00	2774.99	2077.88	59.27	62.49	98.07	83.85	72.61	33.66	14.57
63.00	2782.02	2078.46	59.54	63.38	98.81	82.76	68.90	32.50	16.47
64.00	2791.08	2081.87	59.64	63.73	98.94	83.18	66.34	29.38	19.80
65.00	2800.20	2084.36	59.72	63.67	99.23	84.38	69.05	32.30	17.85
66.00	2805.22	2088.82	60.04	65.54	99.43	84.46	70.80	33.53	16.10
67.00	2809.90	2097.85	59.77	63.54	99.39	84.57	69.41	32.17	17.99
68.00	2813.43	2103.29	59.90	61.67	99.18	82.43	66.51	30.96	18.62
69.00	2820.24	2108.70	60.04	60.62	99.41	83.35	70.04	32.64	18.69
70.00	2825.76	2112.99	60.15	60.78	96.03	82.21	66.69	31.43	19.82
71.00	2834.80	2117.11	60.18	60.92	94.08	80.36	64.00	30.32	20.62
72.00	2839.48	2122.54	60.18	60.92	97.72	81.18	64.55	30.24	20.75
73.00	2843.99	2125.92	60.22	59.82	96.40	83.24	67.53	31.83	20.44
74.00	2851.30	2133.06	60.65	58.56	96.33	81.99	65.85	30.92	20.00
75.00	2888.56	2144.40	61.53	58.06	96.19	82.84	66.05	30.86	21.15

Appendix 7.2.7: Mean body weight, production and reproduction data on ISA Brown Parent-stock flock raised on deep-litter system in the humid South west Nigeria.

Age (week)	Cock weight (gm)	Hen weight (gm)	Egg weight (gm)	HDP (%)	Egg set (%)	Egg fert. (%)	Egg Hatch. (%)	pullet DOC (%)	Rejects (%)
Day-old	36.39	37.28	.	.	.	.	.	.	.
1.00	57.33	62.92	.	.	.	.	.	.	.
2.00	106.40	117.24	.	.	.	.	.	.	.
3.00	163.59	170.79	.	.	.	.	.	.	.
4.00	235.11	245.37	.	.	.	.	.	.	.
5.00	330.91	339.49	.	.	.	.	.	.	.
6.00	402.66	442.57	.	.	.	.	.	.	.
7.00	520.73	510.97	.	.	.	.	.	.	.
8.00	627.93	602.49	.	.	.	.	.	.	.
9.00	742.03	694.27	.	.	.	.	.	.	.
10.00	878.75	780.20	.	.	.	.	.	.	.
11.00	1001.12	870.13	.	.	.	.	.	.	.
12.00	1080.44	965.19	.	.	.	.	.	.	.
13.00	1215.09	1047.63	.	.	.	.	.	.	.
14.00	1313.99	1140.67	.	.	.	.	.	.	.
15.00	1390.33	1203.88	.	0.01	.	.	.	.	.
16.00	1527.27	1280.74	.	0.05	.	.	.	.	.
17.00	1599.34	1358.40	.	0.25	.	.	.	.	.
18.00	1879.50	1426.49	40.22	1.18	.	.	.	.	.
19.00	2019.81	1501.98	41.26	4.86	.	.	.	.	.
20.00	2096.52	1575.69	44.53	12.12	.	.	.	.	.
21.00	2157.46	1606.23	46.00	22.88	.	.	.	.	.
22.00	2198.63	1651.59	47.39	38.98	.	.	.	.	.
23.00	2246.14	1677.92	48.85	56.86	.	.	.	.	.
24.00	2279.73	1699.10	52.52	71.79	90.50	82.45	54.81	31.58	16.95
25.00	2317.80	1709.26	53.40	81.70	98.35	85.84	69.89	36.03	11.41
26.00	2346.12	1723.81	54.14	85.65	97.04	85.34	71.71	35.53	12.32
27.00	2370.49	1730.40	56.18	86.11	98.36	86.61	73.55	35.85	14.06
28.00	2389.65	1734.91	56.54	86.17	97.08	88.57	75.35	36.67	14.06
29.00	2418.62	1738.37	57.56	85.99	99.49	88.57	72.60	35.48	15.93
30.00	2441.47	1742.55	58.04	86.71	98.79	88.00	77.56	37.76	11.64
31.00	2451.81	1744.18	58.49	85.75	98.25	89.79	79.30	39.02	11.24
32.00	2462.47	1748.35	58.62	85.84	97.30	87.15	79.96	39.19	7.71
33.00	2482.06	1752.99	59.13	84.08	96.31	90.15	79.62	38.96	11.23
34.00	2495.50	1759.57	59.33	83.74	95.54	90.35	79.03	39.00	11.94
35.00	2518.63	1769.49	59.36	83.99	99.38	90.16	78.06	38.16	12.76
36.00	2536.63	1778.09	59.50	85.35	99.12	89.73	75.63	36.93	14.73
37.00	2551.79	1783.91	59.40	85.45	99.66	89.58	76.36	37.26	13.79

38.00	2563.08	1774.00	59.70	83.21	98.92	88.88	76.71	37.54	12.74
39.00	2570.32	1797.25	59.65	82.23	99.47	88.50	75.95	37.21	13.29
40.00	2576.40	1802.84	60.09	83.80	99.65	87.86	75.30	36.62	13.10
41.00	2581.17	1806.30	60.13	83.75	99.64	88.15	73.31	35.96	13.64
42.00	2588.18	1812.75	58.87	82.92	95.39	90.45	75.43	36.82	19.66
43.00	2593.25	1817.34	59.63	81.58	99.51	86.17	75.11	36.56	11.65
44.00	2599.92	1820.67	59.81	81.03	98.71	87.17	73.18	34.92	14.61
45.00	2613.12	1824.32	59.32	79.95	99.75	88.62	76.73	37.50	12.58
46.00	2622.53	1840.37	59.41	78.77	91.85	88.20	73.96	35.85	14.57
47.00	2639.69	1844.45	59.74	76.47	98.13	87.71	75.80	36.72	12.54
48.00	2645.03	1850.70	60.36	78.66	97.96	88.09	76.30	36.69	12.72
49.00	2653.69	1858.10	59.63	76.56	96.21	88.51	71.43	34.89	17.81
50.00	2667.30	1867.97	59.79	76.63	97.34	85.94	68.46	33.22	18.26
51.00	2676.93	1872.53	60.16	76.33	92.15	85.74	71.32	34.66	15.35
52.00	2684.75	1874.86	60.07	75.40	99.57	86.30	73.80	35.77	17.01
53.00	2692.85	1877.80	59.84	75.47	99.60	86.77	69.24	32.21	17.92
54.00	2699.69	1881.41	60.43	74.33	99.58	83.60	67.24	32.34	17.29
55.00	2703.13	1887.25	60.35	72.47	99.50	85.61	69.90	33.86	17.29
56.00	2700.32	1894.91	60.45	71.92	99.51	87.76	72.20	35.19	16.24
57.00	2721.32	1896.73	60.89	71.47	99.52	86.32	77.90	38.03	16.07
58.00	2732.46	1903.24	60.81	70.13	99.38	89.46	72.04	34.69	18.35
59.00	2735.10	1909.91	61.11	71.65	99.66	86.56	69.03	32.99	18.34
60.00	2741.23	1912.03	61.35	70.52	99.50	86.85	69.96	33.68	17.71
61.00	2746.09	1916.09	61.40	70.83	99.51	87.36	70.19	33.47	18.14
62.00	2754.46	1919.52	61.24	70.64	99.58	86.63	69.43	32.99	17.95
63.00	2762.26	1922.04	61.14	70.31	99.96	86.96	68.97	33.26	18.72
64.00	2770.73	1923.51	61.39	69.61	99.39	87.09	68.73	33.02	19.38
65.00	2774.68	1925.96	61.78	69.13	99.52	86.64	68.26	32.76	19.36
66.00	2780.40	1928.02	61.80	68.30	99.55	88.39	68.49	32.97	20.74
67.00	2784.41	1931.13	62.92	68.01	99.56	86.09	66.81	32.44	20.22
68.00	2792.33	1937.88	60.94	68.05	99.23	82.37	62.87	30.55	20.41
69.00	2806.16	1940.39	61.57	66.98	99.53	83.14	60.68	29.37	23.42
70.00	2841.47	1944.09	61.56	65.48	98.75	82.57	59.44	28.16	24.49
71.00	2857.82	1946.06	61.28	64.78	95.89	81.97	56.64	24.69	28.74
72.00	2864.30	1950.93	61.56	63.36	94.25	81.87	51.50	24.75	31.29
73.00	2869.07	1954.76	60.70	63.63	96.92	78.86	55.24	26.52	27.32
74.00	2879.39	1960.84	60.89	62.72	99.51	81.52	69.07	33.21	25.47
75.00	2884.93	1974.68	60.75	60.67	98.96	82.87	52.94	25.24	30.72