II. REVIEW OF LITERATURES

The growth and reproductive performances are the main factors, which vary depending on the nutrition, health of birds, disease outbreaks and stressful environmental conditions in the lofts, determining the economic feasibility of pigeon growing for profits (Lyell, 1959). Although basic nourishment of pigeons can provide as much as necessary carbohydrates, proteins, fats, some minerals and vitamins, it was found to be inadequate for having the maximum productive performance in the pigeons (Waldie et al., 1991), and it could not provide enough innate immunity to protect the birds from the deadly diseases caused by bacterial, protozoan, mycoplasma, fungal and viral pathogens (Walker, 2000). Low productive performance of pigeons is partly due to inadequate amount of some dietetic components and partly due to the low feed conversion rate caused by loss of normal intestinal microflora because of the colonization of pathogenic microbes in the intestine and because of antibiotic therapy (Bob Doneley, 2006), which would unquestionably affect the metabolism in the birds to at least some extent. Unless the required nutrients are supplied and the intestinal microflora is rebuilt as it should be, no one can improve the food conversion efficiency, weight gain and reproductive performance of pigeons. Veterinarians have experimentally proved that growth and reproductive performances of birds can be improved by incorporating certain probiotics, vegetable products and powder of marine algae in the diet (Williams and Corrigan, 1994). This thesis attempts to analyze the dietary effects of Lactobacillus acidophilus (probiotic), powder of Andrographis paniculata (herbal) and Sargassum wightii (marine alga) on the growth and reproductive characteristics of Lahore pigeons and associated immune modulations in the pigeons’ blood system.
2.1. Basic Nutrition of Pigeons

The Blue-rock pigeons are seed-eating birds which depend on the grains of cultivated plants such as cereals, peas, beans, lentils and oil-seeds (Vogel et al., 1994), but most of them habitually feed on seeds of weeds, green parts of plants, small fruits, small insects and earthworms (Vogel et al., 1994). It is observed that domestic pigeons most often pick up small stones, grit and coarse earth particles, which are necessary for grinding the seed grains in the intestine. It should be mentioned here that a domestic pigeon performs about 35,000 pick actions per day (Abs, 1983). The gastrointestinal tract of pigeon is about 120cm which is 3.5 times longer than its body length. When pigeons are fed with grains, the food remains in the crop for 3-17 hours, ventriculus for 5-19 hours, and in the intestine for 9-14 hours before defecation (Abs, 1983). Nearly 80% of feed is digested and defecated within 24 hours, but the rest may be retained and excreted after 3 days.

Dietetic studies have shown that pigeon breeds differ from one another in their nutrient rations and food preferences as evidenced in racing pigeons (Janssens et al., 2000), meat-type pigeons (Waldie et al., 1991; Meleg et al., 2000), and fancy pigeons (Gugolek et al., 2013). In most countries pigeons are habitually fed with whole cereal grains and grams or pea seeds and the basal feed ingredients are principally wheat and maize, followed by barley, naked oat, rice and legume seeds (Henry, 1932; Sales and Janssens, 2003). Killeen et al. (1993) have observed that pigeons in lofts tend to prefer larger grains than smaller grains or flour because they tend to choose feed that can quickly gratify their appetite. Regarding the digestibility of food grains, Michalak et al (2001) found out that maize starch has high digestibility in the intestine of pigeons compared to the starch reserves in the other type of food grains, which
implies that maize grains are best for pigeons over the other cereals grains. However, it is concluded that selection of the feed grains as the principal source (wheat, rice, sorghum, millets and sunflower seeds) depends on the availability of the grains, presence of competitors, craving for food, and unavailability of alternative food grains in the vicinity of pigeons (Moon and Zeigler, 1979; Plowright et al., 2004). Williams and Corrigan (1994) concluded that pigeons coming out of the lofts frequently feed even on garbage and livestock manures in open places and the things given intentionally by growers. Gugolek et al (2013) suggested that, although pigeons can consume all the commercial cereals and pulses, their beak length seems to be the key factor that determines the choice of food grains and level of eating the grains; they further argued that low values of reproductive performance in some pigeons may be due to behavioural problems or insufficient warmth during the brooding of two eggs but not due to the problem of selecting various food grains. Formulated feed granules are regularly fed to meat-type pigeons in which weight gain is more expected than the racing and fancy pigeons wherein weight gain is of secondary importance (Waldie et al., 1991; Meleg et al., 2000). Further, notes on food preference of pigeons are available in the works of Broadman (1889), Eagle (1890), Deane (1896), Vandeputte-Poma (1980), Waldie et al. (1991), Edwards (1926), Fleming (1931), Henry (1932), Mitchell (1935), Vogel et al., (1983), Gugolek (2007), Meleg et al. (2000), Savas et al. (2007, 2008), and Kazal Krishna Ghosh et al (2013). Pigeons do not drink running water but prefer standing water; they require 30 ml of water every day (Williams and Corrigan, 1994).

2.1.1. Feed Mixtures

Pigeon growers felt that no one single type of food grains can provide enough amount of calories required for the proper growth and development of pigeons in the
lofts (Lyell, 1959), so that feed mixtures have been preferred by pigeon fanciers (Vogel et al., 1994). Louis Vermeijen (1926) described that pigeons should be provided with 25% maize, 25% wheat, 25% beans and 25% barley, rye and linseeds during the winter season, provided with 35%maize, 15% wheat, 45% beans and 4% buckwheat and linseeds during the active growth phase, and provided with 40% maize, 20% wheat, 35% beans and 5% millets and linseeds during the reproductive phase. According to Louis Vermeijen (1926), food grains alone could not help the birds to grow well and lay fertile eggs because they do not have teeth to grind the grains into flour; grit that can crush the grains, while passing through the intestine, should be given for enhancing the digestibility and assimilation of the grains. Further, carbonaceous substances (lime or charcoal powder, powdered oyster shells and egg shells and table salt) are very important for laying-birds as they supply enough calcium required for them (Louis Vermeijen, 1926). Specific feed mixtures have been formulated by growers using the type of food grains available in plenty to meet the nutritional requirements of pigeons. Daily requirements of nutrition, minerals, vitamins and grit for domestic pigeons were described by Vogel et al. (1994). Feed mixture developed by Mariey et al (2013) contains yellow corn (64%), soybean meal (20%), wheat bran (11.9%), limestone (1.5%), bone meal (2%), table salt (0.3%) and vit-min mix (0.3%). Kazal Krishna Ghosh (2013) formulated a feed mixture containing rice (10%), wheat (70%), cowpea (5%), mustard oilcake (5%), germinating gram (5%), lentil (5%), oyster shell powder (5%), grit (2.5%), table salt (2%) and dicalcium phosphate (2.3%) for domestic pigeons. Morice (1970), Levi (1972), Orban (1975), Moon and Zeigler (1979), Vandeputte-Poma (1980), Csontos (1981), Klein (1974), Botcher et al (1985), Waldie et al (1991), Meleg et al (2000), Gugolek (2007),
Khashaba and Ibrahim (2007), Mellot and Hilliker (2008) and Jalal et al (2011) have also formulated their own feed mixtures while studying the growth and reproductive attributes of fancy pigeons. These feed mixtures give comparatively good results in body weight gain, fast growth, food intake, early maturation, high hatchability of eggs and low mortality of squabs; however, additional use of feed supplements (yeast) have further increased the growth and reproductive performances of pigeons (Mariey et al., 2013).

Digestibility and metabolic energy of various feed components were studied by Goodman and Criminger (1969), Csonos (1981), Janssen (1989), NRC (1994) and Huller et al (1999). Goodman and Griminger (1969) had demonstrated that fat supplementation (3.7 to 8.7%) has enhanced the flight capabilities of pigeons, and concluded that flying pigeons are likely to utilize fat more efficiently than carbohydrates as an energy source. Borghijs and De Wilde (1992) and Janssen et al. (1989) also suggested that carnitine supplementation of the feed had a favorable effect on racing pigeons as it maintains the oxidative processes and prevents muscle damage during prolonged flight. Shultz et al (1953) had studied the essentiality of various vitamins required for normal growth and reproductive performance of pigeons.

Balanced level of nutrients is necessary for the development, maintenance and functioning of the body, so that growth and reproduction will be affected even if there is a slight deficiency of essential nutrients. The growth of birds and their immune responses are positively correlated with each other, which implies that any feed supplement up regulating the innate immunity is indirectly supporting the birds for faster growth as well as egg production and decreasing the incidence of infectious diseases (Cook et al., 1993).
In the present investigation feed mixture that has been regularly used by pigeon fanciers of Kanyakumari district is chosen as the basic feed and attempts have been taken to improve the nutritional efficiency of the basic feed by incorporating a probiotic, a herbal powder and a marine algal powder as organic supplements. In fact, probiotics, herbal products and marine algae have been employed as organic supplements in the diet of fowls and fishes but there was no report of their use in pigeon growing.

2.2. Growth Characteristics of Pigeon

The growth characteristics of avian members are immensely related to changes in the survival rate, body length, body width, weight gain and food intake of birds and their young ones.

2.2.1. Survival Rate

When domestic pigeons are kept in lofts and cared properly as per hygienic standards, these birds can survive up to 15 years or more under certain more fitting circumstances (Williams and Corrigan, 1994; Atanasov, 2008). However, the life-span is comparatively short and hardly ever exceeds three years (Haag, 1991; Johnston and Janiga, 1995). In the practice of many profit-making lofts, they can only be maintained for four or five years because of the seasonal outbreak of various transmittable diseases (Vogel et al. 1994) and because of the loss of reproducing urge between the members of the same pairs (Louis Vermeijen, 1926; Murton et al. 1972). It was estimated that the natural population of pigeons has been reduced at the rate of 25-30% per year (Gronberger, 1911; Mitchell, 1935; Williams and Corrigan, 1994). Fachineli et al. (2004) further stressed that competition among pigeons in the crowded
loft for food even lead to wounding followed by infections of various kinds, which results in the death of some birds in the loft. Nevertheless, not much importance was given to the change in the survival rate of pigeons being maintained in the lofts.

2.2.2. Size and Weight of Pigeons

Various races of *Columba livia* differ from one another in their shape, plumage pattern and size depending on the geographical distribution and phenotypic choice of the breeders (Williams and Corrigan, 1994). Although male and female of a particular race of Rock pigeon (*Columba livia*) are similar in their shape and plumage (Baker and Inglis, 1928), there is a slight size-variation in different genders (Johnston, 1990). Usually, the male is larger and heavier than the female birds as they consume little large amount of feed every day (Vogel *et al*., 1994): the male is 30-36 cm in length while the female measures 29-35 cm length (Williams and Corrigan, 1994) likewise, the males attains 369 g weight while the females attain 340 g (Johnston 1984). But, in the pigeons being maintained in lofts, the size of the birds - both length and width - is somewhat larger than the measurements given above because of the supply of adequate amount of healthy feeds, supplements, vitamins and proper disease managements, which together favour the fast growth of individuals (Mariey *et al*., 2013; Kazal Krishna Ghosh, 2013).

2.2.3. Feed Intake

Earlier experiments have revealed that the rate of increase in the body weight of fowls and veterinary animals is determined by feed intake and subsequent conversion of the feed into various metabolites and body tissues (Golflus *et al*., 1997; Shanawany, 1988; Kuan *et al*., 1990; Beg *et al*., 1994; Tangendjaja and Yoon, 2002).
The feed intake - the amount of food consumed by a bird per day - of birds generally varies greatly depending on the genetic race of the bird, age group and the type of feed supplied to them (Iscan et al., 1996; Thind and Ambrosen, 1998). However, it may be further altered by nutritional supplements added to the feed (Youssef et al., 2001). Works of Hussein (1998), Goh and Hwang (1999), and Abd El-Azeem (2002) make out a clear point that yeast supplementation is responsible for increased feed intake in many breeds of layer and broiler chickens and pigeons (Mariey, 2013). Likewise, Lactobacilli probiotic has enhanced the feed intake of chickens as they can stimulate the appetite of birds (Nahashon et al., 1992), produce digestive enzymes (Lee and Lee, 1990) and decrease the intestinal pH (Rolfe, 2000). Some herbals also have the capacity to increase the growth rate by stimulating the feed intake in poultry (Chen et al., 2003; Mathivanan et al., 2006; Pornakpha Kungsoksomboun, 2007) and fishes (Pandey Govind et al., 2012). Dietary supplementation of Sargassum extract has enhanced the feed intake and body weight gain in poultry (El-Sayed, 1982; El-Deek et al., 1987; Gu et al., 1998; Wong and Cheung, 2001; Sim et al., 2004; El-Deek and Brikaa, 2009; EL-Deek et al., 2011), ducks (Breikaa, 1993) and aquaculture fishes and shrimps (Chin, 1998 and Felix et al. 2004).

2.2.4. Feed Conversion Rate (FCR)

The FCR – the amount of feed utilized by birds in a given time for gaining their body weight - is in fact a genetic factor that determines the growth efficiency of birds (Iscan et al., 1996; Thind and Ambrosen, 1998; Tangendjaja and Yoon, 2002). Youssef et al., (2001) stressed that the FCR of birds can be increased by providing some nutritional supplements that improve the digestibility of feed and assimilation of digested components by body tissues, which was experimentally proved by Hussein
(1998), Goh and Hwang (1999) and Abd El-Azeem (2002), who have proved higher rate of feed conversion in poultry which received yeast cultures along with the basic feed. The similar response was also observed in pigeons by Mariey (2013). The probiotic Lactobacilli have enhanced the FCR of chickens as they can produce digestive enzymes (Lee and Lee, 1990) and decrease the pH of intestinal fluids for facilitating the absorption by intestinal villi (Rolfe, 2000). Extracts of some herbals also have the capacity to augment the growth by improving the feed conversion rate of poultry (Chen et al., 2003; Mathivanan et al., 2006; Pornakpha Kungsoksomboun, 2007) and fishes (Pandey Govind et al., 2012). Likewise, *Sargassum* extract was found to increase the feed conversion rate and weight gain in poultry (El-Sayed, 1982; El-Deek et al., 1987; Gu et al., 1988; Wong and Cheung, 2001; Sim et al., 2004; El-Deek and Brikaa, 2009; EL-Deek et al., 2011) and ducks (Breikaa, 1993).

The FCR of squab was as high as 3.68% in young squabs during the first three weeks, decreased gradually at the fourth and fifth weeks, and less than one after that (Bhuyan et al., 1999; Bokhari, 2002). Darwathi et al (2010) concluded that the reductions in growth rate of squab after the 5th week was due to the fall in FCR, which has shown that feed conversion efficiency after full-flight sage decreases with the increase in age of pigeons (Sales and Janssens, 2003).

2.3. Haematological Parameters of Pigeons

Although clinical standards have not been fully developed for pigeons so far to diagnose the infectious diseases and metabolic disorders, some haematological studies have been conducted as a way to understand the functional physiology of pigeons. Sturkie (1976) has estimated that the volume of blood in pigeons is within the range
of 0.01 - 0.1 ml/gram of pigeon’s body weight, which enables us to assume that an adult pigeon of 400g weight may contain approximately 40 ml blood. Haematological and clinical values of pigeon’s blood have been described by Lumeij (1987), Carlos Junueira et al., (1992), Vogel et al (1994), Fudge (2000), Tollba and Mahmood (2009), and Mubarak and Rizvi (2002).

According to Fudge (2000), the normal range of the PCV of healthy pigeons is 42 -50% but Saleem et al (2008) found that the normal PCV of Columba livia is around 28 -30%. Ritchie et al (1994) have stated that the normal range of RBC count in feral pigeons is 3.1 – 4.5 x 10⁶ /dL. However, Mubarak and Rizvi (2002) had reported that RBC level of healthy pigeon is 2.5 x 10⁶/ dL. Haemoglobin level is nearly 1/3 of the hematocrit value of the blood which depends on the RBC count of the blood (Ramnik Sood, 1994), so that haemoglobin level is positively correlated with the RBC count. According to Fudge (2000), the total leukocytes count (TLC) of pigeon is within the range of 9-13 x 10³/µl, but Saleem et al (2008) had observed the TLC value as high as 27.15 x 10³/µl in healthy pigeons. Fudge (2000) states that the basophils count in healthy Columba livia is less than one cell/µl. Higher proportions of basophils in the blood of pigeons show that the birds have already infected with some sorts of mild pathogens (Saleem et al., 2008). In healthy pigeons, eosinophils count is zero (Fudge, 2000) but there is rise in the eosinophils count in cases where there is worm infestation or infections with pathogenic germs (Coles, 1980; Saleem et al., 2008). Monocytes which are necessary for phagocytosis (Carlos Junueira et al., 1992) were more in infected pigeons (Saleem et al, 2008) but almost zero in the blood of disease-free pigeons (Fudge, 2000). The customary value of lymphocyte count is 5.7 x 10³/µl (Fudge,2000), while it was much higher in pigeons infected by

2.4. Reproductive Characteristic of Pigeons

2.4.1. Maturation Period

Domestic pigeons attain the right stage of sexual maturity to begin their first reproductive cycle in 6 or 7 months (Sturtevent and Hollander, 1978; Kazal Krishna Ghosh, 2013). Darwathi et al (2013) observed that the age of pigeons while laying the first egg was 221±31 days while Khargharia et al. (2003) reported that in Assam the average age of pigeons at the time of laying the first egg was 166.64±0.32 days. Hetmanski (2004) has observed that young males started their reproductive life in 111 days whereas young females started reproduction activities in 174 days. As soon as the birds attain sexual maturity, they begin to show courtship displays as a way to attract the opposite sex for pairing (Castaro and Ghul, 1958; Estein et al., 1980; Johnston and Janiga, 1995): the male first paces towards the female and displays the fluffing of breast feathers, cooing, dragging the tail feathers on the ground and threading the feet on the floor; the accepting female nods, elevates her wings and crouches to allow the male to mount on it for copulation to occur. The copulating male and female live together as a pair (Castaro and Ghul, 1958). Even if the maturation period of pigeons is 6 or 7 months, it can be shortened by feeding the birds with nutritious feeds and supplements (Abed Al-Azeem, 2005; Abou Khashaba and Mariey, 2009; Balevi et al., 2000).
2.4.2. Number of Egg Cycles

It is worth to note here that the breeding season of *Columba livia* is long and lasting all year round, but reproductive peaks occur during the spring and summer (Johnston and Janiga, 1995; Hetmanski, 2004; Giunchi *et al.*, 2007). Interestingly, Murton *et al.* (1972) suggested that the number of egg cycles is habitually increased in pigeon pairs since both parents share incubation for faster embryo development and since they feed the crop milk to young ones (Shetty *et al.*, 1992a). Nevertheless, this is not an acceptable reason for variation in the number of egg cycles per year; for that, Abou Khashaba and Mariey (2009) have quoted another reason that the number of egg cycles produced by a pair varies depending on the age of pigeon pairs, feed composition and genetic race of the birds. Since young birds took nearly six months to attain maturity, the egg cycle number was low in the first year. But, in the subsequent years, birds fed with normal feeds gave $4\pm2$ egg cycles/year (Johnston and Janiga, 1995). When nutritious feeds and adequate supplements are given and the birds are maintained under suitable growing conditions, *Columba livia* may even produce up to twelve broods in a year (Levi 1972).

2.4.3. Length of Egg Cycles

According to Abed Al-Azeem (2005), egg cycle of healthy pigeons is within the range of 45½ -54½ days. Abou Khashaba and Mariey (2009) had observed that dietary supplementation of 1 - 5 g of vitamin and minerals premix/kg of diet had shortened the length of egg cycle from 56.62 to 45.62 days, which points out that rich nutrients had some effects on reducing the length of egg cycle in pigeons. Also, the duration of egg cycle depends on the activity of parents to nurse their squabs and warmth (Mariey, 2013).
2.4.4. Duration between Consecutive Eggs

As a rule pigeons lay two eggs/ pair per clutch (Louis Vermeijen, 1926). In the traditional system of pigeon growing, Levi (1954) observed that pigeons more often than not lay 1-3 eggs / brood, but two eggs per pair/ brood is very common. Darwathi et al (2010) have noted that about 73.4% of experimental pigeon pairs laid two eggs / brood, 20% of pairs had produced only one egg / brood and 6.6% of pairs had laid 3eggs / brood. However, most commercial pigeon growers have experienced that only two eggs were in normal size and fertile and the third egg, even if present, is so small and infertile. Johnston (1998) has stated that the second normal egg of pigeon appears about 40 hours after laying the first egg while Hagg (1991) has investigated that the second egg was laid 30-34 hours after laying the first egg of the brood.

2.4.5. Number of Eggs Produced

The clutch size of a pigeon pair is two, of which the first egg usually hatches into a male squab and the second one hatches into a female squab (Johnston, 1998). Earlier observations give the clear impression that domestic pigeons provided with normal diet had produced 8-10 eggs / year (Lofts and Westwood, 1966; Lofts and Murton, 1968; Johnston, 1984: Hetmanski, 2004). Since breeding activity is high during the spring and summer while low in autumn and winter, many birds laid single eggs during the autumn and winter (Riddle, 1971; Janiga, 1985; Janiga and Kocian, 1985), which was mainly due to some extrinsic factors – unfavourable weather conditions and shortening of photoperiod – that inhibit the gonads development in pigeons (Lofts et al. 1966; Murton et al. 1973). Therefore, there is a chance for variation in the number of eggs produced by a pair/year. Nutritional supplements added to the basic feeds have increased the number of eggs produced by a pair in a year (Kazal Krishna Ghosh, 2013; Marley et al., 2013).
2.4.6. Egg Weight and Size

Ibrahim and Sani (2010) found that the average egg weight is 14.7 cm in pigeons while Darwati et al. (2010) estimated that the egg weight ranged from 10.7 to 23.2 gm. Robinson (2005) noticed that the mean egg weight of domestic pigeon was 18.9gm and at the same time Sales and Janssens (2003) reported the mean egg weight of domestic pigeon was 21.4 gm. Abd El-Azeem et al. (2001) reported that egg weight ranged from 13.78 to 17.38 gm in local Egyptian Baladi pigeon. Dietary supplementation of yeasts (Mariey, 2013) and vitamins and minerals (Abou Khashaba and Mariey, 2009) give large-sized eggs compared to the control. According to Pingel and Jeroch (1997), the egg quality varies depending on the genetic traits of pigeons and nutrition provided to them. Egg weight is unswervingly related to length, width and volume of the eggs (Pikula et al. 1981 and 1982). It was also demonstrated that egg weight of pigeons was considerably correlated with egg length and egg width, and that the egg length was significantly correlated with egg width (Bhowmik et al., 2014).

Egg length and width of pigeon (Columba livia) were 3.68 and 2.85 cm respectively (Saxena et al., 2008). The egg size of birds is mainly determined by the volume of egg white which is in fact affected by the nutritive value of feeds consumed (Tazawa and Whittow, 2000). Fatty acid profile of yolk lipids does not vary in pigeons depending on the type of nutrition (Gugolek et al., 2013). Therefore, it is concluded that nutrition type can alter the volume of egg white to determine the size of eggs. Nutritious feeds increase the volume of egg white and hence the egg size is increased correspondingly (Bhowmik et al., 2014).
2.4.7. Fertile and Infertile Eggs

Meleg (1997) reported that 4.6 – 6.3% of the total laid eggs were found to be infertile because of the failure of the fusion of egg and sperm nuclei. But, Gugolek et al. (2013) have recorded the percentage of unfertilized eggs as high as 15 -23.3 in fancy pigeons, which might be due to low reproductive efficiency of males. The percentage of infertile eggs was high during the summer and winter because of extreme heat and cold (Levi, 1954). Dietary yeasts, which increase the growth and reproductive attributes, improve the quality of semen in pigeons to increase the fertility percentage of eggs (Mariey, 2013) and it is also confirmed in quail hens (Abdel-Al- Azeem et al., 2005). Here, the increase in fertility percentage of eggs is related to higher sexual efficiency and better semen quality of males (Mariey, 2013). The quality and quantity of semen produced by birds are the deciding factors for the fertility of eggs (Sexton, 1983), which usually varies depending on environmental conditions (McDaniel et al., 1995). According to Owen (1941), the semen quantity of domestic pigeons is not at all related to the size of the bird but it appears to be related to the seasons of year. The semen is of superior quality during the spring and summer, so that the fertility of eggs is relatively high during these two seasons (Cheng et al., 2002).

2.4.8. Hatching Percentage and Embryo Death

It is well to mention at this juncture that in about 8-12 days after mating, the female pigeon usually lays two eggs on-by-one in consecutive days. Both the parents incessantly incubate the eggs for 18 days – the male from mid-morning to late afternoon and female from late afternoon to mid-morning (Johnston, 1998). Hatching percentage is within the range of 59.68 - 63.69% in pigeons and is low in spring and
high during the summer (Meleg, 1997; Nam and Lee, 2006; Gugolek et al., 2013). Darwati et al. (2010) observed 77% hatchability in pigeon eggs, which is very high when compared to the pigeon’s egg-hatchability reported by Johnston (1998). The second egg most often hatches in 24 hours after the hatching of the first egg. Probiotic yeasts, which increase the growth and reproductive attributes, increase the hatchability of eggs in pigeon (Mariey, 2013). Dietary supply of vitamins and minerals has also improved the hatchability of the eggs of quail hens (Abdel-Al-Azeem et al., 2005). Therefore, it is believed that nutritious feeds can in general improve the hatchability of eggs.

In natural population of *Columba livia*, egg loss was measured to be 30-32% due to the problem of shell damages, predation, egg abandonment and eggs fallen out of the nests (Hetmanski and Barkowska, 2007). But, when pigeons are maintained in lofts by providing adequate amount of feed and suitable conditions, the egg loss has been reduced to a large extent (Meleg, 1997). The hatching success was greatly affected by embryo death which may be due to defects in embryo development because of the exposure of eggs to moist climate and infectious agents (Cheng, 2002; Hetmanski, 2004). Meleg (1997) reported embryo death as high as 16-19% of eggs during incubation in poorly managed lofts, but Mariey (2013) reported only 2-3% of eggs with dead embryos when pigeons were fed with dietary yeasts. Nutritious feeds reduce the embryo death by facilitating the proper embryo development during incubation and hence the egg loss would be very low (Hetmanski, 2004).
2.4.9. Weight Gain of Squabs

Immediately after hatching the parents feed the squabs with crop milk for 8 – 10 days until the squabs get adapted to feed on food grains (Johnston, 1998). The squabs tend to come out of the nests in 30-35 days, they develop their own habit of self-feeding to lead independent life, and thereafter usually take another 20 days to attain the full-flight stage (Johnston, 1998). In many cases, the parents undergo pairing process as soon as the squabs are ready to come out of the nests, which is responsible for clutch overlapping among the broods of a pair (Burley, 1980; Hetmanski and Barkowska, 2007).

The crop milk is a cheese-like nutritious fluid that is released as whole cell epithelial exudates by the crop of both parents to feed their squabs (Meagan Joy Gillespie, 1912). For the first three days, the squabs are fed with pure crop milk containing lipids, carotenes, proteins, growth factors and maternal antibodies, and thereafter crop milk is mixed with digested foodstuffs to supply enough food to the growing squabs (Horseman and Buntin, 1995). Nutritional composition of crop milk was described by Meagan Joy Gillespie (1912), Carr and James (1931), Reed et al. (1932), Davies (1939), Ferrando et al. (1971), Leash et al. (1971), Hegde (1972 and 1973, Desmeth and Vandeputte-Poma (1980) and Shetty et al. (1990, 1992a, 1992b & 1994). The crop milk can provide innate immunity to the newly hatched squabs for at least 2 two weeks (Johnston and Janiga, 1995; Jacquin et al., 2012). Consequently, the young squabs of pigeons immediately after hatching are more resistant to infections than any other age of life. There is a sudden fall in the level of circulating antibodies in the bloodstream after 14 days (Ahmad Ismail et al., 2013) and hence the squabs are very weak in immunity, which provides much opportunity to contract diseases (Jacquin et al., 2012).
The growth of squabs was very fast during the first three weeks and then it declined gradually towards the fourth and fifth weeks (Bhuyan et al., 1999; Bokhari, 2002; Mariey, 2013). As has been mentioned above, Levi (1954) has stated that the body size of squabs seems to be doubled in six or seven days, and that growth has reached the peak in the 4th week. Moreover, Bokhari (1994) indicated that squabs grow rapidly up to 21 days and the growth continued at slower rate thereafter. Darwathi et al (2010) concluded that the reductions in growth rate of squab after 5th week was due to the fall in FCR, which is agreed by Sales and Janssens (2003).

2.4.10. Embryo Death and Mortality of Squabs

Embryo death after hatching is a matter of serious concern in the reproductive biology of feral, fancy and meat-breeds of pigeons (Levi, 1954; Darwathi et al., 2010; Mariey, 2013). This problem was also observed in other birds including myna and house Sparrow (Dhanda and Dhindsa, 1998). In pigeons, early mortality of squabs is relatively higher than the mortality after flight stage (Meleg, 1997). Feed supplements that promote the growth and reproductive attributes of pigeons have enhanced the survivability of squabs (Mariey, 2013). Dietetic study conducted by Mariey (2013) further concluded that death of young squabs before 28 days of age was not seriously altered while giving yeast supplements, but it was significantly reduced in the squabs of fledging stage. Squab mortality was measured to be as high as 5-15% in before fledging stage (Asaduzzaman et al., 2009; Kazal Krishna Ghosh et al., 2013).

2.4.11. Fecundity

Reproductive potential of individuals, also called fecundity, is very important in the population growth point of view because it determines the rate at which new
individuals come to bearing stage for the production of more and more young ones (Odum, 1971). It is reported that about 40 -47.3% of pigeon squabs grow into adults successfully to attain reproductive stage (Miller, 1972; Marchesan, 2002; Hetmanski and Barkowska, 2007; Asaduzzaman et al., 2009). It was estimated in the natural population of feral pigeons but not in any of the fancy pigeons grown in lofts.

2.5. Nutritional Supplements

In recent years, many organic products of plant and animal origin and harmless bacterial cultures have been used as supplements to the basic diet of poultry and other veterinary animals as they promote their growth and reproductive capabilities. Probiotics, herbal extracts and extract of some marine algae are of great importance as the dietary supplements to poultry and others. For instance, the Livaurfort, which is a tonic to stimulate the liver of poultry, manufactured by AURINKO (Haryana, India), contains the extract of Andrographis paniculata while Probizyme manufactured by the same company for promoting the health of poultry contains Lactobacillus acidophilus (www.aurinkohealthcare.com). But, there has been no report on the use of Lactobacillus acidophilus, Andrographis paniculata and Sargassum wightii as dietary supplement to pigeons.

2.5.1. The Probiotic Lactobacillus acidophilus

A probiotic is said to be a fully characterised strain of bacteria or yeast (Azas-Braesco et al., 2010), that may confer some beneficial properties such as improvement of gastrointestinal microbial environment by adherence to intestinal mucosa, prevention of the attachment of pathogens in intestinal wall, stimulation of the intestinal immune responses, colonization and competition with pathogens for
nutrients in the gut, production of antimicrobial compounds such as bacteriocins and organic acids, improvement of the digestion, and absorption of nutrients (Gupta and Garg, 2009). There are about 50 species of probiotic organisms, of which 42 species, as they are not harmful to humans and fulfill the basic standards required for medicinal use, have been recommended for medicinal use in birds, animals and man (Andersson et al., 2001; Gaggia et al., 2010). Bacillus cereus, B. licheniformis, B. subtilis, Enterococcus faecium, Lactobacillus acidophilus, L. casei, L. farciminis, L. plantarum, L. rhamnosus, Pediococcus acidilactici, Streptococcus infantarius, Lactococcus, Streptococcus, Enterococcus, Pediococcus, Bifidobacterium, Bacteroides, Pseudomonas, Aspergillus, Trichoderma, Saccharomyces cerevisiae and Kluyveromyces (Anadon et al., 2006) have been used as probiotics in Japan since 1960s (Gaggia et al., 2010). Although all the strains of probiotics have a general tendency to protect the animals, even various strains of the same species differ from one another in their metabolic activities and immune modulating efficiency, for that reason some probiotic strains are preferred to use in combinations (Montes and Pugh, 1993). Extensive research works in the field of probiotics on the health of aquaculture fishes, birds, animals and man have been done and reviewed by Kos and Wittner (1982), Hinton and Mead (1991), Kalbane et al. (1992), Montes and Pugh (1993), Havenaar and Spanhaak (1994), Fuller (1986, 1989, 1995), Salminen and Isolauri (1996), Majarmaa and Isolauri (1997), Jin et al. (1997), Balish and Wagner (1998), Andersson et al. (2001), Simon et al. (2001), Weese (2002), Borriello (2003), Gill (2003), Patterson and Burkholder (2003), ), Schocken-Iturrino et al. (2004), Hong et al. (2005), Faria-Filho et al. (2006), Timmerman et al. (2006), Waldenstedt et al. (2006), Haghighi et al. (2006), Delgado et al. (2007), de Vrese and Schrezenmeir
(2008), Sahin et al. (2008), Kabir et al. (2004, 2009), Ng et al. (2009), Gaggia et al. (2010), Mountzouris et al. (2010), Mills et al. (2011), Castilho et al. (2012), Matur and Eraslan (2012), and Alexandre et al. (2014). It is worth to note here that for the first time probiotic culture was used in poultry by Nurmi and Rantala (1973) who had tested its efficacy in checking the pathogenic bacteria in the intestine of chicken and subsequently it has been practiced in other domestic fowls and fancy birds.

As Lactobacilli are the components of the normal microflora of the intestine of most animals and birds and as they produce lactic acid that is a component of glucose metabolism in the intestinal cells, they are found to be superior to the other species in current use as the probiotics (Guerra et al., 2007). At present four strains of lactobacilli - *Lactobacillus plantarum*, *L. casei*, *L. acidophilus* and *L. bulgaricus* - are in common use as probiotics for different animal species (Marie-Agnès Travers et al., 2011). Lactobacilli strains have widely been used as a potential probiotic to tone up the immune response and growth attributes in fishes (Chelladurai et al., 1912), shrimps (Moriarity, 1999), humans (Szajewska et al., 2001), mouse (Alak et al., 1997), chicken (Dalloul et al., 2003), and cattle (Casas and Dobrogosz, 2000), for that reason they have been included in several formulations being recommended as tonics for domesticated birds, veterinary animals and man. For example, Vitabiotic, which is manufactured by the Vital Therapeutics and Formulations Pvt (Ltd), Hyderabad, for promoting the performance of poultry contains *L. acidophilus*, *L. plantarum*, *L. casei* and *L. bulgaricus* along with some other bacteria (www.vitalpharma.in).
While analyzing the changes in the gut microflora of birds, it is confirmed that *Lactobacillus* inhibits the growth of pathogenic bacteria by creating a iron deficiency in the intestine due to the binding of a large amount of ferric hydroxide ions on its surface (Elli *et al.*, 2000) or by secreting siderophores that chelate and transport iron (Oelschlaeger, 2010), which enables us to conclude that Lactobacilli in the intestine compete with the pathogenic bacteria for iron, in the deficiency of which the pathogens cannot flourish in the gut. Lactobacilli also secrete small peptides called bacteriocins (lactacin B, lactacin F, nisin, etc.) that normally destroy closely related bacteria by permeating their membranes or by interfering with essential enzymes (Kuhbacher, 2006). Since all Lactobacilli secrete lactic acid in the intestine, the pH of intestinal fluid seems to be suitably modified for the existence and longevity of microbes which prefer acidic pH and prevent the survival of acid-sensitive microbes (Wohlgemuth, 2010).

Dietary supplementation of *L. acidophilus* to germ-free chicken has elevated the levels of total serum protein, albumin, globulin and hemoglobin concentration, while the packed cell volume has not been changed considerably (Pollmann *et al.*, 1980), which is also true with broiler chickens (Abdul-Rahman *et al.* 1994) and Japanese quil (Abd El-Azeem *et al.* 2001). Abdhulrahim *et al.* (1996) have shown that dietary supplementation of *L. acidophilus* to chickens has increased the layer-quality of the chickens and lowered the cholesterol content in plasma and egg yolk. Fuller (1986) has emphasized that Lactobacilli adhere to the wall of intestinal epithelium by means of some host specific weak receptors, so that proper care should be taken to maintain the bacteria in the gut even after their successful colonization. Pulverer *et al* (1990) have demonstrated that some digestive tract microbes have the capability of
producing low molecular weight peptides that have immune triggering potentials. Fuller (1997) makes out a clear point that dietary supplementation of Lactobacilli has maintained the normal microbial balance in the crop of chicken and reduced the incidence of diseases of crops in poultry. Gill (1998) has demonstrated that Lactobacilli cultures have some stimulating effects on the immune system of mammals. In broilers fed with feed containing Lactobacilli, there is a higher level of mucosal immunity (Dalloul, 2003) and the birds become tolerant to environmental stresses that usually affect poultry (De Angelis and Gobbetti, 2004).

Research findings of Farnnel et al. (2006) in chicken reveal that lactobacilli systemically stimulate heterophils for the health of poultry. Tollba and Mahmood (2009) have shown that there is a significant increase in counts of erythrocytes (RBC’s), leukocytic (WBC’s), lymphocytes, eosinophils and basophils, while heterophil count is low when chicken are fed with Lactobacilli at normal temperature (23ºC). Lillehoj and Chung (1992) had reported elevated lymphocytes count in the intestinal propria of chicken fed with Lactobacilli, which implies that Lactobacilli colonizing in the intestine attract lymphocytes to the lamina propria by secreting some peptides.

To modulate the mucosal immunity of host, the Lactobacilli in the gut interact with the epithelial cells, Peyer’s patches, M cells, and immune cells (Marie-Agnès Travers et al., 2011). Because of these interactions, the immune system is stimulated to produce elevated number of immune cells that produce IgA which is particularly significant in contributing to the barrier against pathogenic organisms (Pulverer et al., 1990; Perdigon et al., 1995; Geber et al., 1999; Szajewska et al., 2001). It is worth
noticing that some secretory peptides of Lactobacilli stimulate the differentiation of Dendritic cells (DCs) responsible for collection of antigens from gut and their presentation to naive T cells which then undergo differentiation into T-helper (Th1, Th2) or T-regulatory lymphocytes (Marie-Agnès Travers et al., 2011). Although the exact mechanism of induction of DC is not clear so far, Konstantinov et al (2008) have justified that protein A in the S layer of L. acidophilus regulates the maturation of dendritic cells and T cell functions. Lactobacilli induce the Th1, Th2 and T-regulatory cells to release IFN-γ, IL-12, IL10 and IGF-β (Choi et al., 1999), which are the cytokines modulating the immune response in birds.

2.5.2. Andrographis Paniculata

According to the Ayurvedic Meteria Medica, there are about 950 medicinal plants in India to cure various ailments in man, of which many of them have been put in the prevention and treatment of diseases in aquaculture fishes, veterinary animals and birds in the recent years (Mukesh Kumar et al., 2012; Hashemi and Davoodi, 2012). Medicinal properties of these plants vary considerably depending on the active principles, which may be alkaloids, flavonoids, pigments, antioxidants, phenolics, terpenoids, essential oils, glucosides, sterols, saponins, or other secretory substances, contained in the plants and their concentration in different plant parts (Ambusta, 1986). Because of the presence of the above said active principles, plants have definite medicinal properties with which diseases can be cured by modulating the immune response and the growth and reproductive capabilities of animals can be enhanced for the benefit of mankind (Devasagayam and Sainis, 2002). The possible uses of medicinal plants in the treatment of diseases, in promoting the growth and reproductive capabilities, and in the immunostimulation of fishes and poultry have

*Andrographis paniculata* – also known as Kalmegh in Ayurveda – has anti-inflammatory (Shen et al., 2002), antipyretic (Madav et al., 1995; Vedavathi and Rao, 1991), antiviral (Chen et al., 1993) and immunostimulatory (Puri et al., 1993) properties and hence it has been used in Siddha, Ayurveda and Homoeopathic systems to treat many ailments. Phytochemicals in different parts of this plant have been reviewed by Gorter (1911), Almain and Connolly (1973), Kulyal et al (2010), Chao and Lin (2010), Ghoseh Kumar Benoy (2012) and Shrinisha and Masten (2013). This plant contains andrographolide, which acts as anticancer and hepatoprotective agent (Mohamed Saleem, 2010), 14-deoxy andrographolide which enhances the proliferation of lymphocytes and production of IL-2 (Kumar et al., 2011), 14-deoxy -11, 12-dehydro andrographolide, which has anticancer property (Kumar et al., 2011), 14-deoxy -11oxoandrographolide which has anti-parasitic property (Lala et al., 2003), Neoandrographolide which has anti-inflammatory property (Liu et al., 2007), andrographide which cures hepatitis and Kalmeghin which cures cold and fever (Koul and Kapil, 1994), and andrographiside which is an antioxidant (Balachandran and Govindarajan, 2005). Researches substantiate that active principles of *A. paniculata* can induce both non-specific and specific immune responses in many animals including fishes, birds and man. Puri et al. (1993) have demonstrated that there was enhanced immune response in birds which were fed with normal diet along with
A. paniculata (1 mg / kg for 7 days), and that there was a significant increase in the macrophage activity in the blood, which was the indication of immune modulation, and rise in the low molecular weight proteins taking part in the activation of the immune system by targeting the macrophages and DCs. However, the mechanism of immune modulation is still not known for many immune modulating proteins (Puri et al., 1993), so that non-specific actions of acute phase proteins, which take part in immune modulation, as a whole give the immune modulation as the output. It is strongly believed that phytochemicals stimulate the expression of many high molecular weight proteins, which are potential PAMPs, to stimulate both the GALT and spleen to show their immune response (Jurg Gertscha et al., 2010).

Ethanolic extract of the leaves of this plant produces delayed type hypersensitivity response Sunil Kumar et al. (2011) while its 14-deoxy andrographolide enhances the proliferation of lymphocytes and production of IL-2 (Kumar et al., 2011), which take part in the immune response. Being an antioxidant andrographolide inhibits the production of neutrophils, TNF-α and IL-2 and inhibits the macrophage migration (Dhiman Anju et al., 2012). When macrophages were incubated with methanol extract containing andrographolide and neoandrographolide, there was an inhibition of LPS-stimulated NO production irrespective of their concentration in the culture (Batkhuu et al., 2002; Chiou et al., 1998). Neoandrographolide is also effective ex vivo in suppressing NO production when macrophages are collected after oral administration of neoandrographolide and subjected to LPS stimulation (Shen et al., 2002). Andrographolide inhibits the LPS-induced increase in tumor necrosis factor-alpha (TNF-α) and GMCSF (Abu-Ghefreh et al. 2009). Sheeja and Kuttan (2008) reported elevated levels of WBC count in mice
which were fed with normal feed supplemented with aqueous extract of *A. paniculata*. Deng *et al.* (1982) and Pandey *et al.* (2012) have demonstrated higher rate of phagocytosis in fishes which were fed with diet containing the residues of *A. paniculata*. Oyewo and Akanji (2011) have demonstrated that aqueous extract of this plant increases the RBC count, WBC count, haemoglobin content, neutrophils, lymphocytes, basophils, monocytes, IL-6 and TNF-α in rats. Puri *et al.* (1993) have shown that extract of this plant increases antibody production and produces delayed type hypersensitivity response in mice; they also proved that it induces proliferation of lymphocytes in the spleen depending on or independent of antigen stimulation. However, in chicken fed with normal diet and *A. paniculata*, there has been a significant increase in the weight gain of birds, although this plant provides some basic immune modulation, but the weight gain is lesser than that in birds fed with Lactobacilli as probiotics (Mathivannan *et al.*, 2006). Immune modulating effects of *A. paniculata* on pigeon have hardly been worked out so far.

### 2.5.3. *Sargassum wightii*

The brown seaweed *Sargassum wightii* is found to be widely distributed on the southern coasts of Tamilnadu and many parts of Asia, and used as animal feed, food ingredients and fertilizer because of the presence of various dietary components, minerals and phytochemicals. *S. wightii* contains a good amount of flavonoids and many other bioactive compounds useful for various medicinal and industrial applications (Meenakshi *et al.*, 2009; Antonisamy *et al.*, 2012). It has been experimentally proved that alcoholic extract of this plant has antiviral, anti-fungal, antioxidant, anti-inflammatory, anti-allergenic, anti-thrombic, anti-carcinogenic, hepatoprotective and cytotoxic activities (Jiang *et al.*, 2008; Jeyaraman Amutha *et al.*, 2006).
2013). These medicinal properties are due to the presence of long-chain fatty acids (Visakh Prabhakar et al., 2011), polyphenols (Chandini et al., 2008; Ganesan et al., 2008), saponins (Rajasulochana et al., 2009), alkaloids, sterols (Sanchez-Machado et al., 2004; Rajasulochana et al., 2009), flavonoids, fucoidan (Yang et al., 1995).

Gas chromatographic studies have revealed that S. wightii has fatty acids like Caproic acid, Caprylic acid, Capric acid, Lauric acid, Tridecylic acid, Myristic acid, Pentadecyclic acid, Palmitic acid, Margaric acid, Stearic acid, Oleic acid, Linoleic acid, $\gamma$-Linolenic acid, $\alpha$-Linolenic acid, Arachidonic acid, dioxo-$\gamma$-linolenic acid, Arachidonic acid, Heneicosylic acid, Eicosapentaenoic acid, Behenic acid, Docosahexaenoic acid and Lignoceric acid (Visakh Prabhakar et al., 2011), of which Myristic acid, Palmitic acid, Oleic acid, Linoleic acid, $\alpha$-Linolenic acid, Arachidonic acid and Eicosapentaenoic acid are found in larger proportions. These fatty acids, especially PUFAs, decrease the levels of the expression of cytokines, by changing the activity of nuclear factor kappa B (NFκB), so that lymphocytes response is shifted from cells mediated response to antibody-mediated response (Klasing and Leshchinsky, 1999). Dietary application of PUFA in the n-3 series can mitigate the growth depression due to inflammatory responses in birds, and can dampen the cell-mediated responses but enhance antibody production (Sijben et al., 2001).

*Sargassum* powder had Na (690 $\mu$g/g), K (182$\mu$g/g), P (45mg/g), Ca (80$\mu$g/ g), Mg (5892$\mu$g/ g), Mn (21.3$\mu$g/ g), Zn (73.4 $\mu$g/ g), Cu (39.5 $\mu$g/ g), Fe (256$\mu$g/ g), Al (182$\mu$g/ g), Co (1.2 $\mu$g/ g), methionine (280mg/g), cystine (260mg/g) and lysine (367 mg/g), so that it would also enrich the diet with all these minerals and enabled the diet to have adequate quantity of manganese and zinc. Essential amino acids present in the
seaweed make it a highly valuable protein in the food (Orr and Watt, 1968; Kanazawa et al., 1979; Bell et al., 1986; Qasim 1991; Vinoj Kumar and Kaladharan, 2007). Sargassum powder contains aspartic acid (1.80%), glutamic acid (1.15%), serine (0.54%), glycine (0.45%), histidine (0.45%), arginine (0.60%), threonine (0.71%), alanine (0.44%), proline (0.38%), tyrosine (0.49%), valine (0.50%), methionine (0.37%), cystine (0.25%), isoleucine (0.55%), leucine (0.55%), phenylealanine (0.63%), tryptophan (0.21%) and lysine (0.50%) (Vinoj Kumar and Kaladharan, 2007), of which methionine, cystine and lysine are the essential amino acids for pigeons (Vogel et al., 1994).

Sargassum wightii contains 15-39% alginic acid (Sobha et al., 2009) which has enhanced the immune response of Penaeus monodon (fish) by inducing the lysozyme activity and heteropils production (Immanuel et al., 2011). The alginic acid in S. wightii is a linear polymer that consists of monomeric units of β- D mannuronic acid and α- L- guluronic acid Uma maheswara Rao (1969), of which the former has strong immune modulating activity. Xia et al. (2005) have extended the use of polymannuroguluronate, which is formed of β- D mannuronic acid and α- L- guluronic acid, as an anti- AIDS drug because of its potentials in the direct activation of T-cell proliferation and the concomitant modulation of cytokines, especially the enhancement of IL-2 and interferon-γ and inhibition of TNF-α release (Alejandro et al., 2009). Besides this, D-mannuronic acid stimulates the activities of peritoneal macrophages (Sone et al., 2001), reduces tumour development in pig (Michio Fujihara et al (1992) and stimulates the haematopoiesis in pig (Halaas et al., 1997).
Saponins present in the brown algae can stimulate the cell-mediated immunity by means of enhanced phagocytosis as well as the humoral immunity by antibody production (Oda et al., 2000). It has been suggested that saponins induce the production of cytokines like interleukins and interferon which are chief regulatory molecules in immune response (Ramsay et al. 1974) of the mucosal immune system (Recchia et al., 1995). Immunomodulatory effect of saponins is concerned with its branched sugar chains or aldehyde groups (Bomford et al., 1992) and acyl residue bearing aglyone (Kensil, 1996). In addition to its immunostimulatory effect, saponins can switch off the inflammatory reactions (Xu et al., 2000) and monocyte proliferation (Delmas et al., 2000).

Dietary supplementation of S. wightii has immune enhancing effect by reducing oxidants in the blood and by enhancing the cell counts and phagocytic activity in Penaeus monodon; Immanuel et al (2011) have concluded that this immune modulation is due to the presence of fucoidan that can induce the expression of Phagocytosis Activating Protein (PAP) gene in Shrimp (Dechamag et al., 2006). Oral intake of the fucoidan may take the protective effects through direct inhibition of viral replication and stimulation of both innate and adaptive immune defense functions through the activation of lymphocytes and macrophages (Hayashi et al., 2008). The immunomodulatory effect of fucoidan has been proved in mice, (Yung-Choon Yoo et al., 2007) and Tiger shrimp (Felix et al., 2004&.2005). In poultry, dietary supplementation of S. wightii has increased the feed conversion rate and weight gain but lowered the blood cholesterol levels (El-Deek et al., 2011).
Although immunomodulatory effect of *S. wightii* has been demonstrated in chicken, fishes, rat, mice and pig, its immune stimulating effect on pigeon has not been investigated so far. Hence, it is included in this research work.