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Correlation of innate immunocompetence traits with economic traits in various indigenous and exotic breeds of chicken

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ABSTRACT

Birds (433) were utilized for investigation at 7 weeks of age and at 45 weeks of age (119). The immunological traits measured included humoral response like HA, MER and MES; non-specific immune responses like CPW and APW complement and PI and CMI response. In two broiler lines, body weight at 6, 7, 8, 9 and 10 weeks of age were measured in addition to body weight at hatch and feed efficiency to 10 weeks of age. In rest of the genetic groups, the economic traits measured included day old body weight, body weight, shank length and keel length at 5, 10, 15 and 20 weeks of age, age at sexual maturity, egg production as number of eggs to 40 weeks of age, egg weight at 40 weeks of age, per cent mortality during different periods up to 20 weeks of age, feed consumption per day, and feed conversion ratio to produce a dozen of eggs or a kg of egg mass. All the traits were measured on individual birds except for per cent mortality and feed efficiency in broilers. For evaluation of humoral and non-specific responses except PI, the birds were immunized with sheep red blood cells (SRBCS) by injecting 1 ml of 25% (v/v) SRBCs suspension in PBS intramuscularly in thigh muscle. The various components of immunocompetence parameters like humoral and nonspecific responses were measured on day 5, 12 and 19-post immunization. Natural antibodies for various immunocompetence traits were also measured on the day of SRBC injection. For evaluation of effect of age, birds of the Aseel, Kadakanath, Naked Neck and Frizzle were immunized against SRBCs at 45 weeks of age and immunocompetence traits were measured on day 0 and 7 p.i. CMI response was estimated by injecting 0.1 ml of PHA-P interdigitally (100 μg PHA-P/0.1 ml of PBS) between the 3rd and 4th toe of the right foot of each chicken as Foot index (FI) and was estimated by measuring the skin swelling.

Data so collected were analyzed statistically utilizing appropriate statistical procedures to evaluate correlation coefficients among immunological and economic traits calculated as simple product moment correlation.

HA was positively correlated with MER, CPW and APW and negatively correlated with FI and PI. The trend remained the same on all the days of study. The correlation of MER with CPW and APW were mostly positive and did not present any definite trend in both magnitude and direction with FI and PI. The correlations between CPW and APW were positive and highly significant. No definite trend was observed for the correlation between CPW with FI and PI. The trend remained the same for APW also. FI and PI were negatively correlated in indigenous breeds and broilers but positively correlated in Dahlem Red and White Leghorns. Irrespective of direction, all the estimates were small. HA was seen to be positively correlated with body weight, shank length, keel length, ASM and negatively correlated with egg production and mortality. MER was positively correlated with body weight, shank length, keel length and ASM and negatively correlated with egg production and mortality. The relationship of FI and PI with body weight, shank length, and keel length was negative. Relation between FI and egg production was negative. The relationship of immunocompetence traits with economic traits presented in the literature as well as realized in this study did not lead to any definite conclusion suggesting more study to quantify the magnitude and direction of relationship for their use in practical breeding programmes.

Key words: ASM, Body weight, Correlation, Egg weight, Immunocompetence traits, Mortality, Production traits

Variation in disease resistance capability which is determined genetically between different strains of birds may be valuable in genetic selection programme (Miller and Cook 1992). The effectiveness of immune system can be determined by quantifying the response of antibody to natural antigen like Sheep Red Blood Cells (SRBCs) or like antigens. Immunocompetence traits are under genetic control and hence are influenced by selection. Genetic control of antibody response is polygenic (Lamont and Dietert 1990). The major parts or systems of the immunological defense are independent genetic control (Biozzi *et al.* 1980). The feasibility of improving genetic resistance to specific diseases and breading for general disease resistance in poultry was reported (Gavora 1990, Bumstead *et al.* 1991). The importance of complement and

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complement receptors for the initiation of the antibody response, the development of immunological memory is well-established (Kinoshita 1991) and genetic influences are possible at several stages in the process. As such, all the domesticated poultry species have been selected exclusively either for high juvenile growth rate or high egg production. Knowledge of genetic relationship of disease resistance with economically important traits, therefore, is very essential for practical breeding. However, to assess such relationship is difficult because when an individual suffers from disease, performance is automatically affected. Under such circumstances, it is impossible to determine whether the bird performed less because the disease affected it or it has lower genetic potential for the growth/production traits measured. In order to overcome this difficulty, there is a necessity to devise ways and means to estimate genetic relationship of healthy birds with those parameters, which provide information about diseases or general disease resistance. Innate immunocompetence traits have been used for this purpose. Relationship with production traits have been reported by many authors (Jayalaxmi *et al.* 2010, Kean *et al.* 1994, Siegel and Gross 1980). Kean *et al.* (1994) reported small and negative phenotypic correlations between production and immunocompetence traits. Siegel and Gross (1980) reported significantly heavier 4 week body weights in low line selected for antibody response to SRBC than the control or high line.

Indian native breeds of chickens are considered to have better general disease resistance for many tropical diseases than imported breeds because they have evolved through natural selection over a long period in the prevailing tropical environment. Breed variations of humoral antibodies in different breeds of native Indian chickens and imported chickens had been reported (Kundu *et al.* 1996, 1997, 1999a, 1999b, 2015a, b, c; De *et al.* 2013). However, the relationship between immunocompetence and economic traits are very scarce and a few available reports are contradictory. Therefore, the present study was conducted to estimate the relationships between immunocompetence traits and economic traits in indigenous and exotic breeds of chickens.

MATERIALS AND METHODS

The indigenous and exotic breeds of chicken viz. Aseel, Kadakanath, Naked Neck (NN), Frizzle, Dahlem Red, White Leghorn, Synthetic broiler dam line, Naked Neck broiler line were maintained at the experimental poultry farm of CARI and constituted the base material for this experiment. All the indigenous stocks have been maintained without any deliberate selection but the white Leghorn and broiler populations have a history of long term selection for part year egg production and 6- week body weight, respectively. Chicks from all these genetic groups were taken from the hatcher on day 22 of incubation; wing banded and brooded under hover type brooders following standard brooding management practices. They were shifted to grower house at 8 weeks of age and to layer cages at 20 weeks of age. Management and feeding regimens were kept identical as far as possible for all the genetic groups under study. They were given a standard ration up to 8 weeks of age, a grower ration from 9 to 20 weeks of age and a layer ration thereafter. All the experimental birds were healthy, apparently free from parasitic infestations and received normal routine health care. The vaccination schedule included Marek's disease (MD), infections Bursal disease (IBD), New Castle Disease (ND), Fowl pox (FP). The MD vaccine was given at 1-day old, IBD at days 14 and 35 by oculo-nasal route (O/N), ND vaccination was with RDF strain at days 5 and 28 by O/N followed by the RD R2B I/M at day 56 and FP at day 42 by the wing web route.

Other livestock used: Four healthy sheep, which were procured from IVRI, were maintained at CARI, Izatnagar till the completion of the study.

General plan of experiment: The innate immunocompetence traits of various indigenous and exotic breeds of chicken were measured against SRBC immunization at 7 weeks of age. Chickens (433) of both sexes and 8 lines comprising and native breeds Aseel (44), Kadakanath (69), Naked Neck (53), and Frizzle (49), Dahlem Red (49), White Leghorn (80), Synthetic dam line (SDL) broiler (43) and Naked Neck (NN) broiler (46) were chosen to be tested for general immune competence response against SRBC immunization at the age of 7 weeks.

Antibody response to sheep red blood cells (*SRBC*): The total antibody response to SRBC was measured on days 0, 5, 12, 19 post immunization using microtitre Haemagglutinin antibody titre (HA) test. The mercapto-ethanol (ME) test (Martin *et al.* 1989, 1990) was used to measure ME resistant (MER) antibody titre or IgG. The ME sensitive (MES) antibody titre was calculated as difference in total HA titre and MER titre. The response in respective titres were the results of difference between the antibody titres (total HA- MER=MES) before and after SRBC immunization. The SRBC immunization dose used was 1 ml of 25% (v/v) SRBC suspension in phosphate buffer saline (PBS) intramuscularly in thigh muscles.

The complement response was measured by the technique described by Demey *et al.* (1993) at days 0, 5, 12 and 19 post immunization of SRBCs in each chicken by calcium dependent pathway or classical pathway (CPW) and calcium independent pathway or alternate pathway (APW). The values were expressed as CH50 (U/ml) using semi-automatic complement assay for chicken sera using a light scattering method.

Cell mediated immune response (*CMI*) *to PHA-P:* The *in-vivo* cell mediated immune response to PHA-P was evaluated per Cheng and Lamont (1988). Phytohemagglutinine type P was used in its mucopolysaccharide form from the red kidney bean, phaseolus vulgaris. PHA-P provokes responses, influenced by subpopulation of T-helper and T-suppressor cells. Good responder to PHA-P means a higher general level of cellular immunity influencing T-cell mechanisms restricting or preventing lymphoma formation. PHA-P (0.1 ml/ml PBS) wass injected inter-digitally between the 3rd and 4th toe of the right foot of the chicken. The left foot served as control and was injected with 0.1 ml PBS. The skin index (foot index was calculated as the difference between the swelling (measured by a cutimetre type Harpenden skin fold caliper) in the right minus left foot), before and 24 hours after injection and expressed as millimeter.

Phagocytic index: Carbon clearance assay, as described by Cheng and Lamont (1988) was used to measure phagocytic activity at the age of 10–11 weeks using intravenous injection of colloidal carbon.

Economic traits

Body weight: Body weight was measured to the nearest of 5 gm of accuracy. The body weights were taken at the time of hatch uniformly in the entire stocks under study. Thereafter body weights were taken 6, 7, 8, 9 and 10 weeks of age in the broiler stocks and at 5, 10, 15 and 20 weeks of age in rest of the stocks.

Conformation traits: Conformation traits like shank length and keel length were measured in the indigenous and White Leghorn breeds only at 5, 10, 15 and 20 weeks of age. A Vernier Calliper was used to measure both the traits. The distance between the hock joint and tarsal metatarsal joint was taken as the shank length. The length of the keel bone was used as keel length. Length of both these parameters was expressed in centimeters.

Egg production: Egg production, as number of eggs, up to 40 weeks was collected for each pullet of the four indigenous breeds viz. Aseel, Kadakanath, Naked Neck and Frizzle as well as in Dahlem Red and White Leghorn.

Age at first egg: Age at first egg was measured in days. The difference in days between the date of hatch and date of laying the first egg was taken as the age at 1st egg. Age at first egg was measured on each individual pullet.

Egg weight: Egg weight was measured to the nearest 1 gm accuracy. Average of the three eggs laid during 40th week of age was taken as the egg weight. Like egg production and age at 1st egg, egg weight was also measured on each individual pullet.

Feed conversion ratio: Food consumption in grams for various genetic groups of indigenous Dahlem Red and White Leghorn was measured from 20–40 week of age on individual birds for every 4 weeks interval.

Feed consumed for producing a dozen and kilo of eggs was calculated using the formula as given below:

Kg feed/Doz. Eggs = Total feed consumed (in kg)/ Dozen of eggs produced × 12

Kg feed/Kg egg mass = Total feed consumed/kg of egg produced

Feed consumed for the two broiler lines was measured at 6, 7, 8, 9 and 10th week of age on group basis. Feed conversion ratio in broilers was calculated at 10 weeks of age using the following formula:

FCR = Average feed consumed (in kg)/ Average gain in body weight (in kg)

Mortality: Mortality was recorded from 0–20 weeks of age on Aseel (143), Kadakanath (251), Naked Neck (116), Frizzle (59), Dahlem Red (178), White Leghorn (87), SDL broiler (50) and Naked Neck Broiler (50) chickens for the whole hatch from where samples of birds were randomly chosen for immunocompetence study.

Statistical analysis

The correlation coefficient among immunological and economic traits was calculated as simple product moment correlation for each genetic group separately as described by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Phenotypic correlation of immunocompetence traits with growth and conformation traits were estimated as simple product moments correlations for each genetic group separately at 7 weeks of age for Dahlem Red, WLH (Tables 1, 2) and for indigenous chickens (Pooled) and broilers (pooled) (Tables 3, 4). Results revealed no consistent trends either in direction or in magnitude. Most of the estimates were small and statistically non-significant.

Correlation among immunocompetence traits (measured at 7 week old birds) like HA, MER, CPW, APW, FI and PI were initially calculated for each genetic group of layers and broilers separately and for Dahlem Red, White Leghorn, indigenous chickens (pooled) and broilers (pooled).The results are presented in Table 5 to 8 respectively.

HA was seen to be positively correlated with MER, CPW and APW and this remained consistent at day 0 as well as day 5, 12, 19 p.i. The estimates ranged from 0.14 to 0.23 except one, which was high. Some of these estimates were found to statistically significant. HA, however, was seen to be negatively correlated with FI and PI. The estimates pooled over indigenous chickens were –0.04 between HA and FI and –0.06 between HA and PI. Trend almost remained the same for the broilers as far as correlations of HA with MER, CPW and APW is concerned. However, most of the estimates appeared to be on the higher side than recorded for indigenous chickens. White Leghorn and Dahlem Red also presented the same trend but with high degree of association than observed for indigenous chickens. The correlation of HA with FI was negative and small for Dahlem Red and White Leghorn as observed for indigenous chickens but small and positive for broilers. Correlation of HA and PI was positive in White Leghorn and negative for broilers with no definite trend for Dahlem Red. All these estimates were however small irrespective of direction and statistically nonsignificant.

MER was seen to be positively correlated with CPW and APW at day 0, 12 and 19 p.i. and negatively correlated at day 5 p.i. in indigenous chickens. The estimate of correlations varied from moderate to high and was statistically significant. The estimates between HA and APW were also moderate in magnitude and statistically significant although negative in direction. Dahlem Red and White Leghorn revealed the same trend of association of MER with CPW and APW but the estimates were somewhat

Table 1. Correlation coefficients of immunocompetence traits with growth and conformation traits in Dahlem Red (7 weeks old)

Immuno competence trait	dpi	Body weight (Weeks) 0	5	10	15	20	B.wt.gain Weeks 0-20	Body conformation 5 SL	5 KL	10 SL	10 KL	15 SL	15 KL	20 SL	20 KL	Gain 5-20 SL	Gain 5-20 KL
HA	5	0.14	-0.12	-0.11	-0.14	-0.39**	-0.39**	-0.14	-0.12	-0.21	-0.09	0.13	0.02	0.07	0.03	-0.34*	-0.31*
	12	0.21	0.02	0.04	-0.30*	-0.27		-0.12	-0.10	-0.31*	0.09	0.11	-0.15	0.08	-0.06		
	19	0.27	-0.17	0.12	-0.25	-0.27		-0.08	0.01	-0.05	0.28	0.07	-0.17	0.07	0.12		
MER	5	0.11	-0.16	-0.10	-0.14	-0.41**	-0.41**	-0.15	-0.13	-0.20	-0.03	0.18	-0.05	0.04	0.15	-0.34*	-0.28
	12	0.27	-0.11	0.17	-0.16	-0.20		-0.09	-0.13	-0.31*	0.20	0.14	-0.15	0.08	-0.18		
	19	0.25	-0.09	0.23	-0.11	-0.15		0.01	-0.10	0.10	0.21	0.00	-0.22	0.02	0.00		
CPW	0	0.00	-0.07	0.20	0.09	0.07		0.09	0.10	-0.23	-0.22	0.03	0.32*	-0.01	-0.12		
	5	0.01	-0.09	0.13	0.07	0.01	0.01	0.22	-0.01	-0.21	-0.13	0.20	0.25	0.20	0.10	-0.08	0.01
	12	0.19	-0.14	0.15	0.18	0.21		0.15	0.14	-0.29*	-0.13	0.10	0.29*	0.40	-0.07		
	19	-0.11	-0.10	0.27	-0.16	0.17		0.18	0.11	-0.20	-0.15	0.04	0.34*	-0.07	-0.14		
APW	0	-0.09	-0.01	0.13	-0.05	0.04		0.11	0.06	-0.16	-0.11	0.17	0.21	0.14	0.00		
	5	-0.14	0.11	-0.03	-0.20	-0.14	-0.14	0.20	0.15	-0.16	-0.05	0.19	0.15	0.23	0.04	-0.20	-0.16
	12	-0.13	0.06	0.08	0.00	0.10		0.11	0.07	-0.17	-0.10	0.18	0.24	0.10	-0.06		
	19	-0.11	-0.04	0.13	-0.05	0.08		0.14	0.02	-0.16	-0.13	0.15	0.25	0.07	0.02		
FI		0.08	-0.06	0.06	0.08	0.02	0.02	-0.02	0.07	0.04	0.08	0.13	0.13	-0.05	0.10	0.12	0.11
PI		-0.22	-0.05	-0.17	-0.15	-0.14	-0.13	-0.16	0.00	0.01	-0.04	0.06	-0.10	0.11	0.10	0.03	-0.01

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

Table 2. Correlation coefficients of immunocompetence traits with growth and conformation traits in White Leghorn (7 weeks old)

Immuno competence trait	dpi	Body weight (Weeks) 0	5	10	15	20	B.wt.gain Weeks 0-20	Body conformation 5 SL	5 KL	10 SL	10 KL	15 SL	15 KL	20 SL	20 KL	Gain 5-20 SL	Gain 5-20 KL
HA	5	-0.04	-0.20	-0.05	-0.18	-0.18	0.10	-0.10	0.07	-0.04	-0.03	0.07	-0.04	-0.05	-0.14	0.18	0.04
	12	-0.09	-0.13	0.04	-0.19	-0.23		-0.05	0.04	-0.07	-0.24*	0.01	-0.05-0.05	-0.10	-0.09		
	19	-0.01	0.05	-0.05	0.07	-0.04		-0.11	0.14	0.05	-0.13	-0.01	-0.10	-0.09	-0.17		
MER	5	-0.07	-0.14	-0.08	-0.12	-0.08	0.14	-0.04	-0.04	-0.04	-0.14	0.09	0.04	0.08	-0.07	0.13	0.06
	12	0.00	-0.16	-0.05	-0.07	-0.04		-0.07	0.00	0.15	-0.14	-0.05	-0.16	-0.13	-0.20		
	19	0.07	-0.14	-0.01	-0.02	-0.01		-0.09	0.17	-0.03	-0.18	-0.06	-0.11	-0.00	-0.04		
CPW	0	-0.05	-0.12	-0.01	-0.13	0.03		-0.04	0.03	-0.04	0.01	0.08	-0.11	-0.01	-0.16		
	5	-0.06	-0.04	0.03	-0.09	0.02	0.23*	0.13	-0.09	-0.06	0.02	0.13	-0.10	-0.09	-0.05	0.13	0.11
	12	0.01	-0.04	0.06	-0.11	-0.01		0.10	-0.05	-0.14	0.05	0.12	-0.08	-0.10	-0.11		
	15	-0.02	-0.11	-0.02	-0.11	0.03		-0.01	0.00	-0.09	0.04	0.15	-0.09	-0.03	0.13		
APW	0	-0.05	-0.21*	-0.04	-0.11	-0.01		0.04	-0.05	0.14	0.11	0.04	0.01	-0.03	-0.22		
	5	-0.07	-0.10	0.12	-0.09	-0.04	0.24*	0.12	-0.05	-0.02	0.15	0.11	-0.04	-0.07	-0.06	0.18	0.15
	12	-0.08	-0.15	0.03	-0.07	-0.03		0.09	-0.04	0.04	0.22*	0.07	-0.05	-0.11	-0.19		
	19	-0.07	-0.08	0.07	-0.06	-0.05		0.01	-0.04	0.10	0.13	0.05	-0.03	-0.03	-0.20		
FI		0.12	-0.21	0.00	-0.08	0.04	-0.08	0.05	0.07	0.01	0.03	-0.21	-0.01	-0.07	-0.18	-0.19	-0.18
PI		0.02	0.05	-0.07	-0.02	0.09	-0.30**	-0.11	-0.01	0.01	0.14	-0.01	0.10	-0.05	-0.02	-0.22	-0.17

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

higher than indigenous chickens. The association was also positive on day 12 p.i., although it was negative for indigenous chickens. In case of broilers, MER was positively correlated with CPW on day 0, 5 and 12 p.i. and with APW on day 19 p.i.

Correlations of MER with FI and PI were small, statistically non-significant and varied in direction in different genetic groups. The trend remained the same when the data was pooled over the genetic groups studied. The phenotypic correlations between CPW and APW were positive, high and mostly significant. The trend remained the same whether the data were analyzed for each genetic group separately or pooled over the genetic groups. The correlation of CPW with FI and PI did not present any definite trend as they varied in direction in different breeds as well as in the pooled data. All these estimates were very small and statistically non-significant. The relationship of APW and CPW with FI and PI presented the same trend as between CPW with FI and PI.

Pullets of 45 weeks of age of indigenous Aseel, Kadakanath, Naked Neck and Frizzle breeds only were evaluated for general immunocompetence status and the correlation among immunocompetence traits is presented in Table 9.

Anti-SRBC antibody response was seen to be positively correlated with CPW, FI, MER and MES and the trend remained the same in all the four indigenous chicken genotypes under study. In most cases, these correlation coefficients ranged from moderate to high and statistically significant. Phenotypic correlation estimates averaged over all the genetic groups were 0.48 between HA response and CPW, 0.42 between HA response and FI, 0.56 between HA response and MER, and 0.71 between HA response and MES. The phenotypic correlation between HA and complement response did not present a definite trend while the estimates were negative for Aseel and Kadakanath, they were positive for Naked Neck and Frizzle. The estimate of –0.13 pooled over genotype was negative and small.

Phenotypic correlation of complement response with all the immunocompetence traits is presented in Table 9. Correlation estimates of CPW with APW and IgM did not present a definite trend as they varied both in direction and magnitude. The estimates pooled over genotypes were 0.13 between CPW and FI, –0.04 between CPW and APW, and 0.10 between CPW and IgM. None of estimates were found to be statistically significant. The phenotypic correlation of CPW with IgG was positive in all the genetic groups under study. The pooled correlation of 0.34 was found to be statistically significant.

Phenotypic correlation of APW with IgG and IgM are presented in Table 9. The estimates pooled over genotypes were –0.15 between APW and IgG and –0.02 between APW and IgM. None of the estimate was found to be statistically significant.

Phenotypic correlation of FI with APW and IgG are presented in Table 9. The estimates for various genetic groups vary both in magnitude and direction. The pooled correlation estimates of 0.25 between FI and APW and –0.35 between FI and IgG were statistically significant.

The phenotypic correlation between IgG and IgM was uniformly negative in all the four genetic groups under study. The estimate pooled over genotypes was –0.26.

Perusal of results obtained in both groups (at 7 weeks and at 45 weeks of age group) indicated a positive relationship of haemagglutinin antibody with IgG, IgM, CPW and APW. This observation remained consistent in all the breeds and in all days of measurement i.e. on day 0, 5, 12 and 19 p.i. at 7 weeks of age study and day 0 and 7 p.i. in 45 weeks of age study. The estimates of phenotypic correlations were on the higher side for the broilers, followed by Dahlem Red and WLH. The estimates were smaller in magnitude for indigenous breeds. The phenotypic correlation of HA with other component traits like MER, MES and CPW were higher in magnitude at 45 weeks of age.

HA was seen to be negatively correlated with FI and PI but the estimates were small and statistically non-significant in the 7 week old chickens (Tables 1–3). The correlation between HA and F1 was positive at 45 weeks of age (Table 9).

The correlations of MER with CPW and APW were mostly positive and did not present any definite trend both in magnitude and direction with FI and PI.The correlations between CPW and APW were positive and highly significant. No definite trend was observed for the correlation between CPW and FI; and CPW and PI. The trend remained the same for the correlation of APW with FI and PI. FI and PI were negatively correlated in indigenous breeds and broilers and positively correlated in Dahlem Red and White Leghorns. Irrespective of direction, all the estimates were small which corroborated with the findings of Kean *et al.* (1994) and Das *et al.* (2014).

HA was seen to be positively correlated with body weight, shank length, Keel length and ASM and negatively correlated with egg production and mortality. MER was positively correlated with body weight, shank length, keel length and ASM and negatively correlated with egg production and mortality. The relationship of FI and PI was negative with body weight, shank length and keel length. Relationship between FI and egg production was negative.

Significant and positive correlations of HA with other immunocompetence traits like MER, CPW and APW was in agreement with the findings of Saxena (1993).

Lasilla *et al.* (1979) could not detect significant influence of IgG allotype on mitogen response in line selected for mitogenic response. Vanderzijpp and Nieuwland (1986) observed that selection for response to sheep RBC does not affect CMI response, although significant effects were identified for IgG and IgM levels. Cheng and Lamont (1990) stated that most of the phenotypic correlations among traits of the humoral, cellular and phagocytosis were negative and statistically significant. According to him, the correlation among these traits as observed in this study as well as those reported earlier might have been due to the

Table 3. Correlation coefficients of immunocompetence traits with growth and conformation traits in indigenous chickens (pooled) at 7 weeks of age

Immuno competence trait	dpi	Body weights					Body conformation							
		weeks					SL	KL	SL	KL	SL	KL	SL	KL
		0	5	10	15	20	5		10		15		20	
HA	0	0.00	0.12	0.16	0.17	0.14	0.09	0.07	0.10	0.15	0.13	0.19	0.11	0.15
	5	-0.08	0.04	0.14	0.25*	0.26**	-0.07	0.03	-0.02	0.10	0.12	0.22*	0.21*	0.24*
	12	-0.07	0.00	0.14	0.23*	0.33**	-0.04	-0.04	0.10	0.09	0.11	0.15	0.23*	0.23*
	19	0.00	0.08	0.22*	0.31**	0.37**	0.06	-0.03	0.17	0.10	0.16	0.19	0.26**	0.28**
MER	0	-0.06	0.02	0.03	0.07	0.06	0.06	0.00	0.05	0.03	0.05	0.09	0.04	0.04
	5	0.08	0.04	-0.12	-0.20*	0.27**	-0.05	0.08	-0.21*	-0.02	-0.14	-0.13	-0.14	-0.18
	12	-0.15	-0.13	-0.06	0.04	0.10	-0.16	-0.21*	-0.03	-0.09	-0.05	-0.07	-0.01	-0.01
	19	-0.09	-0.03	0.13	0.27**	0.30**	0.00	0.08	0.15	0.05	0.11	0.14	0.13	0.17
CPW	0	-0.10	-0.05	0.02	0.18	0.16	-0.08	-0.03	-0.05	0.03	0.12	0.12	0.08	0.14
	5	-0.09	0.00	0.25**	0.37**	0.40**	-0.08	0.60	0.11	0.17	0.21*	0.27**	0.19	0.31**
	12	-0.16	-0.02	0.24*	0.36**	0.38**	-0.04	-0.04	0.15	0.13	0.23*	0.26**	0.19	0.30**
	19	-0.12	-0.01	0.19	0.33**	0.33**	0.01	-0.02	0.12	0.11	0.20*	0.23*	0.17	0.24*
APW	0	0.00	0.15	0.31**	0.43**	0.39**	0.09	0.09	0.21*	0.21*	0.27**	0.33**	0.25**	0.36**
	5	0.01	0.19	0.40**	0.49**	0.52**	0.14	0.11	0.30**	0.26**	0.31**	0.39**	0.26**	0.37**
	12	0.06	0.22	0.45*	0.54**	0.58**	0.14	0.12	0.31**	0.29**	0.36**	0.44**	0.35**	0.47**
	19	0.04	0.19	0.41**	0.53**	0.53**	0.14	0.08	0.29**	0.25**	0.35**	0.42**	0.32**	0.42**
FI		-012	-0.16	-0.06	-0.05	-0.04	-0.13	-0.12	-0.04	-0.06	-0.10	-0.08	-0.10	-0.07
PI		0.03	-0.01	-0.24*	-0.30**	-0.38**	0.12	-0.04	-0.03	-0.16	-0.11	-0.23*	-0.20*	-0.37**

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

fact that the phagocytic activity starts immediately after invasion of foreign material whereas humoral and cellular response are initiated only when the foreign material remains in the body for some time.

Correlation of economic traits with immunocompetence traits

With body weight: Results revealed (Tables 1–4) positive association of HA titres with body weight at 5, 10, 15 and 20 weeks of age for the indigenous breeds of chickens. Magnitude of relationship increased with age of measurement. For Dahlem Red and White Leghorn, no consistent trend in relationship could be established. In case of broilers, body weight at 6 weeks of age was seen to be negatively correlated with HA titres on day 0, 5 and 12 p.i. and positively correlated on day 19 p.i. HA titre was also seen to be positively correlated with body weight at 7, 8 and 9 weeks of age in broilers but the magnitude of correlation coefficients were small which is in agreement with the findings of Das *et al.* (2014).

MER response on day of immunization was seen to be positively correlated with body weight at all ages of measurement except for indigenous domestic breeds of fowls. However, all these estimates were small and non-significant. No conclusive relationship of MER response on day 5, 12 and 19 p.i. with body weight could be obtained. In case of Dahlem Red and White Leghorn, most of the correlation estimates were small, negative and statistically non-significant.

When data pooled over all indigenous breeds were

Table 4. Correlation coefficient of immunocompetence with body weight in broilers at 7 weeks of age

Immuno competence trait	dpi	Body weight					
		Weeks					
		0	6	7	8	9	10
HA	0	0.02	-0.08	0.02	0.09	0.04	-0.08
	5	0.01	-0.12	-0.01	0.02	0.02	-0.13
	12	0.10	-0.02	0.06	-0.04	-0.15	-0.07
	19	0.02	0.15	0.28**	0.20	0.15	0.03
MER	0	0.07	-0.07	0.05	0.18	0.15	-0.01
	5	0.10	-0.13	-0.19	-0.20	-0.16	-0.17
	12	-0.02	0.01	0.05	-0.13	-0.20	-0.18
	19	-0.01	0.14	0.18	0.15	0.18	0.09
CPW	0	0.11	-0.21*	-0.13	-0.06	-0.07	-0.16
	5	-0.02	-0.47**	-0.40	-0.33**	-0.32**	-0.28**
	12	0.04	-0.34**	-0.22*	-0.21*	-0.21*	-0.27**
	19	0.04	-0.26*	-0.19	-0.14	-0.15	-0.22*
APW	0	-0.02	-0.08	-0.04	-0.04	-0.02	-0.18
	5	0.16	0.10	0.08	0.00	-0.11	-0.05
	12	0.03	-0.19	-0.16	-0.24*	-0.22*	-0.34**
	19	0.00	-0.20	-0.16	-0.17	-0.11	-0.24*
FI		-0.16	-0.07	-0.06	-0.16	-0.24*	-0.06
PI		0.10	-0.08	-0.08	-0.12	-0.11	0.03

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

analyzed, body weight at various ages was seen to be positively correlated with CPW and APW. Magnitude of the estimates increased with age and was significant in most instances. However, no trend was available for different days of test post-immunization. No consistent trend was also observed for Dahlem Red and White Leghorn.

With conformation traits

Shank length and Keel length were positively correlated with CPW and APW. Magnitude of correlation coefficients increased with day of measurement although differences were not appreciable on different days of study post-immunization. The relationship of shank length with FI and

Table 5. Correlation coefficient among immunocompetence traits in Dahlem Red at 7 weeks of age

Immuno-competence trait	dpi	HA			MER			CPW			
		5	12	19	5	12	19	0	5	12	19
	1	2	3	4	5	6	7	8	9	10	11
HA	5	1.00									
	12	0.68**	1.00								
	19	0.45**	0.67**	1.00							
MER	5	0.91**	0.59**	0.50**	1.00						
	12	0.59**	0.86**	0.63**	0.54**	1.00					
	19	0.40**	0.56**	0.77**	0.44**	0.71**	1.00				
CPW	0	0.39**	0.29*	0.12	0.34*	0.24	0.19	1.00			
	5	0.42**	0.17	0.07	0.40**	0.15	0.08	0.70**	1.00		
	12	0.38**	0.26	0.04	0.33*	0.21	0.07	0.70**	0.82**	1.00	
	19	0.40**	0.30*	0.12	0.35*	0.27	0.21	0.96**	0.71**	0.78**	1.00
APW	0	0.14	0.07	0.01	0.15	0.07	0.08	0.78**	0.65**	0.48**	0.70**
	5	0.30*	0.23	0.14	0.24	0.10	0.08	0.70**	0.62**	0.44**	0.61**
	12	0.11	0.07	0.00	0.11	0.16	0.04	0.68**	0.67**	0.61**	0.67**
	19	0.12	0.07	0.00	0.12	0.06	0.05	0.75**	0.66**	0.52**	0.70**
FI		-0.01	-0.20	-0.11	-0.10	-0.05	-.07	-0.01	-0.09	-0.10	-0.02
PI		-0.02	-0.22	0.03	0.13	-0.20	0.00	0.12	0.13	0.05	0.06

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

Table 6. Correlation coefficient among immunocompetence traits in White Leghorn at 7 weeks of age

Immuno-competence trait	dpi	HA			MER			CPW			APW					FI	PI
		5	12	19	5	12	19	0	5	12	19	0	5	12	19		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
HA	5	1.00															
	12	0.71**	1.00														
	19	0.22*	0.51**	1.00													
MER	5	0.66**	0.62**	0.32**	1.00												
	12	0.44**	0.55**	0.49**	0.62**	1.00											
	19	0.12	0.36**	0.63**	0.15	0.22*	1.00										
CPW	0	0.91**	0.60**	0.18	0.65**	0.41**	0.14	1.00									
	5	0.73**	0.55**	0.15	0.52**	0.32**	0.13	0.82**	1.00								
	12	0.69**	0.49	0.05	0.43**	0.20	0.06	0.78**	0.80**	1.00							
	19	0.86**	0.54**	0.08	0.58**	0.32**	0.05	0.96**	0.83**	0.86**	1.00						
APW	0	0.76**	0.49**	0.04	0.54**	0.41**	-0.01	0.82**	0.71**	0.64**	0.79**	1.00					
	5	0.62**	0.40**	0.05	0.41**	0.28**	0.00	0.67**	0.64**	0.60**	0.67**	0.75**	1.00				
	12	0.47**	0.26*	-0.02	0.28**	0.22*	-0.05	0.55**	0.52**	0.58**	0.58**	0.76**	0.80**	1.00			
	19	0.64**	0.42**	0.00	0.47**	0.27*	-0.08	0.70**	0.60**	0.60**	0.69**	0.89**	0.81**	0.82**	1.00		
FI		-0.07	-0.06	-0.01	-0.13	0.09	0.11	-0.06	-0.05	-0.04	-0.04	0.10	0.07	0.12	0.00	1.00	
PI		0.01	0.01	0.08	-0.04	0.06	0.08	0.12	-0.06	0.13	0.15	0.20	0.15	0.30**	0.25*	0.03	1.00

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

Table 7. Correlation coefficient among immunocompetence traits in indigenous chickens (pooled) at 7 weeks of age

Immuno-competence trait	dpi	HA				MER				CPW			
		d0	d5	d12	d19	d0	d5	d12	d19	d0	d5	d12	d19
	1	2	3	4	5	6	7	8	9	10	11	12	13
HA	0	1.00											
	5	0.51**	1.00										
	12	0.42**	0.59**	1.00									
	19	0.30**	0.45**	0.74**	1.00								
MER	0	0.64**	0.44**	0.33**	0.25**	1.00							
	5	0.17	0.42**	0.02	-0.12	0.33**	1.00						
	12	0.17	0.32**	0.72**	0.53**	0.21*	0.05	1.00					
	19	0.21*	0.36**	0.61**	0.83**	0.19	-0.20*	0.53**	1.00				
CPW	0	0.17	0.35**	0.20*	0.12	0.1	0.09	0.17	0.14	1.00			
	5	0.14	0.36**	0.36**	0.33**	0.04	-0.12	0.31**	0.36**	0.66**	1.00		
	12	0.14	0.34**	0.40**	0.34**	0.09	-0.14	0.38**	0.38**	0.63**	0.87**	1.00	
	19	0.20*	0.32**	0.36**	0.28**	0.13	-0.08	0.30**	0.27**	0.78**	0.74**	0.79**	1.00
APW	0	0.20*	0.33**	0.25**	0.29**	0.05	-0.20*	0.16	0.30**	0.71**	0.68**	0.67**	0.68**
	5	0.15	0.25**	0.33**	0.42**	0.00	-0.32**	0.25*	0.43**	0.49**	0.75**	0.70**	0.69**
	12	0.21*	0.31**	0.40**	0.46**	0.03	-0.31**	0.26*	0.43**	0.47**	0.75**	0.73**	0.69**
	19	0.23*	0.32**	0.39**	0.44**	0.08	-0.27**	0.25*	0.42**	0.55**	0.73**	0.70**	0.74**
FI		-0.04	-0.10	-0.01	-0.13	0.03	-0.06	0.11	-0.04	0.03	0.00	0.01	-0.01
PI		-0.06	-0.14	-0.14	-0.11	0.09	0.14	-0.07	-0.15	-0.08	-0.28**	-0.21*	-0.16

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

Table 8. Correlation coefficient among immunocompetence traits in broilers (pooled) at 7 weeks of age

Immuno competence trait	dpi	HA				MER				CPW			
		d0	d5	d12	d19	d0	d5	d12	d19	d0	d5	d12	d19
	1	2	3	4	5	6	7	8	9	10	11	12	13
HA	0	1.00											
	5	0.66**	1.00										
	12	0.22*	0.33**	1.00									
	19	0.12	0.28//	0.40**	1.00								
MER	0	0.61**	0.37**	0.09	0.04	1.00							
	5	0.2**	0.46**	-0.01	-0.04	0.28**	1.00						
	12	0.04	0.11	0.37**	0.08	-0.06	0.17	1.00					
	19	-0.07	-0.04	0.12	0.06	-0.04	-0.04	-0.04	1.00				
CPW	0	0.60**	0.64**	0.23*	0.17	0.31**	0.38**	0.04	-0.05	1.00			
	5	0.17	0.51**	0.15	0.10	0.08	0.36**	0.11	-0.09	0.60**	1.00		
	12	0.27**	0.49**	0.08	0.06	0.09	0.32**	0.05	0.00	0.65**	0.80**	1.00	
	19	0.54**	0.78**	0.25*	0.12	0.25*	0.38**	0.08	-0.07	0.92**	0.68**	0.75**	1.00
APW	0	0.43**	0.52**	0.13	0.18	0.18	0.29**	-0.11	0.04	0.58**	0.34**	0.41**	0.58**
	5	0.21*	0.03	0.23	0.21*	-0.03	0.06	-0.01	0.02	0.04	-0.02	0.01	0.03
	12	0.11	0.10	-0.02	-0.05	0.06	0.19	-0.08	0.10	0.21*	0.23*	0.30**	0.22*
	19	0.34**	0.34**	0.04	0.11	0.19	0.31**	-0.15	0.02	0.43**	0.33**	0.39**	0.47**
FI		0.10	0.04	0.25*	-0.07	0.10	-0.15	0.09	-0.12	-0.03	0.07	-0.04	0.04
PI		-0.06	-0.15	-0.08	-0.03	-0.04	0.00	-0.10	0.15	-0.11	0.07	0.06	-0.07

*Significant at P<0.05; **Significant at P<0.01; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50U/ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; dpi, Days post immunization.

PI; and Keel length with the same two immunocompetence traits were negative and small but did show an increasing trend with increase in age of birds. No definite relationship, however, could be observed across the range of genotypes studied between HA and conformation traits and between MER and conformation traits.

With production traits

White Leghorn Pullets matured early and produced more number of average sized eggs compared to Aseel, Kadakanath, Naked Neck, Frizzle and Dahlem Red. Even though the feed consumption was higher, amount of feed required to produce a dozen or kilo of eggs was lowest for

Table 9. Phenotypic correlation among immunocompetence traits (45weeks of age)

Immuno response	Genotype				
	Pooled	Aseel	KN	NN	FZ
HA vs CPW	0.33**	0.12	0.28	0.47**	0.43**
HA vs FI	0.21	0.05	0.02	0.23	0.21
HA vs APW	-0.13	-0.14	-0.21	0.42*	0.39*
HA vs MER (IgG)	0.56**	0.56**	0.49**	0.72**	0.33
HA vs MES (IgM)	0.64**	0.71**	0.57**	0.59**	0.67**
CPW vs FI	0.13	-0.22	0.12	0.11	-0.20
CPW vs APW	0.04	0.09	-0.14	0.19	0.02
CPW vs MER	0.34**	0.17	0.35*	0.46**	0.19
CPW vs MES	0.10	0.00	-0.03	0.13	0.25
APW vs MER	0.15	-0.03	-0.24	0.51**	0.37*
APW vs MES	-0.02	-0.15	0.01	0.00	0.07
FI vs APW	0.25**	-0.02	0.24	-0.45**	0.51**
FI vs MER	-0.35**	0.48**	0.15	0.20	-0.21
MER vs MES	-0.26	-0.18	-0.44**	-0.13	-0.49**

*Significant at $P<0.05$; **Significant at $P<0.01$; HA, Haemagglutinin antibody; MER, Mercaptoethanol resistant antibody (IgG); CPW, Complement (CH 50U/ml) measured by classical pathway; APW, Complement (CH 50 U/ ml) measured by alternate pathway; FI, Foot index for CMI response; PI, Phagocytic index; KN, Kadakanath; FZ, Frizzle; NN, Naked Neck.

White Leghorn (Tables 10). On the other hand, Dahlem Red which matured late produced least number of large sized eggs and consumed more feed to produce a dozen or kilo of eggs. Since Dahlem Red had the highest HA titres and White Leghorn had the least titres (Kundu *et al.* 1999a), there appeared to be strong negative relationship between egg production and IgG; egg production and IgM and egg production and CPW (Kundu *et al.* 2015c) and negative between egg production and APW (Kundu *et al.* 2015c). CPW complement response was highest for Dahlem Red followed by indigenous breeds and White Leghorn in that order. Dahlem Red, which produced least number of eggs, had the highest FI and the White Leghorns which produced maximum number of eggs had the least FI. This suggested an inverse relationship of egg production with FI. The relationship between phagocytic activity and egg production appeared to be negative but inconsistent.

The correlations of ASM with immunocompetence traits were reverse to that of egg production whereas the trend remained the same as that of egg production with feed efficiency.

With mortality percent

Lower mortality and comparatively higher resistance to pathogens have been reported in lines selected for response to SRBC, complement level and mitogens (Gross *et al.* 1980, Schneider 1983, Larang and Hurtle 1985, Leitner *et al.* 1989, Saxena 1993). The mean values for mortality presented in Table 11 and immunocompetence traits presented in our earlier papers (Kundu *et al.*1999a, 1999b 2015a, 2015b and 2015c) revealed that the White Leghorn birds which had the highest mortality from 0 to 10 weeks had the least HA, IgG, IgM, APW, CPW and FI and Dahlem Red with least mortality had the highest values for all the immunocompetence traits. This suggested an inverse relationship of mortality with immunocompetence traits as reported earlier by other workers.

Information on genetic correlation among disease resistance, immune response parameters and production traits are scarce. Warner *et al.* (1987) and Gavora and Spencer (1978) reported a negative genetic relationship between body weight and M.D. resistance. Han and Smyth (1972) showed that higher titres of antibody did not provide protection to M.D., although antigen and antibody titres were positively related.

Vanderzijpp (1983b), Siegel *et al.* (1982), Siegel and Gross (1980) reported a negative relationship between live weight and haemagglutinin antibody titres to SRBC. Siegel

Table 10. Means and standard errors for production traits for chicken lines

Genotype	N	ASM	Egg no. up to 40 wks	EW	FC/d	FC/DE	FC/kgem	FC/kgbwg
Aseel	15	171.47±9.26^{a}	56.60±9.02 ^{a}	46.83±0.62 ^{a}	79.07±3.73 ^{a}	4.73±0.90	8.32±1.55 ^{a}	
KN	21	175.67±3.15 ^{a}	53.71±4.67 ^{a}	41.95±0.67^{e}	75.78±4.58 ^{ab}	4.14±0.36 ^{a}	8.28±0.75 ^{a}	
NN	12	202.50±8.04 ^{b}	32.10±6.45 ^{b}	49.48±1.21 ^{abc}	77.19±1.99 ^{ac}	6.29±0.68 ^{bc}	11.10±1.16^{b}	
FZ	11	191.73±8.13^{c}	37.36±5.36 ^{b}	50.63±1.20 ^{bdf}	88.98±5.18^{d}	3.34±0.41 ^{ad}	5.50±0.64^{c}	
DR	24	197.83±3.99 ^{bc}	21.20±2.45^{c}	54.92±1.30 ^{cd}	79.52±1.35 ^{bc}	7.81±0.67^{c}	12.35±1.04^{cd}	
WL	24	148.71±1.08^{d}	125.33±2.66^{d}	50.26±0.59^{f}	99.66±0.72^{e}	1.73±0.05^{d}	2.87±0.07^{de}	
SDL-B	43							2.28
NN-B	46							2.05

Means having the same superscript (column wise) do not differ significantly ($P<0.05$). EN, Egg Number up to 40 wks; ASM, Age at Sexual Maturity; EW, Egg weight at 40 wks; Fc/d, feed consumption per day in gm; FC/DE, Feed consumption per dozen of eggs in kg; FC/kgem, Feed consumption per kg egg mass; FC/kgbwg, Feed consumption per kg body weight gain in kg; KN, Kadakanath; FZ, Frizzle; NN, Naked Neck; DR, Dahlem Red; WL, White Leghorn; SDL- B, Synthetic dam line broiler; NN-B, Naked Neck broiler; N, Number of birds

Table 11. Per cent mortality for different genetic groups of chickens

Genotype	N	Mortality % at various ages in wks					
		0-5	6-10	11-15	16-20	0-10	11-20
Aseel	119	3.20	2.51	1.73	0.87	5.71	2.60
KN	252	2.17	1.46	0.86	0.73	3.63	1.64
NN	104	3.81	3.04	2.00	1.22	6.85	3.22
FZ	76	4.06	3.06	3.05	1.89	7.12	4.94
DR	176	3.55	1.89	1.01	0.70	5.44	1.71
WL	87	5.04	2.75	1.99	1.90	7.79	3.89
SDL -B	75	5.12	3.12			8.24	
NN-B	75	4.89	2.88			7.77	

KN, Kadakanath; FZ, Frizzle; NN, Naked Neck; DR, Dahlem Red; WL, White Leghorn; SDL-B, Synthetic dam line broiler; NN-B, Naked Neck Broiler; N, Number of birds

and Gross (1980) observed significantly heavier 4 week body weight in the low line selected for antibody response to SRBC whereas the line selected for persistency showed no differences in production traits. Gross *et al.* (1980) found reduced growth in high line and weight loss in low lines. These effects were more severe in high line where mortality was also higher. The capability of high line to produce more antibodies may be partly responsible for these effects. Results realized in the present study between HA and body weights at various ages were mostly negative for Dahlem Red although pooled data for indigenous breeds presented a positive trend. In White Leghorn, most of the estimates were negative but small. In case of broilers, positive trend was noticed between HA and juvenile body weight at various ages on day 19 p.i. but not on other day of measurement.

From the various facts presented in the literature about the usefulness of immunocompetence traits in relation to improving resistance to diseases, it would seem inevitable that selective breeding for improving production traits would have increased resistance in the animals. A fact available in literature suggests that this has not been the case. One reason may be that modern husbandry practices which include vaccination, preventive medication and separation of animals from pathogens mask the genetic capacity of the animals to resist diseases. In addition, some genes may have pleiotrophic effects and antagonistic to improving both production traits and resistance. Adverse effects of selection, when the correlation between production and disease resistance traits is antagonistic, were reported by Gavora and Spencer (1978), Vanderzzijpp (1983a and b, 1984). Han and Smyth (1972) reported that selection for higher growth rate resulted in increased susceptibility to Marek's Disease had lower body weight and produced smaller eggs.

The results presented in literature as well as obtained in this study would suggest that although immunocompetence traits provide the promise for increasing resistance, a clear cut association of these traits with production and growth rates is far from clear. As such the breeder who wants to take advantage of immunocompetence traits for increasing resistance in their production flocks will have to wait for some more time.

The long range goals of poultry breeders are to combine all possible good genes in an individual and to preserve an enhanced heterogeneity in the poultry germplasm. The results obtained in this investigation as well as those available in literature suggested that the disease resistance and the immune response are under genetic control and hence are the possible candidates for use in future poultry breeding programmes. Data on the association of the production traits with disease resistance and immune response are important for devising practical breeding programmes but are still not adequate for domestic animals including poultry for their optimal use.

The relationship of immunocompetence traits with economic traits presented in the literature as well as realized in this study did not lead to any definite conclusion suggesting more study to quantify the magnitude and direction of relationship, for their use in practical breeding programmes.

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