STUDIES ON EFFECT OF DIETARY MANGANESE IN RELATION TO THE LEVELS OF DIETARY CALCIUM IN GROWING JAPANESE QUAILS

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CERTIFICATE

Certified that the research work embodied in this thesis entitled "STUDIES ON EFFECT OF DIETARY MANGANESE IN RELATION TO LEVELS OF DIETARY CALCIUM ON GROWING JAPANESE QUAILS," submitted for the award of Degree of Master in Poultry Science of Indian Veterinary Research Institute, is the original work carried out by the candidate himself under my supervision and guidance.

It is further certified that Dr.Lalhmingthanga has worked for more than 24 months in this Institute and has put in more than 150 days attendance under me from the date of registration for Master degree of the University as required by the relevant ordinance.

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CERTIFICATE

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We have carefully gone through the contents of the thesis and are satisfied with the work carried out by the candidate which is being presented by him for the award of M.V.Sc. degree in this Institute.

It is further certified that the candidate has completed all the prescribed requirements governing the award of M.V.Sc. degree of Indian Veterinary Research Institute.

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"The world is so full of number of things.
I'm sure we should all be as happy as kings"
- Robert Louis Stevenson

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INTRODUCTION

INTRODUCTION

Japanese quail belongs to the genus coturnix of the family phasianidae, hence the name Coturnix coturnix japonica. The coturnix quail was originated as migratory game bird from Europe, Africa and Asia. The domesticated species which is now popularly known as japanese quail, has been raised as pet, for meat and egg purpose. The commercial quail farming has occupied a very significant position in poultry production activities in several thickly populated countries like Japan, Hong kong, Singapore and France. In India development efforts using extensive research methods have been carried out at Central Avian Research Institute since Japanese quail was first introduced in 1977. These efforts have now made it possible to evolve workable package of husbandry practices suitable for this country. Since then quail farming in India is also gaining popularity among the poultry farmers.

Besides offering more alternative options to poultry farmers, this small, fast maturing Japanese species of quail is becoming increasingly popular as a laboratory animal in research works. The ability of Japanese quail to produce 3 to 4 generations in a year makes it a good laboratory animal. Because of similarity to chicken in several aspects, quails have been used as pilot animals for genetic, nutrition and physiological studies. Quails are also useful for endocrinology, embryology, pharmacology and cancer studies.

For efficient application of Japanese quail as laboratory animal and to derive maximum benefit out of commercial quail farming it is necessary to feed balanced diets which will have all the nutrients in optimum proportion. In recent times there has been a growing tendency to formulate poultry diets containing significant amount of non-conventional feedstuffs due to ever increasing price hike on conventional feedstuffs. Inclusion of these nonconventional feedstuffs in the poultry diets may, sometimes, disrupt the mineral balance. Incorporation of any mineral in excess of requirement for optimum performance is not only uneconomical but can also be harmful to the birds. There are reports in the literature that high dietary calcium and phosphorus may cause secondary manganese defeciency leading to perosis, a leg abnormality characterised by slippage of the gastrocnemius tendon (Wilgus et al., 1936; Poll et al., 1967; Underwood, 1981).

Much research works have been done on nutrient requirements of quail under temperate condition (Shim and Vohra, 1984) out of which only one report is available on the requirement of manganese (Harland et al., 1973). Under tropical conditions, Panda et al. (1977) and Shrivastav and Panda (1988) revealed that information on the effect of dietary manganese to the level of calcium in growing Japanese quail is lacking in the literature. The present studies were, therefore, conducted with the following objectives:

1. To investigate the effect of dietary manganese in relation to the level of calcium on the performance of growing Japanese quail.

2. To identify the optimum dietary supplemental level of manganese for optimal performance of growing Japanese quail.

3. To study the requirement of calcium of growing Japanese quail from one to five week of age.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Very limited literatures are available on the requirements of calcium and manganese in the diet of growing Japanese quail. Therefore, literatures available with other related species have also been reviewed in this chapter.

2.1 MANGANESE REQUIREMENT

The avian species are known to have relatively higher requirements for managanese as compared to mammals. It is generally accepted that the relatively high requirements for managanese by avian species is due to less efficiency of absorption of manganese by birds relative to mammals (Underwood, 1981). Turk et al. (1982) estimated that less than 0.01% of an oral dose of radiomanganese was absorbed by Leghorn chicks which was much lower than estimates of 3-4% for rats (Greenberg et al., 1943) and 1% for cattle (Sansom et al., 1976). There are, however, conflicting reports in the literature also. Suso and Edwards (1969) estimated absorption efficiency of manganese to be 2.3% in Leghorn chicks fed a corn soybean meal diet. Halpin et al. (1986) using slope-ratio methodology, calculated an absorption efficiency of managanese to be 1.71% and 2.4% for chicks fed the corn-soybean meal diet and fiber-free casein-dextrose diet respectively. These workers concluded that while absorption phenomena appear to explain the higher dietary requirement for managanese in chicks fed conventional diets than in those fed purified diets, the high avian requirement for manganese relative to mammals would seem not to be due solely to inefficient gut absorption.

Only one report in literature regarding the manganese requirement of growing Japanese quail is available which was determined under temperate condition using purified diet.

Harland _et al_. (1973) conducted studies on mineral requirements of starter japanese quail. Japanese quails were fed adequate purified diets containing 35% soybean protein from hatching to 2 to 4 weeks of age. Inorganic elements were supplied by reagent grade salts and unavoidable dietary contaminants (primarily in protein). They observed that the total requirement of manganese and dietary contaminant levels were 12 mg/kg or less and 2 mg/kg respectively.

For starting and growing Japanese quail NRC (1984) reviewing the nutrition of quail suggested a dietary level of 90 mg/kg. Shim and Vohra (1984) reviewing the nutrition of quail suggested a dietary level of 80 mg/kg. Shrivastav and Panda (1988) reviewing quail nutrition research in the tropics suggested dietary manganese level of 120 mg/kg. ISI has not yet laid down any specification for Japanese quail.

2.1.1 Factors affecting manganese requirement

2.1.1 (a) Diet composition

Manganese requirement is greatly influenced by diet composition.

Kealy and Sullivan (1966) conducted 5 experiments to investigate the manganese requirement and interaction of manganese with zinc and sodium chloride in the diet of young turkeys. They observed that with a dextrose-isolated soybean protein diet, 24 and 54 ppm of manganese respectively, were required for maximum body weight gain and minimum hock disorders. Maximum body weight gain and minimum hock disorders were obtained with only 12 and 22 ppm, respectively, in a dextrose-dried skim milk-casein diet. A practical-type corn-soybean meal diet with no protein of animal origin was used in two experiments. Maximum body weight gain was obtained with 32 ppm of manganese in one experiment and 52 or 72 ppm in the other.

Halpin and Baker (1986a, 1986b) suggested that several poultry feed ingradients, i.e. corn, soybean meal (SBM), fish meal (FM) and wheat bran (WB) markedly reduced the utilization of dietary inorganic manganese in the chicks. These authors in their subsequent studies, suggested that the reduced utilization of manganese due to these feed ingredients resulted from reduced manganese absorption, rather than from enhanced manganese excretion. Their observations indicated that the neutral detergent fiber (NDF) fraction of WB and corn-SBM mixture accounted for virtually all of the Mn-binding capabilities of these ingredients. In contrast, ash fraction was responsible for tissue Mn-lowering capabilities of FM.

2.1.1 (b) Interaction with other minerals

Evidence exists in the literature that high dietary calcium and phosphorus and wide calcium-phosphorus ratios may cause secondary manganese deficiency leading to perosis, a leg abnormality characterised by slippage of the gastrocnemius tendon (Wilgus et al., 1936; Pott et al., 1967; Underwood, 1981).

Caskey and Norris (1938) observed that raising the calcium and phosphorus content in the diet increased the manganese requirement of chicks.

Smith and Kabaija (1985) observed that at normal phosphorus (0.6%) high dietary calcium (2.0%) and (3.0%) disrupted manganese metabolism, causing a high incidence and severity of leg problems and associated bone disorders. In the second experiment they investigated the possibility of managing the condition by increasing dietary manganese using 150 Cobb broilers. The birds were fed five diets containing graded levels of manganese (77.5, 140, 200, 255 and 300 mg/kg) for 6 weeks. All diets contained similar calcium (3%) and phosphorus (0.6%) and adequate levels of other nutrients. They observed that control birds (77.5 mg/kg) had the highest ($P \angle 0.05$) leg abnormality score, which decreased ($P \angle 0.05$) as dietary manganese increased upto and including 200 mg/kg. They observed no additional reduction in leg abnormality ($P \angle 0.05$) above this level. They also observed a similar trend for tibia ash and volume.

2.1.2 Effect of manganese on bone formation

Manganese deficiency in young chicks results-in severe leg deformities (Wilgus et al., 1936). The abnormality is characterised by shortened, thickened bones with swollen and enlarged joints. Frequently, the gastrocnemius tendon slips from its condyle resulting in the condition known as "slipped tendon" or "perosis".

The deficiency of manganese in the embryo result in a skeletal abnormality termed chondrodystrophy (Lyons et al. 1938).

Gallup and Norris (1938) reported that calcification of the bone of chicks fed a low-manganese diet appeared to be normal by x-ray examination even though the bones were perceptibly shorter and thicker than normal.

Caskey et al. (1939) found that the ash content of the bones of chicks fed a diet containing 5.5 ppm manganese was significantly lower than that of chicken fed an adequate diet.

Wolbach and Hegsted (1953) reported that manganese deficiency retarded chondral bone formation.

Parker et al. (1955) used radioactive isotopes of manganese, calcium and phosphorus to determine the effects of manganese deficiency on the deposition of these elements in the bones of chicken. They found that the manganese level in the diet did not significantly affect the amount or location of deposition of Ca^{45} and P^{32} in the tibiae.

Litricin et al. (1966) conducted experiment to study the growth of leg and wing bones of chicks fed diet deficient in manganese from hatching to 13, 30 and 60 days of age. They observed that by 15 day of age the long bones of leg and wings were significantly smaller in deprived birds, and this difference persisted throughout the trial. They also noticed that bones were reduced in diameter as well as in length in contrast to earlier finding recorded by Wilgus et al. (1936).

Leach (1968) observed reduction in width of epiphyseal plate and metaphysis in manganese deficient chick. He suggested that the reduction in the weight of the epiphyseal plate associated with manganese deficiency was the result of an impairment in cartilage matrix production rather than defective calcification. He observed reduction in hexuronic acid content of the cartilage from manganese deficient chicks and that the galactosamine-containing polysaccharide were the most severely affected by manganese deficiency. He concluded that this finding was indicative of a reduction in chondroitin sulfate, the major galactosamine-containing polysaccharide found in chicken cartilage.

Similar observation have been made with young guinea pigs (Tsai and Everson, 1967) which were born from dams receiving inadequate amounts of manganese. In guinea pigs, the concentration of mucopolysaccharides was reduced in both rib and epiphyseal cartilage with chondroitin sulfate being the polysaccharide most severely affected.

In his subsequent studies Leach (1971) showed by both chemical analysis and histological studies that the skeletal and postural defect resulting from manganese deficiency to be associated with a reduction in tissue mucopolysaccharide content. He opined that these observations may be explained by a generalised requirement for Mn^{2+} by many glycosyltransferase enzymes, including those needed for chondroitin sulfate synthesis.

2.2 CALCIUM AND PHOSPHORUS REQUIREMENT

Very limited reports are available on the calcium and phosphorus requirement of young immature Japanese quail.

Consuegra and Anderson (1967) observed that the dietary calcium and phosphorus requirements of Japanese quail were not greater than 0.8% calcium and 0.3% available phosphorus at 2 weeks and 0.48% calcium and 0.3% available phosphorus at 4 weeks of age. They reported that if the ratio between calcium and phosphorus was wider than this, growth of quail was depressed at 2 weeks of age and rickets developed.

Miller (1967) employed all vegetable diet (Corn-soy-alfalfa diet) containing 0.44 to 2.30% calcium and 0.59 to 1.18% total phosphorus for growing Japanese quail. The calcium and phosphorus content of the diet was increased by supplementation with ground limestone and dicalcium phosphate. They observed that the basal diet containing 0.44% calcium and 0.59% total phosphorus of plant origin (0.18%) available phosphorus assuming 30% availability) supported satisfactory weight gain and bone ash was also not impaired. They also observed that a calcium-phosphorus ratio of 0.7 to 1.1 showed better feathering than 2 or higher ratios.

Panda _et_ _al_. (1977) while reviewing the nutrient requirements and feeding of Japanese quail suggested a dietary level of 0.8% calcium from 0 to 3 weeks of age and 0.5% calcium from 4 to 5 weeks of age and 0.3% of available phosphorus from 0 to 5 weeks of age.

Bisoi _et_ _al_. (1980) estimated the calcium and phosphorus requirements of growing Japanese quail from day old to 3 weeks of age in a 4 x 3 factorial experiment comprising 1.5, 0.7, 0.9 and 1.1% calcium and 0.5, 0.6 and 0.7% total phosphorus or 0.2, 0.3 and 0.4% available phosphorus. They observed that Japanese quail chicks upto 3 weeks of age required 0.6 to 0.7% calcium and 0.5 to 0.6% total phosphorus (0.2 or 0.3% available phosphorus).

Reddy _et_ _al_. (1980) employed 4 x 3 factorial experiment comprising 0.5, 0.7, 0.9 and 1.1% calcium and 0.5, 0.6, 0.7% phosphorus to estimate calcium and phosphorus requirement of growing Japanese quail. They observed that the dietary requirement of female Japanese quail during fourth to fifth week of age was 0.5% calcium and not more than 0.5% total phosphorus (0.2% available phosphorus).

Shrivastav and Panda (1988) while reviewing quail nutrition research in the tropics, suggested a dietary level of 0.8% calcium and 0.3% available phosphorus from 0 to 5 weeks of age.

NRC (1984) recommended a dietary level 0.8% calcium and 0.45% available phosphorus for starting and growing Japanese quail.

I.S.I. has not yet laid down the specificiation for calcium and phosphorus in the diet of starting and growing Japanese quail.

2.2.1 Effect of calcium and phosphorus on bone ash

Calcium and phosphorus are known to be closely related to each other in bone metabolism. Calcium constitute almost one-third of the weight of the fat-free dried bone. While bone is composed largely of calcium phosphate, it also contains approximately 13% calcium carbonate, 2% magnesium phosphate, and 5% of other substances, some 0.5 - 3% present as citrates. The calcium deficiency caused marked demineralization of bone in which ash content of bone reduces to about one-half normal. Deficiency of phosphorus and calcium cause rickets in young growing bird. Several reports are available to indicate bone ash to be a sensitive indicator of adequacy of the levels of calcium and phosphorus for chicken (Mehring et al. 1965; Choi and Harms, 1977).

Edwards et al. (1963) observed a definite and consistent increase in the percent of bone ash present in the tibia of four-week old chicks as the level of calcium in the ration was increased to 1.55%. They also observed a slight decrease in the level of bone ash of the tibia when higher levels of calcium were fed. They reported that there was no consistent trend in the tibia ash values from eighth week.

Miller (1967) using diets containing 0.44 to 2.3% calcium and 0.58% (all phosphorus from vegetable) to 1.18% phosphorus for Japanese quail from 1 d to 6 weeks of age observed on all diets equal performance in term of percent bone ash in the tibia. This author also reported that the females had significantly higher bone ash content than the males. The average bone ash content of fat-free tibia was 29.8 percent with a range of 25.8 to 37.0 percent.

Consuegra and Anderson (1967) observed that tibia ash of Japanese quails were significantly affected ($P \angle 0.05$) by six calcium (0.48 to 2.45%) and three phosphorus (0.3, 0.45 and 0.6%) levels and Ca:P ratios at 2 weeks of age. However, at 4 weeks of age significant calcium effect were observed only at 0.3% phosphorus. They also reported that wide Ca:P ratios (5.2 - 8.2) produced severe growth depression and rickets at 2 weeks of age which was accompanied by a marked elevation of phosphatase activity.

Bisoi et al. (1980) observed that at 0.6% dietary phosphorus the bone ash of 3 week Japanese quail chick increased with increase in dietary calcium from 0.5 to 0.7% of the diet. But when dietary calcium was further increased from 0.7 to 0.9 and 1.1% bone ash decreased with each increment of dietary calcium.

Reddy et al. (1980) reported that there were no significant ($P \angle 0.05$) differences in response of bone ash of 4-5 week old Japanese quail due to dietary calcium (0.5, 0.7, 0.9 and 1.1%) and phosphorus (0.5, 0.6 and 0.7%).

2.3 SERUM CALCIUM

Practically all blood calcium is present in plasma. The plasma calcium is in three forms; ionised, protein bound and combined with citrate and other organic acids. The ionised calcium is diffusible, the citrate complex is not ionised, but is also diffusible, the calcium proteinate is not ionised and not diffusible.

The non-laying hen has a total serum calcium of 12 mg/100 c.c. of which the non-dialyzable calcium is 4 mg. The laying hen has a total calcium of 20 mg/100 c.c. of serum of which the non-dialyzable fraction is 12 mg (Stohl, 1939).

Simkiss (1967) reported rise in the concentration of serum calcium from 10 mg% to 16-30 mg% during the 10 days before a pullet start to lay.

2.3.1 Effect of diet and ingredient composition on serum calcium level

Starvation usually has little effect on the serum calcium level. But calcium deficiency will in the end causes blood calcium to fall (Stohl, 1939).

Edwards and Sorenson (1987) observed in broiler chicks that fasting for 2, 4 and 8 hours had no influence on total calcium and ultrafiltrable calcium in serum. They observed, however, that the hour of the day that the birds were bled had a significant influence on the plasma total calcium and dialyzable phosphorus. They concluded that investigation involving plasma total calcium and dialyzable phosphorus must be carefully designed in view of the diurnal rhythms for each mineral in plasma of young broilers.

Hurwitz and Griminger (1961) observed that the laying hens receiving neither calcium nor phosphorus showed a decrease in plasma inorganic phosphorus on the first day of treatment, reaching a minimum by the second day. After the second day, the inorganic phosphorus started to rise. In groups receiving no calcium, but added phosphorus, there was an increase in the inorganic phosphorus level on the first day, followed by decrease on the second day with a return to control values by the 6th and 7th day. Plasma calcium level was decreased in all the calcium depleted groups to approximately half of the original value, thus reaching the value of non-laying hens. Similarly the high calcium diet (4.1%) promoted a higher plasma calcium in pullets at the onset of egg production than low-calcium diet (1.2%) (Hurwitz, 1964).

Jones et al. (1965) reported that subcutaneous injection of estradiol in laying hens would increase serum calcium. Broiler chicks implanted with silastic tubing containing estradiol dispropionate had significantly higher plasma calcium and phosphorus than nonimplanted controls (Bolden et al. 1985a).

Roland et al. (1977) reported that the feeding of 5000 ppm Iodine as KI increased serum calcium in laying hen to as high as 70 mg/100 ml. These authors also reported that combination of KI plus estradiol was significantly more effective in increasing serum calcium than was either compound alone.

Bolden et al. (1985b) reported that the estrogenized chicks fed corn-soybean meal diet had significantly higher plasma calcium and plasma phosphorus than those fed fish meal, alfalfa meal and torula yeast. In the same year they conducted another 3 experiments with White Leghorn laying hens to study the effect of changes in ingredient composition of diets varying in calcium level on various parameters. They compared calcium at 2.75 and 3.5% in a corn-soybean meal diet (CS) or diets containing alfalfa meal, distillers dried grains with solubles (DDGS), torula yeast, fish meal, or a combination of fish meal, alfalfa meal, and torula yeast. They observed that plasma calcium in hens fed C.S. diet was significantly higher than in hens fed all of the more complex diets except the one with DDGS. They also observed that plasma calcium was not affected by level of calcium in the diets.

Atteh and Leeson (1983) reported that inclusion of 8% fatty acids in the presence of low (0.8%) and high (1.2%) calcium in the broiler diets *significantly reduced plasma calcium level relative to the control* diets. They also observed that level of dietary calcium had no significant effect on plasma calcium level.

Kuiumgian and Evans (1980) conducted 2 trials to investigate bone and soft tissue mineralization in growing and laying Japanese quail fed diet containing soy protein and starch with four graded levels of magnesium (200, 500, 800, 1100 ppm) each with two levels of calcium (1 and 1.5% for growing, 2.5 and 3.0% for laying diets). They observed that level of calcium in laying diets had no significant effect on the serum calcium level. They, however, found that in growing quails the plasma calcium increased (P $\angle$ 0.01) with higher calcium diets.

Gadzhiev and Safarov (1983) reported that chicken given napthalene oil at the level of 1 mg/kg body weight mixed with bone meal at the level of 6g/kg body weight had increased in serum calcium, inorganic and acid-soluble phosphorus.

Diz et al. (1983) observed that groups of 10 male Japanese quails weighing about 145 g, fed diets with calcium 1.54, 3.20, 1.57, 3.40 and 2.2% and phosphorus 0.8, 0.81, 1.66, 1.71 and 0.81% respectively had calcium in serum of 12.8, 11.9, 12.5, 11.8 and 12.0 mg/100 ml respectively.

2.4 SERUM INORGANIC PHOSPHORUS

Phosphorus is in three main forms in the blood inorganic, ester and lipid, but the term "plasma phosphate" usually means the plasma inorganic phosphate measured as phosphorus. The ester phosphate in the blood is largely confined to the red cells. The blood contains approximately 35-45 mg of phosphorus per 100 ml. Only about 10% is in the form of inorganic phosphate.

Heller et al. (1934) studied the distribution of phosphorus in different fractions of blood from White Leghorn females at 30-day intervals, from 60 to 370 days of age. Using a diet which contained 1.21 per cent calcium and 0.76 per cent phosphorus they concluded that the amount of plasma inorganic phosphorus remained relatively constant throughout the experimental period. They also observed that the total blood phosphorus rose rapidly concurrent with the onset of laying and that the rise could be attributed to a rise in a total cell phosphorus and the plasma lipid phosphorus.

Variation in the serum phosphate concentration are of great interest because they are directly related to other minerals. Ordinarily there is an inverse relation between the blood serum calcium and phosphate. When the serum calcium is low the serum phosphate is high conversely when the phosphate is high, the calcium is low. But this inverse relation is not always present, both may rise or fall together (Stohl, 1939).

It has been shown by Schmidt and Greenberg (1935) that 2 g of calcium, in the form of any of the soluble salts, caused an increase in the calcium of the serum of about 1.5 mg/100 c.c. The rise reached its maximum in about 2 hours and returned to normal in 4 hours. They also observed that this increase was usually, but not necessarily, accompanied by an increase in inorganic phosphate concentration of the serum and reached its maximum about 6 hours after the calcium ingestion.

Gardiner (1962) conducted 4 experiments to study the plasma inorganic phosphate level of chicks as influenced by level of dietary phosphorus using RIR x LS male chicks. The basal diet used in the experiment contained approximately 0.35 per cent phosphorus of which 0.12 per cent was considered to be inorganic. Reagent grade Na_2HPO_4 was used as the source of phosphorus to vary the phosphorus level in diets. The calcium level was maintained at 1.2% for all diets. Their results showed direct relation between body weight, per cent bone ash, plasma inorganic phosphorus level and the level of dietary phosphorus. They also observed that the level of plasma inorganic phosphorus responded linearly with dietary increases in supplemental phosphorus upto 0.3 per cent and that the level of plasma inorganic phosphorus responded quickly to suboptimal dietary phosphorus levels and to feed withdrawal. They also reported that differences in the availability of phosphorus supplements were detected by changes in the plasma inorganic phosphorus level. They concluded that the level of plasma inorganic phosphorus could be used in place of and/or to supplement bone ash in phosphorus studies in chicks.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experimental procedures and analytical techniques employed to investigate the effect of dietary manganese in relation to calcium and to study the calcium requirements of Japanese quail are briefly described in this chapter.

3.1 EXPERIMENTAL STOCK

Eight hundred day old quail chicks of growth selected line were procured from Quail Unit of Central Avian Research Institute. The chicks were maintained in electrically heated five-tier battery brooder and fed a standard starter ration as suggested by Panda et al. (1977) under tropical condition upto one week of age. Feed and drinking water were provided ad libitum during this period. At the end of one week the chicks were weighed individually and the chicks which were too heavy or too light were discarded. A total of five hundred forty chicks were selected, wing banded and distributed, as uniformly as possible on body weight basis, into 27 groups of 20 birds each.

3.2 FEED INGREDIENT ANALYSIS

The proximate composition (crude protein, crude fiber, either extract, nitrogen free extract, and total ash) and calcium content of the feed ingredients were determined by the methods of the Association of Official Analytical Chemists (1975).

The phosphorus content of the feed ingredients was determined by colorimetric method (Fiske and Subbarow, 1925).

Dry matter was determined by drying the samples of feed ingredients in aluminium moisture cup at 100°C for 12 hours in a hot air oven.

The manganese content of the feed ingredients was determined, after wet digestion with perchloric acid (60%) 1 part, nitric acid (70%) 4 parts by Atomic Absorption Spectrophotometry (AOAC, 1975).

3.3 FORMULATION OF BASAL AND EXPERIMENTAL DIETS

A practical basal diet was formulated to meet the nutrient requirements of growing Japanese quail as suggested by Panda et al. (1977) which was adequate in all the nutrients except the levels of manganese and calcium. The basal diet contained 0.5% calcium and 20.5 mg manganese/kg. The basal diet (Table 1) was composed of maize, 50 parts; soybean meal 42 parts; fish meal, 5 parts; vitamins and minerals mixture, 0.7 part and variable (saw dust) 2.3 parts.

Nine experimental diets (Table 1) containing three levels of calcium (0.5, 0.8 and 1.1%), each at three levels of manganese (60, 90 and 120 mg/kg) in a factorial manner were prepared from the basal diet. All the nine experimental diets contained same amount of nutrients except calcium and manganese. Different levels of calcium and manganese were achieved by addition of calcium carbonate ($CaCO_3$) and manganese sulphate ($MnSO_4.H_2O$) to the basal diet at the expense of saw dust. However, for diet 1, 2 and 3 which were intended to contain 0.5% calcium, addition of calcium carbonate to the basal diet was not required as the basal diet contained sufficient amount of calcium for these three diets.

Table 1. Composition of Experimental Diets

Composition %	0.5% Ca			0.8% Ca			1.1% Ca		m
	60mg/kg Mn	90mg/kg Mn	120mg/kg Mn	60mg/kg Mn	90mg/kg Mn	120mg/kg Mn	60mg/kg Mn	90mg/kg Mn	120mg/kg Mn
Maize	50	50	50	50	50	50	50	50	50
Soybean meal	42	42	42	42	42	42	42	42	42
Fish meal	5	5	5	5	5	5	5	5	5
Vitamins and Mineral mixture	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696
Saw dust	2.286	2.273	2.258	1.686	1.672	1.658	0.936	0.922	0.908
$CaCO_3$	-	-	-	0.600	0.600	0.600	1.35	1.35	1.35
$MnSO_4.4H_2O$	0.018	0.031	0.045	0.018	0.031	0.045	0.018	0.031	0.045

Mineral mixture per 100 kg : Ferrous Sulphate, 40g; Zinc Sulphate, 35g; Copper Sulphate, 2g; Pottasium Iodate, 100mg; Sodium Chloride, 500g

Vitamins mixture per 100 kg: Choline Chloride, 100g; Vitamin A, 825000 I.U.; Vitamin D_3,120000 IU Vitamin B_2 500mg; Vitamin K, 10mg; Pyridoxine hydrochloride, 500mg; Folic acid, 100mg; Calcium pantothenate, 4g; Vitamin E, 5g

Table 2. Nutrient Content of the Experimental Diets

Nutrients	0.5% Ca			0.8% Ca			1.1% Ca		
	60mg/kg Mn	90mg/kg Mn	120mg/kg Mn	60mg/kg Mn	90mg/kg Mn	120mg/kg Mn	60mg/kg Mn	90mg/kg Mn	120mg/kg Mn
Metabolisable Energy* (Kcal/kg)	2876	2876	2876	2876	2876	2876	2876	2876	2876
Crude protein (%)	27.5	27.6	27.5	27.7	27.5	27.4	27.7	27.6	27.5
Calcium (%)	0.56	0.54	0.57	0.79	0.80	0.81	1.08	1.07	1.12
Phosphorus, total (%)	0.69	0.68	0.68	0.68	0.69	0.68	0.69	0.67	0.68
Manganese (mg/kg)	65.1	89.7	121.3	65.3	89.8	121.2	65.2	89.9	121.1
Methionine,* (%)	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Lysine,* (%)	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37

* Calculated values

The samples of the experimental diets (1-9) were analysed for proximate principles and calcium (AOAC, 1975); phosphorus (Fiske and Subbarow, 1925); and manganese by Atomic Absorption Spectrophotometry (AOAC, 1975).

The gross and analysed composition of the experimental diets are given in Table 1 and 2.

3.4 TREATMENTS AND EXPERIMENT DESIGN

The experimental period lasted for 27 days beginning from 8 day to 35 day of age, i.e. from 18th April to 15th May. Triplicate groups of 20 chicks each were randomly assigned to one of the nine experimental diets in a 3 x 3 factorial arrangement. The treatments involved three levels of calcium (0.5, 0.8 and 1.1%) and three levels of manganese (60, 90 and 120 mg/kg).

Feed was offered in a linear-type feeder made of G.I. sheet and covered with aluminium foil to prevent mineral contamination. Water was provided in enamel plate with a plastic mug placed over it in an inverted fashion. Feed and water were provided ad libitum to all the compartments throughout the experimental period.

The chicks were maintained in the same battery brooders throughout the experimental period. However, the positions of the chicks in different tiers of the battery brooders were rotated weekly as it was feared that this may have an effect on feed consumption and body weight gain.

3.5 RECORDING OF BODY WEIGHT GAIN AND FEED CONSUMPTION

The chicks were weighed individually at the beginning of experiment and at weekly intervals thereafter. Feed consumption per replicate group was also recorded at the end of each week. Feed efficiency ratio (Feed g/gain g), calcium intake and manganese intake were calculated from the weekly feed consumption data.

At the end of the experiment (35 days of age) two birds from each replicate group (6 birds per treatment) were selected for the estimation of serum Ca, P and tibial bone weight and ash. Heart blood was collected from each bird for the estimation of serum calcium and phosphorus. The birds were then sacrificed by cervical dislocation and the left tibia was removed for the measurement of tibial bone weight and ash percentage.

3.6 MEASUREMENT OF TIBIAL BONE WEIGHT AND ASH

The tibiae were cleaned of the adhering tissues with the help of scissors and forceps. The tibiae were then placed in boiling water for approximately 1 minute, scraped clean, and dried to constant weight in the hot air oven at 80°C for 24 hr. The tibiae were then weighed individually and the weights were recorded. Each bone was analysed for bone ash percentage after defattening following procedure of AOAC (1975) for vitamin D assay.

3.7 MEASUREMENT OF SERUM CALCIUM

The blood collected from the birds were pooled by replicates and the serum was obtained. The serum calcium was then determined by Trinder's method (1960) using Diagnostic Reagent kit supplied by Span Diagnostics Private Limited.

The following procedure was followed in carrying out the test.

REAGENTS (supplied in the kit)

Reagent 1 : Calcium Reagent
Reagent 2 : EDTA Reagent
Reagent 3 : Color Reagent
Reagent 4 : Working calcium standard, 10 mg% (5 mEq/litre)

PROCEDURE :

	Blank (B)	Standard (S)	Test (T)
Serum sample :	-	-	0.2 ml
Reagent 4 :	-	0.2 ml	-
Reagent 1 :	-	5.0 ml	5.0 ml

The mixture was allowed to stand at room temperature for 30 minutes. It was then centrifuged for 10 minutes at 3,000 rpm. The supernatant was decanted by slowly inverting the tubes.

2.

	Blank (B)	Standard (S)	Test (T)
Reagent 2 :	1.0 ml	1.0 ml	1.0 ml
	The tubes were shaken to suspend the precipitate and the mouth was covered with aluminium cap. And the tubes were heated in a boiling water bath for 10 minutes and allowed to cool		
Reagent 3:	3.0 ml	3.0 ml	3.0 ml

The O.D. of blank (B) Standard (S) and Test (T) were measured against water at 450 nm using the colorimeter with blue filter.

CALCULATIONS:

$$\text{Serum Calium} = \frac{\text{OD Test} - \text{OD Blank}}{\text{OD Std.} - \text{OD Blank}} \times 5 \text{ mEq/litre}$$

$$\text{or} = \frac{\text{OD Test} - \text{OD Blank}}{\text{OD Std.} - \text{OD Blank}} \times 10 \text{ mg/100 ml}$$

3.8 MEASUREMENT OF SERUM PHOSPHORUS

The serum phosphorus was determined by Varley's method (1980) after the blood samples were deproteinized. Diagnostic Reagent Kit supplied by Span Diagnostics Private Limited was used for carrying out the test.

The following procedure was followed in carrying out the test.

Reagent (supplied in the kit) :

Reagent 1 : TCA 10% W/V
Reagent 2 : Molybdate reagent
Reagent 3 : Metol reagent
Reagent 4 : Working phosphorus standard, 5 mg%

PROCEDURE :
Step A. Deproteinization of samples

Reagent 1 :	TCA	10%	w/v	7.2 ml
Serum :				0.8 ml

Allowed to stand at room temperature for 10 minutes after mixing well. Filtered through Whatman No.42 filter paper.

Step B. Colour development

	Blank (B)	Standard (S)	Test (T)
Filtrate (From Step A):	-	-	0.5 ml
Reagent 1 :	5.0 ml	4.5 ml	-
Reagent 4 :	-	0.5 ml	-
Reagent 2 :	1.0 ml	1.0 ml	1.0 ml
Reagent 3 :	1.0 ml	1.0 ml	1.0 ml

Allowed to stand at room temperature in dark after mixing well. The O.D. of Blank (B), Standard (S) and Test (T) were measured against distilled water at 680 nm on the colorimeter with a red filter.

CALCULATIONS :

$$\text{Serum phosphorus, mg/100 ml} = \frac{\text{OD Test} - \text{OD Blank}}{\text{OD Std.} - \text{OD Blank}} \times 5$$

3.9 STATISTICAL ANALYSIS

Data of weekly feed consumption, weekly body weight gain, weekly feed conversion efficiency ratio, caclium intake, manganese intake, tibial bone weight, tibial bone ash percentage, serum calcium and serum phosphorus were analysed by two-way *factorial analysis* (Snedecor and Cochran, 1967). The differences between the treatment means were determined by Duncan's Multiple Range Test (1955).

RESULTS

RESULTS

Investigations were carried out to study the effect of varying dietary manganese, (60, 90 and 120 mg/kg) in relation to different dietary calcium (0.5, 0.8 and 1.1%) levels on the performance of Japanese quails from 1 to 5 weeks of age.

Performance parameters viz., growth, feed conversion efficiency, percent survival; bone parameters, viz., percent bone ash and tibial bone weight and blood parameters viz., serum calcium and serum phosphorus, were taken into account in an attêmpt to identify the optimal levels of dietary manganese and calcium for growing Japanese quail from 1 to 5 week of age.

4.1 FEED INGREDIENT ANALYSIS

The results of the analysis of feed ingredients, viz., maize soybean meal and fish meal for calcium, manganese and phosphorus are shown in Table 3.

The average calcium contents of these feed ingredients, viz., maize, soybean meal and fish meal were found to be 0.26, 0.36 and 7.2% respectively. The averge phosphorus contents were found to be 0.40% for maize, 0.89% for soybean meal and 1.60% for fish meal. The average manganese contents were 12.5, 25.0 and 57.5 ppm for maize, soybean meal and fish meal respectively.

4.2 FEED CONSUMPTION

The responses in cumulative weekly feed consumption due to different levels of dietary calcium and manganese are presented in Table 4 to 5 and Figure 1 to 4.

Table 3. Concentration of calcium, phosphorus and manganese in feed ingredients

Ingredients	n	Manganese (ppm)	Phosphorus (%)	Calcium (%)
Maize	3	12.5	0.4	0.26
Soybean meal	3	25.0	0.89	0.36
Fish meal	3	57.5	1.60	7.2

n - number of analyses

Table 4. Effect of dietary manganese and calcium and cumulative weekly feed consumption of Japanese quail

FEED CONSUMPTION, g ± SE

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Mean for Manganese
		1-2 Week		
60	52.56 ±5.08	50.98 ±3.15	54.87 ±2.04	52.80[A] ±1.19
90	51.97 ±2.37	52.42 ±3.06	53.77 ±1.98	52.72[A] ±0.77
120	49.76 ±4.82	52.60 ±4.43	52.68 ±4.53	51.68[A] ±1.41
Mean for calcium	51.43[a] ±1.30	51.99[a] ±1.07	53.78[a] ±0.95	
		1-3 Week		
60	136.10 ±3.18	128.16 ±8.08	136.09 ±3.74	133.45[A] ±2.06
90	135.75 ±3.93	129.23 ±6.55	132.20 ±4.37	132.39[A] ±1.74
120	127.78 ±7.53	133.80 ±7.83	130.26 ±2.56	130.61[A] ±2.05
Mean for calcium	133.21[a] ±2.03	130.39[a] ±2.34	132.85[a] ±1.35	

Means bearing a common superscript are not significantly (P $\leq$ 0.05) different.

Table 5. Effect of dietary manganese and calcium on cumulative weekly feed consumption of Japanese quail

FEED CONSUMPTION, g ± SE

Manganese mg/kg	Calcium % 0.5	Calcium % 0.8	Calcium % 1.1	Means for Manganese
		1-4 Week		
60	233.96 ±5.58	226.15 ±9.62	238.62 ±9.08	232.91[A] ±3.00
90	223.02 ±11.87	231.65 ±4.68	234.69 ±4.05	229.78[A] ±2.84
120	226.90 ±9.77	235.19 ±8.75	227.89 ±3.71	229.99[A] ±2.62
Means for calcium	227.96[a] ±3.16	231.00[a] ±2.65	233.74[a] ±2.36	
		1-5 Week		
60	345.85 ±.699	340.15 ±14.56	353.03 ±11.26	346.34[A] ±3.74
90	333.87 ±9.77	339.48 ±13.73	348.64 ±3.92	340.66[A] ±3.62
120	345.68 ±11.89	350.20 ±10.65	344.33 ±5.52	346.74[A] ±2.95
Means for calcium	341.80[a] ±3.46	343.28[a] ±4.13	348.66[a] ±2.53	

Means bearing a common superscript are not significantly (P / 0.05) different.

Table 6. Analysis of variance of feed consumption of Japanese quail

		MEAN SQUARES			
Source of variation	d.f.	WEEK			
		1-2	1-3	1-4	1-5
Calcium (Ca)	2	13.496^{NS}	21.156^{NS}	75.127^{NS}	117.625^{NS}
Manganese (Mn)	2	3.520^{NS}	18.516^{NS}	27.500^{NS}	104.00^{NS}
Interation (CaxMn)	4	4.502^{NS}	50.625^{NS}	107.687^{NS}	101.187^{NS}
Error	18	13.569	32.375	63.465	107.347

NS - not significant at $(P < 0.05)$

At 2 week of age the cumulative feed consumption showed an increasing trend with increasing dietary calcium level and decreasing trend with increasing dietary manganese level. However, these differences were not significant (P ∠ 0.05). At 3 week of age the response in cumulative feed consumption due to levels of manganese in diet still showed a decreasing trend with increasing dietary manganese level. The response due to dietary calcium was highest (133.21±2.03) at 0.5% and lowest (130.39±2.34) at 0.8% dietary calcium. At 4 week of age the response showed increasing trend with increasing dietary calcium. And the response due to dietary manganese was highest (232.91±3.00) at 60 mg/kg and lowest (229.78±2.84) at 90 mg/kg. At 5 week of age the response in cumulative feed consumption still showed an increasing trend with increasing dietary level of calcium. But the response due to dietary manganese was highest (346.74±2.95) at 120 mg manganese/kg and lowest (340.66±3.62) at 90 mg/kg. However, these differences observed from 2 upto 5 week of age were not significant (P ∠ 0.05).

The mean squares of analysis of variance for cumulative feed consumption from 2 to 5 week are shown in Table 6. The main effects of calcium and manganese were not significant (P ∠ 0.05) upto 5 week of age. The two-way Ca x Mn interactions were also not significant upto 5 week of age.

4.3 GROWTH

The responses in cumulative body weight gain due to different levels of dietary calcium and manganese are shown in Table 7 to 8 and Figures 5 to 8.

Upto 3 week of age the response in cumulative body weight gain was virtually not affected by the levels of dietary calcium and

Table 7. Effect of dietary manganese and calcium on body weight gain of Japanese quail

WEIGHT GAIN, g ± SE

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
		1-2 Week		
60	26.75 ±1.83	26.02 ±2.33	26.15 ±1.66	26.30[A] ±0.67
90	27.16 ±1.04	25.66 ±1.37	26.09 ±2.10	26.30[A] ±0.50
120	24.90 ±0.01	28.20 ±0.72	25.25 ±1.66	26.12[A] ±0.60
Means for calcium	26.27[a] ±0.49	26.63[a] ±0.62	25.83[a] ±0.65	
		1-3 Week		
60	59.25 ±4.43	58.00 ±5.38	61.18 ±1.59	59.47[A] ±1.27
90	60.02 ±0.30	59.14 ±1.91	60.46 ±0.83	59.87[A] ±0.40
120	56.65 ±0.93	60.84 ±2.76	58.08 ±1.58	58.52[A] ±0.83
Means for calcium	58.64[a] ±0.91	59.33[a] ±1.14	59.90[a] ±0.62	

Means bearing a common superscript are not significantly ($P \angle\ 0.05$) different

Table 8. Effect of dietary manganese and calcium on body weight gain of Japanese quail

WEIGHT GAIN, g ± SE

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
		1-4 Week		
60	87.85 ±2.86	89.33 ±2.55	92.94 ±2.30	90.04^{A} ±1.49
90	83.75 ±3.99	91.45 ±2.62	92.36 ±1.50	89.18^{A} ±2.05
120	86.37 ±0.68	92.33 ±1.59	89.37 ±1.16	89.35^{A} ±1.05
Means for calcium	85.99^{a} ±1.77	91.04^{a} ±1.02	91.56^{a} ±1.03	
		1-5 Week		
60	109.36 ±2.78	115.28 ±3.30	113.73 ±1.50	112.79^{A} ±1.68
90	107.79 ±2.90	112.74 ±3.40	118.00 ±1.52	112.84^{A} ±2.03
120	108.90 ±3.13	114.93 ±1.53	113.30 ±1.58	112.37^{A} ±1.43
Means for calcium	108.68^{a} ±1.59	114.32^{b} ±1.49	115.02^{b} ±1.11	

Means bearing a common superscript are not significantly ($P \angle 0.05$) different.

Table 9. Analysis of variance of body weight gain of Japanese quail

MEAN SQUARE

Source of variation	d.f.	WEEKS 1-2	1-3	1-4	1-5
Calcium (Ca)	2	1.429^{NS}	3.617^{NS}	85.07*	108.391*
Manganese (Mn)	2	0.104^{NS}	4.316^{NS}	1.836^{NS}	0.625^{NS}
Interaction (CaxMn)	4	5.33^{NS}	9.553^{NS}	14.598^{NS}	13.617^{NS}
Error	18	2.952	7.391	17.467	20.908

* significant at $P \leq 0.05$

NS - not significant

manganese. At 4 weeks of age there was a significant ($P \angle 0.05$) increase in body weight gain when dietry calcium was increased from 0.5 to 0.8%. Further increase from 0.8 to 1.1% dietary calcium did not result in further increase ($P \angle 0.05$) of body weight gain. On the other hand, the response due to dietary manganese was highest (90.04±1.49) at 60 mg/kg and lowest (89.18±2.05) at 90 mg/kg. However, this difference in response in body weight gain due to dietary manganese was not significant ($P \angle 0.05$). At 5 week of age the response pattern due to dietary calcium was similar to that in 4 week of age and dietary manganese had virtually no effect on the response in cumulative body weight gain at 5 week of age.

The mean squares of analyses of variance for cumulative body weight gain from 1-5 week of age are shown in Table 9. The main effects of calcium was not significant ($P \angle 0.05$) until upto 3 week of age and become significant ($P \angle 0.05$) from 4 week. The main effects of manganese and two-way Ca x Mn interaction on body weight responses were not significant ($P \angle 0.05$) upto 5 week of age.

4.4 FEED CONVERSION EFFICIENCY

The responses in feed/gain, g, due to different dietary levels of calcium and manganese are shown in Table 10 and 11 and Figures 9 to 12.

Feed conversion efficiency upto 3 week of age was almost not affected by the levels of calcium and manganese in the diet. At 4 week of age there was a significnt reduction ($P \angle 0.05$) in feed/gain g, ratio (cumulative feed consumption/cumulative body weight gain, g) when the dietary calcium was increased from 0.5 to 0.8% but further increase to 1.1% did not result in further improvement of feed conversion efficiency. The response in feed/gain, g, at 4 week due to dietary manganese showed

Table 10. Effect of dietary manganese and calcium on feed conversion efficiency of Japanese quail

FEED/GAIN, g ± SE

Manganese mg/kg	Calcium % 0.5	Calcium % 0.8	Calcium % 1.1	Means for manganese
		1-2 Week		
60	1.964 ±0.122	1.963 0.054	2.112 0.170	2.013^{A} 0.044
90	1.913 ±0.744	2.043 ±0.109	2.067 ±0.192	2.007^{A} ±0.44
120	1.997 ±0.039	1.863 ±0.114	2.085 ±0.084	1.982^{A} ±0.051
Means for calcium	1.958^{a} ±0.039	1.956^{a} ±0.038	2.088^{a} ±0.045	
		1-3 Week		
60	2.307 ±0.216	2.214 ±0.079	2.224 ±0.019	2.248^{A} ±0.042
90	2.262 ±0.055	2.185 ±0.104	2.187 ±0.099	2.212^{A} ±0.028
120	2.254 ±0.099	2.199 ±0.096	2.255 ±0.005	2.236^{A} ±0.025
Means for calcium	2.274^{a} ±0.042	2.199^{a} ±0.027	2.222^{a} ±0.019	

Means bearing a common superscript are not significantly (P / 0.05) different.

Table 11. Effect of dietary manganese and calcium on feed conversion efficiency of Japanese quail

FEED/GAIN, g ± SE

Manganese mg/kg	Calcium % 0.5	Calcium % 0.8	Calcium % 1.1	Means for Manganese
		1-4 Week		
60	2.671 ±0.126	2.532 ±0.014	2.567 ±0.024	2.589[A] ±0.043
90	2.672 ±0.084	2.533 ±0.043	2.541 ±0.024	2.582[A] ±0.036
120	2.627 ±0.079	2.548 ±0.068	2.550 ±0.036	2.575[A] ±0.034
Means for calcium	2.657[a] ±0.049	2.538[b] ±0.024	2.553[b] ±0.015	
		1-5 Week		
60	3.170 ±0.138	2.955 ±0.024	3.104 ±0.083	3.076[A] ±0.055
90	3.099 ±0.054	2.944 ±0.035	2.956 ±0.064	2.999[A] ±0.036
120	3.146 ±0.023	3.047 ±0.072	3.039 ±0.014	3.077[A] ±0.028
Means for calcium	3.138[a] ±0.045	2.982[b] ±0.029	3.033[ab] ±0.035	

Means bearing a common superscript are not significantly (P $\angle$ 0.05) significant

Table 12. Analysis of variance of feed conversion efficiency of Japanese quail

MEAN SQUARES

Source of variation	d.f.	WEEK			
		1-2	1-3	1-4	105
Calcium (Ca)	2	0.051^{NS}	0.013^{NS}	0.038*	0.057*
Manganese (Mn)	2	0.002^{NS}	0.003^{NS}	0.000^{NS}	0.018^{NS}
Interaction (CaxMn)	4	0.014^{NS}	0.002^{NS}	0.001^{NS}	0.006^{NS}
Error	18	0.017	0.011	0.013	0.013

* significant at P $\angle$ 0.05

NS -not significant at P $\angle$ 0.05)

a decreasing trend with increasing dietary manganese, though not significant (P $\angle$ 0.05). At 5 week of age the response in feed/gain, g, due to dietary calcium was lowest (2.982±0.029) at 0.8% calcium, and there was significant increase in response when calcium was reduced to 0.5 or increased to 1.1% in the diet. The response due to dietary manganese was lowest (2.999±0.036) at 90 mg/manganese/kg diet and there was slight increase when manganese was either reduced to 60 mg or increased to 120 mg/kg. However these differences of response in feed/gain, g, were not significant (P $\angle$ 0.05).

The mean squares of analysis of variance for feed conversion efficiency of Japanese quails from 1-5 week of age are shown in Table 12. The main effects of calcium on feed conversion efficiency were not significnt (P $\angle$ 0.05) until upto 3 week of age and become significant from 4 week onward. The main effect of manganese and two-way Ca x Mn interactions were not significant upto 5 week of age.

4.5 <u>MANGANESE INTAKE</u>

The responses in daily manganese intake (mg/bird) due to different dietary manganese levels are shown in Table 13 to 14 and Figure 13.

Daily manganese intake (mg/bird) increased linearly (P $\angle$ 0.01) with the increasing level of manganese in the diet. Dietary calcium had no effect (P $\angle$ 0.05) on the daily manganese intake of Japanese quail. The daily manganese intake (mg/bird) from 1-2 week at 60, 90 and 120 mg manganese/kg diet, were 0.425±0.010, 0.677±0.009 and 0.8860±0.024, respectively. The daily manganese intake (mg/bird) at 60, 90 and 120 mg manganese from 1-3 week were 0.5719±0.008, 0.8507±0.011 and 1.1188±0.017, from 1-4 week of age, 0.6654±0.008, 0.9847±0.036 and

Table 13. Effect of dietary manganese and calcium on daily manganese intake of Japanese quail

MANGANESE INTAKE, mg/bird/day ± SE

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
		1-2 Week		
60	0.4505 ±0.044	0.4369 ±0.027	0.4703 ±0.017	0.4526[A] ±0.010
90	0.6682 ±0.030	0.6738 ±0.039	0.6914 ±0.025	0.6778[B] ±0.009
120	0.8530 ±0.083	0.9017 ±0.076	0.9032 ±0.077	0.8860[C] ±0.024
Means for calcium	0.6572[a] ±0.060	0.6708[a] ±0.068	0.6883[a] ±0.064	
		1-3 Week		
60	0.5833 ±0.014	0.5492 ±0.035	0.5832 ±0.016	0.5719[A] ±0.008
90	0.8726 ±0.025	0.8307 ±0.167	0.8498 ±0.028	0.8507[B] ±0.011
120	1.0952 ±0.064	1.1468 ±0.067	1.1145 ±0.018	1.1188[C] ±0.017
Means for calcium	0.8500[a] ±0.075	0.8422[a] ±0.087	0.8492[a] ±0.077	

Means bearing a common superscript are not significantly (P / 0.05) different.

Table 14. Effect of dietary manganese and calcium on daily manganese intake of Japanese quail

MANGANESE INTAKE, mg/bird/day ± SE

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
		1-4 Week		
60	0.6884 ±0.016	0.6461 ±0.016	0.6817 ±0.026	0.6654^{A} ±0.008
90	0.9557 ±0.050	0.9927 ±0.020	1.0057 ±0.076	0.9847^{B} ±0.036
120	1.2965 ±0.056	±1.3439 ±0.052	1.3022 ±0.021	1.3142^{C} ±0.045
Means for calcium	0.9736^{a} ±0.917	0.9942^{a} ±0.101	0.9966^{a} ±0.089	
		1-5 Week		
60	0.7411 ±0.015	0.7288 ±0.030	0.7564 ±0.024	0.7421^{A} ±0.008
90	1.2732 ±0.372	1.0912 ±0.044	1.1206 ±0.013	1.1616^{B} ±0.068
120	1.4815 ±0.054	1.5008 ±0.046	1.4756 ±0.024	1.3748^{C} ±0.007
Means for calcium	1.1652^{a} ±0.127	1.1069^{a} ±0.112	1.1175^{a} ±0.104	

Means bearing a common superscript are not significantly (P $\underline{/}$ 0.05) different.

Table 15. Analysis of variance of daily manganese intake of Japanese quail

Source of variation	d.f.	MEAN SQUARES WEEK 1-2	1-3	1-4	1-5
Calcium (Ca)	2		0.000^{NS}	0.001^{NS}	0.009^{NS}
Manganese (Mn)	2	0.423**	0.673**	0.947**	1.252**
Interaction (Ca x Mn)	4	0.001^{NS}	0.002^{NS}	0.002^{NS}	0.011^{NS}
Error	18	0.003	0.002	0.001	0.016

** significant at P $\underline{/}$ 0.01

NS - not significant

1.3142±0.045; and from 1-5 week of age were 0.7421±0.008, 1.1616±0.068 and 1.4860±0.013, respectively.

The mean squares of analysis of variance for daily manganese intake (mg/bird) of Japanese quail are shown in Table 15. The main effects of managanese were significant (P /_ 0.01) upto 5 week of age. The main effect of calcium and two-way Ca x Mn interactions were not significant (P /_ 0.05) upto 5 week of age.

4.6 CALCIUM INTAKE

The responses in daily calcium intake due to different dietary level of calcium and manganese from 1-5 week of age are shown in Table 16 to 17 and Figure 14.

Daily calcium intake (g/bird) of Japanese quail increased linearly (P /_ 0.01) with the increasing dietary calcium level. Dietary manganese had no effect (P /_ 0.05) on daily calcium intake. Daily calcium intake 9g/bird) of Japanese quail on different dietary calcium, 0.5, 0.8 and 1.1% were 0.3673±0.009, 0.5942±0.012 and 0.8451±0.015 from 1-2 week; 0.4782±0.007, 0.7454±0.014 and 1.0448±0.011 from 1-3 week; 0.5427±0.007, 0.8803±0.010 and 1.2243±0.013 from 1-4 week and 0.5989±0.024, 0.9807±0.012 and 1.3697±0.009 from 1-5 week respectively.

The mean squares of analysis of variance for daily calcium intake are shown in Table 18. The main effects of calcium were significant (P /_ 0.01) upto 5 week of age. The main effects manganese and two-way Ca x Mn interactions were not significant (P /_ 0.05) upto 5 week of age.

4.7 SERUM CALCIUM

The means and standard errors for serum calcium are shown in Table 19 and Figure 15.

Table 16. Effect of dietary manganese and calcium on daily calcium intake of Japanese quail

CALCIUM INTAKE, g/bird/day ± SE

Manganese mg/kg	Calcium % 0.5	Calcium % 0.8	Calcium % 1.1	Means for Manganese
		1-2 Week		
60	0.3754 ±0.039	0.5826 ±0.036	0.8623 ±0.032	0.6068[A] ±0.072
90	0.3712 ±0.017	0.5989 ±0.035	0.8450 ±0.031	0.6051[A] ±0.069
120	0.3554 ±0.034	0.6012 ±0.050	0.8278 ±0.071	0.5948[A] ±0.070
Means for calcium	0.3673[a] ±0.009	0.5942[b] ±0.012	0.8451[c] ±0.015	---
		1-3 Week		
60	0.4860 ±0.012	0.7323 ±0.046	1.0727 ±0.029	0.7637[A] ±0.086
90	0.4848 ±0.014	0.7384 ±0.037	1.0382 ±0.033	0.7538[A] ±0.030
120	0.4639 ±0.034	0.7655 ±0.046	1.0235 ±0.020	0.7510[A] ±0.081
Means for calcium	0.4782[a] ±0.007	0.7454[b] ±0.014	1.0448[c] ±0.011	

Means bearing a common superscript are not significantly ($P \leq 0.05$) different

Table 17. Effect of dietary manganese and calcium on daily calcium intake of Japanese quail

CALCIUM INTAKE, g/bird/day ± SE

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
		1-4 Week		
60	0.5569 ±0.013	0.8627 ±0.038	1.2498 ±0.047	0.8898^{A} ±0.100
90	0.5309 ±0.028	0.8824 ±0.017	1.2293 ±0.022	0.8809^{A} ±0.101
120	0.5402 ±0.020	0.8959 ±0.033	1.1937 ±0.019	0.8766^{A} ±0.095
Means for calcium	0.5427^{a} ±0.007	0.8803^{b} ±0.010	1.2243^{c} ±0.013	
		1-5 Week		
60	0.6375 ±0.026	0.9717 ±0.040	1.3868 ±0.044	0.9987^{A} ±0.108
90	0.5420 ±0.110	0.9699 ±0.039	1.3696 ±0.015	0.9605^{A} ±0.121
120	0.6173 ±0.022	1.0005 ±0.030	1.3527 ±0.022	0.9902^{A} ±0.106
Means for calcium	0.5989^{a} ±0.024	0.9807^{b} ±0.012	1.3697^{c} ±0.009	

Means bearing a common superscript are not significant (P $\underline{/}$ 0.05) different.

Table 18. Analysis of variance of daily calcium intake of Japanese quail

Source of variation	d.f.	MEAN SQUARES WEEK 1-2	1-3	1-4	1-5
Calcium (Ca)	2	0.514**	0.723**	1.045**	1.337**
Manganese (Mn)	2	0.000^{NS}	0.000^{NS}	0.000	0.004^{NS}
Interaction (Ca x Mn)	4	0.001^{NS}	0.001^{NS}	0.002^{NS}	0.003^{NS}
Error	18	0.002	0.001	0.001	0.002

** significant at P $\angle$ 0.01

NS - not significant

The serum calcium level was not affected by the level of dietary calcium and manganese (P /_ 0.05). The mean squares of analysis of variance for serum calcium are shown in Table 21 The main effect of calcium and manganese and two-way Ca x Mn interactions were not significant (P /_ 0.05).

4.8 SERUM PHOSPHORUS

The means and standard errors for serum phosphorus are shown in Table 19 and Figure 16.

The serum phosphorus level was virtually not affected by the dietary levels of calcium and manganese. The mean squares of analysis of variance for serum phosphorus are presented in Table 21 The main effects of calcium and manganese were not significant (P /_ 0.05). The two-way Ca x Mn interaction was also not significant (P /_ 0.05).

4.9 PERCENT BONE ASH

The response in percent bone ash due to different dietary levels of calcium and manganese is shown in Table 20 and Figure 17.

At low (0.5%) dietary calcium, percent bone ash showed increasing trend with the increasing dietary manganese level. There was a significant (P /_ 0.05) increase in percent bone ash when dietary manganese was increased from 60 to 90 mg/kg. Further increase of dietary manganese to 120 mg/kg resulted in slight increase in percent bone ash though not significant (P /_ 0.05).

Table 19. Effect of dietary manganese and calcium on blood calcium and phosphorus of Japanese quail at 5 week of age

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
	SERUM CALCIUM, mg/100 ml ± SE			
60	14.44 ±1.51	14.88 ±1.04	15.68 ±1.04	14.98[A] ±1.22
90	14.58 ±1.68	15.27 ±1.46	13.88 ±2.01	14.44[A] ±1.76
120	15.70 ±0.84	14.28 ±1.11	13.56 ±1.68	14.32[A] ±1.10
Means for calcium	14.85[a] ±1.22	14.73[a] ±1.11	14.11[a] ±1.75	
	SERUM INORGANIC PHOSPHORUS, mg/100 ml ± SE			
60	6.47 ±1.43	6.73 ±1.07	6.43 ±0.97	6.54[A] ±1.12
90	6.45 ±0.85	6.72 ±0.77	6.46 ±1.57	6.62[A] ±0.98
120	6.66 ±0.99	6.93 ±1.67	6.05 ±2.61	6.47[A] ±1.67
Means for calcium	6.52[a] ±1.10	6.79[a] ±1.58	6.32[a] ±1.50	

Means bearing a common superscript are not significantly ($P \leq 0.05$) different.

At normal level of dietary calcium (0.8%) highest (49.30±0.30) percent bone ash was obtained with 90 mg manganese/kg of diet. There was a slight decrease in percent bone ash when dietary manganese was reduced to 60 mg/kg and significant decrease (P $\underline{/}$ 0.05) in percent bone ash was observed when dietary manganese was increased from 90 to 120 mg/kg.

At high (1.1%) dietary calcium, percent bone ash showed decreasing trend with the increasing dietary manganese level. A significant reduction (P $\underline{/}$ 0.05) in percent bone ash was observed with high dietary calcium when dietary manganese was increased from 60 to 90 mg/kg. Further increase of dietry manganese to 120 mg/kg resulted in slight decrease in percent bone ash though not significant (P $\underline{/}$ 0.05).

Highest percent bone ash (49.56±0.26) was obtained with 0.5% calcium and 120 mg manganese/kg of diet followed by 49.30±0.30 with 0.8% calcium and 90 mg/kg of dietary manganese. The lowest value for percent bone ash (45.21±0.663) was obtained with 1.1% calcium and 120 mg/kg of dietary manganese.

The mean squares of analysis of variance for percent bone ash is shown in Table 21, The main effect of calcium and two-way Ca x Mn interactions on percent bone ash was significant (P $\underline{/}$ 0.05). But the main effect of manganese was not significant (P $\underline{/}$ 0.05).

4.10 TIBIAL BONE WEIGHT

The response in tibial bone weight due to different dietary levels of calcium and manganese is shown in Table 20 and Figures 18.

The response in tibial bone weight due to dietary calcium showed slight increase when calcium was increased from 0.5 to 0.8%

Table 20. Effect of dietary manganese and calcium on bone characteristics of Japanese quail at 5 week of age

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
	PERCENT BONE ASH ± SE			
60	47.21^{b} ±0.72	48.38^{cd} ±1.10	48.96^{cde} ±0.17	48.15 ±0.44
90	48.89^{cde} ±0.94	49.30^{de} ±0.30	46.11^{a} ±0.38	48.10 ±0.53
120	49.56^{e} ±0.26	48.28^{c} ±0.57	45.21^{a} ±0.66	47.68 ±0.69
Means for calcium	48.56 ±0.42	48.62 ±0.38	46.76 ±0.60	
	TIBIAL BONE WEIGHT, g ± SE			
60	0.982 ±0.047	0.979 ±0.058	0.953 ±0.035	0.972 ±0.016
90	0.907 ±0.075	0.994 ±0.013	0.998 ±0.032	0.959^{A} ±0.019
120	0.894 ±0.030	0.937 ±0.034	0.946 ±0.096	0.926^{A} ±0.019
Means for calcium	0.928^{a} ±0.020	0.970^{a} ±0.014	0.959^{a} ±0.019	

Means bearing a common superscript are not significantly ($P \angle 0.05$) different.

Table 21. Analysis of variance of bone and blood characteristics of Japanese quail at 5 week of age

MEAN SQUARES

Source of variation	d.f.	BONE CHARACTERISTICS		BLOOD CHARACTERISTICS	
		% bone ash	Tibial bone weight	Serum calcium mg/100 ml	Serum phosphorus mg/100 ml
Calcium (Ca)	2	10.033*	0.004^{NS}	5.34^{NS}	3.46^{NS}
Manganese (Mn)	2	0.596^{NS}	0.005^{NS}	3.91^{NS}	2.26^{NS}
Interaction (CaxMn)	4	8.221*	0.003^{NS}	4.25^{NS}	7.13^{NS}
Error	18	0.867	0.003	3.56	4.73

* significant at P $\angle$ 0.05)

NS - not significant

though not significant (P / 0.05). On the other hand, the tibial bone weight showed a decreasing trend with increasing level of dietary manganese. The decreases in tibial bone weight due to increasing dietary manganese level, however, were not significant (P / 0.05).

The mean squares of analysis of variance for tibial bone weight are shown in Table 21 The main effect of calcium, manganese and the two-way interactions were not significnt (P / 0.05).

1.11 <u>MORTALITY</u>

The percent survival of Japanese quail receiving different dietary levels of calcium and manganese are shown in Table 22 to 23 and Figure 19 to 22.

More number of chicks (96%) survived upto 5 week of age with 0.8% calcium and 90 mg Mn/kg than with any of the eight other diets. And least number of birds survived (82%) on diet containing 0.5% calcium and 90 mg Mn/kg. However, the percent survival was not signifiantly (P / 0.05) affected by the levels of calcium and manganese in the diets.

The mean squares of analysis of variance for percent survival are shown in Table 24 The main effets of calcium and manganese were not significant (P / 0.05). The two-way Ca x Mn interaction was also not significant upto 5 week of age.

Table 22. Influence of manganese and calcium on percent survival of Japanese quail

PERCENT SURVIVAL

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
		1-2 Week		
60	97.33 ±2.30	98.66 ±2.30	96.00 ±4.00	97.33[A] ±0.94
90	94.66 ±6.11	97.33 ±2.30	96.00 ±4.00	96.00[A] ±1.33
120	97.33 ±2.30	97.33 ±2.30	96.00 ±0.00	96.88[A] ±0.58
Means for calcium	96.44[a] ±1.24	97.77[a] ±0.70	96.00[a] ±0.94	
		1-3 Week		
60	93.33 ±8.33	96.00 ±0.00	96.00 ±4.00	95.11[A] ±1.60
90	94.66 ±6.11	97.35 ±2.30	94.66 ±4.62	95.55[A] ±1.40
120	93.33 ±6.11	96.00 ±4.00	94.66 ±2.30	94.66[A] ±1.33
Means for calcium	93.77[a] ±2.02	96.44[a] ±0.80	95.11[a] ±1.11	

Means bearing a common superscript are not significantly (P / 0.05) different.

Table 23. Influence of dietary manganese and calcium on percent survival of Japanese quail

PERCENT SURVIVAL

Manganese mg/kg	Calcium % 0.5	0.8	1.1	Means for Manganese
		1-4 Week		
60	92.00 ±8.00	94.66 ±2.30	94.66 ±6.11	93.77[A] ±1.77
90	85.33 ±18.47	96.00 ±0.00	94.66 ±4.62	92.00[A] ±3.59
120	93.33 ±6.11	96.00 ±4.00	94.66 ±2.30	94.66[A] ±1.33
Means for calcium	90.22[a] ±3.72	95.55[a] ±0.80	94.66[a] ±1.33	
		1-5 Week		
60	90.66 ±10.06	93.33 ±4.62	94.66 ±6.11	92.88[A] ±2.18
90	82.66 ±16.16	96.00 ±0.00	93.33 ±6.11	90.66[A] ±3.52
120	89.33 ±2.30	94.66 ±4.62	93.33 ±2.30	92.44[A] ±1.24
Means for calcium	87.55[a] ±3.43	94.66[a] ±1.15	93.77[a] ±1.50	

Means bearing a common superscript are not significantly (P $\angle$ 0.05) different.

Table 24 Analysis of variance of percent survival of Japanese quail

MEAN SQUARES

Source of variation	d.f.	WEEK 2	3	4	5
Calcium (Ca)	2	7.703^{NS}	16.000^{NS}	73.477^{NS}	135.109^{NS}
Manganese (Mn)	2	4.148^{NS}	1.781^{NS}	16.586^{NS}	12.445^{NS}
Interaction (CaxMn)	4	2.371^{NS}	1.773^{NS}	20.152^{NS}	24.887^{NS}
Error	18	10.667	23.112	58.667	54.519

NS - not significant at $P \leq 0.05$

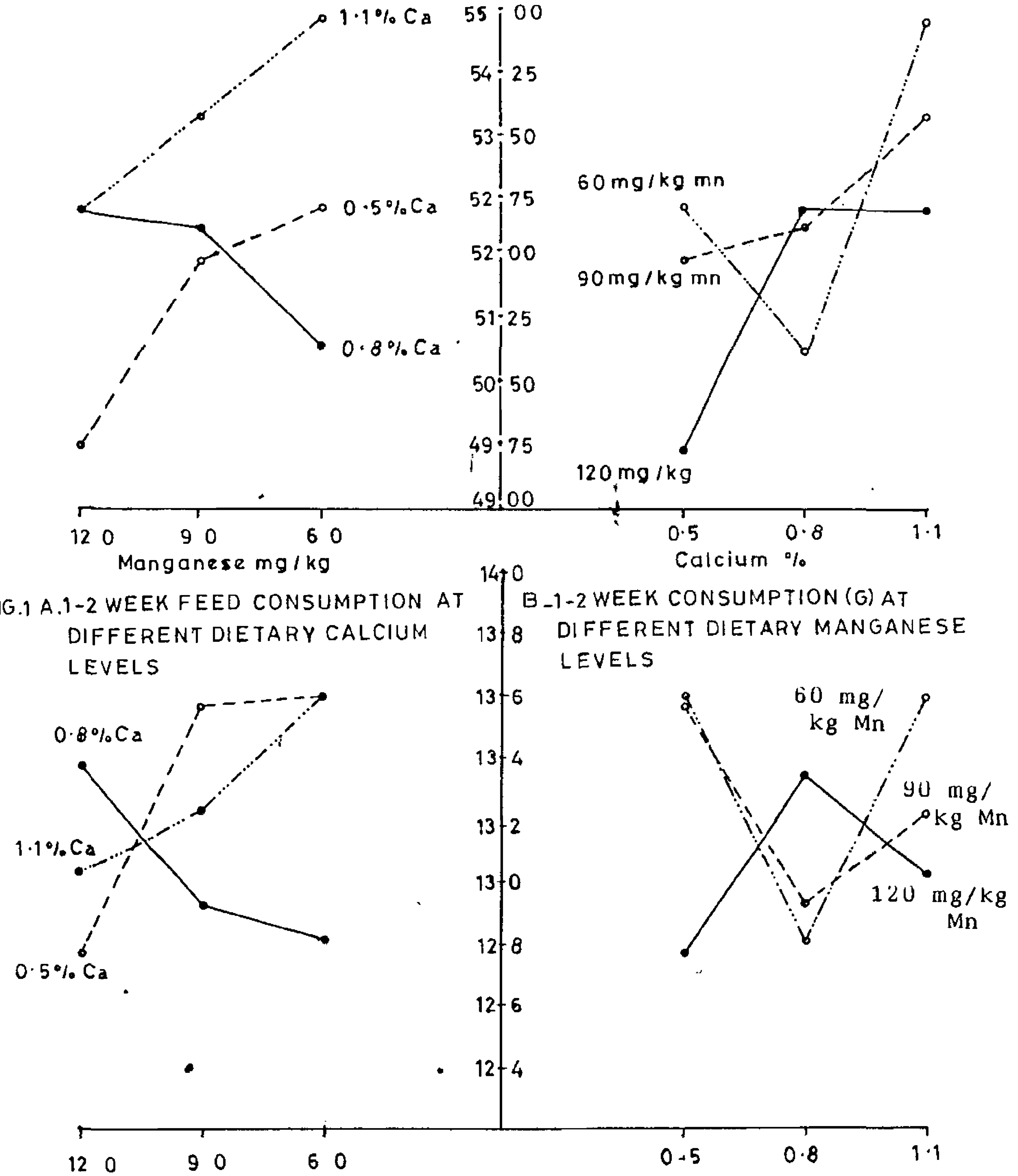


FIG.1 A.1-2 WEEK FEED CONSUMPTION AT DIFFERENT DIETARY CALCIUM LEVELS

B-1-2 WEEK CONSUMPTION (G) AT DIFFERENT DIETARY MANGANESE LEVELS

Fig. 2 A. 1-3 Week feed consumption at different dietary Calcium levels

2 B. 1-3 Week feed consumption at different dietary Manganese levels

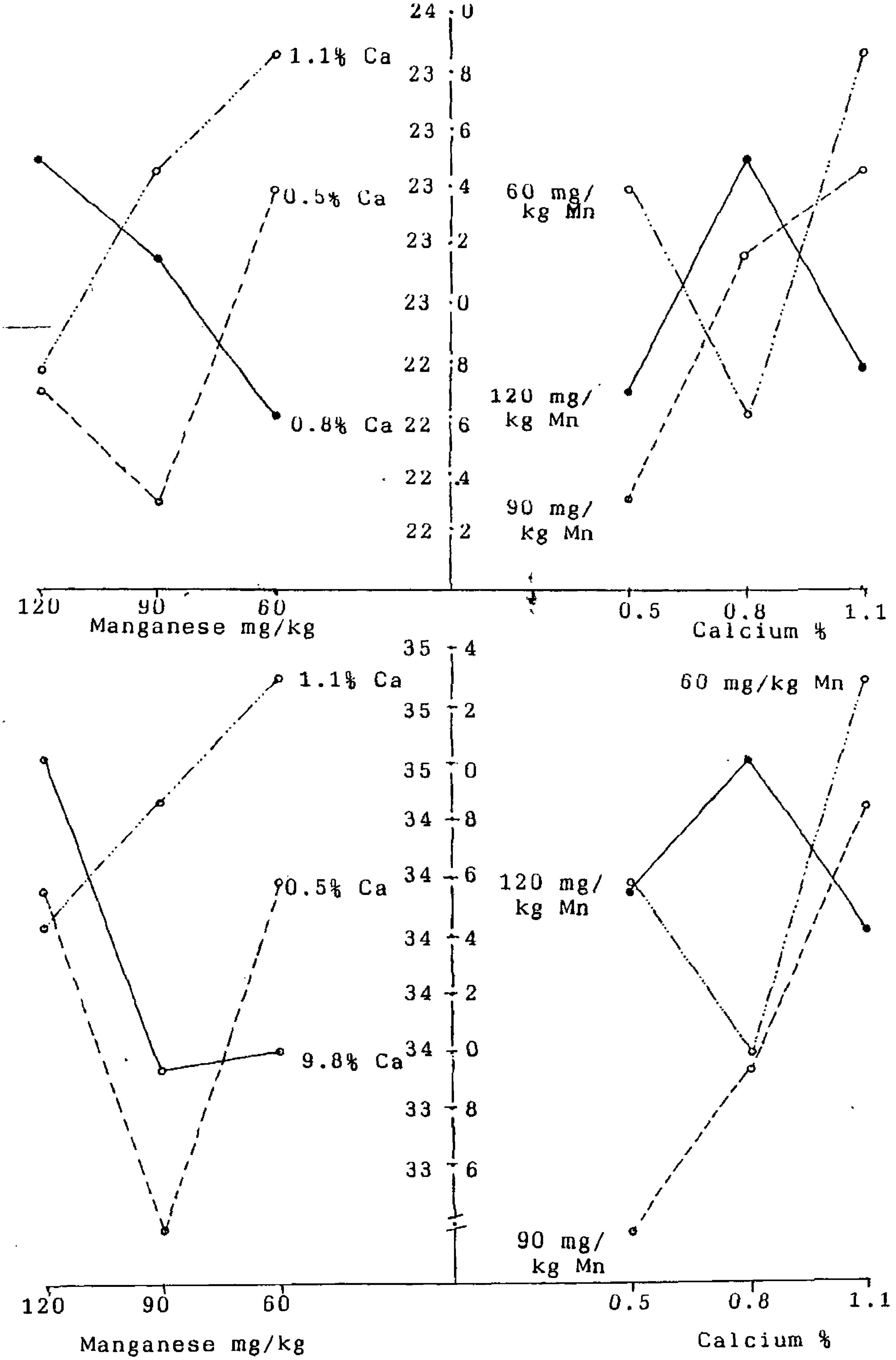
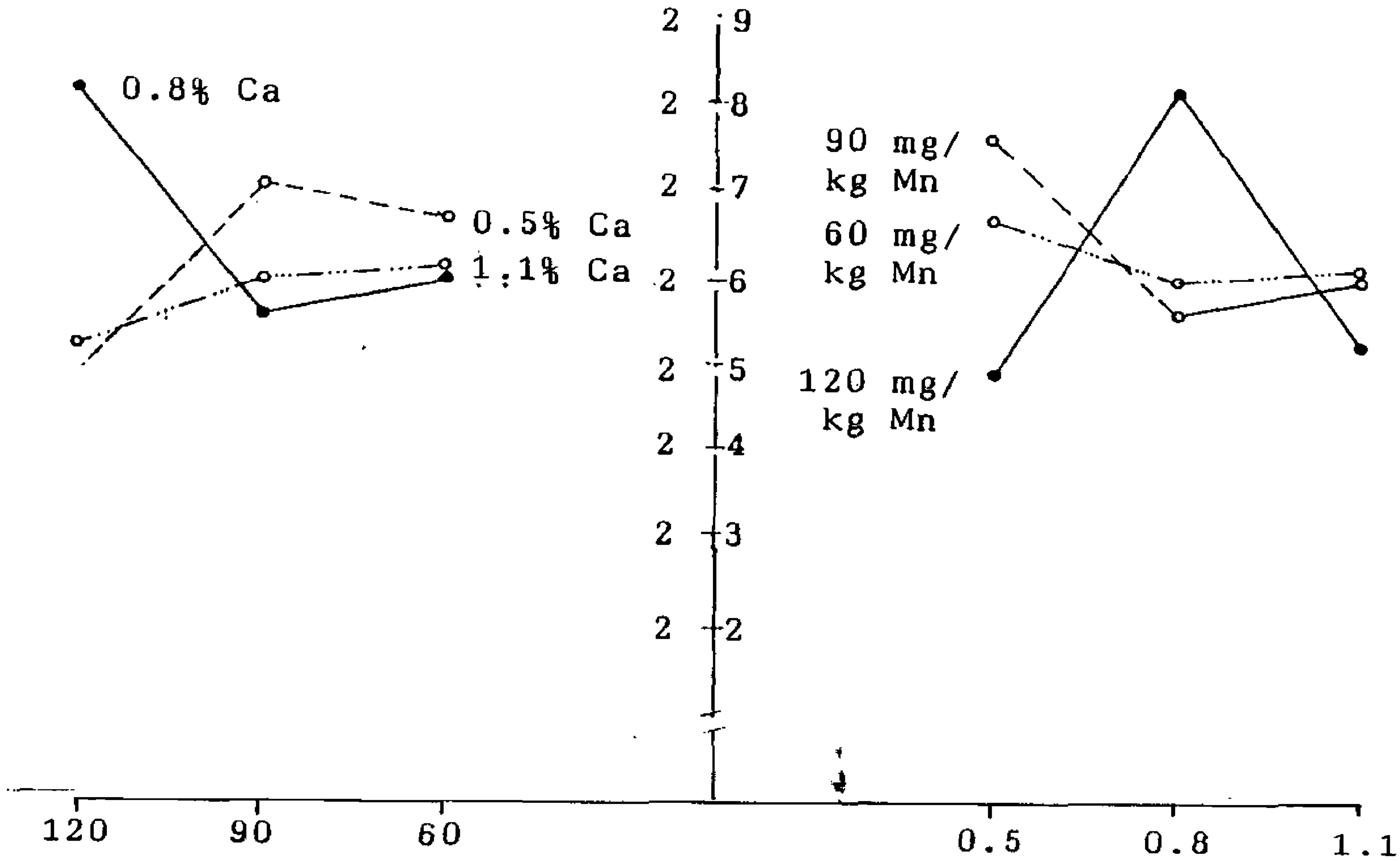

24 0
23 8
23 6
23 4
23 2
23 0
22 8
22 6
22 4
22 2
1.1% Ca
0.5% Ca
0.8% Ca
60 mg/ kg Mn
120 mg/ kg Mn
90 mg/ kg Mn
120
90
60
Manganese mg/kg
0.5
0.8
1.1
Calcium %
35 4
35 2
35 0
34 8
34 6
34 4
34 2
34 0
33 8
33 6
1.1% Ca
0.5% Ca
9.8% Ca
60 mg/kg Mn
120 mg/ kg Mn
90 mg/ kg Mn
120
90
60
Manganese mg/kg
0.5
0.8
1.1
Calcium %

Fig. 3 A. 1-4 Week feed consumption (g) at different dietary Calcium levels

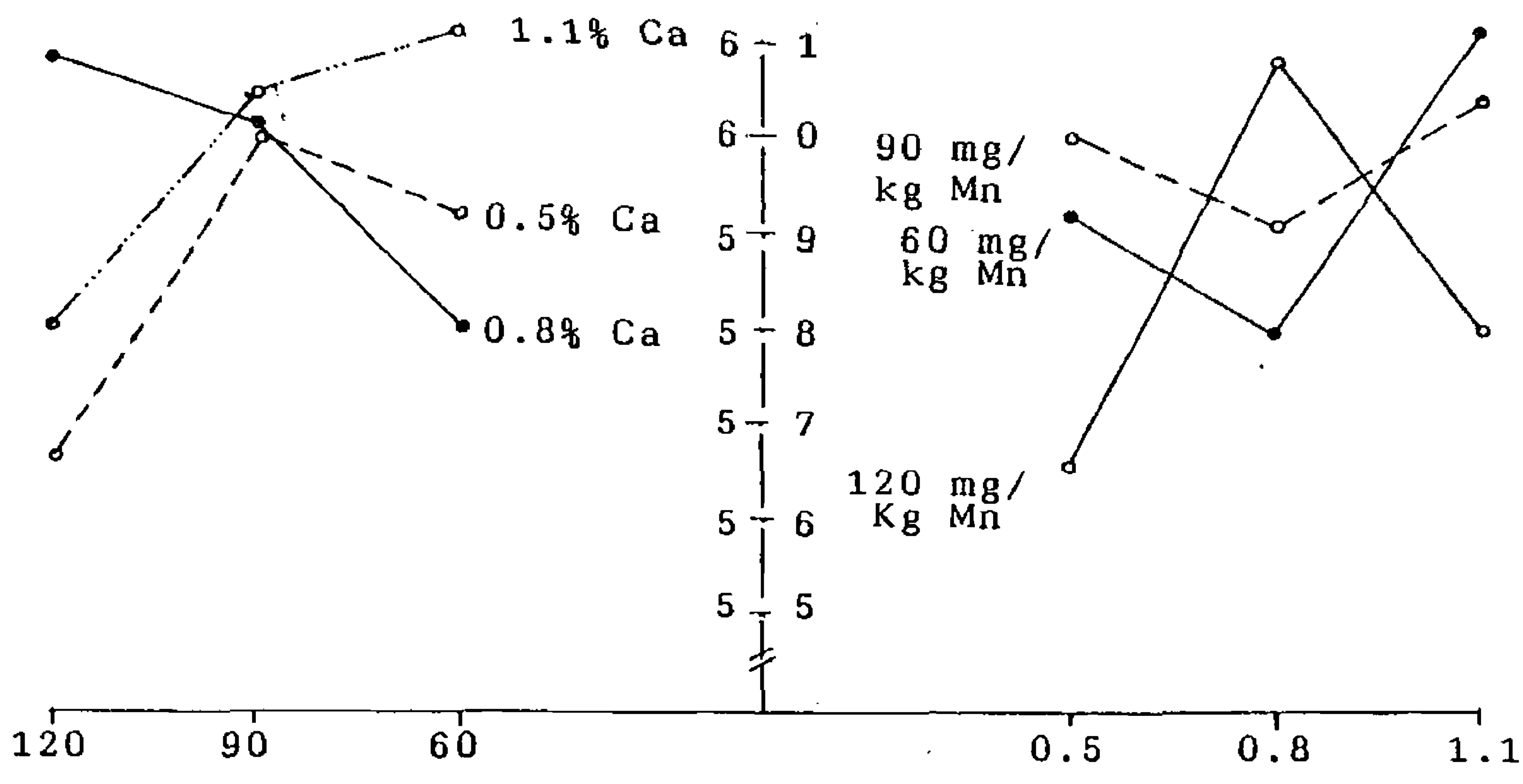
3 B. 1-4 Week feed consumption (g) at different dietary Manganese levels

Fig. 4 A. 1-5 Week feed consumption (g) at different dietary Calcium levels

4 B. 1-5 Week feed consumption (g) at different dietary Manganese levels



0.8% Ca
0.5% Ca
1.1% Ca
2 9
2 8
2 7
2 6
2 5
2 4
2 3
2 2
90 mg/ kg Mn
60 mg/ kg Mn
120 mg/ kg Mn
120
90
60
0.5
0.8
1.1



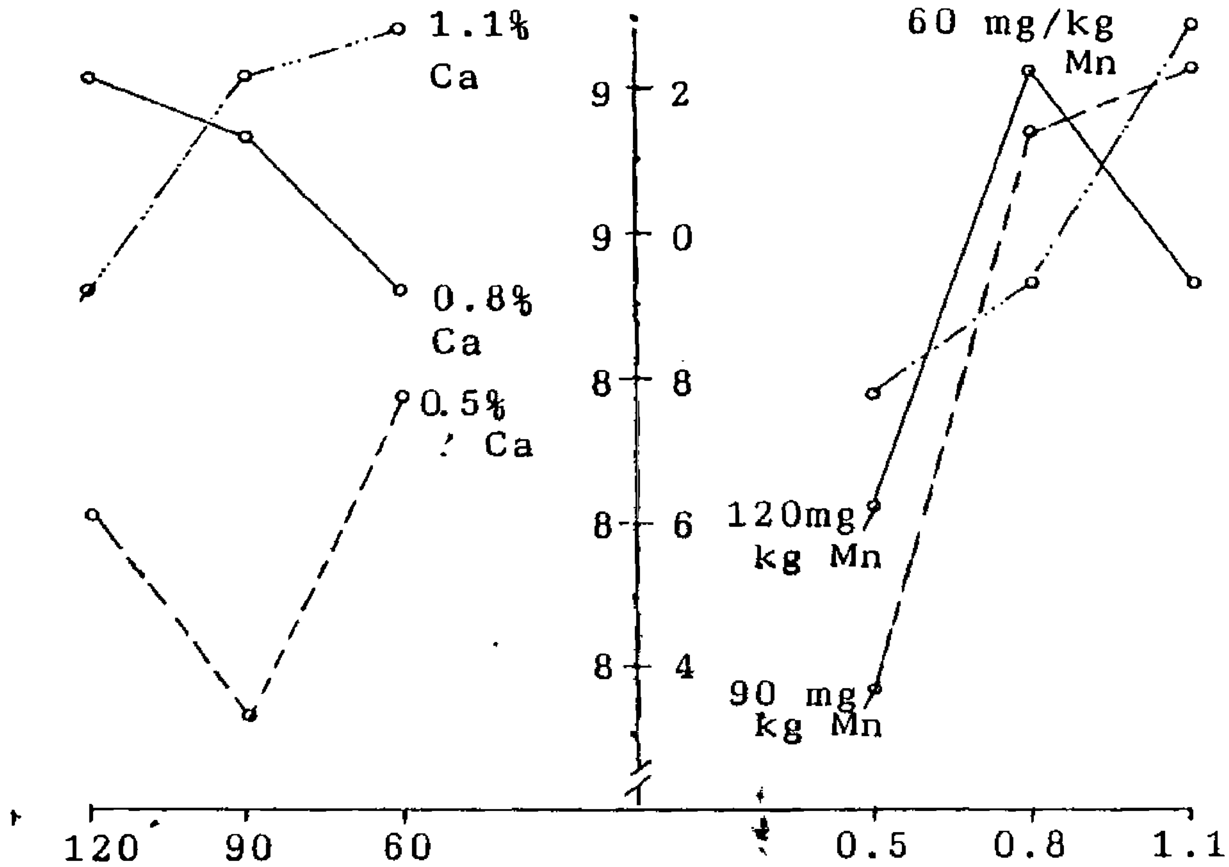
1.1% Ca
0.5% Ca
0.8% Ca
6 1
6 0
5 9
5 8
5 7
5 6
5 5
90 mg/ kg Mn
60 mg/ kg Mn
120 mg/ Kg Mn
120
90
60
0.5
0.8
1.1

Fig. 5 A 1-2 Week weight gain (g) at different dietary Calcium levels

5 B 1-2 Week weight gain (g) at different dietary Manganese levels

Fig. 6 A 1-3 Week weight gain (g) at different dietary Calcium levels

6 B 1-3 Week weight gain (g) at different dietary Manganese levels


1.1%
Ca
0.8%
Ca
0.5%
Ca
9 2
9 0
8 8
8 6
8 4
60 mg/kg
Mn
120mg/
kg Mn
90 mg/
kg Mn
120
90
60
0.5
0.8
1.1

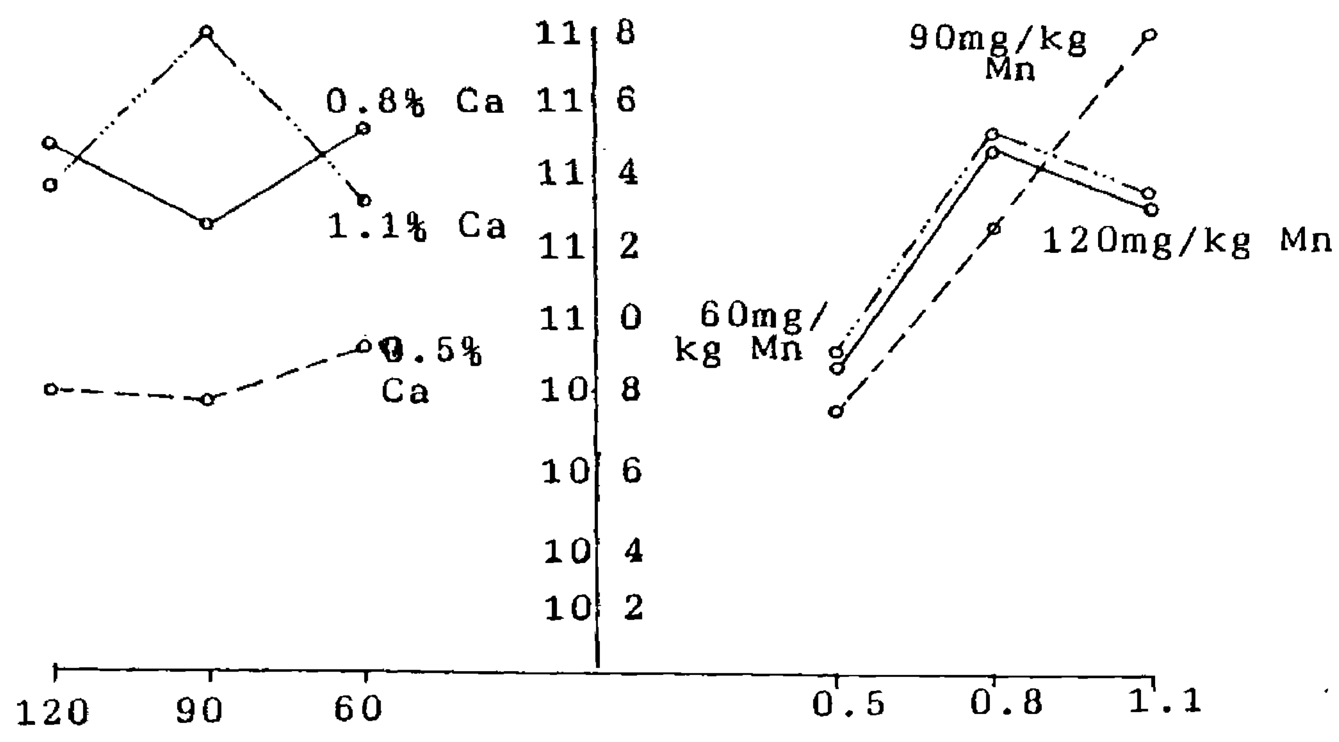
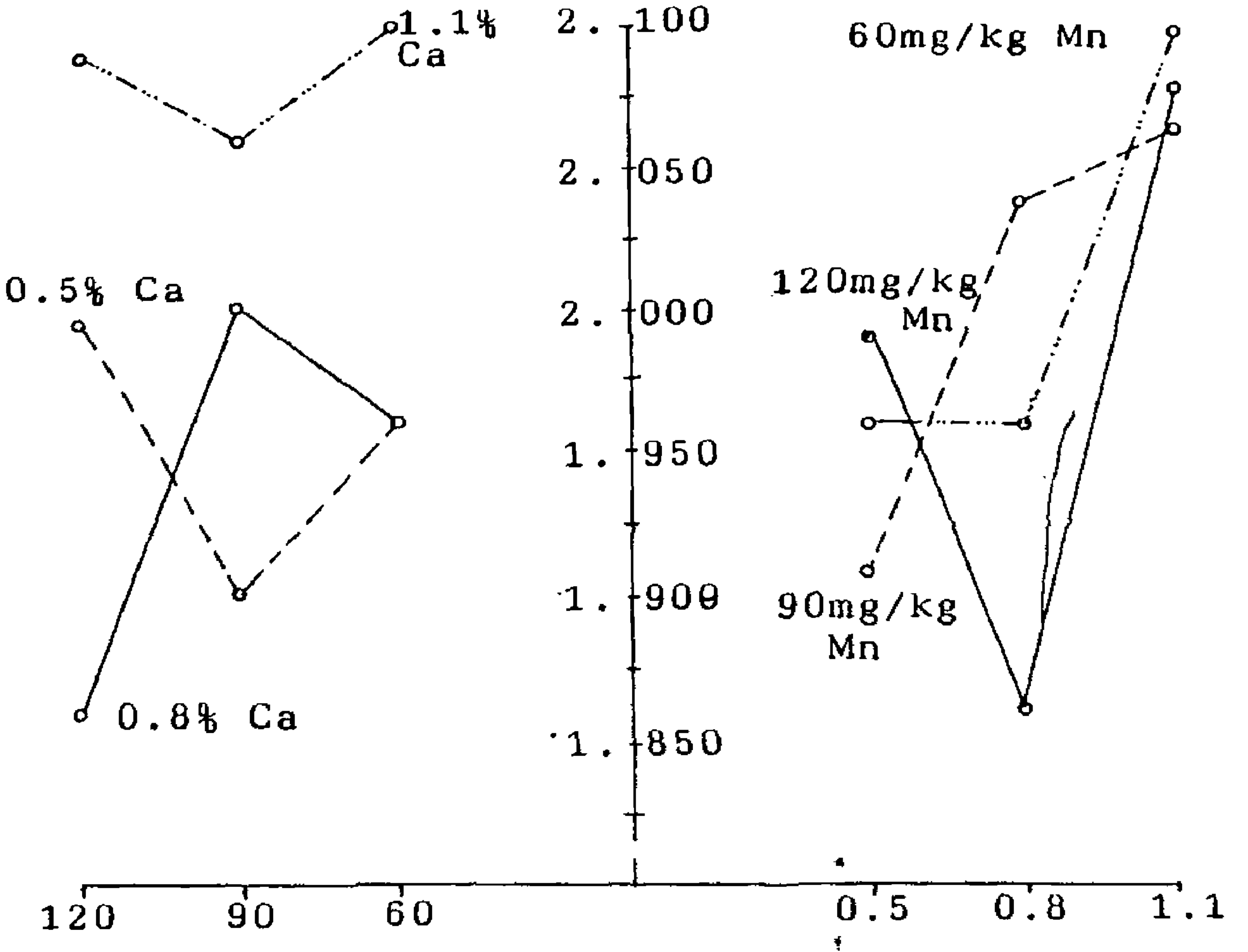

0.8% Ca
1.1% Ca
0.5%
Ca
11 8
11 6
11 4
11 2
11 0
10 8
10 6
10 4
10 2
90mg/kg
Mn
120mg/kg Mn
60mg/
kg Mn
120
90
60
0.5
0.8
1.1

Fig. 7 A 1-4 Week weight gain (g) at different dietary Calcium levels

7 B 1-4 Week weight gain (g) at different dietary Manganese levels

Fig. 8 A 1-5 Week weight gain (g) at different dietary Calcium levels

8 B 1-5 Week weight gain (g) at different dietary Manganese levels


1.1% Ca
0.5% Ca
0.8% Ca
2.100
2.050
2.000
1.950
1.900
1.850
60mg/kg Mn
120mg/kg Mn
90mg/kg Mn
120
90
60
0.5
0.8
1.1

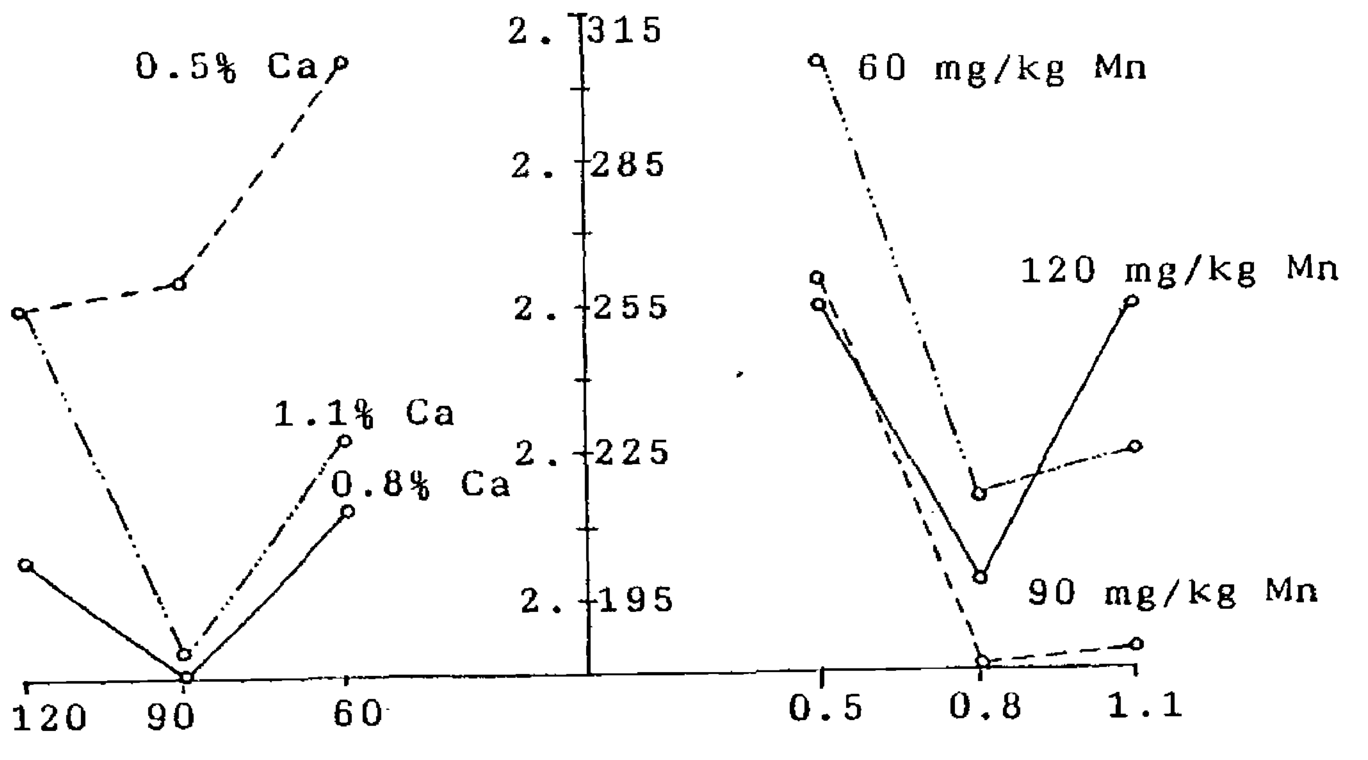
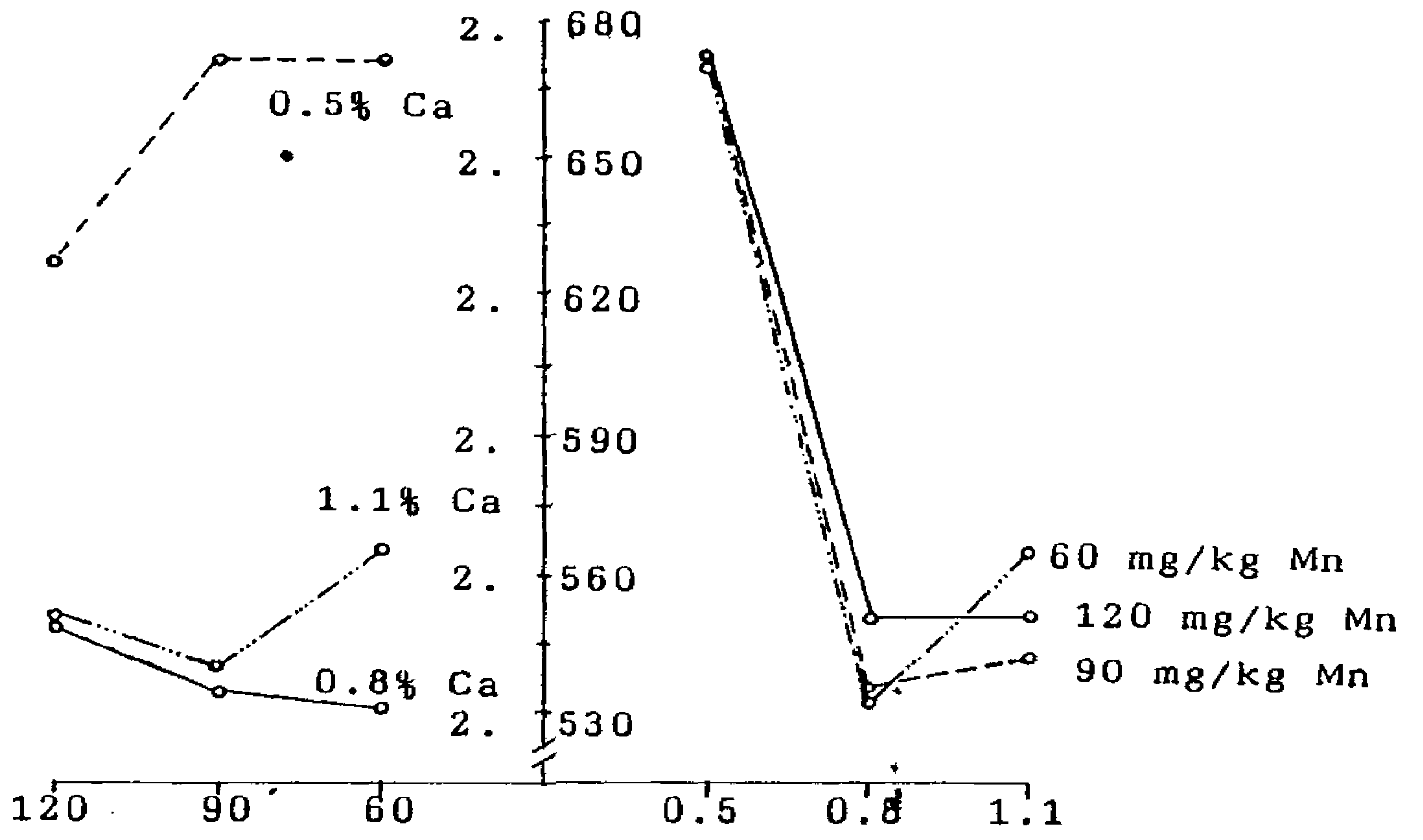

0.5% Ca
1.1% Ca
0.8% Ca
2.315
2.285
2.255
2.225
2.195
60 mg/kg Mn
120 mg/kg Mn
90 mg/kg Mn
120
90
60
0.5
0.8
1.1

Fig. 9 A 1-2 Week feed/gain ratio at different dietary Calcium levels

9 B 1-2 Week feed/gain ratio at different dietary Manganese levels

Fig.10 A 1-3 Week feed/gain ratio at different dietary Calcium levels

10 B 1-3 Week feed/gain ratio at different dietary Manganese levels


2. 680
2. 650
2. 620
2. 590
2. 560
2. 530
0.5% Ca
1.1% Ca
0.8% Ca
120
90
60
0.5
0.8
1.1
60 mg/kg Mn
120 mg/kg Mn
90 mg/kg Mn

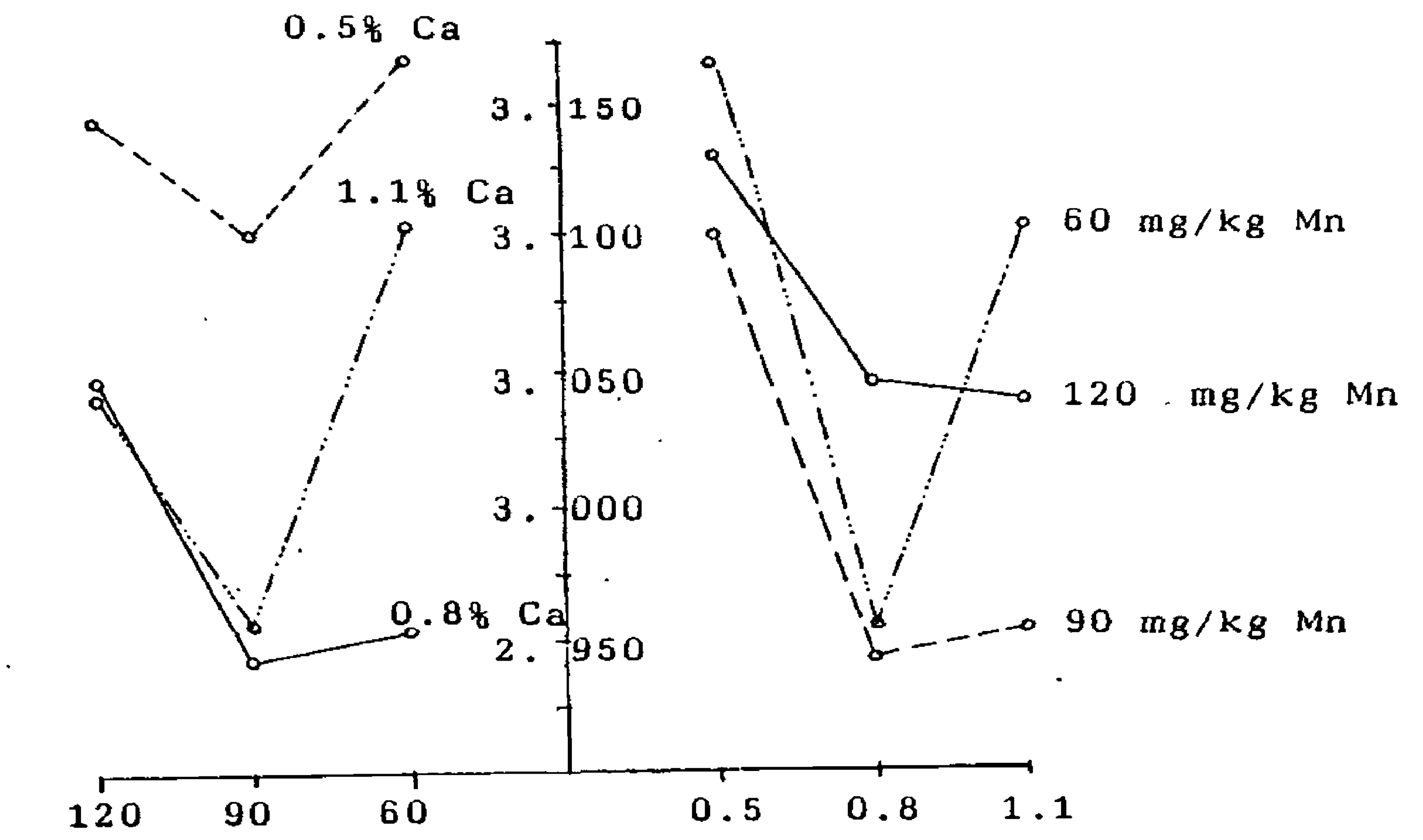

0.5% Ca
1.1% Ca
0.8% Ca
3. 150
3. 100
3. 050
3. 000
2. 950
120
90
60
0.5
0.8
1.1
60 mg/kg Mn
120 mg/kg Mn
90 mg/kg Mn

Fig.11 A 1-4 Week feed/gain ratio at different dietary Calcium levels

11 B 1-4 Week feed/gain ratio at different dietary Manganese levels

Fig.12 A 1-5 Week feed/gain ratio at different dietary Calcium levels

12 B 1-5 Week feed/gain ratio at different dietary Manganese levels

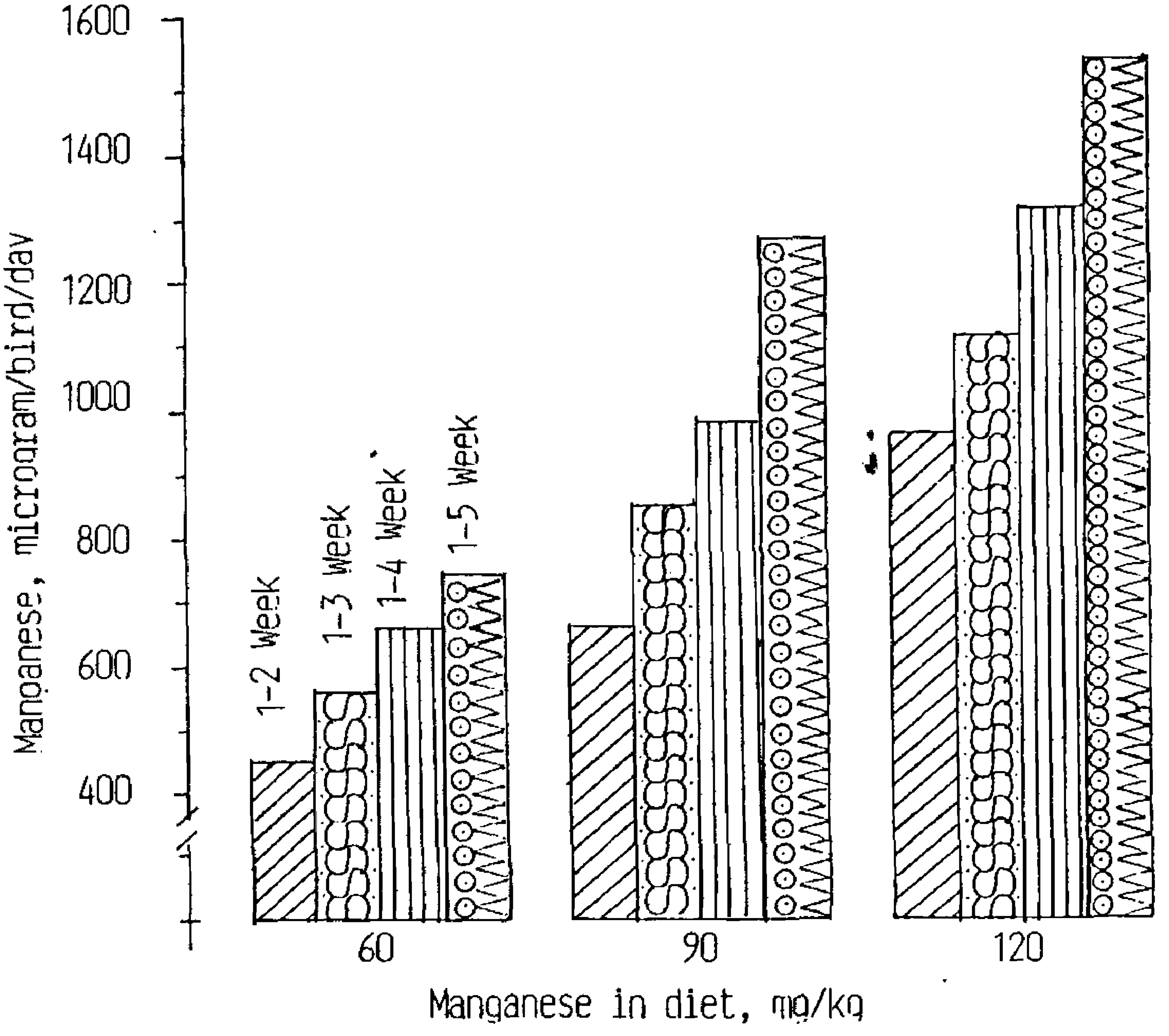


Fig. 13. Daily Manganese intake of Japanese Quail at different dietary Manganese levels

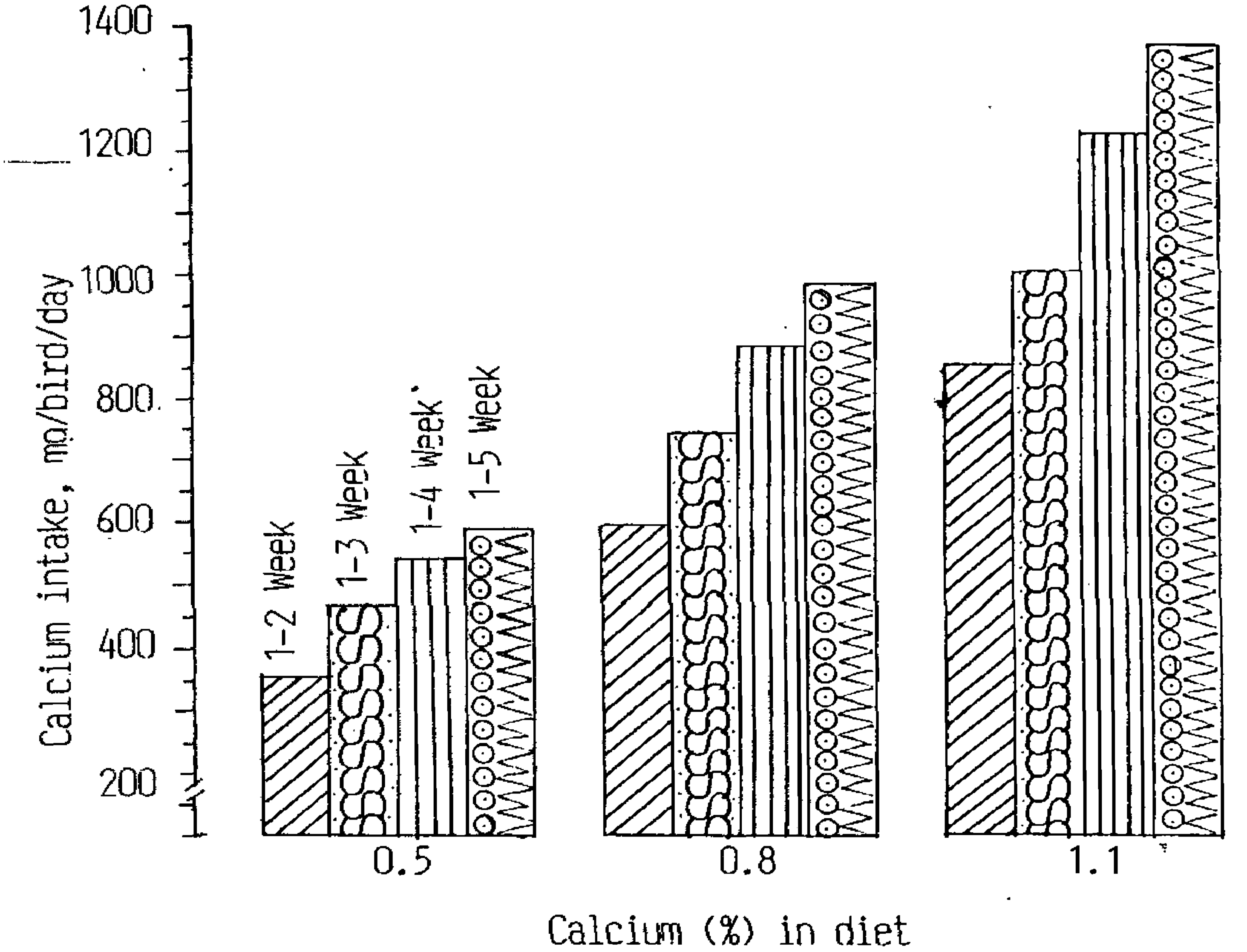
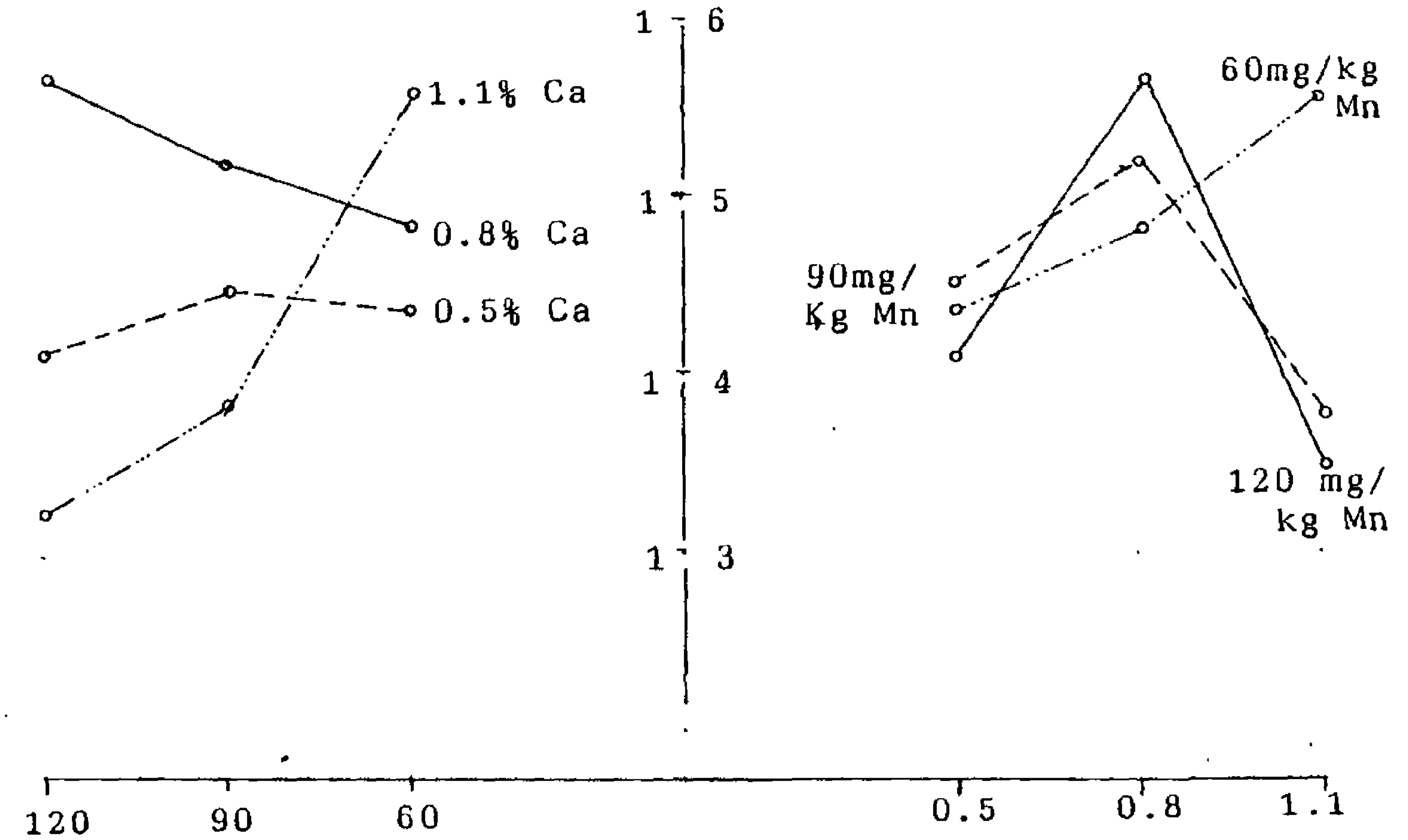


Fig.14. Daily calcium intake (mg) of Japanese Quail at different dietary Calcium levels


1 6
1 5
1 4
1 3
1.1% Ca
0.8% Ca
0.5% Ca
60mg/kg Mn
90mg/ Kg Mn
120 mg/ kg Mn
120
90
60
0.5
0.8
1.1

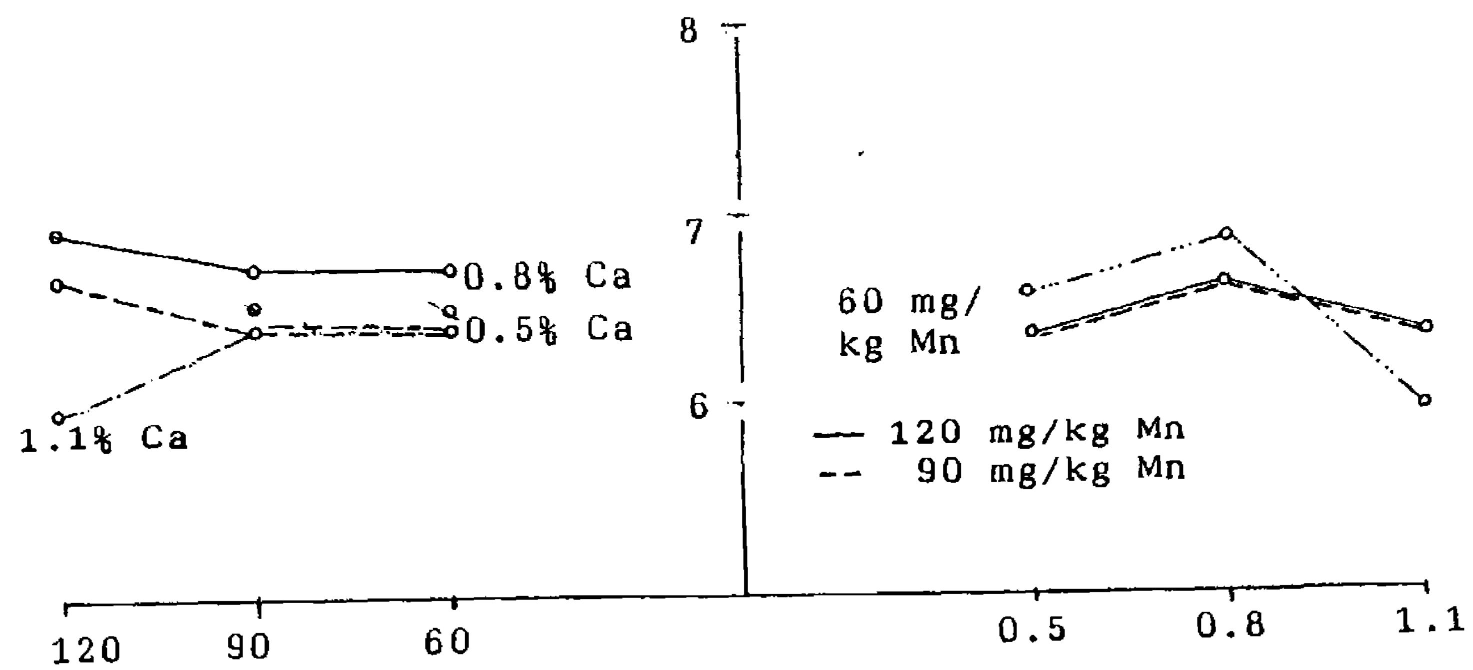
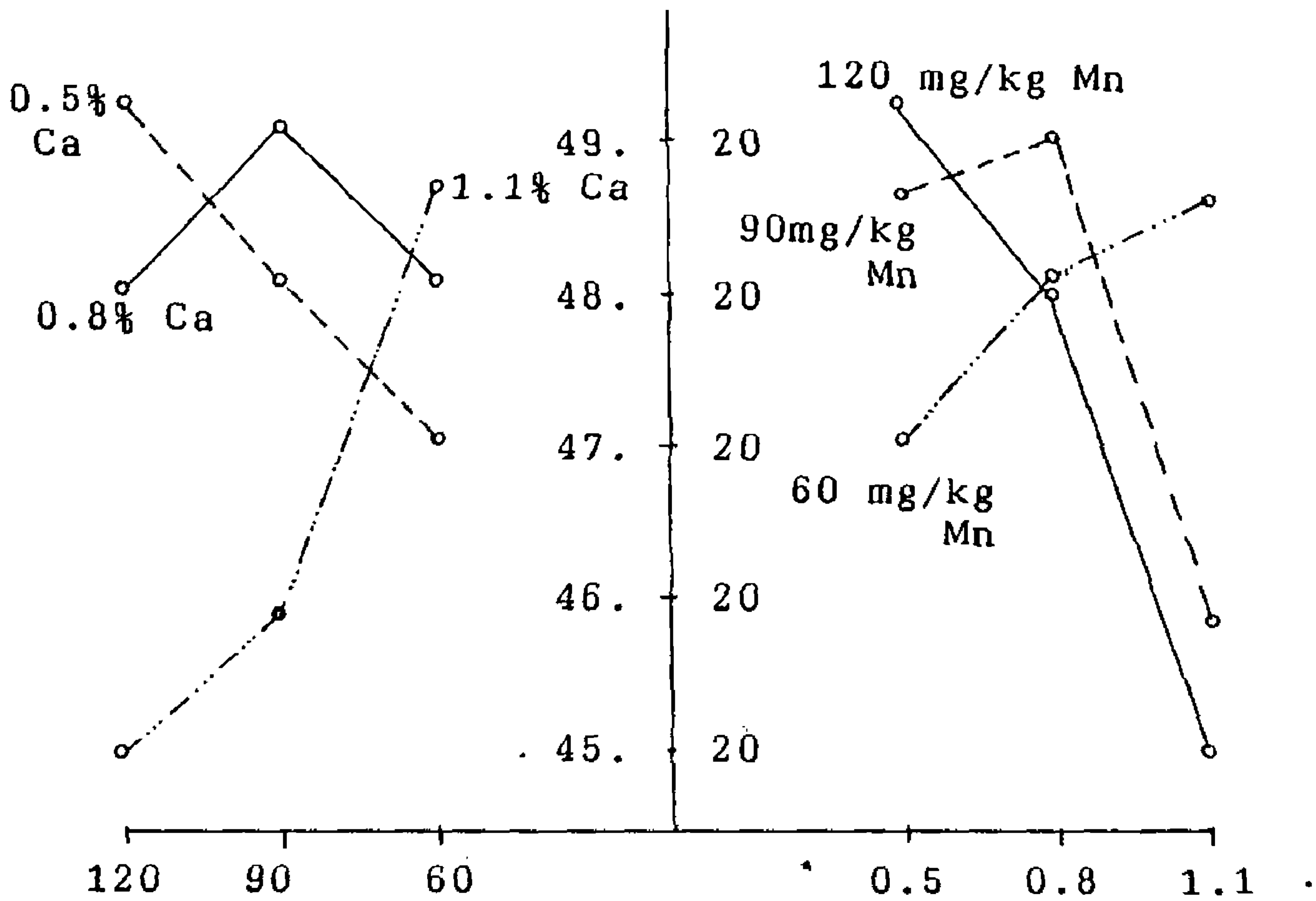

8
7
6
0.8% Ca
0.5% Ca
1.1% Ca
60 mg/ kg Mn
— 120 mg/kg Mn
-- 90 mg/kg Mn
120
90
60
0.5
0.8
1.1

Fig.15 A Serum Calcium (mg/100 ml) at 5 week on different dietary Calcium levels

15 B Serum Calcium (mg/100 ml) at 5 week on different dietary Manganese Levels

Fig.16 A Serum inorganic phosphorus (mg/100 ml) at 5 week on different dietary Calcium levels

16 B Serum inorganic phosphorus (mg/100 ml) at 5 week on different dietary Manganese levels


0.5% Ca
0.8% Ca
1.1% Ca
49.
48.
47.
46.
45.
20
20
20
20
20
120 mg/kg Mn
90mg/kg Mn
60 mg/kg Mn
120
90
60
0.5
0.8
1.1

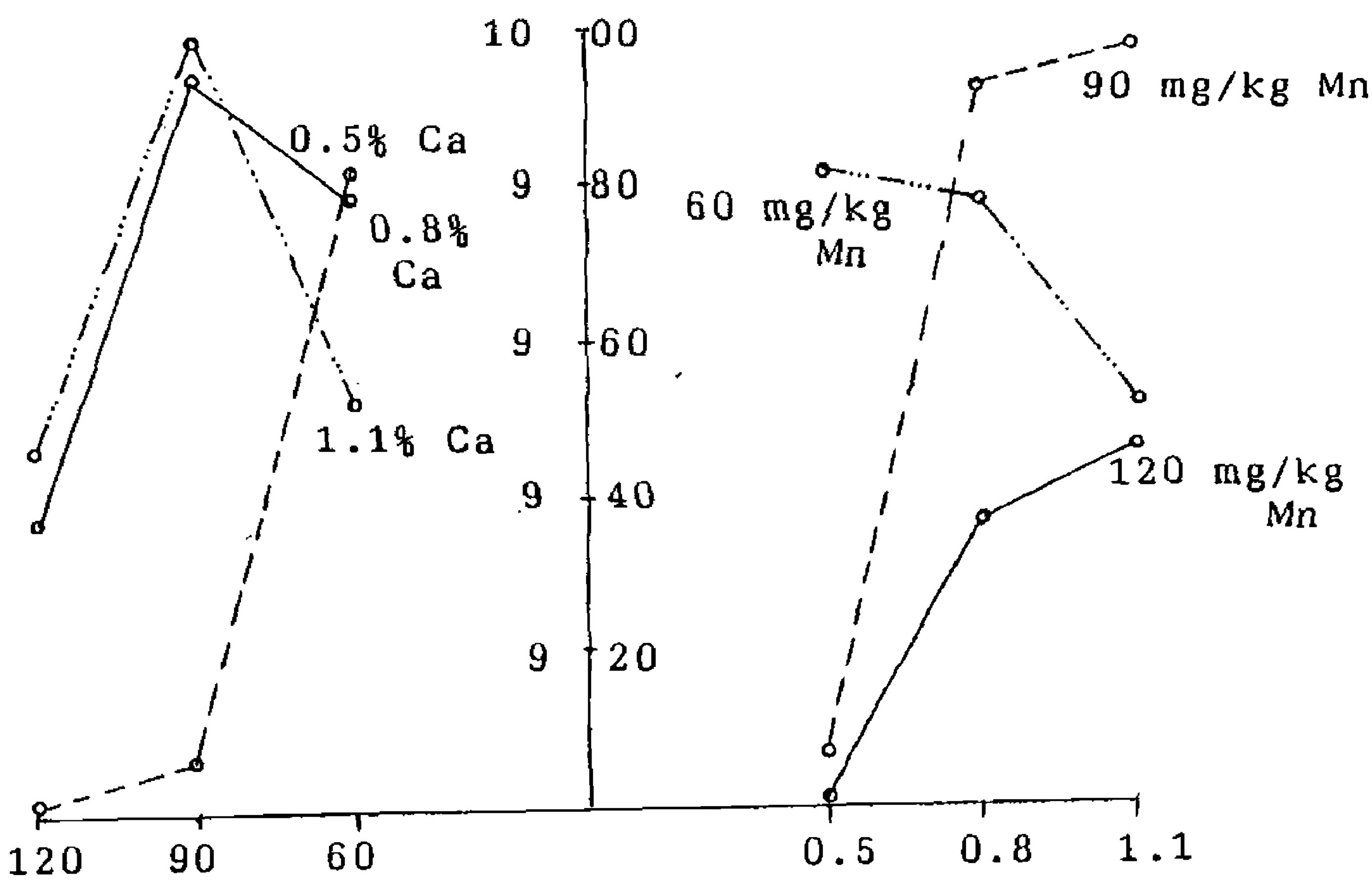
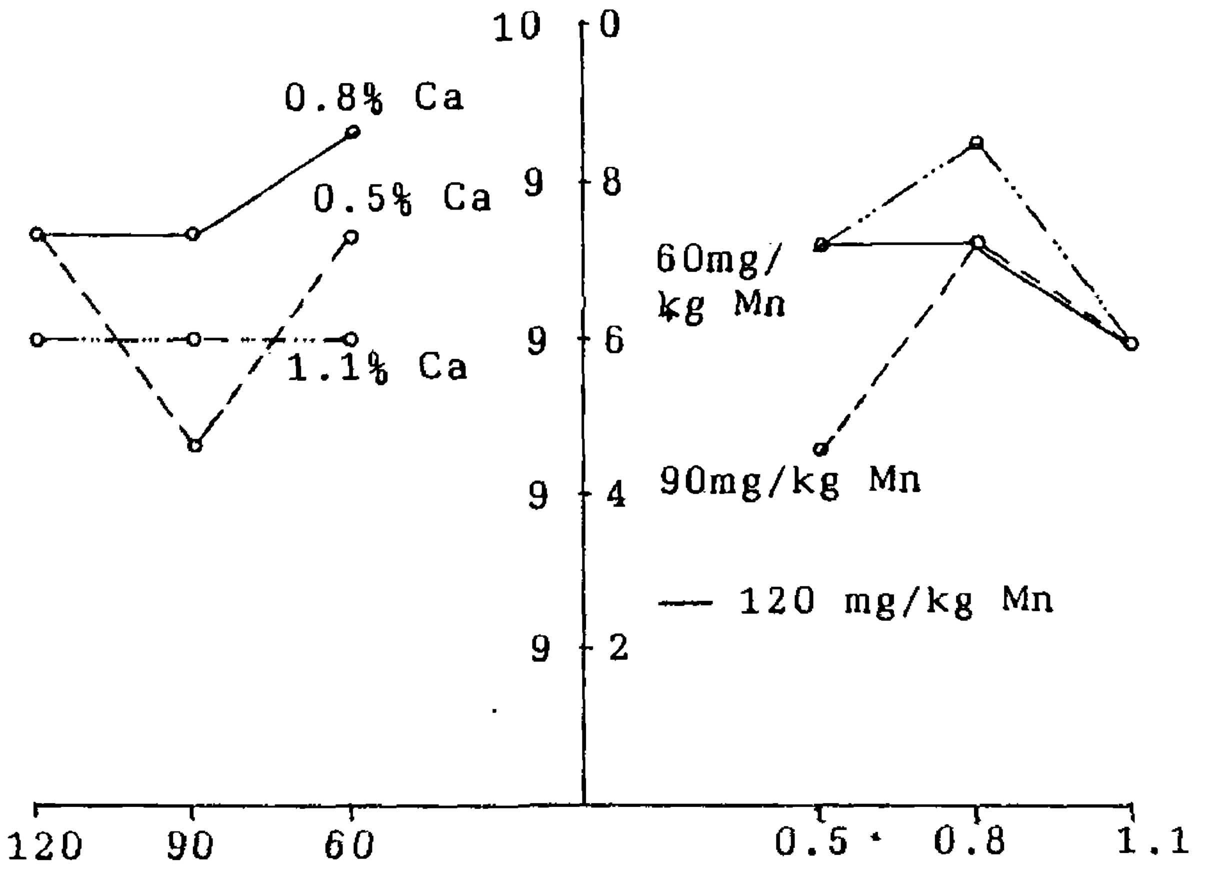

10
9
9
9
9
00
80
60
40
20
0.5% Ca
0.8% Ca
1.1% Ca
90 mg/kg Mn
60 mg/kg Mn
120 mg/kg Mn
120
90
60
0.5
0.8
1.1

Fig.17 A Percent bone ash at 5 week on different dietary Calcium levels

17 B Percent bone ash at 5 week on different dietary Manganese levels

Fig.18 A Tibial bone weight (g) at 5 week on different dietary Calcium levels

18 B Tibial bone weight (g) at 5 week on different dietary Manganese levels


10
9
9
9
9
0
8
6
4
2
0.8% Ca
0.5% Ca
1.1% Ca
60mg/
kg Mn
90mg/kg Mn
— 120 mg/kg Mn
120
90
60
0.5
0.8
1.1

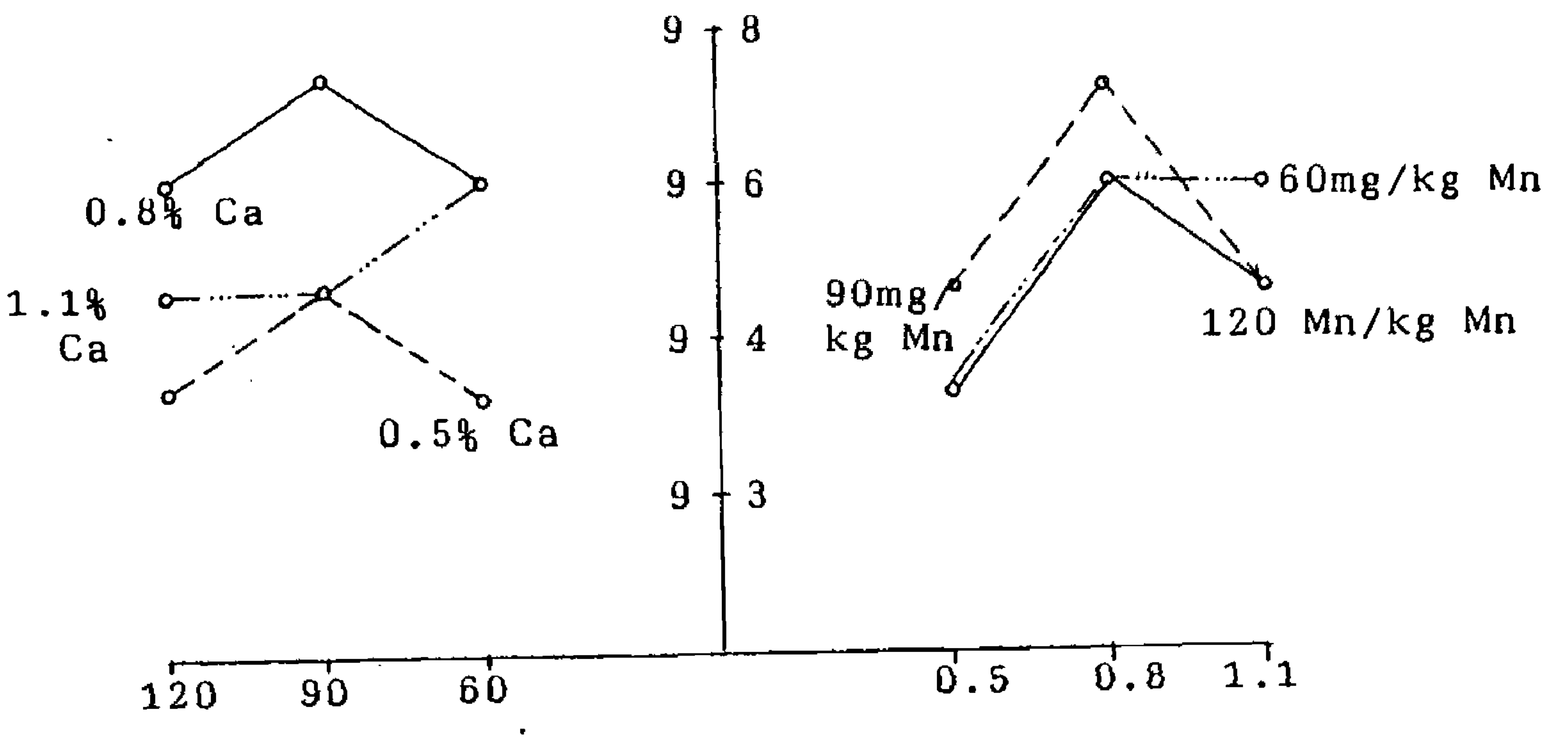
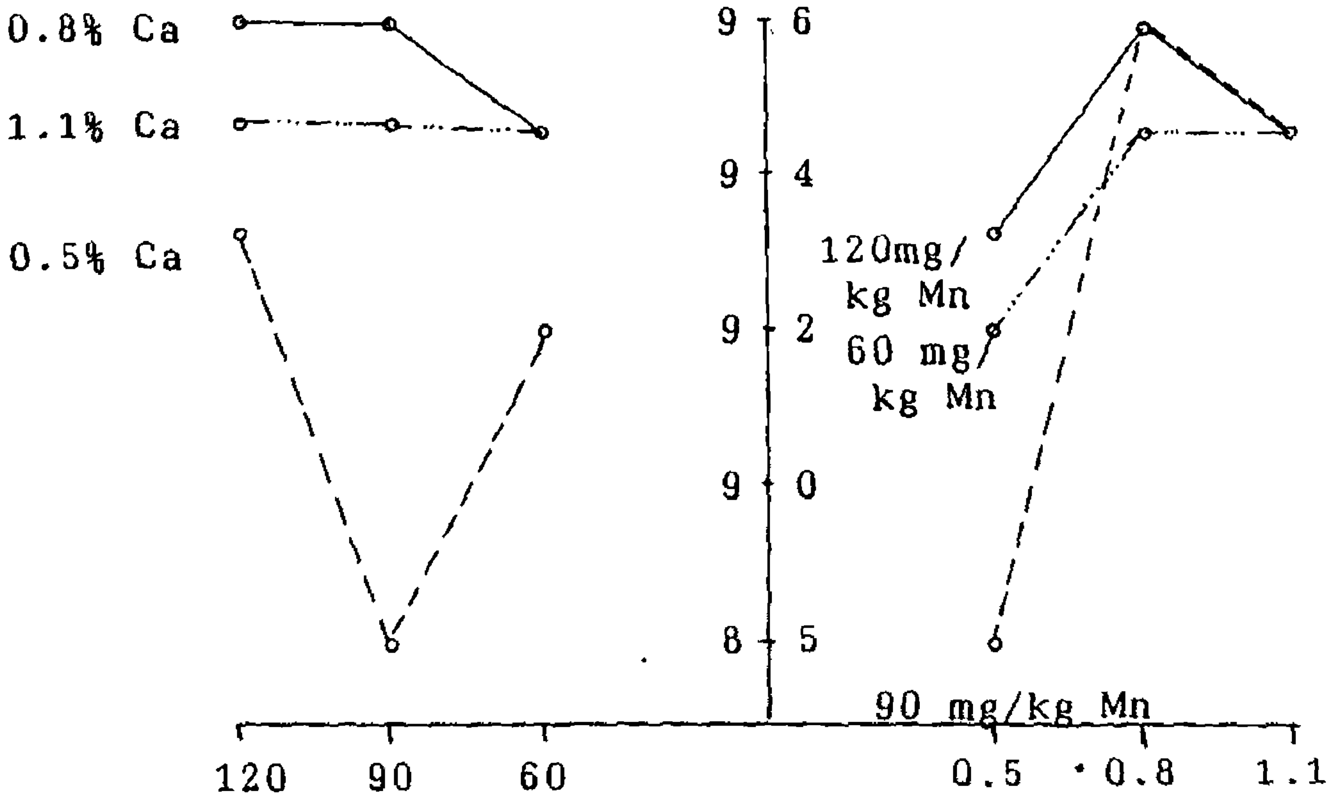

9
9
9
9
8
6
4
3
0.8% Ca
1.1%
Ca
0.5% Ca
60mg/kg Mn
90mg/
kg Mn
120 Mn/kg Mn
120
90
60
0.5
0.8
1.1

Fig.19 A Percent survival at 2 week on different dietary Calcium levels

19 B Percent survival at 2 week on different dietary Manganese levels

Fig.20 A Percent survival at 3 week on different dietary Calcium levels

20 B Percent survival at 3 week on different dietary Manganese levels


0.8% Ca
1.1% Ca
0.5% Ca
9 6
9 4
9 2
9 0
8 5
120mg/
kg Mn
60 mg/
kg Mn
90 mg/kg Mn
120
90
60
0.5
0.8
1.1

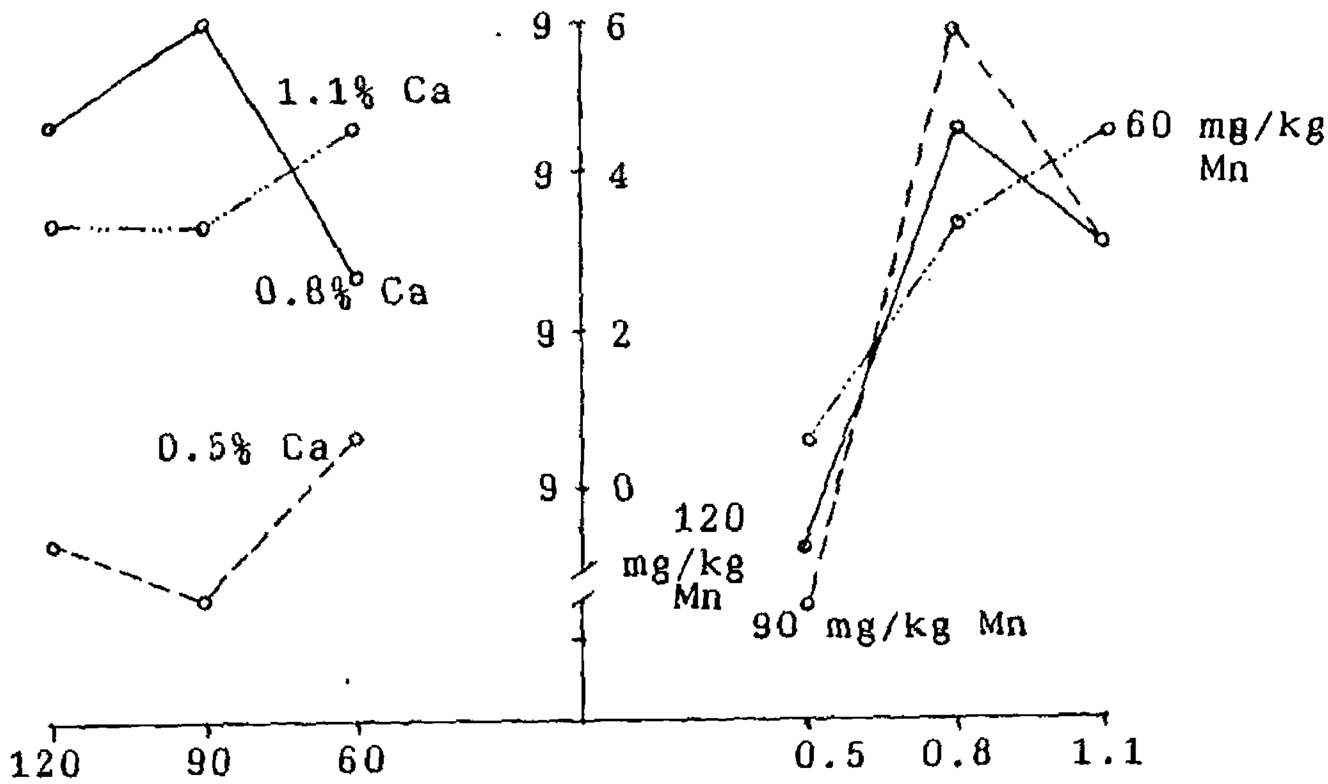

1.1% Ca
0.8% Ca
0.5% Ca
9 6
9 4
9 2
9 0
60 mg/kg
Mn
120
mg/kg
Mn
90 mg/kg Mn
120
90
60
0.5
0.8
1.1

Fig.21 A Percent survival at 4 week on different dietary Calcium levels

21 B Percent survival at 4 week on different dietary Manganese levels

Fig.22 A Percent survival at 5 week on different dietary Calcium levels

22 B Percent survival at 5 week on different dietary Manganese levels

DISCUSSION

DISCUSSION

The results obtained in these investigations as presented earlier in the previous chapter are briefly discussed in this chapter. It has been attempted whenever possible to draw conclusions in order to identify and give suggestion about the optimum level of dietary manganese in relation to dietary calcium for optimal performance of Japanese quail. And also to suggest the dietary calcium requirement of Japanese quail from 1-5 week of age.

5.1 FEED INGREDIENT ANALYSIS

The result of analysis of feed ingredients are presented in Table 3. The manganese content of maize was found to be 12.5 ppm which was higher than the values published by several workers (Ranjan, 1980; Panda et al. 1983; Allen, 1987) which varied from 2.3 to 4.8 ppm. ISI (1980) has given a value of 4.8 mg/kg Mn in maize whereas, Aw-Yong et al. (1983) using Atomic Absorption Spectrophotometry following low temperature dry ashing (450°C) reported the average value of 17 ppm, ranging from 8 to 35 ppm, for manganese content of maize.

The manganese content of soybean meal and fish meal were found to be 25.0 and 57.5 ppm, respectively. The value for soybean meal obtained in this experiment was lower than the value given by ISI (1980) and Panda et al. (1983) which was 35.9 ppm, but agreed with the value (27.5 mg/kg) given by Allen (1987). The value for manganese content of fish meal (57.5 ppm) was higher than the values of these authors which ranged from 10.1 to 38.9 ppm. The variations in the manganese content of these feed ingredients may be due to different soil type, genetic difference, cereal samples, influence of season and state of maturity (Underwood, 1981).

The calcium and phosphorus content of these feed ingredients were found to be 0.26 and 0.40% for maize, 0.36 and 0.59 for soybean meal; and 7.20 and 1.60% for fish meal. These values agreed well with the values given in the feed composition table published by Panda *et al*. (1983) and ISI (1980).

5.2 FEED CONSUMPTION

The cumulative feed consumption upto 5 week of age was not affected (P $\angle$ 0.05) by dietary levels of calcium and manganese. Reddy *et al*. (1980) reported that the dietary calcium levels (0.5, 0.7, 0.9 and 1.1%) had no significant (P $\angle$ 0.05) effect on feed intake of Japanese quail during 4 and 5 week of age. Similar finding was recorded by Smith and Kabaija (1985) who reported that dietary calcium and manganese had no significant effect (P $\angle$ 0.05) on feed intake of Cobb broiler. Henry *et al*. (1987) observed that manganese source and dietary manganese concentration had no significant effect on feed intake of broiler chicks.

The average cumulative feed consumption and weekly feed consumption of quail chicks in this experiment was compared with the data published by Wilson *et al*. (1960). The average cumulative feed consumption (344.9 g) from 1 upto 5 week of age was about 20 percent lower than the data published by Wilson *et al*. (1960). The comparison of weekly feed consumption with the data of Wilson *et al*. (1960) revealed that the chick in this experiment consumed feed on an average about 45 percent less during 1-2 week; 26 percent less during 2-3 week; 12 percent less during 3-4 week; and 1.4 percent less during 4-5 week of age. The chick in the present experiment consumed feed on an average 52.4 g during 1-2 week, 79.75 g during 2-3 week; 98.74 g during 3-4 week; and 113.7 g during 4-5 - week of age.

This lower weekly feed consumption during the first three weeks as compared with the data of Wilson *et al*. (1960) may have been due to handling and sudden change of diet at 1 week when the present experimental period commenced. Wilson *et al*. (1960) fed the chicks the same diet throughout the experimental period from 0-5 week, whereas in this experiment chicks were initially fed a starter diet as suggested by Panda *et al*. (1977) for the first 6 days of life. It seems probable that the chicks in this experiment had taken sometime before they had become accustomed to the experimental diets and overcome the stress of handling, because the discrepancy in comparative weekly feed consumption narrowed progressively each week with the advancement of the experimental period. The 4-5 week feed consumption thereby approached more or less the same level as that of the data published by Wilson *et al*. (1960).

5.3 GROWTH

5.3.1 Effect of dietary calcium

As mentioned earlier under the results (4.3) significant ($P < 0.05$) changes in body weight were evident only from 4 week of age due to dietary calcium levels. There was significant ($P < 0.05$) increase in body weight gain when dietary calcium was increased from 0.5 to 0.8% but further increased to 1.1% calcium did not result either in significant additional improvement or reduction in body weight gain of Japanese quail upto 5 week of age. However, at 5 week of age there was decreasing trend of body weight gain with the increasing level of calcium from 0.8 to 1.1% within the manganese levels of 60 and 120 mg/kg. Whereas, at 90 mg the body weight was found to increase with the increase of calcium level from 0.8 to 1.1%.

At 0.5% dietary calcium 1-4 week weight gain was lowest with 90 mg Mn/kg in the diet. At 0.8% dietary calcium 1-4 week weight gain showed increasing trend with the increasing levels of dietary manganese. On the contrary, at 1.1% dietary calcium 1-4 week weight gain showed decreasing trend with increasing levels of dietary manganese. However, these trend were not significant ($P \angle 0.05$) statistically. At 5 week of age there was no consistent trend in weight gain with increasing dietary manganese levels at each level of calcium as observed with 1-4 week weight gain.

Bisoi et al. (1980), working on calcium and phosphorus requirement of starter Japanese quail, reported similar observation. They observed that increasing dietary levels of calcium from 0.5 to 0.7% at 0.6% phosphorus in the diets resulted in higher 0-3 week body weight gain of Japanese quail. These authors also reported that further increase in dietary calcium from 0.7 to 0.9 and 1.1% resulted in decreased 0-3 week body weight gain.

On the contrary, Miller (1967) using diets containing 0.44 to 2.3% calcium and 0.58% to 1.18% phosphorus for Japanese quail from 1d to 6 week of age, observed on all diets equal performance in terms of body weight gain. The author concluded that the basal diet containing 0.44% calcium and 0.59% phosphorus resulted in satisfactory gains in body weight. This may be due to slower growth rate of the chicks used in his experiment. The author reported that the mean body weight of birds was 94 g at 5 week. Whereas, in this study the mean body weight at 5 week was 129.1 g.

Reddy et al. (1980) reported that response in 4-5 week body weight gain showed no significant ($P \angle 0.05$) differences due to dietary calcium (0.5, 0.7, 0.9 and 1.1%) and phosphorus (0.5, 0.6 and 0.7%) content. This lack of response in weight gain may be due to shorter experimental period in their investigations (Mehring et al., 1965).

Mehring et al. (1965) working on calcium and phosphorus requirement of broiler-type chicken also reported that, at constant level of dietary phosphorus, the growth of chicks was increased when the level of dietary calcium was increased from 0.2 to 0.6 percent, but then tended to decrease as the level of calcium was increased further.

Thus the results obtained in this study on growth were in general agreement with the observations made by earlier workers. All the diets employed in this experiment contained approximately 0.7% phosphorus. This, therefore, means that the dietary calcium level of 0.8% will correspond to a Ca:P ratio of 1.2:1. It can be concluded that the dietary calcium requirement of growing Japanese quail from 1-5 week of age for normal growth was not greater than 0.8% when the diet contained 0.7% total phosphorus (0.3% available phosphorus).

5.3.2 Effect of dietary manganese

The results obtained in this study indicated that the dietary levels of manganese (60, 90, 120 mg/kg) had no significant ($P \angle 0.05$) effect on 1-2, 1-3, 1-4 and 1-5 week body weight gain of growing Japanese quail. However at 0.8% dietary calcium the birds tended to be heavier with increasing dietary levels of manganese and at 1.1% tended to be lighter with increasing dietary levels of manganese. Nevertheless, analysis of variance for body weight gain revealed no significant interaction between the two elements. Harland *et al.* (1973), using purified diets, reported that the manganese requirement of Japanese quail from hatching to 2 and 4 weeks of age for maximum growth was 12 mg Mn/kg or less. No other reports are available on Japanese quail regarding the effect of graded levels of manganese on growth. However, several reports are available on chicken and other species that manganese is essential for growth.

Gallup and Norris (1938) observed that the six week weight gain by new Hampshire chicks on low manganese diet (10 ppm) was significantly lower than those chicks on adequate manganese (50 ppm) diet. These authors concluded that manganese is essential for the growth of chicks. Somewhat similar results were obtained by Kealy and Sullivan (1966), who observed that the average 4-week body weights of poults receiving 9 and 69 ppm of manganese were significantly ($P < 0.05$) less than the weights of poults receiving 24, 54 and 84 ppm. They suggested that the lower body weight of one replicate group of poults fed 69 ppm of manganese was apparently due to unknown experimental error.

Settle et al. (1968) reported that the first addition of manganese (55 mg/kg) to the purified diet resulted in a significant ($P < 0.05$) increase in growth, but further addition of manganese failed to produce additional growth responses. The purified diet was formulated with glucose, isolated soybean protein, corn oil and cellulose. Halpin and Baker (1986) observed that manganese supplementation (14 mg/kg) to casein-dextrose diet significantly improved chick weight gain but rate of gain of chicks fed diets supplemented with either 14 or 1000 mg/kg was similar. The weight gain of chicks increased with increasing Mn below the Mn requirement but plateau once the requirement has been met (Halpin and Baker, 1987).

All these results suggest that the requirement of manganese for normal weight gain is quite low. It may be as low as 7 to 10 mg/kg for broiler chicks (Mathers and Hill, 1968; Watson et al., 1970); 12 to 24 mg/kg for turkey poults (Keally and Sullivan, 1966); and 12 mg/kg or less for growing Japanese quail (Harland et al., 1973). This may present explanation for lack of growth reponse to graded dietary manganese observed in the present studies. Thomas and Lowther (1976), Stock and Latshaw (1981) and Smith and Kabaija (1985) also reported lack of growth response to graded dietary manganese. It can be concluded that the lowest manganese level (60 mg/kg) employed in the present study was sufficient to support normal growth of Japanese quail from 1-5 week of age when these diets contained adequate calcium (0.8%).

5.4 FEED CONVERSION EFFICIENCY

5.4.1 Effect of dietary calcium

The results presented in Table 10 and 11 showed that there were no significant differences between feed conversion efficiency of birds receiving different dietary calcium levels (0.5, 0.8 and 1.1%) upto 3 week of age. Though not significant the feed conversion efficiency tended to improve when dietary calcium was increased from 0.5 to 0.8% but worsen when dietary calcium was further increased to 1.1%. However, the 4 week feed conversion efficiency significantly improved when dietary calcium was increased from 0.5 to 0.8% but further increase to 1.1% resulted in slight increase in feed/gain ratio which was not found to be statistically accountable. At 5 week of age, in addition to the significant improvement of feed conversion efficiency observed when calcium was increased from 0.5 to 0.8%, there was also remarkable increase in feed/gain ratio when calcium was further increased to 1.1%. The differences in feed efficiency ratio of birds receiving 0.5 and 1.1%; and 0.8 and 1.1% dietary calcium were not found to be statistically significant (P / 0.05). This is in agreement with Fuller (1960), and Supplee et al. (1960) who reported that under practical condition excess minerals tended to impair feed utilization.

Miller (1967) observed no significant differences in feed utilization efficiency of 1 d to 6 week old Japanese quail due to different levels of dietary calcium and phosphorus. This was due to non-significant differences in body weight gain of the experimental groups. Consuegra and Anderson (1967) did not report the effect of dietary levels of calcium and phosphorus on feed utilization efficiency of Japanese quail in their paper. Bisoi et al. (1980) did not record the differences in feed consumption because of excessive wastage of feed during the first week making the data unreliable. Reddy et al. (1980), reported that levels of dietary calcium (0.5, 0.7, 0.9 and 1.1%) and phosphorus (0.5, 0.6 and 0.7%) had no significant effect on the feed/gain ratio of 4-5 week old Japanese quail.

This contradictory report compared with the present findings may be due to shorter experimental period used by Reddy et al. (1980). The short term test may not exhibit the full effect of dietary levels of these elements on growth and feed efficiency (Mehring et al., 1965). Several reports are available on chicken to support this.

Simco and Stephenson (1961) reported that 0.15% calcium did not support normal feed utilization efficiency of broiler chicks and for maximum efficiency of feed utilization 0.6% dietary calcium was required. In the subsequent study these authors observed that 0.4% calcium was borderline and 0.5% calcium supported optimum efficiency of feed utilization. However, Edwards et al. (1962) observed no significant differences in feed efficiency of broiler chicks at 4 week of age, fed diets containing 10 levels (0.69 to 1.59%) of calcium.

Kr'steva et al. (1988) reported that feed conversion of broiler chicks was best with 0.7% calcium and with greater amounts (1.0, 1.5 and 2.5%) of calcium, feed/gain ratio increased by 2.2, 4.8 and 11.1%, respectively. This is in agreement with the present finding of worsened feed conversion efficiency observed when dietary calcium was increased from 0.8 to 1.1%. It can be concluded that the dietary requirement of calcium for maximum feed utilization efficiency was definitely higher than 0.5% and less than 1.1%.

5.4.2 Effect of manganese on feed efficiency

No significant differences were observed in the feed utilization efficiency among birds receiving graded levels (60, 90 and 120 mg/kg) of dietary. manganese upto 5 week of age. The feed/gain ratios showed no consistent trend within each level of dietary calcium with the increasing levels of dietary manganese. Harland et al. (1973) using purified diet suggested 12 mg Mn/kg in diet for maximum feed efficiency.

Several reports are available to show the improvement in feed efficiency with increasing graded levels of manganese in the diet of broiler-type chicks and poults (Halpin and Baker, 1986a; 1986b; Kealy and Sullivan, 1966). Halpin and Baker (1986a) observed that the feed efficiency of 8-26 day old broiler chicks improved linearly as graded levels of manganese (0, 7, and 14 mg Mn/kg) were added to the casein-dextrose basal diet but no further improvement when the diet was supplemented with 1000 mg Mn/kg.

On the other hand, several contradictory reports are also available to show no improvement in performance due to graded levels of dietary manganese (Thomas and Lowther, 1976; Stock and Latshaw, 1981; Smith and Kabaija, 1985; Henry et al., 1987). Henry et al. (1987) varied manganese from 102-4000 mg/kg in the diet of broiler. Smith and Kabaija (1985) added graded levels of manganese varying from 75-300 mg/kg in the diet of Cobb broiler chicks.

The lack of response in feed efficiency due to graded levels of dietary manganese observed in this and other studies (Thomas and Lowther, 1976; Stock and Latshaw, 1981; Smith and Kabaija, 1985; Henry et al., 1987) was apparently due to higher levels of dietary manganese in all these studies. Performance of chicks improved linearly with increasing manganese below the manganese requirement but plateau once the requirement has been met (Halpin and Baker, 1987).

The dietary manganese level above which no additional improvement in performance reported for growing Japanese quail was 12 mg/kg (Harland et al., 1973); and for broiler 14 mg/kg (Halpin and Baker, 1986a). This suggested that the dietary levels of manganese used in this and other earlier studies, in which no response in performance to graded level of manganese was observed, were well above the requirement level and hence no response. Feed utilization of 8-22 day old broiler was not affected by excess manganese (3000 mg/kg) in the diet (Southern and Baker, 1983).

5.5 MANGANESE INTAKE

The results presented in Table 13 and 14 showed means and standard error for daily manganese intake on different dietary calcium and manganese level. The daily manganese intake (mg/bird) increased linearly with the increasing dietary manganese (60, 90 and 120 mg Mn/kg). The average daily manganese intake upto 5 week (mg/bird) were 0.7421, 1.1620, 1.4857 on diets containing 60, 90 and 120 mg Mn/kg, respectively. The cumulative manganese consumption on these diets from 1-5 week were 20.78, 32.53 and 46.08 mg respectively. When the cumulative manganese intake was expressed in term of manganese, mg/g, gain, the ratios were 0.1843 mg Mn/g gain, 0.2883 mg Mn/g grain, and 0.3703 mg Mn/g gain.

5.6 CALCIUM INTAKE

The means and standard errors for daily calcium intake (g/bird) on different levels of dietary calcium and manganese are shown in Table 16 and 17. Daily calcium intake increased linearly with increasing levels of calcium in the diet. The average daily calcium intake (g/bird) of Japanese quail from 1-5 week of age on diets containing 0.5, 0.8 and 1.1% calcium were 0.59±0.024; 0.98±0.012; and 1.36±0.009, respectively. The average cumulative calcium intake from 1-5 week on these diets were 16.76, 27.44 and 38.35 g, respectively. The progressive increase in daily calcium intake with increase in dietary calcium level was due to the non-significant alteration in feed consumption of the experimental groups.

When growth and feed efficiency obtained in this study were considered together and the calcium needed for each g, gain expressed as mg Ca/g, gain, the birds on low (0.5%) calcium needed 14.43 mg; on 0.8% calcium, 20.86 mg; and birds on high (1.1%) dietary calcium needed 29.0

mg per g, gain in body weight. As discussed earlier (5.3.1) there was significant increase in growth when dietary calcium was increased from 0.5 to 0.8% but the weight gain tended to decrease when dietary calcium was further increased to 1.1%. Therefore, it can be concluded that the calcium requirement for maximum growth of 1-5 week Japanese quail was 20.86 mg Ca per g, gain, considering the feed utilization obtained in this study. This value was lower than the value reported by Edwards <u>et</u> <u>al</u>. (1960) for 1-4 week broiler chicks which was 15 mg Ca per g, gain. This difference may be apparently due to species factor and poorer feed utilization efficiency in Japanese quail than in broiler chicks.

5.7 <u>SERUM CALCIUM</u>

The results obtained in this study indicated that the dietary levels of calcium and manganese had no significant (P $\angle$ 0.05) effect on the serum calcium level of growing Japanese quail. Though not significant serum calcium showed increasing trend with increasing dietary levels of *manganese at 0.5% dietary calcium. At 0.8% dietary calcium, highest value* (15.27±1.46) for serum calcium was observed with 90 mg Mn/kg diet. On the other hand, serum calcium showed decreasing trend with increasing levels of manganese in the diet at 1.1% dietary calcium.

At low (60 mg/kg) dietary manganese serum calcium showed increasing trend with increasing dietary level of calcium but the trend was reversed at high (120 mg/kg) dietary manganese. The serum calcium, however, showed no consistent trend at dietary manganese level of 90 mg/kg except that the value was highest with 0.8% dietary calcium.

Kuiumgian and Evans (1980), using two levels of calcium (1.0 and 1.5%), reported that plasma calcium of growing quails increased with higher calcium diets. This was contradictory to the present findings. These contradictory reports may be due to lower levels of dietary calcium used *in this study than the levels used by Kuiumgian and Evans (1980).*

Diz et al. (1983), observed no significant differences between the serum calcium of male Japanese quail receiving diets containing 5 levels of calcium (1.54, 1.57, 2.2, 3.20 and 3.4%) and 5 levels of phosphorus (0.8, 0.81, 1.66, 1.71 and 0.8%). They reported the values for calcium ranging from 11.8 to 12.8 mg/100 ml plasma. Whereas, in this study the values for calcium ranged from 13.56 to 15.70 mg/100 ml serum. These higher values may be due to mixing of sexes because the females in this study were already approaching the onset of egg laying. Simkiss (1967) reported rise in the concentration of serum calcium of layer type chicken from 10 mg% to 16-30 mg% during the 10 days before a pullet start to lay.

Some workers (Atteh and Leeson, 1983; Lin and Shen, 1979) working with broiler chicks and mule ducklings also observed no significant differences in serum calcium due to levels of dietary calcium. Several reports are available with laying hens and quails to suggest that dietary calcium do not influence the serum calcium level (Hurwitz and Griminger, 1961; Kuiumgian and Ivans, 1980; Bolden et al., 1984; Bolden and Jensen, 1985).

The present findings, therefore, indicated that serum calcium was not a good index for the determination of the requirement of dietary calcium for 1-5 week Japanese quails.

5.8 SERUM PHOSPHORUS

Means and standard errors for serum inorganic phosphorus obtained in this study are presented in Table 19. Neither dietary levels of calcium nor manganese had significant ($P \angle 0.05$) effect on serum inorganic phosphorus at 5 week of age.

Although not significant, low (0.5%) and high (1.1%) dietary calcium tended to depress the serum inorganic phosphorus. The serum inorganic phosphorus did not show consistent trend with increasing dietary manganese within each calcium level. The present finding is in agreement with the observation made by Steven *et al*. (1982) in serum inorganic phosphorus of turkey poults, using three levels of calcium (0.6, 1.2 and 3.0%) in the diet. They observed that 0.6 and 3.0% dietary calcium depressed plasma inorganic phosphorus ($P < 0.01$) of 2 and 4 week old turkey poults. Bolden and Jensen (1985), however, reported that dietary levels of calcium (2.75 and 3.5%) had no significant effect on plasma inorganic phosphorus of laying White Leghorn hens.

5.9 PERCENT BONE ASH

The means and standard errors for percent bone ash as influenced by dietary calcium and manganese are shown in Table 20 Analysis of variance for bone ash (Table 23) showed a significant effect due to calcium and interaction between calcium and manganese. There was a significant reduction ($P < 0.05$) in percent bone ash when dietary calcium was increased from 0.8 to 1.1%. However, the percent bone ash of birds receiving diets containing 0.5% calcium was not significantly different from those receiving diets containing 0.8% calcium. Significant interactions also revealed different responses due to alteration of one mineral with the other and *vice versa*. At low (0.5%) dietary calcium increasing dietary manganese from 60 to 90 mg/kg significantly increased percent bone ash but further increase to 120 mg/kg resulted in only numerical improvement in percent bone ash. At normal (0.8%) dietary calcium maximum percent bone ash was recorded with 90 mg Mn/kg which on further increase to 120 mg/kg significantly decreased percent bone ash. Whereas, at high (1.1%) dietary calcium maximum bone ash percent was recorded with lowest level of 60 mg/kg Mn which reduced significantly on further increase in dietary manganese to 90 or 120 mg/kg.

The present findings, therefore, indicated that the requirement of dietary manganese for maximum bone ash increased at lower level of dietary calcium and decreased at higher level of dietary calcium. However, Smith and Kabaija (1985) working on Cobb broilers, reported that high dietary calcium (3%) without corresponding increase in dietary manganese led to a thickening of tibia (increased volume) and increased mineral content (increased ash). A concomitant increase in dietary manganese upto and including 200 mg/kg lowered (P / 0.05) both tibial volume and ash content to normal values. Thickening of tibia and increased ash observed by these authors were not due to interaction of manganese and calcium *per se*, but rather the changes were brought about by wide Ca:P ratios. These authors also reported that as dietary Ca:P ratio widened, tibia volume increased, indicating thickening of bone.

The present study suggested that further studies involving Ca, Mn and P are needed to present complete picture of their interactions on bone characteristics.

5.10 TIBIAL BONE WEIGHT

The results presented in Table 20 showed the means and standard errors for tibial bone weight as influenced by dietary calcium and manganese. There were no significant differences between means for calcium and manganese and their interactions. Though not significant (P / 0.05) the tibial bone tended to be heavier when dietary manganese was increased from 60 through 90 to 120 mg/kg, at 0.5% dietary calcium. However, at 0.8% dietary calcium tibial bone weight was found to be heaviest with 90 mg Mn/kg and lightest with 120 mg Mn/kg. The same trend was observed with high (1.1%) dietary calcium.

5.11 MORTALITY

The percent survival of Japanese quails upto 5 week of age on different levels of dietary calcium and manganese are shown in Table 22 and 23.

At 2 week of age highest mortality was observed among birds receiving diets containing 0.5% calcium and 90 mg/kg manganese. The survival rate upto 2 week of age was highest among birds receiving diet containing 0.8% Ca and 60 mg/kg Mn. At high (1.1%) dietary calcium the survival rate was same among birds receiving different dietary levels of manganese.

At 3 week of age, percent survival was lowest among birds receiving low (0.5%) dietary calcium and highest among birds receiving diets containing 0.8% calcium and 90 mg Mn/kg. Within the group, receiving high (1.1%) dietary calcium, highest percent survival was observed among birds with 60 mg Mn/kg.

At 4 week of age, percent survival was lowest among birds receiving low (0.5%) dietary calcium and 90 mg Mn/kg and highest percent survival was observed among birds receiving 0.8% dietary calcium and two higher manganese levels. Within the group, receiving high (1.1%) dietary calcium, the percent survival was same for all the diets.

At 5 week of age, lowest percent survival was observed among birds receiving low (0.5%) dietary calcium and 90 mg Mn/kg. Only 82% of the birds on this diet survived upto 5 week of age. Highest number of birds had survived upto 5 week of age on diet containing 0.8% dietary calcium and 90 mg Mn/kg. The percent survival of birds in this group was 96%.

The high mortality observed among birds receiving low (0.5%) dietary calcium particularly in combination with 90 mg Mn/kg may be due to the levels of these elements in the diet. Nevertheless, post mortem of dead birds did not reveal any specific cause for the mortality. The survival rate of 90 to 96% upto 5 week of age observed in all other groups are quite within the acceptable range recommended under tropical conditions.

These present findings, thus, indicated that the dietary calcium level of 0.8% and manganese level of 60 mg/kg on practical corn-soybean diet were adequate for maximum growth, feed efficiency and bone ash values of Japanese quail from 1 to 5 week of age. Earlier findings (Bisoi et al., 1980) indicated calcium requirement for growth upto 3 week of age as 0.5% at 0.5% phosphorus. But for maximal bone ash the calcium requirement was more (0.7%) Consuegra and Anderson (1967) indicated that the requirements of calcium and phosphorus were not greater than 0.8% calcium and 0.3% available phosphorus at 2 week of age and 0.48% Ca and 0.3% available phosphorus at 4 week of age. Miller (1967) using diets containing 0.44 to 2.3% Ca and 0.58 to 1.18% P for Japanese quail from 1 d to 6 week of age, observed on all diets equal performance in terms of growth and bone ash. Reddy et al. (1980) indicated that growing quails during 4-5 week required not more than 0.5% calcium and 0.5% phosphorus.

NRC (1984) suggested 90 mg/kg of manganese in the diet. Shim and Vohra (1984) suggested dietary level of 80 mg Mn/kg. Shrivastav and Panda (1988) reviewing quail nutrition research in the tropics suggested dietary manganese level of 120 mg/kg. Most of the common feed stuffs used in poultry rations, like soybean meal, maize, fish meal, wheat bran and rice bran, are known to reduce the bioavailability of manganese from inorganic sources (Davis et al., 1962; Halpin and Baker, 1986a and 1986b). This explains why Mn level recommendation in a practical type diet is relatively high (90 mg/kg) for growing Japanese quail (NRC, 1984). Harland et al. (1973) reported the Mn requirement in purified diet as 12 mg/kg or less. In addition to effect of these feed ingredients in lowering the bioavailability of Mn, high dietary calcium and phosphorus and wide Ca:P ratios may also cause secondary manganese deficiency leading to perosis (Wilgus *et al.*, 1936; Poll *et al.*, 1967; Underwood, 1981).

SUMMARY

SUMMARY

Studies were conducted to investigate the effect of graded levels of dietary manganese in relation to levels of dietary calcium on feed consumption, growth, feed efficiency, bone ash, tibial bone weight, serum calcium and serum inorganic phosphorus of Japanese quail. The experimental period lasted for 27 days beginning from 8 day to 35 day of age. Triplicate groups of 20 birds each were assigned to one of the nine experimental diets in a 3 x 3 factorial arrangement. The treatments involved three manganese (60, 90 and 120 mg/kg) and three calcium (0.5, 0.8 and 1.1%) levels. Phosphorus was kept at 0.7% (0.3% available) for all the diets. The basal diet contained 20.5 *mg Mn/kg and 0.5% calcium. Attempts were made to identify the optimum supplemental level of manganese in the diet and dietary calcium requirement for optimal performance of (1-5 week) growing Japanese quails.

The results obtained in these studies indicated that :

1. Feed consumption of Japanese quail from 1-5 week of age was not significantly affected by graded levels of dietary manganese (60, 90 and 120 mg/kg) and levels of dietary calcium (0.5, 0.8 and 1.1%).

2. Weight gain was not significntly affected by graded levels of dietary manganese, whereas, the effect of dietary calcium was evident only from 4 week of age. There was no significant interaction between calcium and manganese on weight gain. The weight gain of birds on 0.8% dietary calcium was significantly higher than those on low (0.5%) dietary calcium. The body weight gain of birds on high (1.1%) dietary calcium was not found to be significntly different from those on 0.8% dietary calcium.

3. Feed conversion efficiency of Japanese quails was not affected by graded levels of dietary manganese upto 5 week of age. The effect of dietary calcium on feed efficiency was significant only from 4 week of age. There was no significant interaction between calcium and manganese on feed efficiency of Japanese quail. The feed utilization efficiency of birds on 0.8% dietary calcium was significantly better than those birds on low (0.5%) dietary calcium. The birds on high (1.1%) dietary calcium had lower feed efficiency than those on 0.8% dietary calcium but the difference in feed/gain ratio was not statistically significant ($P \angle 0.05$).

4. The daily manganese intake of Japanese quail increased linearly with increasing levels of manganese in the diet but it was not affected by levels of dietary calcium

5. The daily calcium intake of Japanese quail also increased linearly with increasing levels of calcium in the diet but levels of manganese in the diet did not alter the calcium intake.

6. The serum calcium level of Japanese quail was not significantly ($P \angle 0.05$) influenced by levels of dietary calcium and graded levels of manganese.

7. The serum inorganic phosphorus level of Japanese quail remained relatively constant over ranges of dietary calcium from 0.5 to 1.1% and manganese from 60 to 120 mg/kg.

8. Bone ash was significantly affected both by levels of calcium and interaction between calcium and manganese. The birds on high (1.1%) dietary calcium had lower percent bone ash than those receiving either 0.8 or 0.5% dietary calcium. The requirement of supplemental manganese for maximum bone ash at 5 week increased (90-120 mg/kg) at lower level (0.5%) dietary calcium and decreased (60 mg/kg) at higher level of dietary calcium (1.1%).

9. The tibial bone weight was not significantly affected by dietary calcium, graded levels of dietary manganese and their interaction. The birds on low (0.5%) dietary calcium had slightly lighter tibia than those on higher levels of dietary calcium. On the other hand, the tibial bone weight tended to increase with decreasing levels of manganese in the diet.

10. More number of birds died (12.5%) receiving low (0.5%) dietary calcium irrespective of manganese level. Survival rate during the course of the experiment varied from 87.55 to 94.66 percent.

Basing on the results obtained conclusions were thus made :

The dietary calcium requirements of growing (1-5 week) Japanese quails as judged by maximal growth, feed efficiency, bone ash and mortality, was not more than 0.8% when the diet contained 0.7% total phosphorus (0.3% available phosphorus) corresponding to Ca:P ratio of 1.2:1.

The dietary manganese levels of 60 mg/kg on conventional corn soy diet was found adequate to support maximal growth, feed efficiency, bone ash and survival rate when the diet contained adequate calcium (0.8%).

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