STUDIES ON THE FERTILITY AND HATCHABILITY OF SOME BREEDS OF CHICKEN SUITABLE FOR BACKYARD FARMING

M.V.Sc. Thesis

By

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RAIPUR (C.G.)

2010

STUDIES ON THE FERTILITY AND HATCHABILITY OF SOME BREEDS OF CHICKEN SUITABLE FOR BACKYARD FARMING

Thesis

Submitted to the
Indira Gandhi Krishi Vishwavidyalaya, Raipur

by
Abhay Kumar

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Veterinary Science
in
Livestock Production and Management

NOVEMBER, 2010

Roll No.11236 **ID No. 420108003**

VITA

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November, 2010

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CERTIFICATE – I

This is to certify that the thesis entitled "**Studies on the Fertility and Hatchability of Some Breeds of Chicken suitable for Backyard Farming"** submitted in partial fulfilment of the requirements for the degree of **Master of Veterinary Science** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Dr. Abhay Kumar** under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: **Dr. Keshab Das**

Chairman, Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member **(Dr. M. Mondal)** : …………………………………….

CERTIFICATE – II

This is to certify that the thesis entitled "**Studies on the Fertility and Hatchability of Some Breeds of Chicken suitable for Backyard Farming"** submitted by **Dr. Abhay Kumar** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in the partial fulfilment for the degree of **Master of Veterinary Science** in the Department of Livestock Production & Management, College of Veterinary Science and Animal Husbandry, Anjora, Durg has been approved by the Student's Advisory Committee after oral examination in collaboration with the external examiner.

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Date

ACKNOWLEDGEMENTS

There is a saying "In the field of observations, the chance favours only prepared minds". Though generally one's work is always the product of one's own labour but one cannot forget to express the gratitude he owes towards persons who have contributed in various ways.

A formal word of acknowledgement will hardly fulfill the end of justice while expressing my deep sense of gratitude and indebtedness to my major advisor Dr. Keshab Das, Associate Professor, Department of Livestock Production & Management, College of Veterinary Science and A.H., Anjora, Durg, C.G.; anything that I say about him is matchless, an ideal inculcator, ever patient, known for his ability to dig the treasures in oneself and fills confidence in students. He sets himself as an epitome of humility and always brought smile on my face, encouraging me to ride on the high hills. His positive attitude and simple approach to any grave problem makes winners out of mediocre. I am running short of words in describing him. His fatherly attitude always calmed me at the time of distress. From the bottom of my heart with no place for flattery, I take pride in calling him "the best Teacher I have ever come across".

I feel the proud privilege and honour to express my profound sense of gratitude to respected Dr. K.C.P. Singh, Dean, College of Veterinary Science and A.H., Anjora, Durg, C.G., for his overwhelming support, incessant motivation and valuable suggestions.

I express my deepest sense of indebtedness to Dr. S.K.Chourasia, Professor and Head, Department of Livestock Production & Management, for help in all possible capacities and valuable suggestions and for providing all necessary assistance and facilities during the course of research work.

I am grateful and feel highly esteemed to express my sincere thanks and kind regards to the members of advisory committee Dr. Sharad Mishra, Professor, Department of Livestock Production & Management, Dr. Kishore Mukherjee, Associate Professor, Department of Animal Genetics and Breeding and Dr. Mrityunjay Mondal, Assistant Professor, Department of Veterinary Pathology, College of Veterinary Science and A.H., Anjora, Durg, for their persistent encouragement, noble guidance, valuable suggestions and generous help throughout the course of investigation.

Heartily, I express my sincere obligation and earnest thanks to Dr. Ajit Kumar Santra, Associate Professor, Dr. Dhirendra Bhonsle, Assistant Professor and Dr. Vikash Khune, Assistant Professor, Department of Livestock Production & Management for their invaluable assistance, generous support and all possible help during the course of this research work.

I am highly grateful to Dr. N.P.Singh, In-charge of Government Poultry Farm, Durg (C.G.), Dr. Namrata Sharda and other staff members (Shri Belchandra, Kunjam and Bhim

Singh) for providing me all necessary assistance and facilities during the course of research work in the Government Poultry Farm.

I am extremely delighted to extend my sincere thanks to my seniors Drs. Kamlesh Gurmita, Mukesh Sinha, Upan Dang, Sanjit Singh, Mahendra Ram, Sandip Manderia, Bhushan Sahu, M.C. Deshmukh, Nilmani Kerketta, Nishma Singh and others for their valuable help and co-operation throughout the course of work.

My departmental Colleagues Drs. Ashutosh Dubey, Rupal Pathak, Rekha Mire, and juniors Ashish, Arvind and Nutan are just ideal as I demanded from GOD. They always helped me whenever I needed. I am extremely privileged to have colleagues & juniors like those. A deep hearted thanks to all of them.

It is my great pleasure to acknowledge the memorable company of my friends Drs. Alok Bharti, Ranwir, Jyoti, Raju Ranjan, Neelam, R. Modi, Akhileshwar, Subhankar, O.P. Paikra, Bhupendra, Samprikta, Narayani, Ritu, Ranjana and others for their continuous support and encouragement during the time when it was most needed. I am also extremely thankful to the juniors Drs. Abhishek Singh, Avinash Gyani, Piyusha, Amit Kunal, Jnanesh, Ranjit, Pankaj Jain, Neeta and others for their immense co-operation and generous help throughout the course of investigation.

I am also thankful to Shri Sampat, Vishnu, Basant and Smt. Anita, non-teaching staff of the Department of Livestock Production & Management for their help and services rendered to me during the course of work.

*I thank the **ICAR** (New Delhi) for funding and facilitating my research work.*

Where emotions are concerned words fail to express the feelings. My profound regards are forwarded to my parents for their blessings, forever love, immense support and innumerable sacrifices which made this event achievable. I am highly indebted to my elder siblings; brother, Dr. Amar and sisters Poonam and Sandhya, for their lifetime unconditional love, support and encouragement. This manuscript would not be completed if I forget to mention names of my brother-in-laws Mr. Raj Kishore and Dr. Rakesh, and nephews Yash and Harsh.

I also take the privilege to thank the Almighty for giving me patience, wisdom and strength to overcome the difficulties that paved my way to accomplish this endeavour.

At last I want to reserve a special word of thanks for all those who have helped in many different ways directly or indirectly for completion of the whole work.

Anjora, Durg *(Abhay Kumar)*

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
%	Percent
<	Smaller than
>	Greater than
±	Plus or minus
≤	Smaller or equal to
≥	Greater or equal to
^{0}C	Degree Celsius
^{0}F	Degree Fahrenheit
B	Brown
BR	Black Rock
cm	centimetre
CW	Creamy white
df	Degree of freedom
EB	Egg breadth/ width
EEM	Early embryonic mortality
EL	Egg length
et al.	and other (Latin et alii)
etc.	so on (Lain et cetera)
EW	Egg weight
FES	Fertile egg set basis

Fig.	Figure
g	gram
GP	Gramapriya
LB	Light brown
LEM	Late embryonic mortality
M.S.	Mean sum of square
MEM	Mid embryonic mortality
mm	millimetre
No.	Number
p<	Probability to be less
SE	Standard error
SI	Shape index
ST	Shell thickness
TES	Total egg set basis
VR	Vanaraja
vs	versus
χ^2	Chi-square

CHAPTER-I
Introduction

CHAPTER- I
INTRODUCTION

Chickens (fowls) are reared in many parts of the world irrespective of the climate, traditions, life standard or religious taboos relating to consumption of eggs and chicken meat unlike those for pork or beef (Tadelle, 2003). To the poor majority in rural areas, local chicken serve as an immediate source of meat and source of income when money is needed for urgent family needs (Ekue *et al*., 2002). It constitutes a significant contribution to human livelihood and contributes significantly to food security (Gondwe, 2004).

Poultry is fastest growing sector of Indian agriculture today. Presently India ranks 4^{th} in the world egg production (Anon., 2008). Poultry industry in India has registered a phenomenal growth during the last four decades making it one among the world leaders in poultry production. Today poultry farming has transformed itself into an organized industry. Good farm management, access to the latest inputs in birds health, genetic improvement and quality feed have all contributed to this phenomenal success. The number of egg production in India has increased to 51billion in 2007 (Anon., 2008) but it is not same with meat production as we are not a prominent figure in the world poultry meat production. In spite of the manifold increase in the industry, we need to improve in meat production. However, the growth in the sector, both egg and meat production, could be enormous if the vast rural poultry in India could be strengthened thereby increasing the total national production.

For improving meat and egg production now improved varieties of fowls are being reared as backyard farming. The development of organized poultry has infact masked the contribution of backyard poultry or house hold poultry in rural sector. Poultry farming in India was mostly a backyard venture till 1960s. Indigenous chicken constituted the major share. As per the latest livestock census, rural poultry constitute about 52% of the total poultry population at national level. Though precise information is not available, yet it is certain that backyard poultry is significantly contributing to the nutritional and livelihood security amongst rural poor. Backyard poultry farming is gaining wider importance and acceptance among the rural people as source of income generation, supplementary livelihood activity and an effective means to fight malnutrition. The egg and meat quality and quantity are the most important factors for popularization of the backyard farming. It seems, therefore a laudable proposition that more attention is given to the genetically improved and developed variety birds (improved breeds) in order to ameliorate the present acute shortage of animal protein to the poor sections in the country. These varieties are suitable for rural areas for backyard farming similar to the traditional poultry keeping in the villages. Such varieties are popular and well accepted by the small, marginal and landless farmers across the country.

Though lot of work has been carried out on egg quality traits of established breeds, the information on varieties developed and being popularized for backyard farming in rural and tribal areas are limited. The detailed characterization of these breeds with respect to its egg production, hatchability and growth performance traits are generally unavailable. This information must necessarily precede their genetic improvement for commercial traits. The objective of the present work is to characterize these breeds for fertility and hatchability.

The success and profit of a hatchery depends on the production or procurement of eggs having high fertility, their proper handling and successful incubation. It is generally agreed that fertility and hatchability are major economic traits in poultry industry and now a days many commercial hatcheries claim more than 90% successful hatchability but this result may be obtained with commercial layer breeds and not with the improved varieties of fowl which are promoted for backyard rearing.

In our country about 30% of eggs set in the incubator fail to hatch, partly because of infertility (about 10- 15%) and the rest due to other causes. A number of factors including breed, egg age, storage condition, age of flock, system of husbandry and rearing technology, mating system, incubation relative humidity, temperature and eggs turning angle have been shown to influence the hatchability of poultry eggs. Improved management of eggs during incubation may therefore help to increase the hatchability of eggs. These causes of poor hatch can broadly be classified as genetic and environmental. The most important genetic causes are breed and strain differences and shape and size of eggs. The important environmental factors include packing and transportation of fertile eggs, their storage time and humidity, sanitization, turning during storage and the season of incubation.

The proposed study is aimed at evaluating egg traits, hatchability, fertility and chick hatch weight of commercial Black Rock, Gramapriya, and Vanaraja breeds of fowl reared in same management conditions. Out of the three breeds Black Rock is an established cross breed which was developed in America by crossing Rhode Island Red as male line and Barred Plymouth Rock as female line. The rest two are the new varieties developed to serve the interest of backyard poultry farming propagable under little care and attention. Gramapriya variety was developed by Project Directorate on Poultry (PDP) (Rajendranagar, Hyderabad) using Random bred meat control population as male line and White Leghorn population as female line. This is an egg type improved chicken variety. Vanaraja was also developed by PDP (Rajendranagar, Hyderabad) utilizing the Red Cornish as male line and random bred meat control population as female line. It is a dual purpose improved chicken variety. These varieties are suitable for free range or backyard or family poultry farming, in rural and tribal areas, where plenty of natural feed base is available. The natural feed (fallen grains, insects, worms, kitchen waste, green grass, etc.) available under rural or tribal backyard can be ploughed back into human food chain in the form of nutritious and delicious egg and chicken meat. Rural poultry farming with such improved chicken varieties, which demand low input in terms of management and feed, would enhance the nutritional and economic status of rural or tribal population. Besides the fertility and hatchability of three breeds, present study would be helpful to express a preference for the appropriate breed.

Therefore, the present investigation has been undertaken with the following objectives:-

Objectives:

1. To study the fertility and hatchability in some backyard breeds of chicken:

   The fertility and hatchability traits of above breeds/ varieties have not yet been studied extensively. It is desirable to know the performance of these above mentioned breeds under local conditions of Chhattisgarh (India). However, information on these birds is hardly available in the literature as researches on these lines had rarely been carried out under Chhattisgarh (India) conditions. The present study was designed to study these important economic traits.

2. To evaluate the effect of genetic and certain egg quality traits on fertility and hatchability:

   Fertility and hatchability are multi-factorial properties and affected by a number of factors. Therefore, the effects of genetic and certain egg quality traits have been evaluated in the present investigation.

3. To observe the embryonic mortality pattern in the above backyard breeds of chicken:

   This is an important observation which may helps us to study the embryonic mortality of the backyard breeds being popularized for rearing.

CHAPTER-II

Review of Literature

CHAPTER-II
REVIEW OF LITERATURE

History is a record of memorable things of past. Any branch of science including the Poultry Science have witnessed a number of scientific studies through the ages in order to make improvements in the field. In the search of scientific informations the researchers in the related field have come out with valuable findings. Systematic reviews are needed to efficiently integrate valid information and provide a basis for rational decision making. The use of explicit, systematic methods in reviews limits bias (systematic errors) and reduces chance effects, thus providing more reliable results upon which to draw conclusions and make decisions.

2.1 FERTILITY

Fertility of the eggs is of utmost importance in commercial hatchery operation. Fertility is calculated on the basis of egg containing a developing embryo out of total number of eggs set for incubation. About 10- 15 % infertility in a hatchery enterprise may be considered as normal, which also includes the embryonated eggs unidentified by candling on or around the third day of incubation. Therefore, early embryonic deaths undetectable by candling also go as infertiles.

The problem of unfertilized eggs has long been identified as one the most critical factors limiting the success of breeding programmes and ranges from 10.0- 98.2% both within and between farms (Hicks, 1993; Deeming, 1995; 1996a;

Dzama *et al*., 1995; More, 1996; Badley, 1997; Schalkwyk van *et al*., 2000; Park *et al*.,2001; Malecki and Martin, 2003a; Mushi *et al*., 2008; Dzoma and Motshegwa, 2009).

The fertility is influenced by various factors which have been reported by several investigators. Time of mating (Parker, 1950), social dominance (Guhland and Warren, 1946), season and environmental temperatures (Hays and Sanborn, 1939; Parker and Mespadden, 1942; Hewang, 1944; Blyth, 1945), and age of breeder (Insko *et al.*1947; Hamond, 1954; Hafez and Kamar, 1955; Singh, 1961) are some of the factors that have been known to affect fertility.

2.1.1 Breed:

Certain strains and breeds differ among themselves in fertility have been reported by different workers. Munro (1940) found that White Wyandottes were less fertile in comparison to some of the other breeds of domestic chickens.

Ishibashi *et al.* (1962) while working in purebred White Leghorn, New Hampshire, Barred Plymouth Rock and crosses from WL x NH and BPR x WL found that fertility was higher in spring than in summer in all the breeds and crosses.

Hussaini (1963) also observed a high percentage of infertility in New Hampshires.

Chhabra and Sapra (1972) observed that White Rock produces the eggs with inferior fertility and hatchability as compared to New Hampshire and White Cornish.

Hussaini and Desai (1972) found that purebreds had an infertility of only 9.2% whereas the crossbreds showed an overall infertility of 12.8%. They also observed that the specific mating of RIR males x NH females gave infertility to the extent of 38.6%. So they inferred that New Hampshire is inferior to White Leghorn and Rhode Island Red and the former gives about three times more infertile eggs than the latter.

Basnet (1973) investigated that there was no significant difference in the rate of fertility among White Leghorn, White Rock, New Hampshire and White Cornish breeds of chicken.

Tam and Wong (1974) compared fertility among Cantonese, Wai Chow, White Leghorn and New Hampshire where the fertility were 84.30, 83.62, 89.59 and 88.95% respectively.

Acharya and Kumar (1984) investigated that fertility in indigenous breeds like Naked Neck, Aseel, Kadaknath and Black Bengal was 80%, 55%, 90% and 86% respectively when reared in intensive systems.

Nwakpu *et al.* (1999) observed significant difference in fertility percentages among different genotypes of layer- type chicken. They observed that the black Olympia and Hubbard and Nick strains were 20% and 19% (respectively) higher in egg fertility than the investigated Nigerian local chicken. They were of the opinion that the intensive management given to the traditionally scavenging local chicken may have negated their performance.

Ahmad *et al.* (2000) conducted experiment on various breeds of chicken, and found that light breeds had higher fertility as compared to heavy breeds.

Singh *et al*. (2000) investigated in their study that in Aseel, an indigenous breed of chicken fertility was 84.28%.

Bandyopadhyay *et al.* (2003) found that the mean percentage of fertility fluctuated widely over generations between 68.85- 93.39 and 74.38- 91.04 in IWH and IWC strains of White Leghorn breed.

In local breeds of Ethiopia viz. Tukur, Melata, Kei, Gebsima and Netch, fertility was 56%, 60%, 57%, 53% and 56% respectively (FAO, 2004).

Rama Rao *et al.* (2004) reported average fertility among Vanaraja breed was 87% reared in several districts of Andhra Pradesh.

Fayeye *et al.* (2005) reported that fertility in the Fulani-ecotype chicken in Nigeria was 76%.

Niranjan and Singh (2005) observed that mean fertility percentage was 81.25% in Gramapriya breed when reared under intensive and free-range conditions of Tripura.

Narayanakutty *et al.* (2008) investigated that there was significant difference in the fertility in two strains (IWN- 98.9% and IWP- 96.8%) of White Leghorn breed.

Malago and Baitilwake (2009) reported that fertility was 92.0±4.14, 91.1±4.42, and 94.5±2.21 for local, Rhode Island Red, and crossbred chickens respectively.

2.1.2 Egg Weight:

Sharma and Bora (1966) investigated the relationship of egg weight with that of fertility. They obtained result from various size groups of egg weight in a White Leghorn flock, that lack of significant differences in fertility is independent of egg weight.

Khati *et al.* (1992) reported that in broilers, at higher altitude medium sized eggs were having higher fertility as compared to small and large sized eggs. They also investigated that there were no significant difference in the fertility of small and large egg sized egg.

Senapati *et al.* (1996) reported that in Japanese quail, fertility in different groups ranged from 71.43- 100.00%. There was a slight low negative correlation (-0.15) between egg weight and fertility.

Ahmad *et al.* (2000) found in their experiment that medium sized eggs (50- 60g) had higher fertility (85%) than either too small (<50g) or too large (>60g) sized eggs.

Narayanakutty *et al.* (2008) observed no significant difference for different egg weight categories in two strains of White Leghorn breed for fertility.

2.1.3 Shape Index:

Senapati *et al.* (1996) investigated in Japanese quail that shape index ranged from 79.53- 81.69 and there was a quite low but a positive correlation (0.14) between shape index and fertility of eggs.

Ahmad *et al.* (2000) reported that cylindrical eggs had higher fertility in comparison to oval and roundish eggs in various breeds of chicken.

Churchil *et al.* (2008) investigated that there was no significant difference for fertility between shape index classes in White Leghorn breed.

2.1.4 Shell Thickness:

Bennett (1992) observed in his studies that for most ages of breeders the fertility of thin shelled eggs was 1- 5% lower than the fertility of thick shelled eggs. Only in the 50.0- 54.9 week old breeder flocks did the thin shelled eggs have lower fertility because they tend to be larger eggs, laid by heavier and less fertile hens.

2.2 HATCHABILITY

The term hatchability is used by poultrymen to mean two different things. Hatchery operators generally use the term with respect to number of chicks hatched per hundred eggs incubated. Hatchability denotes the percentage of fertile eggs that hatch successfully following an appropriate incubation period. Hatchability therefore, basically involves losses owing to embryonic death at various stages of development.

The production of first-quality chicks depends on the breeding and hatching performance of the parent flocks. Failure to hatch is caused by infertility or by embryo death after fertilization. Before incubation, it is impossible to test whether an egg is infertile or not without destroying it (Austic and Nesheim, 1990).

Generally, the success of hatchery management is monitored by the percentage of eggs set that are hatched (hatchability) and the number of chicks that are placed for grow-out (saleable chicks). Reasons for low hatchability could be improper management of the breeder flock, an incorrect incubation procedure, or a failure within any step between the breeder flock and the final hatch.

Hatchability of eggs is known to have a genetic basis in domestic fowl (Moseley and Landauer, 1949) and is known to be affected by numerous environmental and nutritional factors (Taylor, 1949). Breeder factors that affect hatchability include strain, health, nutrition and age of the flock, egg size, weight and quality, egg storage duration and conditions, egg sanitation, and season of the year (Kirk *et al*., 1980; Wilson, 1991, 1997; Elibol *et al.*, 2002; Tona *et al*., 2005, 2007). Age of the breeders affects hatchability, because it is related to the quality of hatching egg such as the internal egg composition or ratio, egg weight, and shell quality, whereby the incubation condition and the development of the chick embryo are influenced (Wilson, 1991; Vieira and Mora, 1998; Tona *et al*., 2004; Joseph and Moran, 2005a). Hatchability is influenced by storage of eggs, because the quality of the egg depreciates whereby the metabolic activity of the chick embryo is affected, which in turn influences the embryonic development of the chick (Lapao *et al.*, 1999; Christensen *et al.*, 2001; Tona *et al.*, 2004; Decuypere and Bruggeman, 2007; Fasenko, 2007). Samli *et al.* (2005) also found an interaction between prolonged egg storage and high storage temperature with albumen pH and quality (Haugh), air cell size, specific gravity, and egg weight loss, which are important characteristics of the quality of hatching eggs. Additionally, hatchery factors that are related with hatchability include egg handling and storage condition and incubation conditions such as temperature, humidity, turning frequency, ventilation, and egg orientation (Elibol and Brake, 2006; Decuypere and Bruggeman, 2007).

High hatchability was found during summer, although the greatest and lowest hatchability varied with season in different hatcheries in the Netherlands (Yassin *et al.*, 2008). In contrast to the result of this study, Chowdhury *et al*. (2004) and Tona *et al*. (2007) found high hatchability in fall and winter and lower hatchability in the summer using data from broiler flocks in Belgium and data from a duck-breeding farm in Bangladesh, respectively.

2.2.1 Breed:

Breed differences in respect of hatchability has been studied by Hussaini (1963) who concluded that New Hampshire had lower hatchability of 49% against White Leghorn with highest hatchability of 76.9%.

Chhabra and Sapra (1972) obtained the hatchability of 80.43 and 78.21% respectively on the fertile eggs set, in White Cornish and New Hampshire breeds.

North (1972) observed that the hatchability was higher in Rhode Island Red breed than that of White Leghorn in his study.

Breeds have significant effect on the hatchability (Singh *et al*., 1983; Kalita *et al*., 1985 and Singh and Balsare, 1991).

Acharya and Kumar (1984) observed that hatchability in indigenous breeds like Naked Neck, Aseel, Kadaknath and Black Bengal were 61%, 45%, 61% and 68% respectively when reared in intensive systems.

Experiment conducted by Ahmad *et al.* (2000) on various breeds of chickens, it was found that light breeds had better hatchability in comparison with heavy breeds.

Singh *et al*. (2000) investigated in their study that in Aseel, an indigenous breed of chicken the overall hatchability of total and fertile eggs was 73.97 and 85.11%, respectively.

Farooq *et al*. (2001) observed significant difference among Desi, Fayumi and Rhode Island Red breeds of chicken in hatchability on TES and FES both.

Veterany *et al.* (2001) reported that the Rhode Island Red breed (88.55±10.35%) had slightly better hatchability than that of the ISA 715 Vedette hybrid (86.95±8.56%).

Gul *et al.* (2002) studied in non-descript desi chicken that hatchability on the basis of total eggs set was smaller (48.33±0.02%) than that on the basis of fertile eggs (74.04±0.01%).

Mwalusanya *et al.* (2002) founded that in Tanzania in local breeds of chicken, hatchability was 83.6%.

Local breeds of Ethiopia viz. Tukur, Melata, Kei, Gebsima and Netch had hatchability that of 42%, 42%, 44%, 39% and 39% respectively (FAO, 2004).

Rama Rao *et al.* (2004) reported average hatchability in Vanaraja breed was 80% reared in several districts of Andhra Pradesh.

Buragohain *et al.* (2005) reported that the average hatchability in Vanaraja breed varies from 17.86 to 76.04% (Average 56.73%) in high altitude areas of Arunachal Pradesh.

The hatchability in the Fulani-ecotype chicken in Nigeria was 47% as reported by Fayeye *et al.* (2005).

In Gramapriya breed mean hatchability TES and FES percentage was 64.71% and 79.97% respectively when reared under intensive and free-range conditions of Tripura as reported by Niranjan and Singh (2005).

Narayanakutty *et al.* (2008) observed no significant difference in hatchability in terms of TES (85.38% vs 84.13%) and FES (86.33% vs 86.92%) in two strains of White Leghorn breed.

Malago and Baitilwake (2009) reported that hatchability varied significantly at $p<0.05$ (80.6±1.43 in crossbred, 64.0±2.16 in RIR, and 52.2±2.54 in local chickens).

2.2.2 Egg Weight:

Because it is a rather simple matter to control the weight of an egg, many investigations have been directed towards establishing a relationship between egg weight and hatchability.

The average or medium sized egg gives the better hatchability than that of large eggs (Warren, 1934; Godfrey, 1936).

Within a flock of chickens, turkeys, or ducks, intermediate- sized eggs hatch better than their small or large counterparts (Rendel, 1943; Brunson and Godfrey, 1953; Morris *et al.*, 1968; Petersen, 1984; Connor, 1986; Wilson, 1991), and this appears to be the case in ostrich eggs as well (Gonzalez *et al*., 1999).

A similar result was obtained by Skoglund and Mumford (1948) from the New Hampshire eggs weighing 52- 57g. They also found the lower hatchability in very large as well as in very small eggs.

Czarnecka (1954) observed good hatchability of 74.8% from the large eggs weighing over 65g although eggs weighing 60.1- 65.0g gave the better hatchability of 81.1%. Their study also revealed that hatchability of the large eggs may be low if they come from the hens that normally lay small eggs.

Sharma and Bora (1966) found an inverse relationship between egg weight and hatchability and observed that the rate of hatchability is highest in eggs with weight range of 50.1- 60.0g.

Nordskog and Hassan (1971) found that hatchability was maximum when eggs weighed about 50g. A 10g increase in egg weight above this optimum value lowered hatchability by 10.7%, whilst a 10g decrease lowered it by 3.9%.

Basnet (1973) reported that egg weighing 50.1- 60.0g had significantly higher hatchability than the eggs weighing from 45.1- 50.0g.

The curvilinear relationship between egg weight and hatchability was investigated by Shatokhina (1975), who discovered that the hatchability of eggs weighing between 46 and 50g as well as those weighing between 66 and 74g was between 8 and 10.5% lower than for eggs of average weight (50- 66g).

Timothy and Hengemuchle (1989) have also reported better hatchability in medium size eggs.

Khati *et al.* (1992) investigated that at higher altitude, in broilers medium sized eggs were having better hatchability on the basis of total egg set in comparison to smaller and larger sized eggs.

French (1994) found turkey hatchability to progressively decrease with increasing egg size at high air temperature (38.5°C) but that large eggs exhibited improved hatchability when incubated at a reduced air temperature (36.5°C) during the second half of incubation mainly due to a decrease in late embryo mortality.

Zgobica and Wezyk (1995) concluded that in Isabrown hens, hatchability decreases when egg weight exceeded 70g.

Ahmad *et al.* (2000) conducted experiment on various breeds of chicken and concluded that medium sized eggs (50- 60g) had better hatchability (81.82%) than either too small (<50g) or too large (>60g) sized eggs.

The influence of different egg set weights of the Rhode Island breed and the ISA 715 Vedette hybrid on chicken egg hatching was investigated by Veterany *et al.* (2001). The highest hatchability (88.55±10.35 and 86.95±8.56%, respectively) was determined for eggs of medium weight (58.0±0.5 and 59.0±0.5g, respectively).

Gul *et al.* (2002) observed lower hatchability (40.98±0.02%) for heaviest eggs (>55g) and higher (around 85%) for small and medium sized eggs (>28 to <less or ≥50g) in non-descript indigenous (desi) chicken.

Kang *et al.* (2002) divided eggs of Yuzhou brown-shell breeding layers into six groups. These were A (<50g), B (50- 53g), C (53- 56g), D (56- 59g), E (59- 62g), and F (>62g). Eggs were hatched under the same conditions and the hatchability of fertile eggs was investigated and highest hatchability was recorded in group C.

Khurshid *et al.* (2003) concluded that in Japanese quails, large sized eggs resulted in better hatching performance as compared to small sized eggs.

Fertile hatchability decreased in the large egg weight group primarily due to an increased percentage late dead (Elibol and Brake, 2008).

Narayanakutty *et al.* (2008) concluded that egg weight had very low correlation with that of hatchability.

2.2.3 Shape Index:

Egg shape, which can be easily described in terms of the ratio of the maximum breadth and length, remains constant during the whole period of incubation. Therefore, this parameter has to meet the necessary requirements from the early stages of incubation up to the time of hatching.

Kumar and Shingari (1969), Tsarenko (1988) and Burtov *et al.* (1990) have all reported that eggs of normal shape hatch more successfully than those shaped abnormally.

Sarda *et al.* (1978) and Jay *et al.* (1985) observed that oval eggs had better hatchability (TES) than either cylindrical or roundish eggs.

Zgobica and Wezyk (1995) reported that in Isabrown hens hatchability decreases when the shape index exceeded 80%.

Senapati *et al.* (1996) investigated in Japanese quail that shape index ranged from 79.53- 81.69 and there was a low negative association of -0.05 was observed between shape index and fertility of eggs.

Ahmad *et al.* (2000) reported that shape index had no significant effect on the hatchability (TES) and cylindrical eggs had lower hatchability than oval and roundish eggs.

Shape index is one of the most influential egg parameter in successful hatching (Farooq *et al*., 2001 and Narushin and Ramanov, 2002).

Brar *et al.* (2002) reported that hatchability percentage was higher for shape index values between 69 and 75% than for the extremely low or high shape index values in a long-term selected strain of White Leghorn hens where shape index ranges (66.3 to 86.7).

Narushin and Ramanov (2002) reported that the incubation process is more successful if the eggs are more pointed rather than round.

Churchil *et al.* (2008) investigated that there was no significant difference for hatchability on both fertile and total egg set between shape index classes in White Leghorn breed.

2.2.4 Shell Thickness:

The eggshell performs a double function during embryo development. It has to be thick and strong enough to protect the embryo from external cause. At the same time, the shell should be sufficiently thin and fragile not to act as a strong barrier to the hatching process.

Koneva (1968) found that the contribution of shell thickness of turkey eggs to their hatchability was around 40%.

Andrews (1972) observed that the hatchability of turkey eggs with thinner shells was higher.

Sergeyeva (1986) reported that an increase in shell thickness of one micrometer in the range of 0.29- 0.35mm led to an increase in hatchability of about 2%.

Sharlanov *et al*. (1988) observed that when the shell thickness of turkey eggs increased from 0.44 to 0.50mm, their hatchability increased from 67 to 85%.

Tsarenko (1988) found that the hatchability of thick-shelled eggs was 30% higher than those with thin-shells.

Bennett (1992) investigated that hatchability of thin shelled eggs was 3- 9% less than that of thick shelled eggs in 30- 60 week old breeder flocks. At no time did the eggs appear too thick to hatch properly and overly thick shells do not appear to be a concern in commercial breeders.

Satteneni and Satterlee (1994) found that ostrich eggs that are thick shelled or of low porosity do not hatch well.

Roque and Soares (1995) reported higher hatchability in thick shelled eggs of broiler breeder.

Narahari (2000) observed that when egg shell is thin then it get damaged and reduces hatchability by increasing evaporative loss, leading to embryonic dehydration.

Gul *et al.* (2002) studied in non-descript desi chicken that differences in hatchability with respect to eggshell thickness were non-significant.

Narushin and Ramanov (2002) reported that the incubation process is more successful if the shell is thicker than average, both thick shells and firm interiors, which are accepted as being higher than average, lead to an increase in egg weight, which probably results in the more successful hatching of embryos from heavier eggs.

Khurshid *et al.* (2003) concluded that increase in eggshell thickness resulted in deterioration in hatching performance of Japanese quails.

2.2.5 Shell Colour:

Jull (1952) studied that the white shelled eggs lose more moisture and have less specific gravity, which result in low hatchability.

North (1972) reported that the hatchability was higher in Rhode Island Red eggs with brown shell than that of White Leghorn eggs. The reason may be the positive association of the density of pigment with hatchability, apart from thicker shell with more calcium and high specific gravity of brown shelled eggs.

Zgobica and Wezyk (1995) investigated that hatchability increased as shell colour intensity increased.

Shafey *et al.* (2005) reported better hatchability in dark brown shell eggs in comparison to light brown and medium brown shell eggs in chickens.

Moyle *et al.* (2008) observed that the hatchability in extremely light coloured eggs is lower than the darker eggs.

2.3 EMBRYONIC MORTALITY

Embryonic mortality occurs at all the times during incubations have been accepted by various workers, but according to Payne (1919) over 65% of the total embryonic mortality occurs during 4^{th} – 5^{th} and 18^{th} – 19^{th} days of incubation.

Byerly (1930) found the first peak period of embryonic mortality on 3^{rd} day of incubation.

El Ayadi (1956) reported an embryonic mortality of about 22.2% and 6.9% during the 1^{st} and 2^{nd} week of incubation respectively and 19.4% dead in shell.

Mannel (1965) stated that embryonic mortality occur more frequently in the eggs of highly fertile hens.

Mannel and Woelke (1965) reported the embryonic mortality of 13.5% and 21.9% during 1^{st} to 18^{th} and 19^{th} to 21^{st} days of incubation respectively.

North and Bell (1990) stated that the early embryo mortality period was a result of failure of the embryo to resume development after having been stored and placed in the setter.

Weis (1991) observed from his study on guinea fowls that the highest embryonic mortality occurred before hatching.

As described in the literature, eggs from young breeders have thick shells and produce smaller chicks that may have less physical strength to break the shell during hatching, resulting in embryo mortality after pipping (Pedroso *et al*., 2005).

Besides, genetic strain and parent flock age influence daily embryonic metabolism during the early and latter days of incubation, which coincides with the incidence of greater embryonic mortality during this period of incubation (Hamidu *et al*., 2007).

Abudabos (2010) reported that the mid embryo mortality period was usually related to nutritional deficiencies in the broiler breeder diet or embryonic abnormalities and the late embryonic mortality peak represented death due to abnormal positioning, complications in physiological changes, lethal genes and pipped not hatched represented death due to chick failure to penetrate eggs at the time of hatching.

2.3.1 Breed:

Byerly and Olsen (1934) observed embryonic mortality was highest in White Leghorn than in Rhode Island Red breed in first three days of incubation.

Basnet (1973) reported that embryonic mortality was higher in New Hampshire and White Cornish than White Leghorn and White Rock.

As the flock ages, there was more infertility and early embryonic mortality in eggs from Ross 308 compared with Cobb 500 (Deeming and Van Middelkoop, 1999).

Ahmad *et al.* (2000) reported that lighter breeds had lower late embryonic mortality.

2.4 CHICK WEIGHT

Raju *et al.* (1997) stated that day old chick weight increased significantly with increase in egg weight which may also be for the difference of genotype.

Ahmad *et al.* (2000) observed that breeds had significant effect on chick weight as a percent of egg weight. The heavy breeds produced heavier chicks (69.68% of egg weight) in comparison to light breeds (67.34% of egg weight).

Islam *et al.* (2002) observed that comparatively large size eggs always not resulted heavier chicks; breed also plays a significant role. So, chick weight was not just a function of egg weight but might be altered by genetic background of breeds.

Rama Rao *et al.* (2004) reported average day old chick weight (34- 40g) of Vanaraja breed much higher than that of indigenous fowl (25- 28g).

Average day old chick weight in Gramapriya was 36g reported by Rama Rao *et al.* (2004).

CHAPTER-III

Materials and Methods

CHAPTER-III
MATERIALS AND METHODS

The present investigation was conducted at the Government Poultry Farm, Durg (Chhattisgarh). The data were collected in three different breeds of chickens, such as Black Rock, Gramapriya and Vanaraja. The breed of Black Rock was originated from the Harco/Arbor Acres breeders of America. They are a true first-cross hybrid from especially selected strains of Rhode Island Red (male line) and a Barred Plymouth Rock (female line). Gramapriya variety was developed by Project Directorate on Poultry (PDP), Rajendranagar, Hyderabad, using Random bred meat control population as male line and a White Leghorn selected population as female line. These birds have more white plumage, medium in size and good egg laying capacity. Project Directorate on Poultry has also evolved Vanaraja variety utilizing the Red Cornish as male line and random bred meat control population as female line. All the layer birds for research were maintained at Government Poultry Farm, Durg in deep litter system of management with standard management and health care practices. All the birds were kept at an uniform stocking density of 3sq feet floor space per bird. The experimental birds belonged to the same age group (28- 35 weeks) and the sex ratio or the female to male ratio maintained was 10: 1.2. The study was conducted in April and May months of 2010.

A total of three trials were conducted in the present study. Data were collected from three consecutive hatches, the interval being seven days between the hatches. The main objective of the study was to assess the effect of breed, egg weight, shape index, shell colour and shell thickness on the fertility and

Fig. 1: Female bird of Black Rock breed

Fig. 2: Male bird of Black Rock breed

Fig. 3: Female bird of Gramapriya breed

Fig. 4: Male bird of Gramapriya breed

Fig. 5: Female bird of Vanaraja breed

Fig. 6: Male bird of Vanaraja breed

hatchability of chicken eggs. Some other associated traits such as inter-relationship between breed and chick weight and stage of embryonic mortality were also investigated.

Eggs were collected daily and stored at 21^0C temperature. After collection of eggs, all the eggs were sampled and eggs with visible external abnormalities were screened out. In this process extra large or very small eggs and misshapen eggs were discarded. The eggs with cracks and fissures or heavily soiled eggs were also rejected during screening. A total of 180 numbers of eggs from each breed were selected and numbered with permanent marker to identify the individual egg. Data on egg weight (g), length (cm), width (cm) and shell colour were recorded prior to setting eggs in the incubator. Data on shell thickness of the eggs and weight of chicks were recorded when hatching process was over.

All the eggs of different breeds after marking were considered for study of different parameters as follows:

3.1 Egg weight:

Individual egg weight was recorded during the entire experimental period by a electronic weighing balance with one gram precision. The eggs under study were classified in three groups as:

(i) 40- 46g

(ii) 47- 53g

(iii) 54- 60g

Fig. 7: Numbered eggs with different shell colour

Fig. 8: Weighing of egg with electronic weighing balance

3.2 Shape index:

The length and width of an egg were measured with the help of Vernier calipers with minimum unit reading up to 0.01 cm. Two observations of the egg width were recorded and the average value was considered. The shape index was calculated according to Reddy *et al*. (1979) as per the formula.

$$\text{Shape index} = \frac{\text{Width of egg}}{\text{Length of egg}} \times 100$$

Here also all eggs were classified into three different groups as:

(i) 70- 73%,

(ii) 74- 77%

(iii) 78- 81%

3.3 Shell colour:

Shell colour of the above breeds were of different intensity ranging from deep brown to almost white. It was observed manually and categorized into three different classes as:

(i) Brown

(ii) Light Brown

(iii) Creamy White

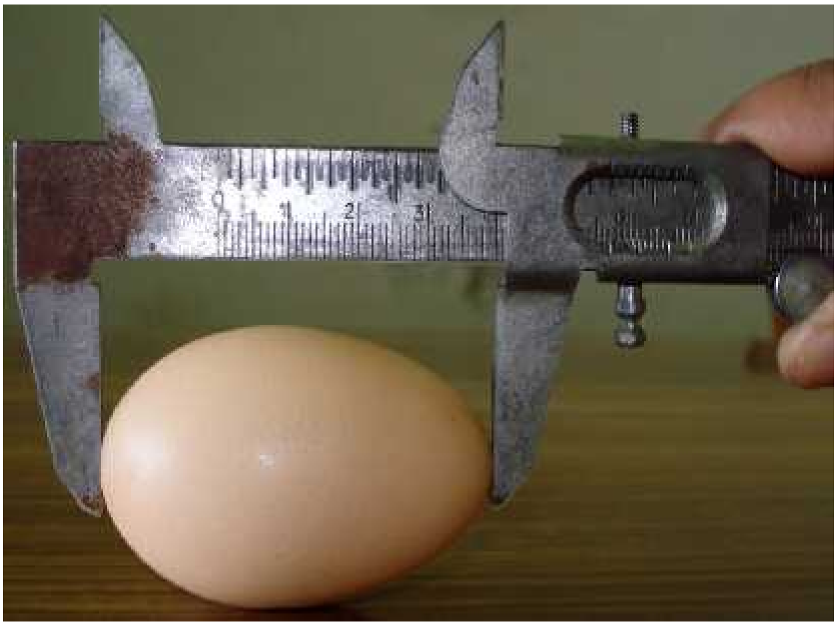

Fig. 9: Measurement of egg length by Vernier calipers

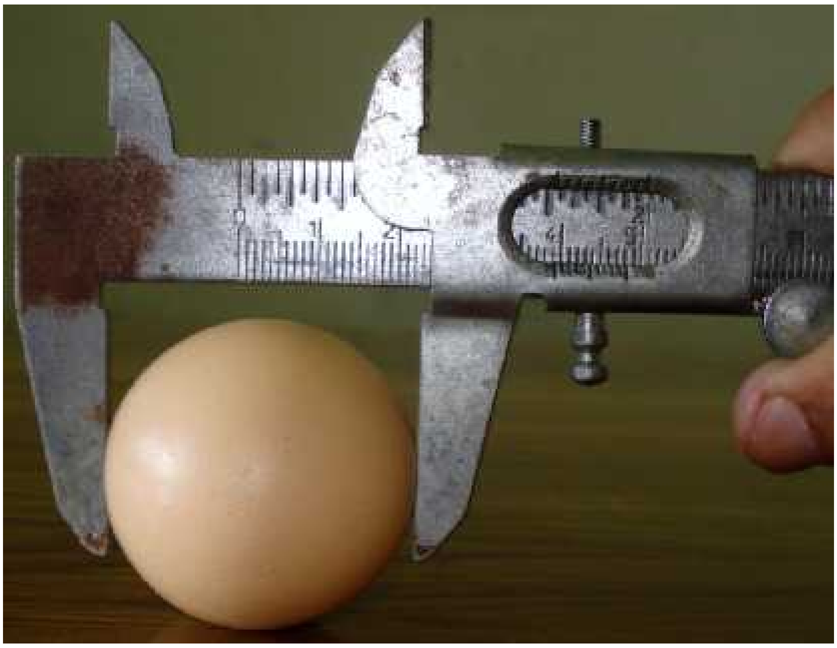

Fig. 10: Measurement of egg width by Vernier calipers

3.4 Shell thickness:

The eggs after candling which were recorded as either dead in germs or infertile were broken and shell thickness was measured with the help of screw gauze with 0.01mm precision. And again after successful hatching egg shells were collected carefully and measured according to Chowdhury (1987). On the basis of shell thickness also the fertility and hatchability was evaluated. Therefore, eggs were divided into three classes as:

(i) ≤0.20- 0.26mm

(ii) 0.27- 0.33mm

(iii) 0.34- ≥0.40mm

3.5 Incubation:

All experimental eggs were incubated in an automated sanitized electrical incubator at 99.50^0 F- 99.75^0 F and 60-65% relative humidity and turning hourly. Candling was done on 6^{th} day to determine infertile eggs and dead in germs, respectively. Removed or sorted eggs were broken for examination to study the early embryonic death and also to record the shell thickness.

On 18^{th} day 2^{nd} candling was done to record the dead in germs and to transfer the alive embryos to the hatcher. On 22^{nd} day of incubation chicks were taken out from hatcher and percentage hatchability was recorded. The rest pipped or unpipped embryos were taken into account as dead in shells or late embryonic

Fig. 11: Eggs arranged in setter tray for incubation

Fig. 12: Automated incubator

mortality. All dead in shells were opened individually to observe the different stages of embryonic death.

3.6 Embryonic mortality:

Removed eggs after candling and unhatched eggs were investigated for the observation of embryonic mortality. The mortality was then grouped depending upon the size and weight and classified as:

(a) Early embryonic mortality (≤7 days)

(b) Mid embryonic mortality (8- 17 days)

(c) Late embryonic mortality (18- 21days)

3.7 Fertility:

The percentage of fertility was calculated on the basis of total eggs set:

$$\text{Fertility percentage} = \frac{\text{Number of fertile eggs}}{\text{Total number of eggs set}} \times 100$$

3.8 Hatchability:

Hatchability percentage was estimated on the basis of total egg set i.e. both fertile and infertile included and on the basis of fertile eggs as per following formulae:

Fig. 13: Dead embryo in early stage (Early embryonic mortality)

Fig. 14: Dead embryo in mid stage (Mid embryonic mortality)

Fig. 15: Dead embryo in late stage (Late embryonic mortality)

i) Hatchability percentage (on total egg set basis):

Hatchability on total egg set (TES) was determined as the ratio of number of chicks hatched to the total number of eggs incubated.

$$\text{Hatchability \% on TES basis} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs (both fertile and infertile)}} \times 100$$

ii) Hatchability percentage (on fertile egg set basis):

Hatchability on fertile egg set (FES) was calculated as the ratio of number of good chicks hatched to the total number of fertile eggs incubated.

$$\text{Hatchability \% on FES basis} = \frac{\text{Number of eggs hatched}}{\text{Total number of fertile eggs set}} \times 100$$

3.9 Chick's weight:

Chick weight was recorded after completion of hatching during the entire experimental period by a precise weighing balance with 1g precision.

3.10 Statistical analysis:

(a) For quantification and variability of each parameter mean, standard deviation and standard error was calculated as per standard procedures.

Fig. 16: Pipped up chick

Fig. 17: Hatching of chick

Fig. 18: Newly hatched chick

Fig. 19: Day old chicks of Black Rock breed

Fig. 20: Day old chicks of Gramapriya breed

Fig. 21: Day old chicks of Vanaraja breed

Fig. 22: Weighing of day old chick

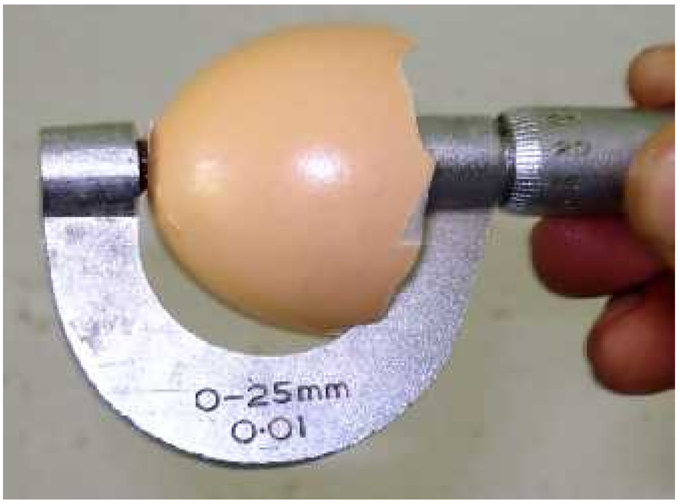

Fig. 23: Shell thickness being measured by screw gauge

(b) The effect of breed and certain egg quality traits on the fertility and hatchability was calculated by chi-square (χ^2) test for independence as per procedure given by Snedecor and Cochran (1967).

(c) Analysis of variance with one way classification was applied to see the effect of breed on day old chick weight as per procedure given by Snedecor and Cochran (1967) followed by Duncan's Multiple Range Test (DMRT).

CHAPTER-IV

Results and Discussion

CHAPTER-IV

RESULTS AND DISCUSSION

The primary objective of this experiment was to study the effect of breed, egg weight, shape index, shell thickness and shell colour on fertility and hatchability of some improved breeds of chicken used for backyard farming. With this aim in view, eggs were collected daily during April and May, 2010 from Black Rock (BR), Gramapriya (GP) and Vanaraja (VR) breeds of chicken. Data were collected on three consecutive hatches and the experimental eggs were stored upto 7 days in each hatch.

The egg traits such as egg weight (EW), egg length (EL), egg breadth (EB), shape index (SI), shell thickness (ST) of 1620 eggs or 540 eggs from each breed maintained at the Government Poultry Farm, Durg (Chhattisgarh) were weighed, measured and recorded during the study. The means and S.E. of different egg traits are shown in Table- 4.1.

4.1 EFFECT OF BREED ON THE FERTILITY AND HATCHABILITY

In present investigation, Black Rock had mean fertility 87.96%, followed by Vanaraja (87.78%) and Grampriya (87.22%), respectively (Table- 4.3). Result showed that there was no significant difference in the fertility among three breeds taken for study. In present study, the mean fertility percentage was slightly higher in VR than was reported by Rama Rao *et al.* (2004), who observed 87 percent average fertility among Vanaraja. However, Niranjan and Singh (2005) observed

Table- 4.1: Average means and standard errors (X±S.E.) of different egg traits in improved breeds of chicken.

Breed	Set	Egg weight (g)	Egg length (cm)	Egg breadth (cm)	Shape index (%)	Shell thickness (mm)
Black Rock	**I**	50.07±0.25	5.40±0.02	4.14±0.01	76.82±0.24	0.31±0.003
	II	48.06±0.29	5.33±0.02	4.08±0.01	76.79±0.25	0.27±0.003
	III	48.05±0.29	5.36±0.02	4.07±0.01	76.05±0.26	0.25±0.003
	Pooled	48.73±0.17	5.36±0.01	4.10±0.004	76.55±0.14	0.28±0.002
Gramapriya	**I**	52.67±0.25	5.49±0.01	4.20±0.01	76.68±0.19	0.32±0.003
	II	50.63±0.32	5.44±0.02	4.15±0.01	76.37±0.27	0.29±0.003
	III	50.54±0.29	5.41±0.02	4.14±0.01	76.58±0.24	0.29±0.003
	Pooled	51.28±0.17	5.44±0.01	4.16±0.005	76.54±0.13	0.30±0.002
Vanaraja	**I**	51.20±0.24	5.42±0.01	4.16±0.01	76.67±0.20	0.30±0.003
	II	49.13±0.27	5.39±0.01	4.10±0.01	76.28±0.22	0.27±0.003
	III	49.91±0.29	5.42±0.02	4.11±0.01	75.86±0.24	0.26±0.003
	Pooled	50.08±0.16	5.41±0.01	4.12±0.005	76.27±0.13	0.28±0.002

Table- 4.1 (a): Frequency of different shell colour groups in improved breeds of chicken.

Breed	Set	Brown	Light Brown	Creamy White
Black Rock	I	68 (37.78%)	84 (46.67%)	28 (15.56%)
	II	71 (39.44%)	85 (47.22%)	24 (13.33%)
	III	58 (32.22%)	83 (46.11%)	39 (21.67%)
	Pooled	197 (36.48%)	252 (46.67%)	91 (16.85%)
Gramapriya	I	107 (59.44%)	71 (39.44%)	2 (1.11%)
	II	94 (52.22%)	77 (42.78%)	9 (5.00%)
	III	106 (58.89%)	71 (39.44%)	3 (1.67%)
	Pooled	307 (56.85%)	219 (40.56%)	14 (2.59%)
Vanaraja	I	116 (64.44%)	54 (30.00%)	10 (5.56%)
	II	76 (42.22%)	76 (42.22%)	28 (15.56%)
	III	65 (36.11%)	96 (53.33%)	19 (10.56%)
	Pooled	257 (47.59%)	226 (41.85%)	57 (10.56%)
Overall		761 (46.98%)	697 (43.02%)	162 (10.00%)

Values in the parenthesis are percentage (%).

Table- 4.2: Overall, hatch wise fertility, hatchability and embryonic mortality in all three different breeds.

ALL THREE BREEDS	UNIT	1st HATCH	2nd HATCH	3rd HATCH	TOTAL
Set eggs	Number of eggs	540	540	540	1620
Fertilized eggs	Number of eggs	482	468	470	1420
Fertilized eggs %	%	89.26	86.67	87.04	87.66
Embryonic mortality	Number of eggs	79	105	123	307
Embryonic mortality %	%	16.39	22.44	26.17	21.62
Hatched chicks	Number of eggs	403	363	347	1113
Hatchability(TES)	%	74.63	67.22	64.26	68.70
Hatchability(FES)	%	83.61	77.56	73.83	78.38

Table- 4.2 (a): Hatch wise fertility, hatchability and embryonic mortality in Black Rock breed.

BLACK ROCK	UNIT	1st HATCH	2nd HATCH	3rd HATCH	TOTAL
Set eggs	Number of eggs	180	180	180	540
Fertilized eggs	Number of eggs	161	157	157	475
Fertilized eggs %	%	89.44	87.22	87.22	87.96
Embryonic mortality	Number of eggs	32	46	54	132
Embryonic mortality %	%	18.33	29.30	34.39	27.79
Hatched chicks	Number of eggs	129	111	103	343
Hatchability(TES)	%	71.67	61.67	57.22	63.52
Hatchability(FES)	%	80.12	70.70	65.61	72.21

Table- 4.2 (b): Hatch wise fertility, hatchability and embryonic mortality in Gramapriya breed.

GRAMAPRIYA	UNIT	1st HATCH	2nd HATCH	3rd HATCH	TOTAL
Set eggs	Number of eggs	180	180	180	540
Fertilized eggs	Number of eggs	159	152	160	471
Fertilized eggs %	%	88.33	84.44	88.89	87.22
Embryonic mortality	Number of eggs	26	29	33	88
Embryonic mortality %	%	16.35	19.08	20.62	18.68
Hatched chicks	Number of eggs	133	123	127	383
Hatchability(TES)	%	73.89	68.33	70.56	70.93
Hatchability(FES)	%	83.65	80.92	79.38	81.32

Table- 4.2 (c): Hatch wise fertility, hatchability and embryonic mortality in Vanaraja breed.

VANARAJA	UNIT	1st HATCH	2nd HATCH	3rd HATCH	TOTAL
Set eggs	Number of eggs	180	180	180	540
Fertilized eggs	Number of eggs	162	159	153	474
Fertilized eggs %	%	90.00	88.33	85.00	87.78
Embryonic mortality	Number of eggs	21	30	36	87
Embryonic mortality %	%	12.96	18.87	23.53	18.35
Hatched chicks	Number of eggs	141	129	117	387
Hatchability(TES)	%	78.33	71.67	65.00	71.67
Hatchability(FES)	%	87.04	81.13	76.47	81.65

81.25 percent mean fertility percentage in Gramapriya which was much lower than the mean fertility (87.22%) recorded in present investigation.

The highest mean of hatchability on total egg set basis (TES) recorded in VR was 71.67 percent and for GP and BR, mean hatchability (TES) were 70.93 percent and 63.52 percent respectively. Hatchability on fertile egg set basis (FES) showed same trend, as Black Rock had the lowest mean of hatchability (FES) (72.21%) and the highest mean was recorded for Vanaraja (81.65%) followed by Gramapriya (81.32%).

Rama Rao *et al.* (2004) reported average hatchability (80%) in Vanaraja in several districts of Andhra Pradesh and Buragohain *et al.* (2005) reported average hatchability in Vanaraja varies from 17.86 to 76.04 percent (Average 56.73%) in high altitude areas of Arunachal Pradesh and in both the cases hatchability was lower than present finding on FES. Niranjan and Singh (2005) reported lower mean hatchability percentages than the present findings on TES (64.71%) and FES (79.97%) in Gramapriya when reared under intensive and free-range conditions of Tripura.

No information is available to make any useful corroboration for Black Rock breed in these traits.

4.1.1 Fertility:

The fertility trait was observed in present study for breeds of Black Rock, Gramapriya and Vanaraja. The average percentage of fertility during three consecutive hatches were 89.44, 87.22 and 87.22 for BR, 88.33, 84.44 and 88.89

for GP and 90.00, 88.33 and 85.00 for VR (Table- 4.3). And the mean fertility percentages were found to be 87.96 in Black Rock, 87.22 in Gramapriya and 87.78 in Vanaraja. Differences among the breeds were not significant in three consecutive hatches as well as in the mean fertility. Present study showed that fertility can vary even within the same breed may be due to poor management or ability of males in the flock to produce viable sperms. The results of the present study alludes that the 1.2: 10 cock to hen proportion in all three breeds used for this study had similar fertility rate in natural mating and all of them are equally potential fertile breed.

No significant difference was found among three breeds for fertility rate in the present study which was in accordance with the findings of Basnet (1973) but for other breeds, who reported no significant difference in the rate of fertility among White Leghorn, White Rock, New Hampshire and White Cornish breeds of chicken. Although, in contrary Acharya and Kumar (1984) and Narayanakutty *et al.* (2008) presented breed differences in rate of fertility.

4.1.2 Hatchability:

Hatchability was calculated for each breed on the basis of total eggs set as well as on the basis of fertile eggs set for each breed.

4.1.2.1 Hatchability on total eggs set basis (TES)

In the present study the mean percentages of hatchability in three different hatches based on total eggs set were 71.67, 61.67 and 57.22 for Black Rock, 73.89, 68.33 and 70.56 for Gramapriya and 78.33, 71.67 and 65.00 for Vanaraja respectively, where as pooled percentage was 63.52 for Black Rock, 70.93 for Gramapriya and 71.67 for Vanaraja (Table- 4.3).

Differences between the breeds were highly significant for the hatchability based on TES when taken three hatches together. Though, in first two hatches differences among all three breeds were non significant but in third hatch difference was significant statistically (Table- 4.3). The most probable causes for breed difference might be the genetic makeup of the breed or the adverse climate. Breed had a significant effect on hatchability (TES) as suggested by Farooq *et al.* (2001) and present study observation was also in accordance with their findings.

4.1.2.2 Hatchability on fertile eggs set basis (FES)

For all the three breeds the mean percentage of hatchability on fertile eggs set basis in three hatches were 80.12, 70.70 and 65.61 for Black Rock, 83.65, 80.92 and 79.38 for Gramapriya and 87.04, 81.13 and 76.47 for Vanaraja respectively, and when taken together for all three hatches the hatchability percentage was 72.21 for Black Rock, 81.32 for Gramapriya and 81.65 for Vanaraja (Table- 4.3).

On the basis of FES, there was no significant difference in first hatch, but in second and third hatch and when three hatches taken together the difference was significant among all three breeds (Table- 4.3).

In the present investigation Gramapriya and Vanaraja breeds were almost equal in the hatchability percentage and both the breeds were superior in hatchability percentage over Black Rock. The possible reasons for the differences

Table- 4.3: Effect of breed on the fertility and hatchability of different improved breeds of fowl.

FERTILITY				
VARIABLES	**BLACK ROCK**	**GRAMAPRIYA**	**VANARAJA**	**χ^2 - VALUE**
SET-I	89.44% (161)	88.33% (159)	90.00% (162)	0.270^{NS}
SET-II	87.22% (157)	84.44% (152)	88.33% (159)	1.250^{NS}
SET-III	87.22% (157)	88.89% (160)	85.00% (153)	1.215^{NS}
OVERALL	87.96% (475)	87.22% (471)	87.78% (474)	1.148^{NS}
HATCHABILITY (TES)				
SET-I	71.67% (129)	73.89% (133)	78.33% (141)	2.191^{NS}
SET-II	61.67% (111)	68.33% (123)	71.67% (129)	4.170^{NS}
SET-III	57.22% (103)	70.56% (127)	65.00% (117)	7.031^{*}
OVERALL	63.52% (343)	70.93% (383)	71.67% (387)	10.20^{**}
HATCHABILITY (FES)				
SET-I	80.12% (129)	83.65% (133)	87.04% (141)	2.816^{NS}
SET-II	70.70% (111)	80.92% (123)	81.13% (129)	6.397^{*}
SET-III	65.61% (103)	79.38% (127)	76.47% (117)	8.595^{*}
OVERALL	72.21% (343)	81.32% (383)	81.65% (387)	16.05^{**}

NS- Not significant, *P<0.05, **P<0.01

Values in the parenthesis are number of the eggs.

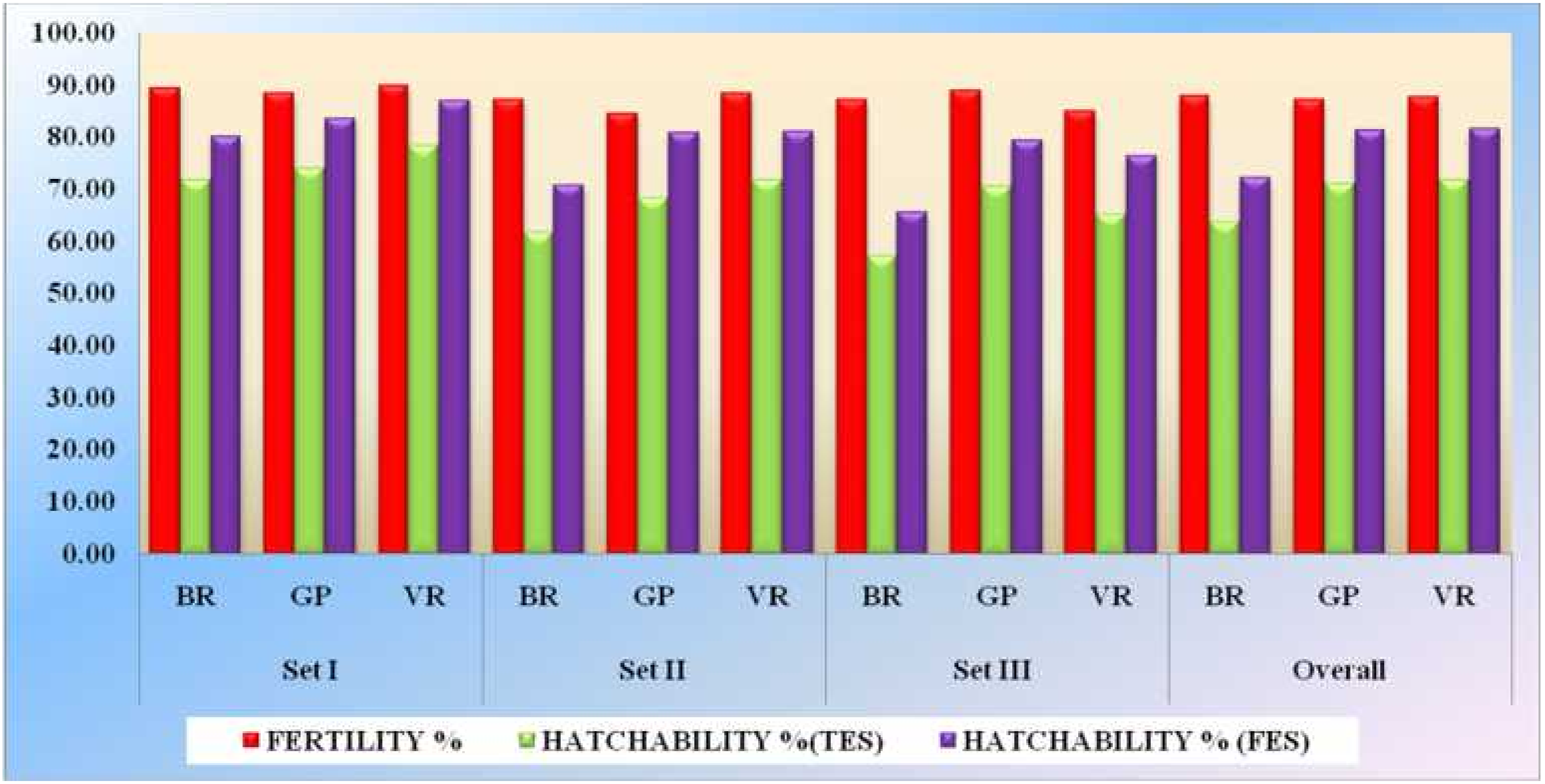

Fig. 24: Effect of Breed (Set wise and Overall) on the Fertility and Hatchability on TES and FES.

in the hatchability may be due to the genetic difference. Since the climate of Chhattisgarh state is usually hot and dry and too hot during summer, hence, it appears from the present study that Gramapriya and Vanaraja breeds were better acclimatized to high temperature and Black Rock was vulnerable. Olsen (1951) also noticed considerable variation among the breeds in their adaptation to high temperature.

Breeds have significant effect on the hatchability as reported by several workers (Singh *et al*., 1983; Kalita *et al*., 1985 and Singh and Balsare, 1991). A significant difference between breeds for hatchability was observed in this study on FES basis, which was in agreement with the findings of earlier workers that differential hatchability is a breed characteristic.

4.2 EFFECT OF EGG WEIGHT ON THE FERTILITY AND HATCHABILITY

In present investigation the overall average mean egg weight pooled for three hatches were 48.73±0.17g for Black Rock, 51.28±0.17g for Gramapriya and 50.08±0.16g for Vanaraja, respectively (Table- 4.1). In general, Gramapriya had better egg weights during entire study period in comparison to Vanaraja and Black Rock. The higher egg weights in Gramapriya may be because of the exotic female line utilized for developing them. Niranjan *et al.* (2008) reported average egg weights 50.85g (28- 32 weeks) for Gramapriya and 48.55g (28- 32 weeks) for Vanaraja which was lower than the findings in the present study. The reason for higher egg weights recorded in the present study might be due to better adaptability of breeds in the local environment.

Eggs from the different breeds were classified into three weight classes such as 40- 46g, 47- 53g and 54- 60g in order to establish the relationship between egg weight with the fertility and hatchability.

4.2.1 Fertility:

Number and percentage of fertile eggs in each weight class for the three breeds are tabulated in Table- 4.4. The mean percentages of fertility for weight class of 40- 46g, 47- 53g and 54- 60g respectively were 84.71, 88.11 and 96.36 in Black Rock; 75.44, 88.95 and 87.77 in Gramapriya; 85.54, 87.60 and 90.43 in Vanaraja; and the overall, breed wise and set wise fertility was recorded 83.16, 88.21 and 90.28 in the three different egg weight classes. While the mean percentages for egg weight classes irrespective of breeds were 94.44, 88.27 and 90.70 in Set-I; 83.58, 87.38 and 88.89 in Set-II; and 79.53, 88.96 and 91.03 in Set-III.

In present study, there was no significant difference in the fertility of different egg weight classes in the first and second sets whereas difference was significant and in the third set. When data were analyzed breed wise, then there were no significant difference for Black Rock and Vanaraja breeds. But, in case of Gramapriya, difference was significant for fertility in different egg weight classes. The difference was significant ($P<0.05$) when all sets or breeds are taken together.

Egg weight classes have significant effect on the fertility as suggested by workers like Khati *et al.* (1992) and Ahmad *et al.* (2000). This present study was also in agreement with the above workers that egg weight class has significant effect but was in contrast to observation of earlier workers (Narayanakutty *et al.*,

2008) who observed no significant difference for different egg weight categories in two strains of White Leghorn breed for fertility.

4.2.2 Hatchability:

4.2.2.1 Hatchability on total eggs set basis (TES)

The mean percentages of hatchability (TES) for egg weight class of 40- 46g, 47- 53g and 54- 60g respectively were 54.78, 67.99 and 61.82 in Black Rock; 64.91, 72.38 and 69.78 in Gramapriya; and 61.45, 74.66 and 69.15 Vanaraja. χ^2 – test revealed highly significant differences in the hatchability of egg weight classes in Black Rock and Vanaraja breeds whereas in case of Gramapriya, difference was non-significant (Table- 4.4).

Set wise hatchability of different egg weight classes were 80.56, 76.27 and 68.22 in Set-I; 61.19, 69.23 and 69.14 in Set-II; and 49.61, 69.25 and 66.67 in Set-III. χ^2 – test revealed no significant differences in first two sets, but Set-III showed significant differences in the hatchability of different eggs weight classes (Table- 4.4).

The average hatchability irrespective of breeds and sets was 58.59 percent for the eggs weighing between 40- 46g, 71.79 percent for the eggs weighing between 47- 53g and 68.06 percent for the eggs weighing between 54- 60g. Statistically there was highly significant ($P<0.01$) difference in egg weight class hatchability (Table- 4.4).

It may be mentioned that a higher value ($P<0.01$) for hatchability (TES) was observed in middle group, indicating suitability of medium sized eggs for

Table- 4.4: Effect of egg- weight on the fertility and hatchability in improved breeds of fowl.

VARIABLES		40- 46 g	47- 53 g	54- 60 g	χ^2 - VALUE
FERTILITY					
BREED WISE	BR	84.71% (133)	88.11% (289)	96.36% (53)	5.238 NS
	GP	75.44% (43)	88.95% (306)	87.77% (122)	8.064*
	VR	85.54% (71)	87.60% (318)	90.43% (85)	1.011 NS
OVER ALL MEAN		83.16% (247)	88.21% (913)	90.28% (260)	7.661*
HATCH WISE	SET-I	94.44% (34)	88.27% (331)	90.70% (117)	1.673 NS
	SET-II	83.58% (112)	87.38% (284)	88.89% (72)	1.594 NS
	SET-III	79.53% (101)	88.96% (298)	91.03% (71)	8.540*
OVER ALL MEAN		83.16% (247)	88.21% (913)	90.28% (260)	7.661*
HATCHABILITY (TES)					
BREED WISE	BR	54.78% (86)	67.99% (223)	61.82% (34)	8.073*
	GP	64.91% (37)	72.38% (249)	69.78% (97)	1.442 NS
	VR	61.45% (51)	74.66% (271)	69.15% (65)	6.161*
OVER ALL MEAN		58.59% (174)	71.79% (743)	68.06% (196)	18.77**
HATCH WISE	SET-I	80.56% (29)	76.27% (286)	68.22% (88)	4.000 NS
	SET-II	61.19% (82)	69.23% (225)	69.14% (56)	2.940 NS
	SET-III	49.61% (63)	69.25% (232)	66.67% (52)	15.71**
OVER ALL MEAN		58.59% (174)	71.79% (743)	68.06% (196)	18.77**
HATCHABILITY (FES)					
BREED WISE	BR	64.66% (86)	77.16% (223)	64.15% (34)	9.024*
	GP	86.05% (37)	81.37% (249)	79.51% (97)	0.896 NS
	VR	71.83% (51)	85.22% (271)	76.47% (65)	8.794*
OVER ALL MEAN		70.45% (174)	81.38% (743)	75.38% (196)	15.408**
HATCH WISE	SET-I	85.29% (29)	86.40% (286)	75.21% (88)	7.976*
	SET-II	73.14% (82)	79.23% (225)	77.78% (56)	1.670 NS
	SET-III	62.38% (63)	77.85% (232)	73.24% (52)	9.366**
OVER ALL MEAN		70.45% (174)	81.38% (743)	75.38% (196)	15.408**

NS- Not significant, *P<0.05, **P<0.01

Values in the parenthesis are number of the eggs.

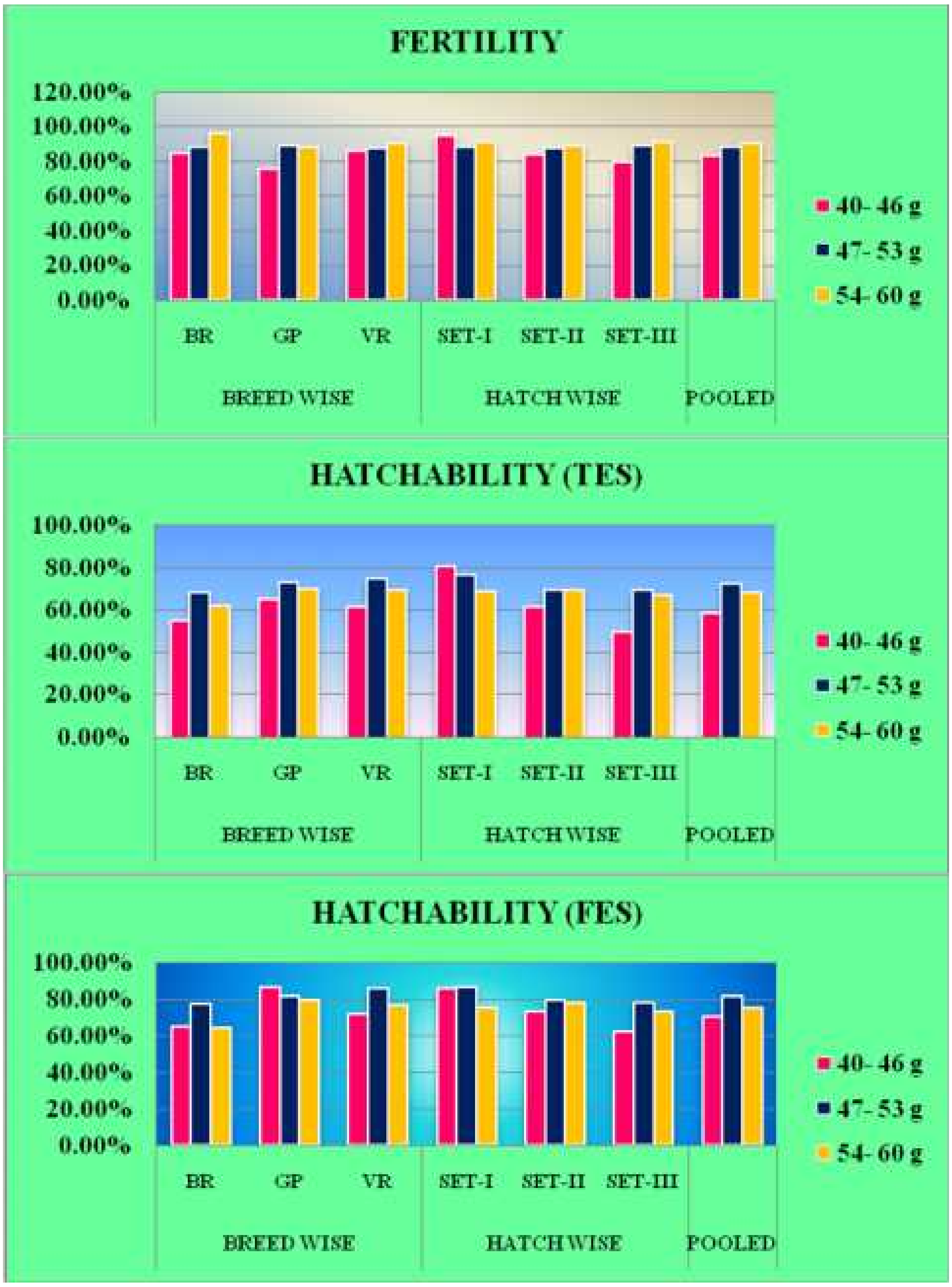

Fig. 25: Effect of Egg weight (Breed wise, Set wise and Overall) on the Fertility and Hatchability on TES and FES.

incubation. This finding was in close agreement with earlier workers like Khati *et al.* (1992).

4.2.2.2 Hatchability on fertile eggs set basis (FES)

The mean percentages of hatchability on FES for egg weight class of 40- 46g, 47- 53g and 54- 60g respectively were 64.66, 77.16 and 64.15 in Black Rock; 86.05, 81.37 and 79.51 in Gramapriya; and 71.83, 85.22 and 76.47 in Vanaraja. Black Rock and Vanaraja, both the breeds showed significant differences in the hatchability of different egg weight classes, but in Gramapriya difference was non-significant.

When hatchability was considered set wise then mean percentages of different egg weight classes were 85.29, 86.40 and 75.21 in Set-I; 73.14, 79.23 and 77.78 in Set-II; and 62.38, 77.85 and 73.24 in Set-III. χ^2 – test revealed highly significant difference in Set-III ($P<0.01$), significant difference in Set-I ($P<0.05$) and no significant difference in Set-II (Table- 4.4).

The average hatchability on FES, irrespective of breeds and sets was 70.45 percent for the eggs weighing between 40- 46g, 81.38 percent for the eggs weighing between 47- 53g and 75.38 percent for the eggs weighing between 54- 60g. Difference was highly significant ($P<0.01$) statistically (Table- 4.4).

In present investigation it was clear that medium egg weight class having better hatchability than small and large egg weight classes. This finding was in agreement with the result obtained by several workers (Muhammed *et al.*, 1987; Ahmad *et al.*, 2000), who stated that average sized eggs hatch better than very large and very small eggs. Veterany *et al.* (2001) recorded better hatchability in medium sized class. The present study also support the results obtained by Kang *et al.* (2002).

4.3 EFFECT OF SHAPE INDEX ON THE FERTILITY AND HATCHABILITY

The average pooled mean shape index value was observed to be 76.55±0.14 in Black Rock, whereas, in Gramapriya and Vanaraja, the average pooled mean shape indices were found to be 76.54±0.13 and 76.27±013 respectively (Table- 4.1). Result showed that average value of shape index in all three breeds had almost equal averages. Normal shape index of chicken eggs ranges from 70 to 75 (Sreenivasaiah, 2006). Findings in the present study were just higher than the normal range. However, findings in the present study were in close agreement with the report of Chakravarthy (1977). There was not much difference between three breeds in average shape index values so present study was in accordance with Sapra and Agarwal (1971) who did not find significant difference in the shape of eggs among Indian breeds.

In order to establish the relationship between shape index with the fertility and hatchability, eggs from the different breeds were classified into three classes such as 67- 72 percent, 73- 78 percent and 79- 84 percent.

4.3.1 Fertility:

The overall percent values were statistically similar in all the groups irrespective of breeds or hatches for fertility (Table- 4.5). The mean percentages of fertility for shape index class of 67- 72 percent, 73- 78 percent and

79- 84 percent respectively were 90.63, 88.04 and 86.67 in Black Rock; 89.80, 86.93 and 87.05 in Gramapriya; 92.00, 89.54 and 80.34 for Vanaraja; and the overall, breed wise and set wise fertility was recorded 90.80, 88.20 and 84.98 for three different shape index classes. While the mean percentages for shape index classes irrespective of breeds was 91.18, 87.43 and 93.57 in Set-I; 86.44, 88.63 and 81.88 in Set-II; and 94.29, 88.60 and 78.91 in Set-III.

There was no significant difference among groups for fertility in Black Rock and Gramapriya while difference was significant in Vanaraja breed (Table- 4.5). The values for fertility were statistically similar in first and second hatches and difference was significant in the third hatch.

Though difference among groups were non-significant for fertility which is close to the result of Churchil *et al.* (2008) who found no significant difference in the shape index classes in the White Leghorn breed. However, result shows that cylindrical eggs had slightly higher fertile percentage than those of oval or roundish shaped eggs irrespective of breeds or hatches was in agreement with the earlier findings of Ahmad *et al.*, 2000. In present study, Vanaraja breed and third hatch showed significant difference in the fertility in different classes. In both cases, cylindrical eggs had higher fertility rate which also support the findings of Ahmad *et al.* (2000).

4.3.2 Hatchability:

4.3.2.1 Hatchability on total eggs set basis (TES)

The overall, breed wise and hatch wise hatchability (TES) percentages for all three shape index groups has been shown in Table- 4.5. The percent values for different groups were 57.81, 66.26 and 60.00 in Black Rock; 73.47, 71.31 and 69.06 in Gramapriya; and 72.00, 72.39 and 69.23 in Vanaraja. Statistically, there was no significant difference in any breed among three shape index groups. In this investigation, pooled percent values were 66.87, 70.12 and 65.76 and difference was non-significant when analyzed by χ^2 – test. These findings are in close agreement with the reports of Churchil *et al.* (2008). Hatch wise percent values for three hatches were 58.82, 73.22 and 82.14 for Set-I; 67.80, 70.26 and 59.42 for Set-II; and 70.00, 66.67 and 54.69 for Set-III. However, there was significant difference among groups in first and third Set. It may be due to less number of eggs and conclusion on less number of samples would not be reliable, when overall sample are considered there was no significant difference. Therefore, present findings were in agreement with the observations of early workers like Ahmad *et al.* (2000). However, it may be mentioned that a higher value for hatchability (TES) was observed in mid group, indicating oval eggs had better hatchability (TES) than either cylindrical or round eggs. Present finding was in agreement with the earlier findings of Sarda *et al.* (1978) and Jay *et al.* (1985).

4.3.2.2 Hatchability on fertile eggs set basis (FES)

Trends for hatchability on FES was same as hatchability on TES, only percent values differs and for different breeds were 63.79, 75.26 and 69.23 in

Table- 4.5: Effect of shape index on the fertility and hatchability in improved breeds of fowl.

FERTILITY					
VARIABLES		67- 72%	73- 78%	79- 84%	χ^2 - VALUE
BREED WISE	BR	90.63% (58)	88.04% (287)	86.67% (130)	0.668 NS
	GP	89.80% (44)	86.93% (306)	87.05% (121)	0.322 NS
	VR	92.00% (46)	89.54% (334)	80.34% (94)	7.946*
OVER ALL MEAN		90.80% (148)	88.20% (927)	84.98% (345)	4.472 NS
HATCH WISE	SET-I	91.18% (31)	87.43% (320)	93.57% (131)	4.121 NS
	SET-II	86.44% (51)	88.63% (304)	81.88% (113)	3.878 NS
	SET-III	94.29% (66)	88.60% (303)	78.91% (101)	23.81**
OVER ALL MEAN		90.80% (148)	88.20% (927)	84.98% (345)	4.472 NS
HATCHABILITY (TES)					
BREED WISE	BR	57.81% (37)	66.26% (216)	60.00% (90)	2.756 NS
	GP	73.47% (36)	71.31% (251)	69.06% (960	0.412 NS
	VR	72.00% (36)	72.39% (270)	69.23% (81)	0.440 NS
OVER ALL MEAN		66.87% (109)	70.12% (737)	65.76% (267)	2.872 NS
HATCH WISE	SET-I	58.82% (20)	73.22% (268)	82.14% (115)	9.042*
	SET-II	67.80% (40)	70.26% (241)	59.42% (82)	5.260 NS
	SET-III	70.00% (49)	66.67% (228)	54.69% (70)	6.974*
OVER ALL MEAN		66.87% (109)	70.12% (737)	65.76% (267)	2.872 NS
HATCHABILITY (FES)					
BREED WISE	BR	63.79% (37)	75.26% (216)	69.23% (90)	3.954 NS
	GP	81.82% (36)	82.03% (251)	79.34% (96)	0.420 NS
	VR	78.26% (36)	80.84% (270)	86.17% (81)	1.781 NS
OVER ALL MEAN		73.65% (109)	79.50% (737)	77.39% (267)	2.845 NS
HATCH WISE	SET-I	64.52% (20)	83.75% (268)	87.79% (115)	9.919**
	SET-II	78.43% (40)	79.28% (241)	72.57% (82)	2.156 NS
	SET-III	74.24% (49)	75.25% (228)	69.31% (70)	1.390 NS
OVER ALL MEAN		73.65% (109)	79.50% (737)	77.39% (267)	2.845 NS

NS- Not significant, *P<0.05, **P<0.01

Values in the parenthesis are number of the eggs.

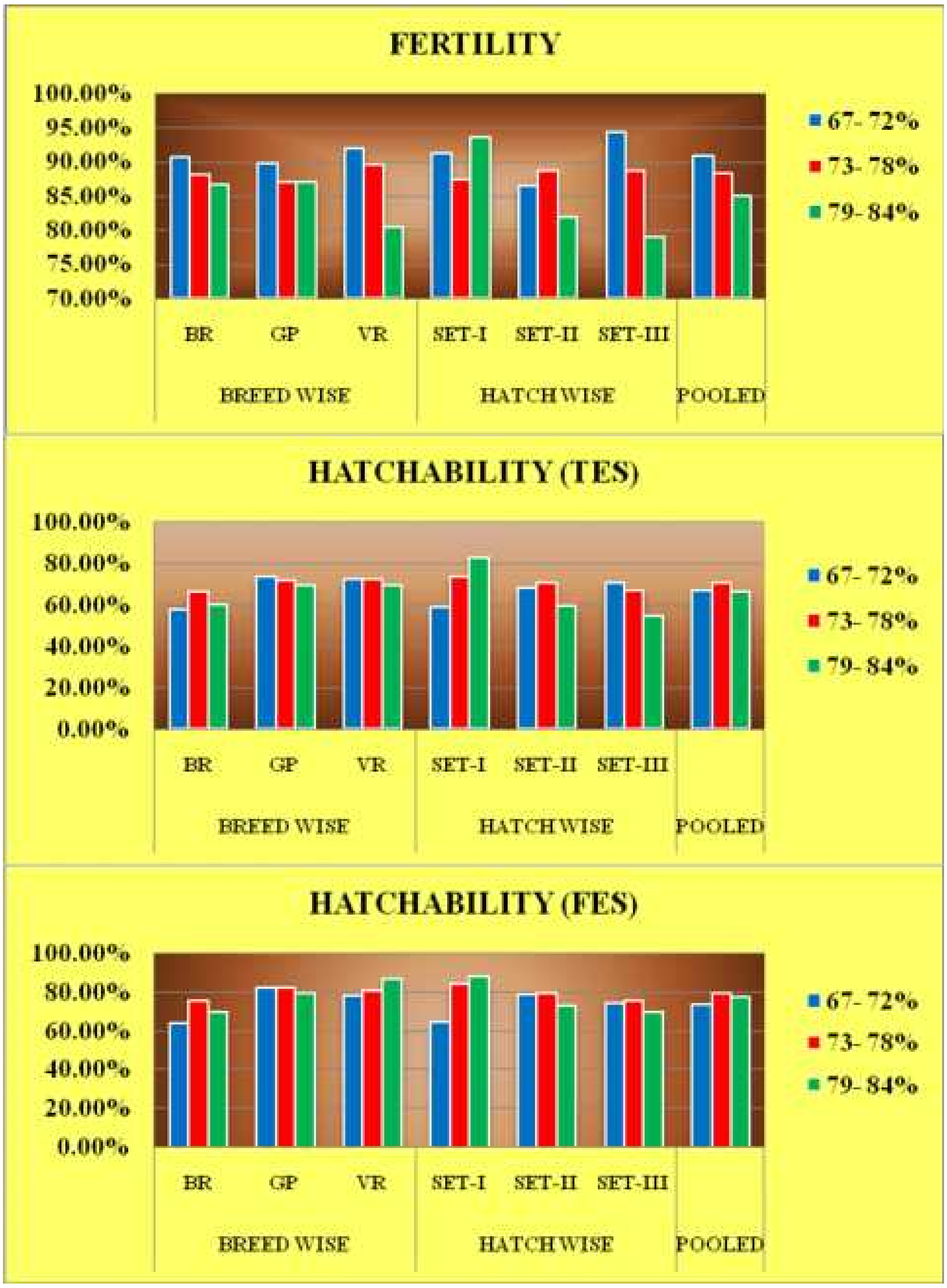

Fig. 26: Effect of Shape index (Breed wise, Set wise and Overall) on the Fertility and Hatchability on TES and FES.

Black Rock; 81.82, 82.03 and 79.34 in Gramapriya; and 78.26, 80.84 and 86.17 in Vanaraja. While the overall values were 73.65, 79.50 and 77.39 respectively. χ^2 – test revealed no significant difference within breed or overall groups of shape index.

Set wise values for different groups were 64.52, 83.75 and 87.79 for Set-I; 78.43, 79.28 and 72.57 for Set-II; and 74.24, 75.25 and 69.31 for Set-III respectively. Statistically, there was no significant difference except in Set-I. This may be due to less number of eggs in first group of Set-I. Whereas, on overall basis no significant difference was revealed by χ^2 – test.

The findings of the present study are in close agreement with the reports of Churchil *et al.* (2008). However, results showed slightly better hatchability (FES) in mid group of shape index which supported findings of Brar *et al.* (2002). On the contrary, Narushin and Romanov (2002) found better hatchability in round shaped eggs having higher shape index.

4.4 EFFECT OF SHELL THICKNESS ON THE FERTILITY AND HATCHABILITY

The average pooled mean shell thickness was observed 0.28±0.002mm in Black Rock. Whereas, in Gramapriya and Vanaraja, the average pooled mean shell thickness were 0.30±0.002 and 0.28±0.002mm respectively (Table- 4.1). Highest average value for shell thickness was observed in Gramapriya, whereas average value was same for Black Rock and Vanaraja. Parmar *et al*. (2006) reported higher average value for shell thickness in Kadaknath breed than the findings of the present study. The reason behind the poor shell thickness of these breeds might be due to high (above 25^0C) environmental or shed temperatures during the study period, which may affect the feed and therefore calcium intake of the bird, thus, resulting in a decreased availability of calcium for shell deposition (Okoli *et al*., 2006).

4.4.1 Fertility:

The fertility of different groups of shell thickness influenced by breeds or batches are presented in Table- 4.6. Among three breeds as well as batches, shell thickness had highly significant ($P<0.01$) difference. Pooled Fertility percentage irrespective of breed or batch was highest (90.43%) in mid group, intermediate (88.83%) in first group and lowest (74.72%) in third group. In the last batch, the difference was non significant.

The shell thickness effect on fertility was reported by Bennett (1992) who investigated lower fertility in thin shelled eggs in comparison to thick shelled eggs. In the present study, findings were not in accordance with prior findings as group 'a' and 'b' had more mean fertility percentage. The probable cause may be very less number of eggs in the group 'c'.

4.4.2 Hatchability:

4.4.2.1 Hatchability on total eggs set basis (TES)

Hatchability (TES) was significantly affected ($P<0.01$) by shell thickness irrespective of breeds or batches (Table 4.6). Means were 65.20, 74.72 and 51.53% for groups 'a', 'b' and 'c', respectively. The group 'b' had highest hatchability followed by groups 'a' and 'c'.

Table- 4.6: Effect of shell thickness on the fertility and hatchability in different breeds (a: <0.20- 0.26 mm; b: 0.27- 0.33 mm; c: 0.34- >0.40 mm).

VARIABLES		<0.20- 0.26 mm	0.27- 0.33 mm	0.34- >0.40 mm	χ^2 - VALUE
FERTILITY					
BREED WISE	**BR**	89.95% (197)	89.15% (230)	76.19% (48)	9.408**
	GP	85.58% (89)	91.14% (319)	73.26% (63)	20.130**
	VR	89.24% (199)	90.74% (245)	63.83% (30)	27.780**
OVER ALL MEAN		88.83% (485)	90.43% (794)	74.72% (141)	51.69**
HATCH WISE	**SET-I**	98.61% (71)	94.50% (309)	72.34% (102)	58.02**
	SET-II	86.24% (188)	88.70% (259)	70.00% (21)	8.289*
	SET-III	88.28% (226)	87.26% (226)	72.00% (18)	5.373^{NS}
OVER ALL MEAN		88.83% (485)	90.43% (794)	74.72% (141)	51.69**
HATCHABILITY (TES)					
BREED WISE	**BR**	60.73% (133)	69.77% (180)	47.62% (30)	11.960**
	GP	59.62% (62)	78.29% (274)	54.65% (47)	26.690**
	VR	72.20% (161)	74.81% (202)	51.06% (24)	11.170**
OVER ALL MEAN		65.20% (356)	74.72% (656)	51.53% (101)	44.75**
HATCH WISE	**SET-I**	81.94% (59)	81.04% (265)	56.03% (79)	17.56**
	SET-II	63.76% (139)	71.92% (210)	46.67% (14)	9.860**
	SET-III	61.72% (158)	69.88% (181)	32.00% (8)	15.62**
OVER ALL MEAN		65.20% (356)	74.72% (656)	51.53% (101)	44.75**
HATCHABILITY (FES)					
BREED WISE	**BR**	67.51% (133)	78.26% (180)	62.50% (30)	8.921*
	GP	69.66% (62)	85.89% (274)	74.60% (47)	14.220**
	VR	80.90% (161)	82.45% (202)	82.45% (24)	0.332^{NS}
OVER ALL MEAN		73.40 % (356)	82.61 % (656)	71.63% (101)	19.30**
HATCH WISE	**SET-I**	83.10% (59)	81.04% (265)	56.03% (79)	3.880^{NS}
	SET-II	73.94% (139)	81.08% (210)	66.67% (14)	4.696^{NS}
	SET-III	69.91% (158)	80.09% (181)	44.44% (8)	14.42**
OVER ALL MEAN		73.40 % (356)	82.61 % (656)	71.63% (101)	19.30**

NS- Not significant, *P<0.05, **P<0.01

Values in the parenthesis are number of the eggs.

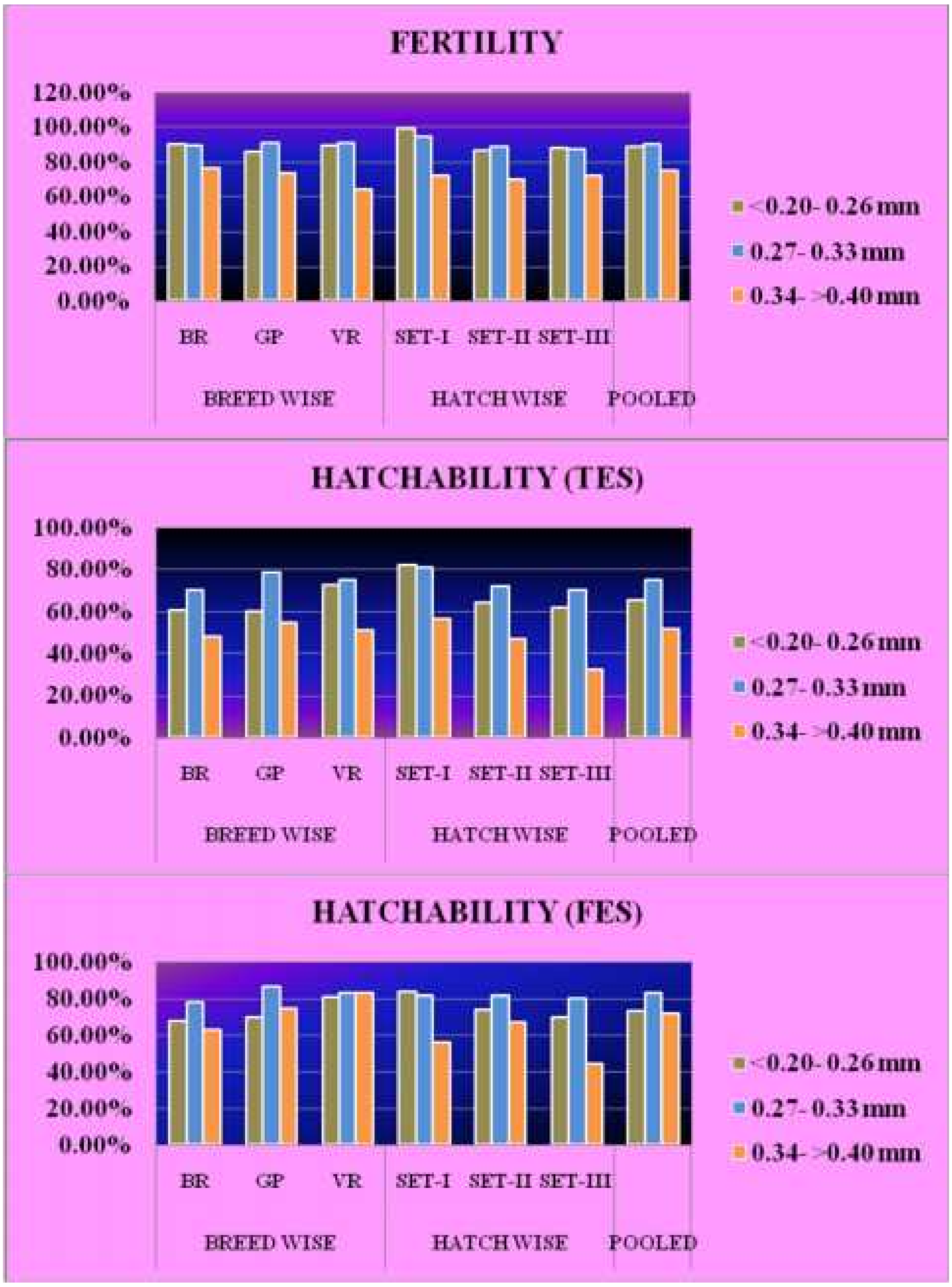

Fig. 27: Effect of Shell thickness (Breed wise, Set wise and Overall) on the Fertility and Hatchability on TES and FES.

Findings in present study were in close agreement with Andrews (1972) who reported higher hatchability percentage in turkey with thinner shell eggs.

4.4.2.2 Hatchability on fertile eggs set basis (FES)

Pooled means of hatchability (FES) percentage for groups 'a', 'b' and 'c' were 73.40, 82.61 and 71.63 respectively. Hatchability on FES basis followed same trend as in hatchability on TES basis and pooled means of groups irrespective of breeds or batches had highly significant ($P<0.01$) difference (Table- 4.6). But hatchability (FES) did not differ significantly in Vanaraja and in batches-I and II.

In general, smaller eggs have thick shell whereas large eggs having thin shell as hens have a finite capacity to deposit calcium in the shell and as a result, the same amount of calcium spreads over a larger area (Butcher and Miles, 2003; and Rajkumar *et al.*, 2009). Many workers observed lower hatchability rate in large sized eggs and present study also supported these workers. But, in contrary, the present investigation showed hatchability on TES and on FES basis rate were lower in thick shelled eggs. Most probable cause may be too little number of eggs in thick shelled group. These findings are in close agreement with Andrews (1972). However, in contrast many workers (Sergeyeva, 1986; Roque and Soares, 1995; and Narushin and Ramanov, 2002) reported better hatchability in thick shelled eggs as thin shelled eggs cracks easily and there is higher water vapour loss during the entire incubation process, resulting in dehydration and higher embryonic mortality.

4.5 EFFECT OF SHELL COLOUR ON THE FERTILITY AND HATCHABILITY

While observing the overall average for shell colour among the three breeds brown shell colour (46.98%) was found to be most frequent as compare to light brown (43.02%) and creamy white (10.00%) colours respectively (Table- 4.1a). Gramapriya and Vanaraja breed had same trend as overall pooled average with higher percentage of brown shell colour followed by light brown and creamy white. However, in Black Rock, the light brown (46.67%) was most frequent observed shell colour. Gramapriya had highest frequency of brown shell colour with 56.85 percent followed by Vanaraja with 47.59 percent and least percentage was observed in Black Rock (36.48%). Least percentage was recorded for Gramapriya in light brown (40.56%) and creamy white (only 2.59%), whereas Black Rock was leading breed in these two groups with 46.67 and 16.85 percent respectively and for Vanaraja frequency percentage was 41.85 and 10.56 percent, respectively. Parmar *et al*. (2006) also observed brown shell colour most frequently (67.87%) in eggs of Kadaknath birds followed by light brown colour (32.12 %). The shell colour is breed characteristic but it may be influenced by so many factors that may affect the frequency of different shell colour of eggs. The most common factors are stress, age of the bird, chemotherapeutic agents and disease (Chukwuka *et al.*, 2010).

4.5.1 Fertility:

Results in Table- 4.7, showed that there were highly significant (P<0.01) difference in fertility percentage among three different classes of shell colour of eggs irrespective of breeds or batches. Highest pooled mean was in brown shell colour (90.80%) followed by light brown (85.22%) and creamy white (83.33%). However, no significant difference was found in Black Rock and Gramapriya as well as in second hatch among different shell colour groups.

In present investigation brown shell coloured eggs showed higher rate of fertility over light brown and creamy white shell coloured eggs. No information is available to make any useful corroboration about the fertility based upon the shell colour.

4.5.2 Hatchability:

4.5.2.1 Hatchability on total eggs set basis (TES)

In the observation based on three shell colour groups the hatchability (TES) percentage irrespective of breeds or hatches were 73.72 for brown, 67.00 for light brown and 52.47 for creamy white shell coloured eggs respectively (Table- 4.7). The result revealed the influence of shell colour on the hatchability of eggs (TES). This difference of hatchability rate on the shell colour of eggs was found highly significant ($P < 0.01$) indicating the higher hatchability in brown shell coloured eggs. However, no significant difference was observed among three different shell colour groups of Gramapriya and hatches I and II.

Most probable cause of lower hatchability in lighter colour eggs might be due loss of higher moisture content and have less specific gravity, which result in low hatchability. Similar findings were observed by Jull (1952) who reported lower hatchability percentage in white shelled eggs.

Table- 4.7: Effect of shell colour on the fertility and hatchability in improved breeds of fowl.

FERTILITY					
VARIABLES		Brown	Light Brown	Creamy White	χ^2 - VALUE
BREED WISE	BR	89.85% (177)	86.90% (219)	86.81% (79)	1.041^{NS}
	GP	88.60% (272)	85.84% (188)	78.57% (11)	1.835^{NS}
	VR	94.16% (242)	82.74% (187)	78.95% (45)	19.250^{**}
OVER ALL MEAN		90.80% (691)	85.22% (594)	83.33% (135)	13.57^{**}
HATCH WISE	SET-I	91.41% (266)	85.17% (178)	95.00% (38)	6.428^{*}
	SET-II	87.97% (212)	85.29% (203)	86.89% (53)	0.743^{NS}
	SET-III	93.01% (213)	85.20% (213)	72.13% (44)	20.01^{**}
OVER ALL MEAN		90.80% (691)	85.22% (594)	83.33% (135)	13.57^{**}
HATCHABILITY (TES)					
BREED WISE	BR	68.53% (135)	63.49% (160)	52.75% (48)	6.690^{*}
	GP	71.66% (220)	69.86% (153)	71.43% (10)	0.202^{NS}
	VR	80.16% (206)	68.14% (154)	47.37% (27)	27.080^{**}
OVER ALL MEAN		73.72% (561)	67.00% (467)	52.47% (85)	29.70^{**}
HATCH WISE	SET-I	75.95% (221)	71.29% (149)	82.50% (33)	2.804^{NS}
	SET-II	70.95% (171)	65.97% (157)	57.38% (35)	4.377^{NS}
	SET-III	73.80% (169)	64.40% (161)	27.87% (17)	44.25^{**}
OVER ALL MEAN		73.72% (561)	67.00% (467)	52.47% (85)	29.70^{**}
HATCHABILITY (FES)					
BREED WISE	BR	76.27% (135)	73.06% (160)	60.76% (48)	6.618^{*}
	GP	80.88% (220)	81.38% (153)	90.91% (10)	0.701^{NS}
	VR	85.12% (206)	82.35% (154)	60.00% (27)	16.300^{**}
OVER ALL MEAN		81.19% (561)	78.62% (467)	62.96% (85)	22.17^{**}
HATCH WISE	SET-I	83.08% (221)	83.71% (149)	86.84% (33)	0.345^{NS}
	SET-II	80.66% (171)	77.34% (157)	66.04% (35)	5.220^{NS}
	SET-III	79.34% (169)	75.59% (161)	38.64% (17)	31.90^{**}
OVER ALL MEAN		81.19% (561)	78.62% (467)	62.96% (85)	22.17^{**}

NS- Not significant, *P<0.05, **P<0.01

Values in the parenthesis are number of the eggs.

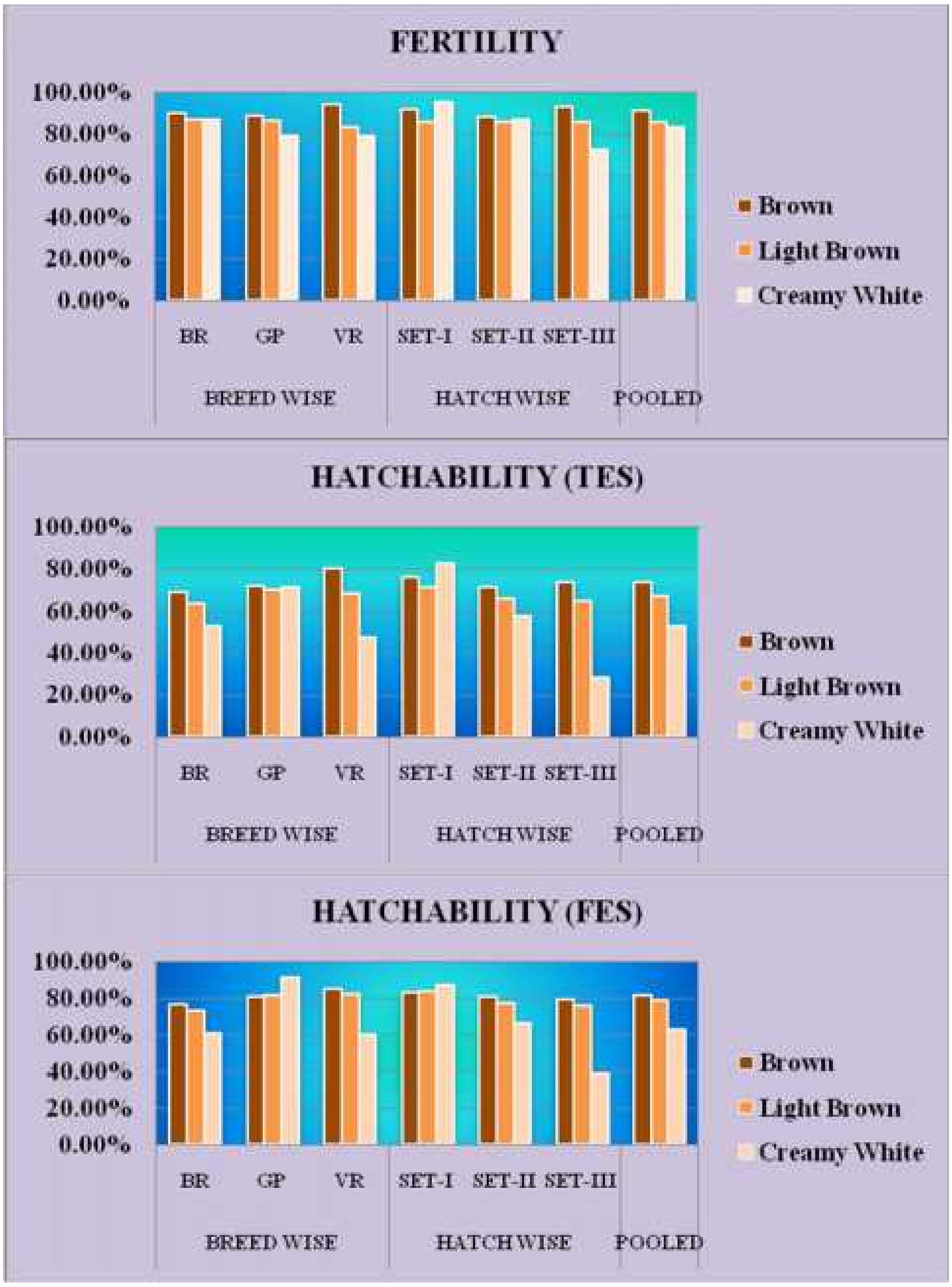

Fig. 28: Effect of Shell colour (Breed wise, Set wise and Overall) on the Fertility and Hatchability on TES and FES.

4.5.2.2 Hatchability on fertile eggs set basis (FES)

The data obtained for hatchability (FES) on the basis of different shell colour are presented in the Table- 4.7. The pooled hatchability on FES percentage followed same trend as in the case of hatchability on TES and brown shelled eggs group had higher hatchability rate with 81.19 percent followed by light brown (78.62%) and creamy white (62.96%) respectively. Results showed highly significant ($P<0.01$) difference among different shell colour groups irrespective of breeds or hatches. However, χ^2 – test could not reveal significant difference in the hatchability of three different shell colour groups of Gramapriya and batches I and II.

The higher hatchability rate among brown shelled eggs was probably due to shell pigments which are deposited on shell just prior to the egg being laid and light egg colour may be a sign of prematurely laid eggs caused by some type of environmental stress. Another reason might be due to the positive association of the density of pigment with hatchability, apart from thicker shell with more calcium and high specific gravity of brown shelled eggs.

The results of this study concur with North (1972), Zgobica and Wezyk (1995) and Moyle *et al.* (2008) who also reported better hatchability rate in darker eggs.

4.6 EMBRYONIC MORTALITY PATTERN IN DIFFERENT BREEDS

Table- 4.2 showed that the average embryonic mortality was 21.62 percent, the highest happened in the third hatch (26.17%), in the first and second hatch the embryonic mortality has been lower (16.39% and 22.44%

respectively). Embryonic mortality for the entire incubation was the lowest in Vanaraja (18.35%), intermediate in Gramapriya (18.68%) and the highest in Black Rock (27.79%). Embryonic mortality during incubation was not evenly distributed in time in the whole group and neither in the individual breed. The embryonic mortality of all the breeds (pooled mean) was the highest during the early period of incubation, i.e. early embryonic mortality (44.30%), the lowest (27.04%) in the mid stage of incubation and it was again high (28.66%) in the late stage of incubation (Table- 4.8). However, this trend was not observed in the third hatch as well as in the Black Rock breed where embryonic mortality in mid stage was higher than that of late stage embryonic mortality. The embryonic mortality pattern in Black Rock was early embryonic mortality (EEM) (39.39%), 31.82 percent mid embryonic mortality (MEM) and 28.79 percent late embryonic mortality (LEM), whereas in Gramapriya, pattern was 48.86 percent (EEM), 20.45 percent (MEM) and 30.68 percent (LEM) and it was 47.13 percent (EEM), 26.44 percent (MEM) and 26.44 percent (LEM) in Vanaraja (Table- 4.8). χ^2 – test revealed that there was highly significant difference in the stages of embryonic mortality in Gramapriya and Vanaraja. However, no significant difference was observed in the stage of embryonic mortality of Black Rock. Results for embryonic mortality followed same trend when considered hatch wise and the frequencies for Set-I were 39.24 percent (EEM), 25.32 percent (MEM) and 35.44 percent (LEM). In case of Set-II values were 51.43 percent (EEM), 21.90 percent (MEM) and 26.67 percent (LEM) and for Set-III values were 41.46 percent (EEM), 67.48 percent (MEM) and 26.02 percent (LEM), respectively. Statistically, there was no significant difference in stages of embryonic mortality in Set-I. However, Set-II and Set-III showed significant differences in stages of embryonic mortality at the level of 1% and 5%, respectively. Overall pooled mean values for stage of embryonic mortality irrespective of breed or sets were 44.30 percent (EEM), 27.04 percent (MEM) and 28.66 percent (LEM). Statistically, difference was highly significant (P<0.01) in stages of embryonic mortality.

There are three stages of embryonic mortality: early (first seven days of incubation), mid (between day eight and 18 day of incubation) and late (during last three days of incubation). The most probable cause of early embryonic mortality is a result of failure of the embryo to resume development after having been stored and placed in the setter (North and Bell, 1990). The mid embryonic mortality is usually related to nutritional deficiencies in the parent diet or embryonic abnormalities (Abudabos, 2010). The late embryonic mortality might be due to abnormal positioning, complications in physiological changes, lethal genes and chick failure to penetrate egg at hatching (Abudabos, 2010). In present study, higher percentage of LEM was observed in Gramapriya and this could be explained by stronger egg shell of this breed. On the basis of comparisons of the embryonic mortality of the individual breeds it was observed that embryonic mortality was the highest in Black Rock followed by Gramapriya and Vanaraja. Present study was in close agreement with Basnet (1973) but in other breeds, who reported that embryonic mortality was higher in New Hampshire and White Cornish than White Leghorn and White Rock. Overall pooled mean showed that EEM and LEM both higher frequencies than MEM and this findings was also in

Table- 4.8: Pattern of embryonic mortality in improved breeds of fowl.

SET WISE				
VARIABLES	**EARLY E.M.**	**MID E.M.**	**LATE E.M.**	**χ^2 - VALUE**
SET-I	39.24% (31)	25.32% (20)	35.44% (28)	3.684^{NS}
SET-II	51.43% (54)	21.90% (23)	26.67% (28)	23.74^{**}
SET-III	41.46% (51)	67.48% (40)	26.02% (32)	6.659^{*}
OVERALL	44.30% (136)	27.04% (83)	28.66% (88)	25.10^{**}
BREED WISE				
VARIABLES	**EARLY E.M.**	**MID E.M.**	**LATE E.M.**	**χ^2 - VALUE**
BLACK ROCK	39.39% (52)	31.82% (42)	28.79% (38)	3.545^{NS}
GRAMAPRIYA	48.86% (43)	20.45% (18)	30.68% (27)	16.40^{**}
VANARAJA	47.13% (41)	26.44% (23)	26.44% (23)	11.17^{**}
OVERALL	44.30% (136)	27.04% (83)	28.66% (88)	25.10^{**}

NS- Not significant, *P<0.05, **P<0.01

Values in the parenthesis are number of the eggs.

close accordance with the findings of El Ayadi (1956) who reported an embryonic mortality of about 22.2 percent and 6.9 percent during the 1st and 2nd week of incubation respectively and 19.4 percent dead in shell. Hamidu *et al.* (2007) observed influence of genetic strain and parent flock age on daily embryonic metabolism during the early and latter days of incubation.

4.7 EFFECT OF BREED ON DAY OLD CHICK WEIGHT

The weight of chicks immediately after completion of hatch was recorded for each breed. The mean weights of chicks hatched from different breeds thereof have been presented in Table- 4.9. The average mean weights values of day old chicks in three consecutive hatches for Black Rock was 33.71±0.21g, 31.84±0.25g and 32.67±0.26g Whereas, the average mean weight values of day old chicks were 35.49±0.21g, 33.52±0.32g and 33.53±0.25g for Gramapriya and 34.60±0.22g, 32.29±0.25g and 33.92±0.15g for Vanaraja, respectively. The overall pooled mean value of day old chick for Black Rock, Gramapriya and Vanaraja was 32.79±0.14g, 34.21±0.16g and 33.63±0.15g, respectively. In present investigation, there was highly significant ($P<0.01$) difference in all three hatches separately among three breeds in chick hatch weight. Statistically, highly significant ($P<0.01$) difference was observed when all hatches pooled together. The data obtained from all the three hatches indicated that the weight of day old chicks increased with the increase in the weight of eggs of eggs, and chicks of Gramapriya and Vanaraja weighed significantly heavier than the chicks of Black Rock. It is anticipated that breeds with light eggs produce small chicks and breed with heavy eggs produces large sized chicks. However, average day old chick weights of Gramapriya and Vanaraja obtained in this study were slightly lower

Table- 4.9: Average day old chick weight (X±S.E. in gram) in three different breed.

Particulars	Black Rock	Gramapriya	Vanaraja
Set- I	33.71 ± 0.21^{a}	35.49 ± 0.21^{c}	34.60 ± 0.22^{b}
Set-II	31.84 ± 0.25^{a}	33.52 ± 0.32^{c}	32.29 ± 0.25^{b}
Set-III	32.67 ± 0.26^{a}	33.53 ± 0.25^{b}	33.92 ± 0.15^{b}
Overall	32.79 ± 0.14^{a}	34.21 ± 0.16^{c}	33.63 ± 0.15^{b}

Mean values bearing same superscript row wise (a, b, c) do not differ significantly (P<0.05)

Table- 4.9(a): Analysis of variance for day old chicks body weight showing the effect of breed.

SOURCE OF VARIATION	SET- I			SET- II			SET- III			OVERALL		
	d.f.	M.S.	F	d.f.	M.S.	F	d.f.	M.S.	F	d.f.	M.S.	F
Between breed	2	104.13	17.30^{**}	2	90.19	10.04^{**}	2	44.48	5.64^{**}	2	182.49	21.85^{**}
Error	400	6.02		360	8.98		344	7.89		1110	8.35	

$^{*}P < 0.05$, $^{**}P < 0.01$

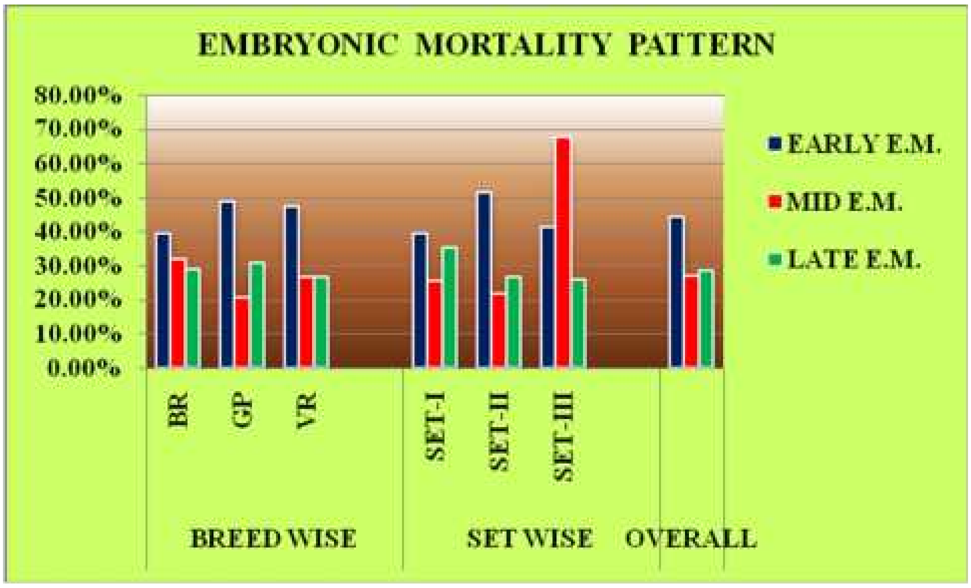

Fig. 29: Embryonic mortality pattern in the different Breeds of chicken.

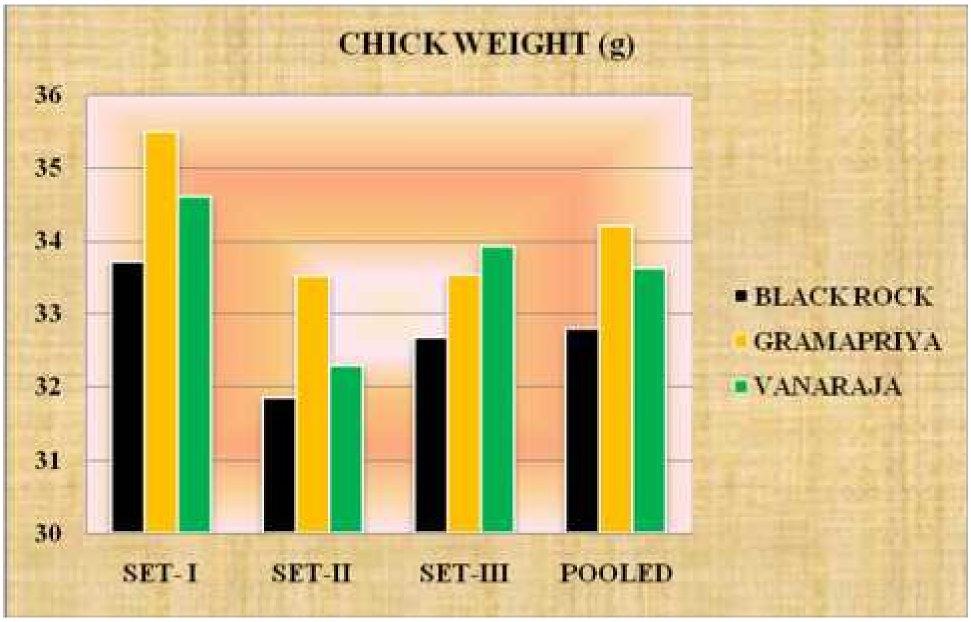

Fig. 30: Effect of Breed on Day old chick weight.

than that of reported by Project Directorate on Poultry, Hyderabad. The smaller weight of the newly hatched chick in the present study might be due to age of parent as the data have been collected from 28- 35 weeks age groups and Project Directorate on Poultry, Hyderabad has not mentioned parent age in their report. Although, in present investigation egg weight was found slightly higher in Gramapriya and Vanaraja for particular age groups reported here. So, lower value of day old chick weight in this study may not represent the true potential of these breeds. There was not sufficient information available to make any useful corroboration for Black Rock about day old chick weight.

Present findings showed significant effect of breed on day old chick weight and were in close agreement with Raju *et al.* (1997) and Islam *et al.* (2002) who stated that day old chick weight increased significantly with increase in egg weight which may also be for the difference of genotype.

CHAPTER-V

Summary, Conclusions and Suggestions for Future Research Work

CHAPTER-V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK

Poultry production is an important segment of animal husbandry which has shown tremendous progress during the last few decades. The stupendous increase in poultry meat and egg production is mainly due to the use of improved varieties of birds and their crosses.

Even though we have achieved much progress it is not sufficient to meet the minimum requirements of poultry meat or table egg in this country. To augment the poultry production attention is needed to improve the production in the remote villages of the country. Improved varieties of chicken and their crosses need to be introduced and propagated in the vast rural India which would greatly improve the national production. Thus emphasis only on highly input oriented commercial poultry farming should be avoided. Equal attention towards commercial poultry farming as well as improved backyard farming perhaps would be a better approach to increase the national poultry production. The increased production should also be supplemented with evaluation of the fertility and hatchability traits of these newly introduced birds replacing the traditional and indigenous birds.

It is known that a breed with higher fertility and hatchability rate can improve the poultry production so it is of great importance to rear such breeds only that have a superior fertility and hatchability rate.

The major objective of the present study was to evaluate the differences in the fertility and hatchability traits of Black Rock, Gramapriya and Vanaraja breeds of chicken. Other objectives were to see the embryonic mortality pattern i.e. stage of mortality and breed effect on the day old chick weight.

Evaluation of the fertility and hatchability rates were made in three different breeds of Black Rock, Gramapriya and Vanaraja maintained at Government Poultry Farm, Durg (Chhattisgarh) in deep litter system. Experimental birds were of same age group (28- 35 weeks). The parameters used to study the fertility and hatchability rates were breed, egg weight, shape index, shell thickness and shell colour.

The overall mean fertility percentage of three breeds was reported to be 87.96 in Black Rock, 87.22 in Gramapriya and 87.78 in Vanaraja, respectively. When the data were subjected to χ^2 – test, the breed difference were found to be non-significant.

The overall mean hatchability (TES) percentage of three breeds was found to be 63.52 for Black Rock, 70.93 for Gramapriya and 71.67 for Vanaraja. Effect of breed on hatchability (TES) was highly significant ($P<0.01$).

Overall mean percentage of hatchability (FES) of three breeds was 72.21 for Black Rock, 81.32 for Gramapriya and 81.65 for Vanaraja and χ^2 – test revealed highly significant ($P<0.01$) difference among breeds.

The pooled value of three different egg weight class showed significant ($P<0.05$) difference in the fertility, when data were analyzed breed wise as well as set wise.

The pooled value of different egg weight class (breed wise as well as set wise) showed highly significant (P<0.01) difference in the hatchability on the basis of TES and FES both, when the data were analyzed by χ^2 – test. The mid class (47- 53 g) had higher hatchability rate on the basis of total egg set as well as on fertile egg set basis.

The overall value of three different classes of shape index showed no significant difference in the fertility, hatchability (TES) and hatchability (FES). The result revealed that cylindrical eggs (67- 72%) had higher fertility rate, whereas hatchability, both on total egg set and fertile egg set basis, was higher in the mid group/ class (73- 78%).

The overall value of three different classes of shell thickness had great effect on the fertility rate. The results revealed that mid class (0.27- 0.33mm) had higher fertility rate and difference among three classes were highly significant (P<0.01).

The overall highest hatchability percentage was observed in mid group (0.27- 0.33mm) both on the basis of total eggs set and fertile eggs set. Effect of shell thickness was very much found and data showed highly significant (P<0.01) difference between three different classes.

The overall value showed highest fertility rate for brown shell coloured eggs. Effect of shell colour on the fertility has been reported to be highly significant (P<0.01) among three different classes.

The brown shelled eggs had higher hatchability rate on total eggs set and fertile eggs set basis. The results revealed highly significant ($P<0.01$) difference in three different classes of egg shell colour.

Overall value was higher for the early embryonic mortality rate. A highly significant ($P<0.01$) difference was observed in the three stages of embryonic mortality.

Overall average body weight of day old chick in Black Rock, Gramapriya and Vanaraja was 32.79±0.14g, 34.21±0.16g and 33.63±0.15g, respectively. Overall Gramapriya breed showed higher body weight in day old chicks. The result of analysis of variance revealed a very highly significant effect ($P<0.01$) of breed on the day old chick body weight.

Conclusions:

1. Black Rock, Gramapriya and Vanaraja had almost similar fertility rate and there was no much difference among them as far as fertility is concerned. Breed had great effect on the hatchability both on total eggs set and fertile eggs set basis. Gramapriya and Vanaraja breeds had higher hatchability rate than Black Rock breed.

2. The certain egg traits like egg weight, shell thickness and shell colour had significant effect on the fertility and hatchability in the present study, whereas shape index had no significant effect.

3. From the present study, it could be concluded that Medium and large sized eggs had better fertility rate than the smaller sized eggs. Hatchability rate

was much higher in the medium sized eggs in comparison to larger and smaller sized eggs.

4. The cylindrical and oval eggs had higher fertility rate in comparison to rounded eggs, whereas oval shaped eggs hatches better.

5. Very thin or thick shelled eggs had lower fertility rate and also do not hatch well than that of eggs with medium shell thickness.

6. It is concluded that dark coloured eggs had higher fertility rate and also hatched at higher rate than did light coloured eggs.

7. Early embryonic mortality was much higher than mid and late embryonic mortality.

8. Egg weight influences the day old chick weight and higher average body weight was observed in the breed with higher average egg weight.

9. Breeds like Gramapriya and Vanaraja are more suitable for backyard farming in Chhattisgarh (India) than Black Rock breed especially in summer season.

10. Management plays an important role in controlling all of these factors to produce eggs of high quality. Practice of necessary steps is required to prevent disease, giving balanced feed and to control other physiological disturbances in the flock mainly in the summer season, as egg quality deteriorates with the increase in the environmental temperature.

Suggestions for future work:

In spite of the fact that Gramapriya and Vanaraja breeds possess the better ability than Black Rock to perform and reproduce under harsh conditions, their potentials have not been fully exploited in Chhattisgarh (India). Therefore, suggestions for future works are:

1. The data should be of larger size.
2. More number of breeds especially some Indian breeds and their crosses may be included.
3. More number of eggs should be used in all the three important seasons of the year so that the performance of the breeds can be evaluated throughout the year and a sound inference on the fertility and hatchability of the respective breeds can be drawn.
4. Period of study could be spread over few years.
5. Different management effect such as feeding schedule, feed quality and stocking density on the fertility and hatchability traits may be studied.

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Abstract

ABSTRACT

Title of thesis: **Studies on the fertility and hatchability of some improved breeds of chicken suitable for backyard farming.**

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Although our country has witnessed much progress in poultry production, yet it is not sufficient to meet the minimum requirements of poultry meat or egg for our population. The situation can be improved if the rural poultry production could be strengthened. Improved varieties of chicken and their crosses need to be introduced and propagated in the rural India to improve the national production. The increased production is needed to be supplemented with evaluation of the fertility and hatchability traits of the improved breeds suitable for backyard farming.

The present study was undertaken to evaluate the fertility and hatchability traits of Black Rock, Gramapriya and Vanaraja breeds of chicken maintained at Government Poultry Farm, Durg (Chhattisgarh). The birds under study were maintained under uniform and standard management practices. The findings of the present study are as follows:

The overall mean fertility percentage of three breeds was reported to be 87.96 in Black Rock, 87.22 in Gramapriya and 87.78 in Vanaraja, respectively. When the data were subjected to χ^2 – test, the breed difference were found to be non-significant.

The overall mean hatchability (TES) percentage of three breeds was found to be 63.52 for Black Rock, 70.93 for Gramapriya and 71.67 for Vanaraja. Effect of breed on hatchability (TES) was highly significant ($P<0.01$).

Overall mean percentage of hatchability (FES) of three breeds was 72.21 for Black Rock, 81.32 for Gramapriya and 81.65 for Vanaraja and χ^2 – test revealed highly significant ($P<0.01$) difference among breeds.

The pooled value of three different egg weight class showed significant ($P<0.05$) difference in the fertility, when data were analyzed breed wise as well as set wise.

The pooled value of different egg weight class (breed wise as well as set wise) showed highly significant ($P<0.01$) difference in the hatchability on the basis of TES and FES both, when the data were analyzed by χ^2 – test. The mid class (47- 53 g) had higher hatchability rate on the basis of total egg set as well as on fertile egg set basis.

The overall value of three different classes of shape index showed no significant difference in the fertility, hatchability (TES) and hatchability (FES). The result revealed that cylindrical eggs (67- 72%) had higher fertility rate, whereas hatchability, both on total egg set and fertile egg set basis, was higher in the mid group/ class (73- 78%).

The overall value of three different classes of shell thickness had great effect on the fertility rate. The results revealed that mid class (0.27- 0.33mm) had higher fertility rate and difference among three classes were highly significant ($P<0.01$).

The overall highest hatchability percentage was observed in mid group (0.27- 0.33mm) both on the basis of total eggs set and fertile eggs set. Effect of shell thickness was very much found and data showed highly significant ($P<0.01$) difference between three different classes.

The overall value showed highest fertility rate for brown shell coloured eggs. Effect of shell colour on the fertility has been reported to be highly significant ($P<0.01$) among three different classes.

The brown shelled eggs had higher hatchability rate on total eggs set and fertile eggs set basis. The results revealed highly significant ($P<0.01$) difference in three different classes of egg shell colour.

Overall value was higher for the early embryonic mortality rate. A highly significant ($P<0.01$) difference was observed in the three stages of embryonic mortality.

Overall average body weight of day old chick in Black Rock, Gramapriya and Vanaraja was 32.79±0.14g, 34.21±0.16g and 33.63±0.15g, respectively. Overall Gramapriya breed showed higher body weight in day old chicks. The result of analysis of variance revealed a very highly significant effect ($P<0.01$) of breed on the day old chick body weight.

(Keshab Das)
Major advisor