# EFFECT OF FORTIFICATION OF MULBERRY LEAVES WITH VERMIPRODUCTS ON MULBERRY SILKWORM, *Bombyx mori* L.

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Thesis submitted to the
*University of Agricultural Sciences, Dharwad*
*in partial Fulfillment of the requirements for the*
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**BY**

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# UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD
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## CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF FORTIFICATION OF MULBERRY LEAVES WITH VERMIPRODUCTS ON MULBERRY SILKWORM, *Bombyx mori* L. " submitted by Ms. CHAITHRA J., for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL ENTOMOLOGY to the University of Agricultural Sciences, Dharwad is a record of research carried out by her during the period of her study in this University, under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

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**JUNE, 2016**

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# 1. INTRODUCTION

Sericulture is both an art and science of raising silkworms for silk production. Silk as a weavable fibre was first discovered by the Chinese empress Xi Ling Shi during 2640 BC and its culture and weaving was a guarded secret for more than 2500 years. Though commodities like amber, glass, spices and tea were also traded along with silk which indeed rapidly became one of the principal elements of the Chinese economy and hence, the trade route got the name 'SILK ROUTE'. Even today, silk reigns supreme as an object of desire fabric of high fashion. Being a rural based industry, the production and weaving of silks are largely carried out by relatively poor sections of the society and this aspect of sericulture has made it popular and sustainable in countries like China and India.

India is the second largest producer of raw silk after China and the biggest consumer of raw silk and silk fabrics. An analysis of trends in international silk production suggests that sericulture has better prospects for growth in the developing countries like India rather than in the advanced countries, but also due to climatic restrictions imposed on mulberry leaf availability in temperate climate that allows only two cocoon crops per annum. Thus, India has a distinct advantage of practicing sericulture throughout the year, yielding a stream of 4- 6 crops as a result of its tropical climate.

In India, sericulture is not only a tradition but also a living culture. It is a farm based, labour intensive and commercially attractive economic activity falling under the cottage and small scale sector. It particularly suits to a rural farmers, entrepreneurs and artisans, as it requires low investment but with potential for relatively higher returns. It provides income and employment to the farmers with small land holdings and the marginalized and weaker sections of the society. Several socio economic studies have affirmed that the benefit cost ratio in sericulture is highest among comparable agricultural crops.

India is a home to vast varieties of silk secreting fauna which also includes an amazing diversity of silk moths. This has enabled India to achieve the unique distinction of being a producer of all the five commercially traded varieties of natural silks *viz.,* Mulberry (*Bombyx mori* L.), Tropical tasar (*Antheraea mylitta)*, Oak Tasar (*Antheraea proylei*), Eri (*Samia Cynthia ricini*) and Muga (*Antheraea assamensis*). Silk obtained from sources other than mulberry are generally termed as non mulberry or vanya silks.

Currently the total raw silk production in the country is around 28,708 MT (2014-15). The bulk of the silk produced is mulberry silk accounting for 21,390 MT that is obtained from 2,19,819 ha of mulberry. Eri, Tasar and Muga silks contributes 4,726, 2,434 and 158 MT, respectively by employing 80.30 lakh persons. The domestic demand for all silks is nearly 33,000 MT and the gap is bridged by importing 3489 MT of silk (Anon., 2014). In India bulk of silk is produced by Karnataka, Andhra Pradesh, Tamil Nadu and Jammu & Kashmir states. Karnataka has the highest mulberry raw silk production of 9645 MT in the country from 88489 ha of mulberry.

Nutrition plays an important role in improving the growth and development. In silkworms the growth and development and their economic characters are influenced to a great extent by the nutritional content of mulberry leaf (Shivakumar, 1995). Matsumara *et al.* (1958) reported that the quality of mulberry leaves (38.20%) and environmental conditions (37.10%) contributes significantly for quality cocoon production. Correlation between the nutrient content of mulberry on growth and development of mulberry silkworm is amply documented. Good larval growth, good quality of the cocoon and silk depends on the nutritional content of mulberry (Legay, 1958; Seki and Oshikane, 1959). However, nutrient constituents of mulberry greatly depends on the conditions of the environment, soil type, core of fertilizer, mulberry varieties and field practices employed. The best strategy to supplement the balanced nutrients to silkworms is enrichment of mulberry leaves. The nutritional supplements include proteins, carbohydrates, amino acids, vitamins, sterols, hormones, flour diets etc., (Sannappa *et al.,* 2002). The vermiproducts like vermiwash, vermicoelomic fluid and vermimeal obtained during the vermicompost production serve as best nutrient source for supplementation. Vermiwash contains enzyme cocktail of proteases, amylases, urease and phosphatase and secretions of earthworms which would stimulate the growth and yield of crops and even develop resistance in crops receiving this spray (Mahmood *et al.,* 2002; Dhiraj and Venkatesh Kumar, 2012). Yatheesh *et al.* (2011) reported that the vermiwash smeared mulberry leaves grown with vermicompost showed significant increase in the weights of larvae, silk glands, cocoons, shell and floss content of the cocoon. Thangard *et al*. (2003) reported the influence of vermiwash on increasing the level of soil nutrients as well as yield of paddy. Vermicoelomic fluid contain different enzymes including proteases, amylases and phosphatases, harmones like auxin and cytokinins and essential nutrients like K, Ca, Mg, Cl, Cu, P and Na. (Packialakshmi and Mahalakshmi, 2014). Karuna *et al.* (1999) reported the positive effects of vermicoelomic fluid as a spray to the tissue cultured crinkle red variety of *Anthurium andreanum*. Hatti *et al.* (2014) proved that earthworm coelomic fluid is having antibacterial property and also has immune mechanism to inhibit the pathogenic fungi. Vermimeal is a promising high quality animal protein and protein content is greater than that of fish meal and soybean meal protein (Kale *et al*., 1985).

Scanning the literature on utilization of vermiproducts in sericulture, a scanty work has been carried out on the enrichment of mulberry leaves with vermiproducts *viz.,* vermiwash, vermibodywash and vermimeal. Hence a study is being carried out to know the effect of fortified mulberry leaves with vermiproducts to silkworms with the following objectives:

1. To find out the safety of vermiproducts (vermiwash, vermibodywash and vermimeal) to mulberry silkworm.
2. Effect of fortification of mulberry leaves with vermiproducts on silkworm growth, cocoon yield and silk quality of mulberry silkworm.

# 2. REVIEW OF LITERATURE

The literature pertaining to the fortification of vermiproducts *viz.,* vermiwash, vermicoelomic fluid and vermimeal to mulberry silkworm is very much scanty. Hence, the literature related to the fortification of vermiproducts, vitamins, proteins, minerals, hormones and plant products to silkworm and other animals is reviewed and presented in this chapter.

## 2.1 Effect of fortification of mulberry leaves with vermiproducts on mulberry silkworm, *Bombyx mori* L.

Yoshida and Hoshii (1978) reported that the earthworms were used as protein substitution in feeds of pigs and poultry. The earthworm protein has been meal, valued equally important and useful as fish meal and meat meal in nutritional quality and quantity (Veeresh, 1984; Lee, 1985).

The food utilization, growth and conversion efficiency of cat fish, *Mostu vittatus* was higher when it was directly fed on earthworms (Arunachalam and Palanichamy, 1984).

Feeding of earthworms to chicks, crabs, fishes and tad poles which helped in stimulating the growth rate and also noticed that there was no difference in the body weight of broilers when the fishmeal was substituted with vermimeal as poultry feed (Kale and Bano, 1985).

The earthworm meal nutritional value gained good results in weights of poultry birds in 14 per cent vermimeal (1.104 kg) as commercial mash (1.159 kg) and was better than other treatment of fishmeal. The vermimeal 10-14 per cent showed good net profit results as commercial mash. Thus vermimeal can be used as substitute to imported fishmeal as it is a good feed to increase the body weight of broilers than compared to 6, 10 and 14 per cent fishmeal (Barcelo, 1988).

Doss *et al.* (2011) studied the performance of Pure Mysore × $NB_4D_2$ by feeding mulberry leaves supplemented with coelomic fluid of earthworm at 1ml/10 g of leaves and resulted in significant higher mature larval weight (2.80 g), silk gland volume (1.66 ml) and a significant increase in cocoon weight (1.42 g), pupal weight (1.13 g), shell weight (0.27 g), shell percentage (19.30 %) and silk productivity (3.90 cg/day) than compared to control.

The air breathing cat fish, *Clarias batrachus* had better growth when fed on earthworm (*Perionyx sansibaricus*) compared to *Pila bengalensis* and goat liver (Verma *et al.,* 2011). The maximum growth rate was observed in the prawns when fed on earthworm meals (Langer *et al*., 2011).

Purusothaman *et al.* (2012) reported that the weight of larvae, silk gland, cocoon and pupa and shell weight of silkworm was significantly increased upon with supplementation of vermiwash at different concentrations. Mulberry leaves enriched with vermiwash 50 per cent showed the maximum larval weight (3.416 g), silk gland weight (0.738 g), cocoon weight (1.374 g) and shell weight (0.315 g). While, 10 and 25 per cent recorded 0.552 and 0.661g of silk gland weight and 1.243 and 1.296 g of cocoon weight and 0.198 and 0.247 g of shell weight as compared to 0.511, 1.065 and 0.171g respectively. There was significant increase in the carbohydrate, protein and lipid of fat body. Acid phosphatase and alkaline phosphatise content also significantly increased in the body of *B. mori*.

## 2.2 Effect of fortification of nutrients to mulberry silkworm, *Bombyx mori* L.

Feeding of silkworms with mulberry leaves fortified with two percent jaggery solution did not posses any significant improvement of economic characters (Kumaraj *et al.,* 1972).

The final instar of *Bombyx mori* L. fed with mulberry leaves supplemented with *Spirulina fusiformis* (Worohichin) attained maturity in only six days and gained maximum larval weight (2090 mg) as against the control (nine days and 1470 mg). The study further revealed that quantity of feed, assimilation and conversion efficiencies increased substantially and the economic characters *viz*., cocoon, pupal and shell weight were significantly improved in *Spirulina* supplemented silkworms (Mathavan *et al.,* 1984).

Roger and Chen (1984) reported that the powder of blue-green algae, *Spirulina platensis* (Nordst) could be used in the artificial diet for silkworm during the fifth instar. Larvae reared on diets with 30 to 40 per cent algal powder had shorter larval duration, higher shell weight (0.73 ± 0.01 g) and shell ratio (19.25 ± 0.08).

Ganga and Gowri (1990) evaluated the cocoon characters of silkworm by feeding mulberry leaf along with three flour diets namely rice, wheat and ragi. Supplementation of cereal flours increased the larval weight, silk gland weight and commercial cocoon characters as compared to unsupplemented check. A shell ratio of 16 to 18 per cent was obtained from the rearing with supplemented sources as compared to 15 per cent in the rearing with unsupplemented control. Higher cocoon weight (2.18 ± 0.13 g) occurred for wheat flour supplementation, maximum larval weight (3.12 ± 0.25 g) and shell ratio (18.95 ± 0.21 %) was reported for rice flour supplementation. Fibroin percentage was maximum (87.32 ± 4.19 %) in the silk from rice powder supplementation.

The silkworms fed with mulberry leaves dipped in suspension of soybean protein varying from 0.5 to 5.0 g per decilitre (dl), an increase in larval weight and reduction in larval duration by 24 hours was noticed. At 0.5 gram soybean per decilitre, weight of larva cocoon, shell ratio and fecundity was maximum, whereas, five gram of soybean flour per decilitre caused 100 per cent mortality of silkworms (Rathinam *et al.,* 1992).

Dusting of defatted soybean flour at ratio of 12.5 g / kg mulberry leaves, once during third, fourth and fifth instar of *Bombyx mori* L. increased cocoon yield (Nalini *et al.*, 1994).

Matsura (1994) compared the economic characters of silkworms reared on artificial diet containing protein source namely blood meal and soybean meal. The economic characters registered significant differences, cocoon weight was maximum in soybean meal (3.13 ± 0.06 and 2.25 ± 0.04 g) as compared to blood meal ( 2.87 ± 0.16 and 2.20 ± 0.14 g ) for female and males (619 and 535 mg ) and shell percentage (21.1 and 25.1) was higher in case of blood meal diet.

The fifth instar bivoltine hybrid (Jd6 × $SF_1$9) reared on artificial diet containing soybean and defatted soybean as protein supplements had a short larval duration (12 days) and significant improvement in single cocoon weight as compared to larvae reared on mulberry leaf alone (Roychoudhary *et al.*, 1994).

Sarkar and Absar (1994) observed that silkworms supplemented with an artificial diet containing wheat bran along with mulberry powder showed higher values in larval, cocoon and shell weights compared to other diets. However, larvae fed on mulberry leaves performed better than those reared on artificial diet.

Vanishree *et al.* (1994) reported that the use of soya protein as feed supplementation resulted in increased larval weight in silkworm.

Krishnan *et al.* (1995) studied the effect of feeding mulberry leaves with hydrolysed protein on larval growth, economic characters and haemolymph protein profile of *Bombyx mori.* At two per cent, same parameters were higher than those of control, less than at two percent the hydrolysed protein, P- soyatose was ideal for sericulture industry.

The growth of *Bombyx mori* larvae improved significantly on feeding mulberry leaves supplemented with different nutrients. The larval weight, silk gland weight and total protein in silk gland, single cocoon weight, shell weight and filament length were found to be highest for treatment, soya milk + sugar + vitamins + potassium iodide salt followed by glycine + alanine + sugar + vitamins + potassium iodide salt and milk powder + sugar + vitamin + potassium iodide salt treatments and also produced highest cocoon yield (Sarkar *et al.*, 1995).

Reshma (1997) recorded maximum larval weight of 2.58 and 2.43 g in the larvae fed with mulberry leaves supplemented with aqueous leaf extracts prepared from seedling stage of potato and tomato respectively.

According to Santhoshkumar (1997) irrespective of the rearing seasons, fifth instar larvae of Pure Mysore (PM) race was most responsive to five per cent dust formulation of *Lantana camara* and *Clerodendron inermae.* Further, the larvae of PM, $NB_{18}$ and PM × $NB_{18}$ grew vigorously and had maximum larval weight of 19.11 g and 18.45 g, 30.84 g and 30.37 g and 28.00 g and 26.95 g per ten worms, respectively. Whereas, cocoon weight increased to 9.65 g and 9.20 g, 17.09 g and 16.45 and 16.48 and 15.43 g per ten samples as compared to lime powder which registered 7.93, 15.77 and 14.12 g per ten samples, respectively. Similarly, higher shell ratio, silk filament length and superior denier were recorded in larvae dusted with *L. Camara* and *C. inermae* in PM, $NB_{18}$, PM × $NB_{18}$ silkworms during September-October rearing.

Krishnaprasad *et al.* (2000) concluded that the supplementation of mulberry leaves with potato leaf extract at 1:4 concentration to the silkworm (PM × NB4D2 ), twice during fifth instar resulted in higher cocoon weight (1.69 g), shell weight (0.27 g), shell percentage (15.98 %) and filament length (650.0 m) as compared to absolute control.

Raj *et al.* (2000) fed the mulberry dusted with soybean protein flour to fifth instar NB4D2 silkworm. The larval weight, larval volume, silk gland volume, silk gland weight and silk gland ratio were significantly higher. Larval period during fifth instar was also reduced. However, the number of cocoons per litre was significantly less.

Laskar and Datta (2000) reported that the fortification of mulberry leaves with alfalfa tonic and its inorganic ingredients resulted in increased fifth instar larval weight.

Rajegowda *et al.* (2000) reported that the worms were fed with seripro dusted leaves twice and thrice a day from fifth instar second day onwards could significantly increase the cocoon weight, shell weight, shell ratio, silk productivity and filament length. The pupal weight and effective rate of rearing were higher with single dusting, while higher mature worm weight was recorded with two dusting per day.

Jeyapaul and Padmanatha (2003) studied the fortification of mulberry leaves to silkworms treated with 0.25, 0.5 and 1.0 per cent of *Coffea arabica* (L.) leaf extract and its effect on food consumption and utilization. Leaf extract at 0.25 per cent recorded significantly higher cocoon weight (1.699 g), pupal weight (1. 403 g) and shell weight (0.296 g).

Manimegalai *et al.* (2003) concluded that supplementation of soyaflour at 10g/kg of mulberry leaves to fourth and fifth instar larvae of PM × NB4D2 twice in shoot rearing method produced higher larval weight (3.97 g), cocoon weight (1.63 g), shell weight (0.26 g), shell ratio (15.95 %), silk filament length (740 m) compared to leaf feeding method and different doses of soyaflour.

The silkworm CSR2 × CSR4 fed on mulberry leaves supplemented with 80 per cent fine mesh ragi flour in addition with 20 per cent horsegram fine mesh flour showed superiority in silk gland tissue somatic index (SGTSI), silk productivity, filament length and enhanced fibroin. Whereas, reduced sericin content when provided from fourth instar until spinning compared to supplementation during fifth instar stage or with absolute control (Vanitha *et al.*, 2006).

According to Nguku *et al.* (2007) supplementing mulberry leaves with royal jelly significantly increased the larval, cocoon and pupal weights, but had no significant effect on shell weights and denier. Similarly, filament length, weight and filament reeling breaks were significantly different between controls and royal jelly fed groups.

Supplementation of *Spirulina* at 100, 200 and 300 ppm resulted in highest cocoon weight in 300 ppm (1.08 g), followed by 200 ppm (0.94 g) and 100 ppm (0.91 g). The shell weight and silk filament length were also highest in 300 ppm (24.50 cg and 866.61 m). *Spirulina* at 300 ppm has showed high impact on the cocoon characters (Kumar *et al.,* 2009).

Patil (2010) reported that fifth instar larvae of mulberry silkworm (PM × CSR2) fed with aqueous azolla smeared leaves had significantly increased the mature larval weight, cocoon and shell weight and pupal weight but non significant in shell per cent over the control.

Manimuthu and Isaiarasu (2010) reported that the overall performance of *Bombyx mori* including growth and cocoon parameters in response to *Aloe vera* tonic at 2.0 per cent treatment could be improved with the supplementation.

Feeding of fifth instar larvae of PM × CSR2 and CSR2 × CSR4 by supplementing mulberry leaves with nine flours of cereal and pulses at two ratios (1:10) (1:20) (flour: leaf), showed significantly higher filament length, finer denier, more fibroin percentage and lower sericin content for the cocoons spun by silkworm reared on flour supplemented leaf over the control. Among different flours, soybean (1:10) yielded longest filament length in CSR2 × CSR4, followed by (1:20). Overall performance was good in both the hybrids supplemented with different flours (Rekha and Neelu, 2010).

Saravanan *et al*. (2010) reported that feeding silkworm (NB4D2) at third, fourth and fifth instar on mulberry leaves enriched with 7.5 per cent of *Dolichos lablab*, gained significantly more cocoon weight (2.54 ± 0.03), shell weight (0.47 ± 0.005) and shell/cocoon ratio (18.49 ± 0.20 %) as compared to those fed with normal MR2 mulberry leaves (1.85 ± 0.03, 0.29 ± 0.005 and 16.07 ± 0.03), respectively. There was a significant increase in the haemolymph glucose, cholesterol, urea, total protein, aspartate transaminase, alanine transaminase and alkaline phosphatase. But, haemolymph uric acid was significantly decreased.

Masthan *et al*. (2011) studied the impact fortification of mulberry leaves with food probiotic microorganisms like *Spirulina* and *Saccharomyces cerevisiae* on cocoon quantitative parameters and observed that average cocoon weight, average cocoon shell weight and pupal weight was found to be highest with 300 ppm treatment of *Spirulina* (0.83 g). The shell percentage was highest in control (25.98 %), followed by *Spirulina* at 100 ppm (25.25 %), 200 ppm (24.62 %) and 300 ppm (22.64 %), silk filament length was highest (866.61 m) in case of *Spirulina* at 300 ppm concentration, followed by 200 ppm (682.20 m), 100 ppm (664.58 m) and control (661.94 m).

Amala Rani *et al.* (2011) reported that the mixture of jiwamrita increased the quality and quantity of mulberry leaves thereby increasing the silk production and showed the significant enhancement of cocoon weight (45.67 ± 0.32), shell weight (2.23 ± 0.38), pupal weight (43.44 ± 1.86), shell ratio (21.60 ± 0.78), filament length (888 ± 7.2), sericin (43.02 ± 2.10), renditta (9.32) and fibroin content (43.92 ± 1.32).

Pallavi *et al*. (2011) revealed that, food additives were found effective in increasing the protein, carbohydrate and lipid content in chawki worms. Among silkworm hybrids PM × CSR2, CSR2 × CSR4, APM1 × APS8, APM2 × APS12 and (CSR6 × CSR26) × (CSR2 × CSR27), recorded highest protein content of 19.91 mg, 21.44 mg, 19.83 mg, 19.71 mg and 24.03 mg, respectively on soya flour dusted batches @ 10g/kg of leaves compared to control (17.63 mg, 18.02 mg, 17.58 mg, 17.51 mg and 22.72 mg).

Sarithakumari *et al.* (2011) found the highest larval weight in first (0.062 g/10 larvae), second (0.221 g/10 larvae), third (1.18 g/10 larvae), fourth (4.93g/10 larvae) and fifth (29.56 g/10 larvae) instars, high silk productivity (3.94 cg/day), increased filament length (912.50 m) and reduced denier (2.41) was noticed in *P. niruri* administered lots followed by *A. vasica* and *T. arjuna* as compared to control (0.024, 0.101, 1.00, 4.24, 28.98 g / 10 larvae; 3.54 cg/day, 874.95 m and 2.41, respectively).

According to Khyade and Shendage (2012) dietary supplementation of *Aloe vera* at 2 per cent to (PM × CSR2) during fifth instar resulted in higher larval growth and increased the weight of cocoon, mean larval weight, relative growth rate, effective rearing rate, larval consumption index, pupal weight, shell weight, shell ratio and the fibroin content of the cocoon shell.

The cocoon weight was maximum when the larvae were supplemented with soya flour 10 g/kg of leaves. Among the hybrids highest weight of 2.053 g followed by 1.800 g, 1.77 g, 1.395 g and 1.293 g recorded in CSR2 × CSR4, PM × CSR2, APM1 × APS8 and APM2 × APS12, respectively as compared to control. The highest shell weight of 0.383 g and 0.513 g was recorded in CSR2 × CSR4, [(CSR6 × CSR26) × (CSR2 × CSR27)], respectively. The shell ratio was also improved and the highest was recorded in APM2 × APS12 and (CSR6 × CSR26) × (CSR2 × CSR27) (21.47 and 24.99 %) (Pallavi and Muthuswami, 2012).

Patil and Chandrashekhar (2013) reported that mulberry leaves fortified with 1 and 5 per cent roasted coffee bean extract gave uniform and good growth of silkworm at 5 per cent concentration.

Saravanan *et al.* (2013) concluded that significant gain in cocoon weight (2.46 ± 0.16g), shell weight (0.46 ± 0.024 g), shell ratio (18.79 ± 0.43) was achieved by supplementing 7.5 per cent cowpea to silkworm (NB4D2) from third till the end of fifth instar. There was significant increase in haemolymph glucose, cholesterol, urea, total protein, aspirate transaminase, alanine transaminase and alkaline phosphatase.

Fourth instar silkworm fed with mulberry leaves supplemented with 100 ppm of milk powder and nival solution resulted in best performance in length of cocoon (3.26 ± 5.1 cm, 3.64 ± 2.3 cm), width of the cocoon (1.79 ± 0.67 cm, 1.99 ± 2.1 cm), shell ratio (16.80 ± 0.05 %, 17.58 ± 0.28 %), filament length (880 ± 2.5m, 890 ± 6.5m), denier (1.98 ± 1.22, 3.14 ± 0.52), sericin content (34.1 ± 1.00 %, 41.2 ± 1.32 %), fibrion content (34.77 ± 0.14 %, 40.34 ± 0.08 %) as compared to 500 ppm and control (Ranjitsingh *et al*., 2013)

Gad (2013) studied the effect of some honey bee products; royal jelly (RJ 10 mg/ ml), pollen (P 50 mg/100 ml), propolis (PR 30 mg/100 ml), honey (H 1g/ 100ml) on biological and physiological parameters of the fifth larval instar and resulted the increased weights of mature larvae, pupae, fresh cocoons and cocoon shells. Larvae fed on mulberry leaves treated with RJ showed a significant increase in weights, followed by honey and then pollen in the brood strain. While, in the local strain, RJ gave the maximum weights followed by pollen and then honey.

Niharika *et al.* (2013) showed that larvae gained 82.5 per cent more weight by the end of fifth instar when fed with mulberry leaves dipped in bovine milk than when fed with fresh mulberry leaves without milk. The larvae fed with milk-treated leaves gained 310 per cent weight from day 1 to day 7 of the fifth instar, while the larvae fed with fresh leaves gained 153 per cent weight in the same time span. In addition, cocoon weight was also increased by 8 per cent when milk was added.

Administration of zinc chloride, pyridoxine, methoprene at 2 µg/ml and with mixed dose (Zn + B6 + H) 2 µg/ml each on alternate days in fourth and fifith instar significantly elevated economic parameters of the cocoon (Lakshmidevi and Yellamma, 2013).

The supplementation of 0.01 mg/lit $FeCl_3$ significantly increased larval weight and economic parameters such as cocoon weight, shell weight and shell ratio (Srivastava, 2013).

Pardeshi and Bajaj (2014) noticed that oral supplementation of 2 per cent *Amaranthus hybridus* plant extract was highly effective in enhancing the larval and cocoon characteristics of *Bombyx mori*. The mean larval weight, pupal weight, shell weight, shell ratio and filament length were increased at 2 per cent concentration of dietary supplementation over the control. Whereas, 2.5 per cent caused adverse effect on the economic parameters.

Srinivas (2014) reported that the eri silkworm, *Philosamia ricini* of fifth instar (day one) fed on castor leaves sprayed (after spraying the amino acid, leaves were allowed to dry before feeding with amino acids (valine and leucine). The significant enhancement in body weight, duration of fifth instar worms and cocoon weight was found.

Hossain *et al*. (2015) studied that supplementation of cow milk to fifth instar silkworm daily once during fifth instar increased the cocoon weight ( 1.330 g), shell weight (0.148 g), shell ratio (14.3 %) compared to control (1.119 g, 0.139 g and 12.8 %), respectively.

# 3. MATERIAL AND METHODS

The details of materials used and the methodology adopted for the study on "Effect of fortification of mulberry leaves with vermiproducts (vermiwash, vermicoelomic fluid, vermimeal) on mulberry silkworm, *Bombyx mori* L.," is outlined below. The study was carried out at Sericulture section, Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad, during October- November, 2015.

Dharwad is situated in northern transition zone (Zone-8) of Karnataka between 15°17' north latitude and 76°46' east longitude at an altitude of 678 MSL. The annual rainfall varies between 619 to 1303 mm, temperature varies between 18 to 32° C and relative humidity varies between 65 to 70 per cent.

## 3.1 Mulberry garden

The study was conducted in established V-1 mulberry garden that was planted during 2000 in medium black soil.

Victory – 1 (V-1)

It is a hybrid (S-30 × C-776) evolved at Central Sericultural Research and Training Institute, Mysore. The branches are erect and fast growing with large, unlobed dark green leaves. Leaves are succulent and thick with high moisture content (75 %). The variety has proven excellent under efficient farming system with high fertilizer input (350:140:140 NPK kg/ha/yr) and irrigation. The hybrid has a potential to yield up to 65,000 kgs/ha/yr.

Mulberry cultivation

Before the initiation of experiment, mulberry plants were bottom pruned during second fortnight of June, 2015, followed by ploughing and inter cultivation. Farm yard manure (FYM) recommended was of 20 t /ha /year and for the experiment plot of five gunta, 100 kg FYM was applied and thoroughly mixed in soil and applied. The recommended chemical fertilizers of 350 kg of Nitrogen, 140 kg of Phosphorous and 140 kg of Potassium per hectare per year was applied in five splits. For the first and third crops 70 kg each of NPK and for second, fourth and fifth crop only 70 kg of N was applied. The study was made during the second crop and urea was given as nitrogenous source according to package of practice. Irrigation was provided at ten days interval depending upon the climatic conditions and at thirty days of pruning inter cultivation was carried out followed by manual weeding to keep the field clean.

## 3.2 Preparation of vermiproducts

### 3.2.1 Procurement of Vermiwash

Vermiwash for the study was procured from the vermiculture unit, Main Agricultural Research Station, Dharwad.

### 3.2.2 Extraction of Vermicoelomic fluid

The earthworms (*Eudrillus euginae*) weighing one kilogram were placed in a dry enamel tray for 15 to 20 min to clear out the cast that will be excreted due to handling. They were carefully separated from their excreta and placed in a plastic bowl having 500 ml of luke warm water (37-40℃). The worms were agitated for 3 to 5 min and removed and placed into another bowl containing 500 ml of distilled water and were rinsed thoroughly to collect the exudates adhering to their body wall. The contents in the two bowls were mixed and used for the study (Karuna *et al.,* 1999).

### 3.2.3 Preparation of Vermimeal

One kilogram of live earthworms (*Eudrillus euginae*) were washed thoroughly with clean water to remove the dirt and dust and earthworms were killed by placing in a basin having warm water ($60^0$C) for 5 min. The dead worms were sundried for 48 hours and oven dried at 50-$60^0$C for an hour for complete removal of moisture. The dried earthworms were grinded in a grinder, made into a fine powder and used for the study (Guerrero, 2009).

### 3.2.4 Silkworm rearing:

Prior to commencement of silkworm rearing, rearing room and equipments were cleaned, washed and thoroughly disinfected with 3 per cent formalin @ 500 ml/10 $m^2$ using rocker sprayer (Dandin *et al.,* 2000). The room was kept air tight for 48 hours for effective disinfection. A day prior to rearing, room was opened to diffuse the traces of formalin and the rearing equipments were arranged for silkworm rearing.

## 3.3 Procurement of Chawki worms and rearing

The chawki silkworms of commercial cross breed hybrid, Pure Mysore × CSR2 (Kolar gold) and Bivoltine hybrid (FC1 × FC2) were procured from private chawki rearing centre at Holalaapura and Shirahatti of Gadag district. The chawki worms of both the hybrids were reared separately in wooden trays (2.5' × 2.5') by feeding four times a day (8.00 am, 2.00 pm, 6.30 pm and 9.00 pm) with chopped leaves. Whereas, from fourth instar onwards 100 healthy worms were randomly picked and reared in each tray by providing cut shoots (10 to 15 cm length) thrice daily (8:00 am, 2:00 pm and 7:00 pm). Bed cleaning was done thrice during third instar and two times during fourth instar (once after third moult and before settling for fourth moult) and daily once during fifth instar. During rearing, optimum spacing was provided according to the age of worms. Lime powder was dusted on silkworms during each moult so as to keep the bed dry and to facilitate easy moulting. During late age rearing, silkworms were protected from uzifly menace by covering the rearing stand with fly proof nylon net (Dandin *et al.,* 2000). The matured silkworms were handpicked from the rearing bed and mounted on bamboo chandrike at 50 worms/sq.ft for cocoon spinning. The cocoons were harvested on fifth day after mounting.


**Plate 1: Silkworm rearing trays and stand used for the study**

## 3.4 Experiment 1

### 3.4.1 The safety of vermiproducts to mulberry silkworm

Methodology

To study the safety of vermiwash, vermicoelomic fluid and vermimeal by silkworms, hundred second instar silkworms were placed in each rearing tray. The mulberry leaves were dipped in different concentrations of vermiwash, vermicoelomic fluid and vermimeal solution separately, shade dried and fed to silkworms daily once in the morning as per the treatments and remaining two feeds with normal leaves. While, vermimeal powder of different concentrations was prepared by mixing with talc powder and dusted on mulberry leaves and fed to the silkworms. Daily once the mortality count was made and continued till zero mortality was observed

Treatment details

No. of larvae/replication : 100

Treatments : 3 × 4

Mulberry variety : V-1

Silkworm Race : PM × CSR2

Season of Rearing : Oct- Nov., 2015

| Treatment details | Concentrations (%) |
|---|---|
| Vermiwash | 25, 50, 75, 100 |
| Vermicoelomic fluid | 25, 50, 75, 100 |
| Vermimeal powder | 25, 50, 75, 100 |

## 3.5 Experiment II

### 3.5.1 Fortification of vermiproducts to mulberry silkworm

From the results of first experiment the safe concentrations of vermiproducts were selected for the second experiment to fortify the mulberry leaves for silkworm feeding.

The study was made with Kolar gold and Bivoltine hybrid. On first day of fifth instar, hundred silkworms of both the hybrid were used for each treatment and three replications were maintained. The mulberry leaves were dipped in vermiwash and vermicoelomic fluid at 5, 10, 15, 25 and 50 per cent concentrations separately and fed to silkworms daily once during morning feed. While, vermimeal powder at 5, 10, 15, 25 and 50 per cent concentrations was arrived by mixing with talc powder and dusted on mulberry leaves in a thin cloth bag. Remaining two feedings of the day was given with normal leaves. The fortification study was made up to the day of spinning by the silkworms.

Methodology:

| | |
|---|---|
| Experimental Design | : CRD |
| Treatments | : 3 × 5 × 2 |
| Replication | : 3 |
| No. of larvae/ replication | : 100 |
| Mulberry variety | : V-1 |
| Silkworm Race | : Kolar Gold and Bivoltine hybrid |
| Season of Rearing | : November- December, 2015 |

Treatment details:

| Vermiwash | Vermicoelomic fluid | Vermimeal |
|---|---|---|
| 5% | 5% | 5% |
| 10 % | 10 % | 10 % |
| 15 % | 15 % | 15 % |
| 25 % | 25 % | 25 % |
| 50 % | 50 % | 50 % |
| Treated control | Treated control | Treated control |
| Untreated control | Untreated control | Untreated control |

## 3.5.4. Observations recorded

3.5.4.1 Mature larval weight (g/ 10 larvae) A day before the spinning, ten mature silkworms were randomly picked in each replication and weighed on electronic balance.

3.5.4.2 Fifth instar larval duration (hr): From beginning of fifth instar to the time of 50 per cent spinning was recorded as fifth instar larval duration.

3.5.4.3 Effective rate of rearing (ERR %): Effective rate of rearing was calculated by using the below mentioned formula.

$$ERR\ (\%) = \frac{\text{Number of cocoons harvested}}{\text{Number of worms brushed}} \times 100$$

3.5.4.4 Silk productivity (cg/day): Silk productivity was computed by using the following formula as suggested by Iyengar *et al.* (1983).

$$\text{Silk productivity (cg/day)} = \frac{\text{Weight of the shell (cg)}}{\text{V instar larval duration (days)}}$$

3.5.4.5 Cocoon weight (g/10 cocoons): Ten healthy cocoons were randomly picked from each replication and weighed.

3.5.4.6 Pupal weight (g/10 pupae): Cocoons from the respective replication were cut open to remove the pupa and weighed.

3.5.4.7 Cocoon shell weight (g/10 shells): After removing the pupae the empty shells from the respective replication were weighed after removing the exuviae.

3.5.4.8 Cocoon shell ratio (%): Cocoon shell ratio was calculated by using the formula.

$$\text{Cocoon shell ratio (\%)} = \frac{\text{Weight of the cocoon shell (g)}}{\text{Weight of whole cocoon (g)}} \times 100$$

3.5.4.11 Cocoon yield (g/dfl): Cocoon yield in each replication was recorded and computed to yield per disease free laying.

3.5.4.9 Cocoon filament length (m): Ten cocoons from each replication were randomly picked and reeled on epprouvette.

Cocoon filament length = Number of revolutions x circumference of wheel (1.125 m).

3.5.4.11 Denier: Denier of the reeled silk filament was worked out by using the formula.

$$D = \frac{W}{L} \times 9000$$

Where,

D = Denier

W = Weight of silk filament (g)

L = Length of single cocoon filament (m)

9000 = Constant

3.5.4.10 Fibroin and Sericin (%): Fibroin and Sericin was estimated by following the procedure suggested by Orlandi (1954).

### 3.5.5 Statistical analysis:

The data were analysed as suggested by Gomez and Gomez (1984). Duncan's multiple Range Test (DMRT) was applied for comparing the treatments mean.

# 4. EXPERIMENTAL RESULTS

The results of Effect of fortification of mulberry leaves with vermiproducts *viz.,* vermiwash, vermicoelomic fluid and vermimeal on growth and cocoon parameters of mulberry silkworm, *Bombyx mori* L. conducted during 2015-2016 are presented in this chapter.

## 4.1 Safety of vermiproducts to mulberry silkworm, *Bombyx mori* L.

The safety of vermiproducts *viz.,* vermiwash, vermicoelomic fluid, vermimeal was studied by fortifying mulberry leaves at 25, 50, 75, 100 per cent concentrations. Results revealed that vemiwash and vermicoelomic fluid at all concentrations (25 to 100 per cent) were found safe and accepted by the silkworms without any mortality in all the instars. While, vermimeal fortification was found safe to silkworms up to 50 per cent and accepted the fortified leaves. 75 and 100 per cent showed 5 and 7 per cent mortality of silkworms (Table 1).

## 4.2 Effect of fortification of mulberry leaves with vermiwash on mulberry silkworm, *Bombyx mori* L.

### 4.2.1 Growth and development

#### 4.2.1.1 Fifth instar larval duration (hr)

Fortification of mulberry leaves with vermiwash had a significant influence on fifth instar larval duration. Vermiwash fortification at 15 per cent significantly reduced the fifth instar larval duration in Kolar Gold (160.23 hr) and Bivoltine hybrid (158.63hr). The larval duration of 160.37 hr was recorded in treated control in Kolar Gold hybrid was on par with vermiwash 15 per cent. Fortification of 10 per cent vermiwash and was the next best in reducing the larval duration in both Kolar Gold (161.17 hr) and Bivoltine hybrid (160.67 hr), feeding unfortified leaves recorded 162.37 hr and 170.10 hr in Kolar Gold and Bivoltine hybrid, respectively (Table 2).

#### 4.2.1.2 Mature larval weight (g/ 10 larvae)

The mature larval weight was significantly influenced by vermiwash fortification. Kolar Gold silkworms fed with 15 per cent vermiwash recorded highest weight of 40.15 g, followed by 10 per cent (39.09 g), 25 per cent (38.36 g) and 50 per cent (36.95 g) and were on par with vermiwash 15 per cent. Further, treated control (36.39 g) was also on par with vermiwash 15 per cent. While 5 per cent vermiwash fortification recorded 34.31 g of weight and untreated control (34.24 g) was on par with 5 per cent vermiwash. Bivoltine hybrid recorded 39.29, 38.27 and 38.15 g of weight by feeding mulberry leaves fortified with vermiwash at 15, 10 and 25 per cent and all were on par. Fortification of 50 and 5 per cent vermiwash recorded 35.65 and 33.95 g and were on par with treated control (35.06 g) (Table 3).

**Table 1: Safety of vermiproducts to mulberry silkworm, *Bombyx mori* L.**

| T.C. (%) DAT | Mortality (%) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vermiwash | | | | Vermicoelomic Fluid | | | | Vermimeal | | | | Control |
| | 5 | 0 | 7 5 | 1 00 | 5 | 50 | 75 | 100 | 25 | 50 | 75 | 100 | |
| **1** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 02 | 02 | 00 |
| **2** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 08 | 05 | 00 |
| **3** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 05 | 04 | 00 |
| **4** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 03 | 08 | 00 |
| **5** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 07 | 12 | 00 |
| **6** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 03 | 09 | 00 |
| **7** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 05 | 08 | 00 |
| **Mean** | 0 | 0 | 0 0 | 0 0 | 0 | 00 | 00 | 00 | 00 | 00 | 05 | 07 | 00 |

DAT– Days after treatment T.C – Treatment concentrations

**Table 2: Effect of fortification of mulberry leaves with vermiwash on fifth instar larval duration of mulberry silkworm**

| Treatments | Fifth instar larval duration (hr) | |
|---|---|---|
| | Kolar gold | Bivoltine hybrid |
| Vermiwash -5% | 162.30[e] | 162.73 [c] |
| Vermiwash -10% | 161.17[b] | 160.67 [b] |
| Vermiwash-15% | 160.23[a] | 158.63 [a] |
| Vermiwash-25% | 162.20[c] | 170.08 [e] |
| Vermiwash-50% | 168.33[e] | 172.23 [f] |
| Treated control | 160.37[a] | 164.33 [d] |
| Control | 162.37[c] | 170.10 [e] |
| **S.Em ±** | **0.27** | **0.21** |
| **CD at 5%** | **0.77** | **0.61** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

#### 4.2.1.3 Silk productivity (cg/day)

Vermiwash fortification to mulberry leaves showed significant effect on silk productivity of both Kolar Gold and Bivoltine hybrid. Kolar Gold silkworms exhibited highest silk productivity at15 per cent (6.04 cg/day) vermiwash, followed by 10 per cent (5.26 cg/day), 25 per cent (5.06 cg /day). Bivoltine hybrid silkworms showed highest silk productivity 6.3 cg/ day in 15 per cent, 10 per cent (5.99 cg /day) and 5 per cent (5.75 cg /day) vermiwash fortification (Table 3).

#### 4.2.1.4 Pupal weight (g/ 10 pupae)

Data presented in the Table 4 indicated that mulberry leaves fortification with vermiwash had a significant effect on pupal weight. Vermiwash at 15 per cent fortification showed highest pupal weight of 15.02 g in Kolar Gold, followed by 10 per cent (14.63 g), 50 per cent (14.37 g) and 25 per cent (14.27 g) and were on par with each other. While, unfortified mulberry leaves gave 12.34 g of pupal weight in Kolar Gold. The Bivoltine hybrid pupal weight of Bivoltine hybrid was significantly high in 15 per cent (14.28 g) fortification. It was followed by 10 per cent (13.64 g) and 50 per cent (13.40 g) fortification. While, it was 12.93 g and 12.27 g in 5 and 25 per cent fortification and 10.40 g in untreated control.

#### 4.2.1.5 Effective rate of rearing (ERR %)

The effective rate of rearing in Kolar Gold was significant and higher in vermiwash 10 per cent (99.67 %) fortification and was on par with untreated control (99.67 %). It was followed by vermiwash 15 per cent (99.00 %) and on par with vermiwash 10 per cent and untreated control. Fortification of vermiwash with 5, 25 and 50 per cent produced 97.00, 96.00 and 95.00 per cent of rearing rate. The Bivoltine hybrid silkworms produced 99.67 per cent by fortifying 15 and 10 per cent vermiwash and were on par with untreated control (100 %) (Table 4).

### 4.2.2 Cocoon parameters

#### 4.2.2.1 Cocoon weight (g/ 10)

Kolar Gold registered significantly highest cocoon weight of 20.70 g with 15 per cent vermiwash, followed by vermiwash 10 per cent (18.60 g) and 25 per cent (17.84 g) (Plate 2). In Bivoltine hybrid, 15 per cent vermiwash recorded highest cocoon weight (18.65 g), followed by 10 per cent (17.72 g), 25 per cent (17.53 g) and 50 per cent (17.50 g) and were on par with each other (Table 5) (Plate 3).

#### 4.2.2.2 Cocoon shell weight (g/ 10 shells)

The shell weight was higher in mulberry leaves fed with 15 per cent vermiwash fortified leaves to Kolar Gold (4.03 g) and Bivoltine hybrid (3.96 g). In Kolar Gold, 15 per cent vermiwash fortification was followed by vermiwash 10 per cent (3.69 g), 5 per cent (3.43 g), 25 per cent (3.42 g) and 50 per cent (3.33 g) as compared to 3.42 g and 2.66 g in water treated mulberry leaves and untreated treatments. In Bivoltine hybrid, 15 per cent fortification was followed by 10 per cent (3.92 g), 5 per cent (3.90 g), 50 per cent (3.87 g) and 25 per cent (3.60 g) which were all on par. While, untreated treatment yielded 2.67 g of cocoon shell weight (Table 5).

**Table 3: Effect of fortification of mulberry leaves with vermiwash on mature larval weight and silk productivity of mulberry silkworm**

| Treatments | Mature larval weight (g/10 larvae) | | Silk productivity (cg/ day) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermiwash -5% | $34.31^{b}$ | $33.95^{b}$ | $4.83^{c}$ | $5.37^{bc}$ |
| Vermiwash -10% | $39.09^{a}$ | $38.27^{a}$ | $5.26^{b}$ | $5.99^{ab}$ |
| Vermiwash-15% | $40.15^{a}$ | $39.29^{a}$ | $6.04^{a}$ | $6.31^{a}$ |
| Vermiwash-25% | $38.36^{a}$ | $38.15^{a}$ | $5.06^{bc}$ | $5.75^{ab}$ |
| Vermiwash-50% | $36.95^{ab}$ | $35.65^{b}$ | $4.96^{bc}$ | $5.39^{bc}$ |
| Treated control | $36.93^{ab}$ | $35.06^{b}$ | $4.12^{bc}$ | $4.97^{c}$ |
| Control | $34.24^{b}$ | $27.90^{c}$ | $3.94^{d}$ | $3.76^{d}$ |
| **S.Em±** | **1.6** | **0.82** | **0.11** | **0.23** |
| **CD at 5%** | **3.39** | **2.39** | **0.31** | **0.69** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

**Table 4: Effect of fortification of mulberry leaves with vermiwash on pupal weight and effective rate of rearing of mulberry silkworm**

| Treatments | Pupal weight (g/10 pupae) | | Effective rate of rearing (%) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermiwash -5% | 13.17[cd] | 12.93 [c] | 95.00 [b] (77.09) * | 93.00 [bc] (74.71) * |
| Vermiwash -10% | 14.63[a] | 13.64 [b] | 99.67 [a] (88.05) * | 99.67 [a] (88.05) * |
| Vermiwash-15% | 15.02[a] | 14.28 [a] | 99.00 [a] (85.34) * | 99.67 [a] (88.05) * |
| Vermiwash-25% | 14.27[ab] | 12.27 [d] | 96.00 [b] (78.49) * | 93.00 [bc] (74.65) * |
| Vermiwash-50% | 14.37[ab] | 13.40 [bc] | 97.00 [b] (80.09) * | 96.00 [b] (78.49) * |
| Treated control | 13.50[bc] | 12.35[d] | 90.00 [c] (71.59) * | 92.00 [c] (73.57) * |
| Control | 12.34[d] | 10.4 [e] | 99.67 [a] (88.05) * | 100.00 [a] (89.96) * |
| **S.Em±** | **0.29** | **0.17** | **1.59** | **1.42** |
| **CD at 5%** | **0.86** | **0.51** | **4.65** | **4.15** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
* Figures in parentheses are angular transformed values

**Table 5: Effect of fortification of mulberry leaves with vermiwash on cocoon and shell weight of mulberry silkworm**

| Treatments | Cocoon weight (g/10 cocoons) | | Cocoon shell weight (g/10 shells) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermiwash -5% | $16.72^{de}$ | $17.19^{c}$ | $3.43^{c}$ | $3.90^{a}$ |
| Vermiwash -10% | $18.60^{b}$ | $17.72^{b}$ | $3.69^{b}$ | $3.92^{a}$ |
| Vermiwash-15% | $20.70^{a}$ | $18.65^{a}$ | $4.03^{a}$ | $3.96^{a}$ |
| Vermiwash-25% | $17.84^{bc}$ | $17.53^{bc}$ | $3.42^{c}$ | $3.60^{ab}$ |
| Vermiwash-50% | $17.78^{c}$ | $17.50^{bc}$ | $3.33^{c}$ | $3.87^{ab}$ |
| Treated control | $17.06^{cd}$ | $16.45^{d}$ | $3.42^{c}$ | $3.41^{b}$ |
| Control | $15.82^{e}$ | $13.82^{e}$ | $2.66^{d}$ | $2.67^{c}$ |
| **S.Em ±** | **0.27** | **0.15** | **0.07** | **0.15** |
| **CD at 5%** | **0.78** | **0.43** | **0.21** | **0.44** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

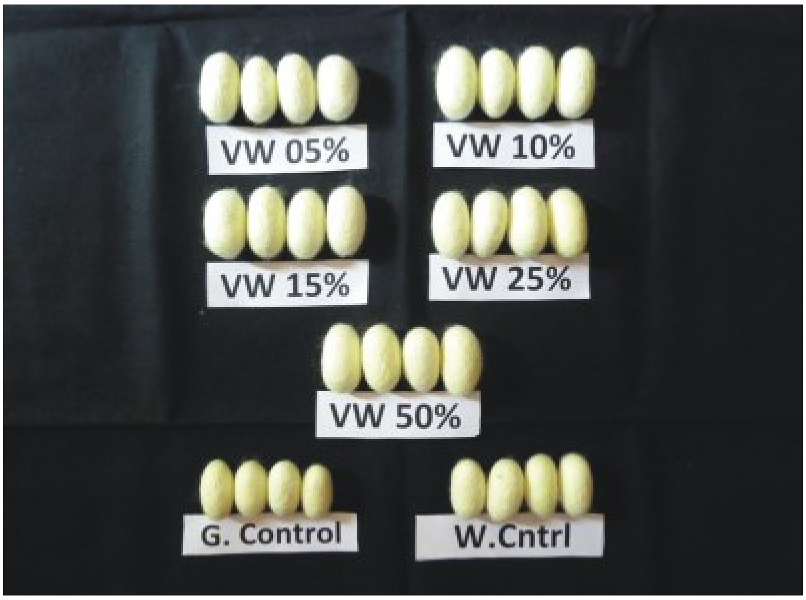


**Plate 2: Cocoons of Kolar Gold obtained by fortifying mulberry leaves with vermiwash**

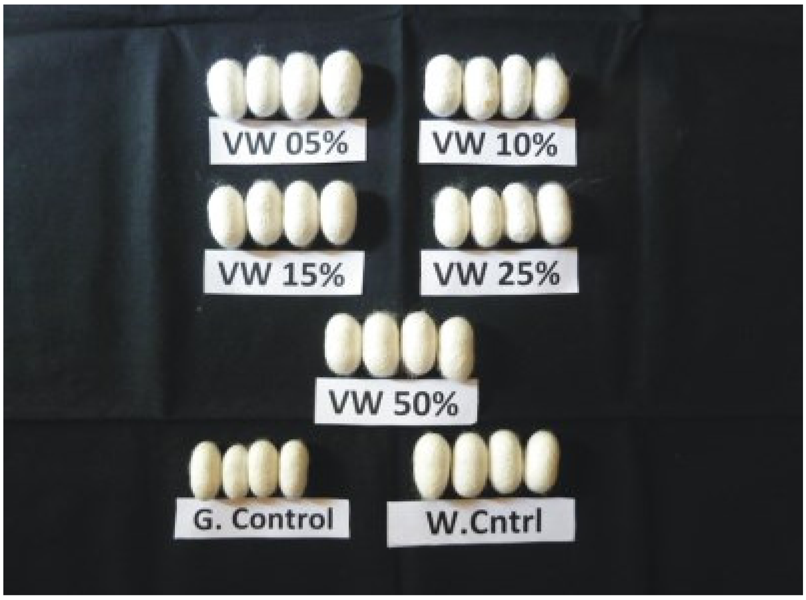


**Plate 3: Cocoons of Bivoltine hybrid obtained by fortifying mulberry leaves with vermiwash**

VW : Vermiwash

G.C: General control

W.C : Water Treated control

#### 4.2.2.3 Cocoon shell ratio (%)

Mulberry leaves fortified with vermiwash produced significant effect on shell ratio in Kolar Gold and Bivoltine hybrids (Table 6). Feeding Kolar Gold silkworms with vermiwash at 15 per cent produced significantly high shell ratio (20.77 per cent), followed by 10 per cent (20.07 %), 25 per cent (19.82 %), 5 per cent (18.87 %) and 50 per cent(18.59 %) as compared to treated (17.16 %) and untreated control (16.80 %). In Bivoltine hybrid highest shell ratio being in 15 per cent (22.70 %), followed by 10 per cent (22.14 %), 25 per cent (22.10 %), 5 per cent (21.25 %) and 50 per cent (20.49 %) and all were on par. While, treated control yielded 20.72 per cent shell ratio and it was 19.33 per cent in untreated control.

#### 4.2.2.4 Cocoon yield (g/dfl)

Vermiwash 15 per cent fortification in Kolar Gold yielded 740 g of cocoons, followed by 10 per cent (720 g/dfl). While, Bivoltine hybrid silkworms fed with 10 and 15 per cent vermiwash fortified leaves produced 760 g of cocoons/dfl, followed by 50 per cent (737 g) and 25 per cent (733 g). While, untreated and treated leaves recorded 670 g and 700 g of cocoons/dfl (Table 6).

### 4.2.3 Silk parameters

#### 4.2.3.1 Silk filament length (m)

Silk filament was significantly longer in Kolar Gold silkworms supplemented with vermiwash 15 per cent (855.50 m), 10 per cent (819.75 m), 5 per cent (782.75 m), 25 per cent (772.38m), 50 per cent (766.88 m) and treated control (770.13 m) which were on par as compared with untreated control (556.38 m). Bivoltine hybrid cocoon filament was longer in 15 per cent vermiwash fortification (1275.25 m), followed by 10 per cent (1275.25 m), 25 per cent (1255.63 m), 50 per cent (1203.39m) and were on par with each other. Five per cent vermiwash and treated control gave 1139.25 m and 1117.18 m of silk filament and were the next best treatments (Table 7).

#### 4.2.3.2 Denier

Kolar Gold and Bivoltine hybrid fed with vermiwash fortified mulberry leaves produced finer denier as compared to unfortified mulberry leaves feeding. The fortification of vermiwash at 15 per cent gave finer denier (2.71), followed by 10 per cent (3.11). They were followed by 25 per cent (3.25), 5 per cent (3.32) and 50 per cent (3.38) as compared to coarser denier in treated control (3.59) and untreated control (3.55). The bivoltine hybrid gave finer denier in 15 per cent (1.90), 25 per cent (2.00), 10 per cent (2.04), 5 per cent (2.13) and 50 per cent (2.14) which were all on par as compared to treated control (2.33) and untreated control (2.67) (Table 7).

#### 4.2.3.3 Fibroin (%)

The fibroin of silk filament was enhanced significantly in silkworms reared with vermiwash fortified mulberry leaves as compared to unfortified leaves. Among the five concentrations fortified to fifth instar silkworms, maximum fibroin content in silk was evident with 15 per cent in Kolar Gold (79.50 %) and Bivoltine hybrid (83.52 %) and 10 per cent (75.59 % ) and (81.62 %) than compared to untreated control (70.96 and 77.07 %) in both the hybrids (Table 8).

**Table 6: Effect of fortification of mulberry leaves with vermiwash on Cocoon shell ratio and cocoon yield of mulberry silkworm**

| Treatments | Cocoon shell ratio (%) | | Cocoon yield (g/dfl) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermiwash -5% | $18.87^{ab}$ $(25.72)^{*}$ | $21.25^{ab}$ $(27.44)^{*}$ | $700^{c}$ | $710^{c}$ |
| Vermiwash -10% | $20.07^{ab}$ $(26.60)^{*}$ | $22.14^{ab}$ $(28.04)^{*}$ | $720^{b}$ | $760^{a}$ |
| Vermiwash-15% | $20.77^{a}$ $(27.10)^{*}$ | $22.70^{a}$ $(28.44)^{*}$ | $740^{a}$ | $760^{a}$ |
| Vermiwash-25% | $19.82^{ab}$ $(26.42)^{*}$ | $22.10^{ab}$ $(28.02)^{*}$ | $700^{c}$ | $733^{b}$ |
| Vermiwash-50% | $18.59^{ab}$ $(25.53)^{*}$ | $20.49^{ab}$ $(26.89)^{*}$ | $700^{c}$ | $737^{b}$ |
| Treated control | $17.16^{c}$ $(24.46)^{*}$ | $20.72^{ab}$ $(27.06)^{*}$ | $640^{e}$ | $700^{d}$ |
| Control | $16.83^{c}$ $(24.21)^{*}$ | $19.33^{b}$ $(26.03)^{*}$ | $580^{f}$ | $670^{d}$ |
| **S.Em±** | **0.37** | **0.15** | **2.56** | **2.83** |
| **CD at 5%** | **1.08** | **0.45** | **7.47** | **8.25** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

* Figures in parentheses are angular transformed values.

4.2.3.4 Sericin (%)

The sericin content was lesser in silk of Kolar Gold (20.49 %) and Bivoltine hybrid (16.47 %) obtained by 15 per cent vermiwash fortification. Whereas, it was higher in untreated control (29.04 and 22.92 %, respectively) (Table 8).

## 4.3 Effect of fortification of mulberry leaves with vermicoelomic fluid on mulberry silkworm, *Bombyx mori* L.

### 4.3.1 Growth and development

4.3.1.1 Fifth instar larval duration (hr)

The fortification of vermicoelomic fluid showed significant reduction in fifth instar larval duration of Kolar Gold and Bivoltine hybrid. Vermicoelomic fluid at 15 per cent reduced the fifth instar larval duration to 158.30 hr and 160.23 hr in both Kolar Gold and Bivoltine hybrid as compared to 162.37 hr and 170.10 hr respectively in silkworms fed with unfortified mulberry leaves. The larval duration of Kolar Gold silkworms in treated control and vermicoelomic fluid fortification at 10 per cent recorded 160.37 hr and 160.67 hr and were on par with each other and next best to 15 per cent. 25 per cent (162.13 hr) was followed by five per cent (162.30 hr) and 50 per cent (172.23 hr). In Bivoltine silkworms, 15 per cent was followed by 10 per cent fortification of vermicoelomic fluid (161.17 hr), five per cent (162.20 hr), treated control (164.33 hr), 25 per cent (168.30 hr) and 50 per cent (170.33 hr) (Table 9).

4.3.1.2 Mature larval weight (g/ 10 larvae)

Vermicoelomic fluid fortification at 15 per cent to Kolar Gold silkworms enhanced the larval weight of 39.36 g, followed by 10 per cent (39.21 g). In Bivoltine hybrid vermicoelomic fluid fortification at 15 per cent significantly increased the larval weight (40.95 g) over treated control (35.06 g) and untreated control (27.90 g).It was followed by 10 per cent (40.58 g) and was on par with 15 per cent vermicoelomic fluid fortification (Table 10).

4.3.1.3 Silk productivity (cg/day)

Fortification of vermicoelomic fluid showed significant enhancement in silk productivity of Kolar Gold and Bivoltine hybrid. Kolar Gold silkworms registered significantly highest silk productivity when fortified with 15 per cent (5.26 cg/ day), 10 per cent (5.13 cg/ day), 25 per cent (4.91 cg/day) and 5 per cent (4.82 cg/ day) and all were on par with each other. They were followed by 50 per cent (4.5 cg/ day) and treated control (4.12 cg/ day). While, the silk productivity in unfortified treatment (3.94 cg/ day). Bivoltine silkworms fortified with 15 per cent (6.38 cg/ day) vermicoelomic fluid showed highest productivity, followed by 10 per cent (5.81 cg/day) and 25 per cent (5.35 cg/day). Whereas, treated control (4.97 cg/ day) and 50 per cent (4.59 cg/ day) were next best treatments. Unfortified treatment recorded 3.76 cg/ day of silk productivity (Table 10).

**Table 7: Effect of fortification of mulberry leaves with vermiwash on silk filament length and denier of mulberry silkworm**

| Treatments | Silk filament length (m) | | Denier | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermiwash -5% | 782.75 [a] | 1139.25 [bc] | 3.32 [b] | 2.13 [ab] |
| Vermiwash -10% | 819.75 [a] | 1275.25 [a] | 3.11 [ab] | 2.04 [ab] |
| Vermiwash-15% | 855.50 [a] | 1275.25 [a] | 2.71 [a] | 1.90 [a] |
| Vermiwash-25% | 772.38 [a] | 1255.63 [ab] | 3.25 [b] | 2.00 [ab] |
| Vermiwash-50% | 766.88 [a] | 1203.39 [abc] | 3.38 [b] | 2.14 [ab] |
| Treated control | 770.13 [a] | 1117.18 [cd] | 3.59 [b] | 2.33 [bc] |
| Control | 556.38 [b] | 1004.69 [c] | 3.55 [b] | 2.67 [c] |
| **S.Em ±** | **28.14** | **39.18** | **0.16** | **0.11** |
| **CD at 5%** | **82.15** | **114.35** | **0.48** | **0.32** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

**Table 8: Effect of fortification of mulberry leaves with vermiwash on fibroin and sericin composition of mulberry silk**

| Treatments | Fibroin (%) | | Sericin (%) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermiwash -5% | 71.51 $^{c}$ (57.73) * | 78.40 $^{d}$ (62.31) * | 28.48 $^{a}$ (32.27) * | 21.59 $^{b}$ (27.63) * |
| Vermiwash -10% | 75.59 $^{b}$ (60.40) * | 81.62 $^{b}$ (64.60) * | 24.40 $^{b}$ (29.60) * | 18.37 $^{d}$ (25.33) * |
| Vermiwash-15% | 79.50 $^{a}$ (63.08) * | 83.52 $^{a}$ (66.03) * | 20.49 $^{c}$ (29.67) * | 16.47 $^{e}$ (23.97) * |
| Vermiwash-25% | 71.49 $^{c}$ (57.73) * | 80.00 $^{c}$ (63.44) * | 28.50 $^{a}$ (32.33) * | 20.00 $^{c}$ (26.56) * |
| Vermiwash-50% | 75.28 $^{b}$ (60.20) * | 78.00 $^{de}$ (62.03) * | 24.71 $^{b}$ (29.87) * | 22.00 $^{ab}$ (27.97) * |
| Treated control | 75.00 $^{b}$ (60.00) * | 79.48 $^{c}$ (63.08) * | 25.00 $^{b}$ (30.00) * | 20.15 $^{c}$ (26.71) * |
| Control | 70.96 $^{c}$ (57.42) * | 77.07 $^{e}$ (61.41) * | 29.04 $^{a}$ (32.58) * | 22.92 $^{a}$ (28.59) * |
| **S.Em ±** | **0.22** | **0.32** | **0.23** | **0.32** |
| **CD at 5%** | **0.64** | **0.94** | **0.66** | **0.94** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
*Figures in parentheses are angular transformed values.

**Table 9: Effect of fortification of mulberry leaves with vermicoelomic fluid on fifth instar larval duration of mulberry silkworm**

| Treatments | Fifth instar larval duration (hr) | |
|---|---|---|
| | **Kolar gold** | **Bivoltine hybrid** |
| Vermicoelomic fluid -5% | 162.30 [c] | 162.20 [c] |
| Vermicoelomic fluid -10% | 160.67 [b] | 161.17 [b] |
| Vermicoelomic fluid -15% | 158.63 [a] | 160.23 [a] |
| Vermicoelomic fluid -25% | 162.13 [c] | 168.30 [e] |
| Vermicoelomic fluid -50% | 172.23 [d] | 170.33 [f] |
| Treated control | 160.37 [b] | 164.33 [d] |
| Control | 162.37 [c] | 170.10 [f] |
| **S.Em±** | **0.22** | **0.22** |
| **CD at 5%** | **0.64** | **0.65** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

**Table 10: Effect of fortification of mulberry leaves with vermicoelomic fluid on mature larval weight and silk productivity of mulberry silkworm**

| Treatments | Mature larval weight (g/10 larvae) | | Silk productivity (cg/ day) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermicoelomic fluid -5% | 38.75 [a] | 38.50 [c] | 4.82 [ab] | 5.18 [bc] |
| Vermicoelomic fluid -10% | 39.21 [a] | 40.58 [ab] | 5.13[a] | 5.81 [ab] |
| Vermicoelomic fluid -15% | 39.36 [a] | 40.95 [a] | 5.26 [a] | 6.38 [a] |
| Vermicoelomic fluid -25% | 39.02[a] | 38.83 [bc] | 4.91 [ab] | 5.35 [bc] |
| Vermicoelomic fluid -50% | 38.70 [a] | 35.89 [d] | 4.5 [b] | 4.59 [c] |
| Treated control | 36.93 [ab] | 35.06 [d] | 4.12 [c] | 4.97 [bc] |
| Control | 34.24 [b] | 27.90 [e] | 3.94 [d] | 3.76 [d] |
| **S.Em±** | **1.13** | **0.64** | **0.14** | **0.28** |
| **CD at 5%** | **3.30** | **1.86** | **0.41** | **0.81** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

#### 4.3.1.4 Pupal weight (g/ 10 pupae)

The weight of pupa was significant and highest in 15 per cent vermicoelomic fluid fortification (15.63 g). It was followed by 10 per cent (14.37 g), 50 per cent (13.80 g), five per cent (13.60 g) and treated control (13.50 g). While, it was 13.24 g in 25 per cent as compared to untreated treatment (12.34 g). Pupa of Bivoltine hybrid registered highest weight of 14.18 g in 15 per cent fortification. It was followed by 10 per cent (13.26 g), five per cent (12.90 g) and 50 per cent (12.83 g) and were on par with each other. Treated control (12.35 g) and 25 per cent fortification (11.57 g) were the next best treatments. While, it was 10.49 g in untreated control (Table 11).

#### 4.3.1.5 Effective rate of rearing (ERR %)

The effective rate of rearing in Kolar Gold was significant and highest rearing rate was observed in 15 per cent (99.67 %), unfortified treatment (99.67 %) and 5 per cent (97.00 %) and were on par with each other. They were followed by 25 per cent (95.67 %), 50 per cent (93.33 %) and treated control (90.00 %). While, vermicoelomic fluid at 10 per cent recorded least rearing rate (90.00 %). The effective rate of rearing in Bivoltine hybrid was highest in unfortified treatment (100 %), followed by 10, 15 and 25 per cent and uniformly recorded 99.67 per cent rearing rate. They were followed by five per cent (94.00 %) and 50 per cent (93.00 %) and treated control (92.00 %) (Table 11).

### 4.3.2 Cocoon parameters

#### 4.3.2.1 Cocoon weight (g/ 10 cocoons)

The highest weight was obtained in Kolar Gold when fed with 15 per cent (20.77 g), followed by 10 per cent ( 18.46 g), 25 per cent ( 17.84 g), five per cent (17.30 g) and treated control (17.06 g) as compared to 50 per cent ( 16.62 g) (Plate 4). In Bivoltine hybrid, the cocoon weight was significantly high in 15 per cent (18.79 g) vermicoelomic fluid fortification, followed by 10 per cent (17.65 g). Whereas, vermicoelomic fluid at 25 per cent (16.95 g), 50 per cent (16.51 g), five per cent (16.50 g) and treated control (16.45 g) were the next best treatments and were on par with each other. However, unfortified treatment gave minimum cocoon weight (13.82 g/ 10 cocoons) (Table 12) (Plate 5).

#### 4.3.2.2 Cocoon shell weight (g/ 10 shells)

Kolar Gold silkworms produced highest shell weight at 15 per cent (3.57 g), followed by treated control (3.42 g) and 25 per cent (3.29 g), which were all on par. They were followed by 10 per cent (3.23 g), five per cent (3.18 g) and 50 per cent (3.15 g) and all were on par. While, unfortified treatment produced 2.66 g of shell weight. Vermicoelomic fluid fortification at 15 per cent (4.15 g) also showed highest shell weight in Bivoltine hybrid. While, 10 per cent (3.91 g) and 25 per cent (3.76 g) were on par with 15 per cent. They were followed by 50 per cent (3.46 g). While, unfortified treatment gave 2.67 g shell weight (Table 12).

**Table 11: Effect of fortification of mulberry leaves with vermicoelomic fluid on pupal weight and effective rate of rearing of mulberry silkworm**

| Treatments | Pupal weight (g/10 pupae) | | Effective rate of rearing (%) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermicoelomic fluid -5% | 13.64 [bc] | 12.90 [bc] | 97.00 [abc] (80.03) * | 94.00 [c] (75.82) * |
| Vermicoelomic fluid -10% | 14.37 [b] | 13.26 [b] | 90.00 [d] (71.57) * | 99.67 [b] (86.69) * |
| Vermicoelomic fluid -15% | 15.63 [a] | 14.18 [a] | 99.67 [a] (86.69) * | 99.67 [b] (86.69) * |
| Vermicoelomic fluid -25% | 13.24 [cd] | 11.57 [d] | 95.67 [bcd] (77.99) * | 99.67 [b] (86.69) * |
| Vermicoelomic fluid -50% | 13.80 [bc] | 12.83 [bc] | 93.33 [cd] (75.04) * | 93.00 [b] (74.66) * |
| Treated control | 13.50 [bc] | 12.35 [c] | 90.00 [d] (71.59) * | 92.00 [c] (73.57) * |
| Control | 12.34 [d] | 10.49 [e] | 99.67 [a] (86.69) * | 100.00 [a] (90.00) * |
| **S.Em±** | **0.31** | **0.20** | **2.57** | **1.06** |
| **CD at 5%** | **0.91** | **0.57** | **7.51** | **3.09** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
*Figures in parentheses are angular transformed values.

**Table 12: Effect of fortification of mulberry leaves with vermicoelomic fluid on cocoon and shell weight of mulberry silkworm**

| Treatments | Cocoon weight (g/10 cocoons) | | Cocoon shell weight (g/10 shells) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermicoelomic fluid -5% | 17.30 $^{d}$ | 16.50 $^{c}$ | 3.18 $^{b}$ | 3.26 $^{c}$ |
| Vermicoelomic fluid -10% | 18.46 $^{b}$ | 17.65 $^{b}$ | 3.23 $^{b}$ | 3.91 $^{ab}$ |
| Vermicoelomic fluid -15% | 20.77 $^{a}$ | 18.79 $^{a}$ | 3.57 $^{a}$ | 4.15 $^{a}$ |
| Vermicoelomic fluid -25% | 17.84 $^{c}$ | 16.95 $^{c}$ | 3.29 $^{ab}$ | 3.76 $^{abc}$ |
| Vermicoelomic fluid -50% | 16.62 $^{e}$ | 16.51 $^{c}$ | 3.15 $^{b}$ | 3.46 $^{bc}$ |
| Treated control | 17.06 $^{de}$ | 16.45 $^{c}$ | 3.42 $^{ab}$ | 3.41 $^{bc}$ |
| Control | 15.82 $^{f}$ | 13.82 $^{d}$ | 2.66 $^{c}$ | 2.67 $^{d}$ |
| **S.Em ±** | **0.17** | **0.20** | **0.10** | **0.18** |
| **CD at 5%** | **0.49** | **0.59** | **0.31** | **0.53** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

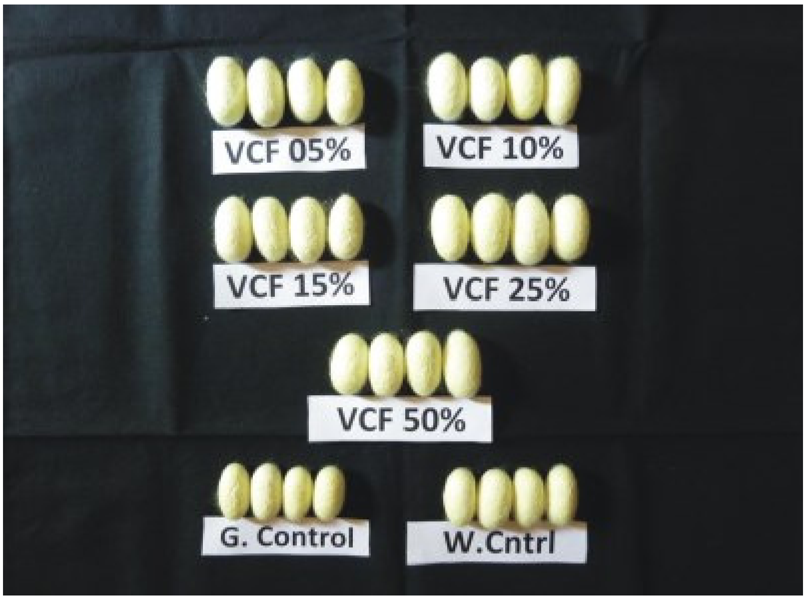


**Plate 4: Cocoons of Kolar Gold obtained by fortifying mulberry leaves with vermicoelomic fluid**

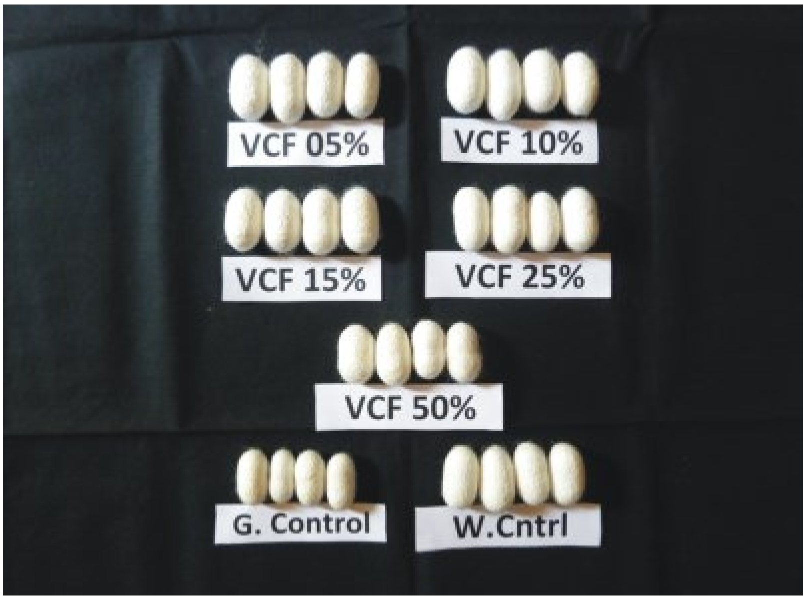


**Plate 5 : Cocoons of Bivoltine hybrid obtained by fortifying mulberry leaves with vermicoelomic fluid**

**Table 13: Effect of fortification of mulberry leaves with vermicoelomic fluid on shell ratio and cocoon yield of mulberry silkworm**

| Treatments | Cocoon shell ratio (%) | | Cocoon yield (g/dfl) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermicoelomic fluid -5% | 18.40 [ab] (25.39) * | 19.80 [ab] (26.34) * | 640 [c] | 711 [b] |
| Vermicoelomic fluid -10% | 18.15 [ab] (25.18) * | 20.99 [ab] (27.25) * | 660 [b] | 725 [a] |
| Vermicoelomic fluid -15% | 20.07 [a] (26.60) * | 23.53 [a] (29.01) * | 700 [a] | 742 [a] |
| Vermicoelomic fluid -25% | 19.79 [a] (26.40) * | 20.00 [ab] (26.54) * | 640 [c] | 720 [a] |
| Vermicoelomic fluid -50% | 18.11 [ab] (25.17) * | 23.04 [ab] (28.67) * | 600 [d] | 711 [b] |
| Treated control | 17.16 [b] (24.46) * | 20.72 [ab] (27.06) * | 640 [c] | 700 [b] |
| Control | 16.83 [b] (24.21) * | 19.33 [b] (26.03) * | 580 [e] | 670 [c] |
| S.Em ± | **0.48** | **0.87** | **2.44** | **2.06** |
| CD at 5% | **1.39** | **2.54** | **7.12** | **6.00** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
*Figures in parentheses are angular transformed values.

#### 4.3.2.3 Cocoon shell ratio (%)

Vermicoelomic fluid fortification effected a significant improvement in shell ratio. In Kolar Gold, 15 per cent (20.07 %) fortification gave highest shell ratio. It was followed by 25 per cent (19.79 %), 5 per cent (18.40 %), 10 per cent (18.15 %) and 50 per cent (18.11 %) which were on par with 15 per cent. While, water treatment (17.16 %) and unfortified leaves (16.83 %) which were on par with five per cent vermicoelomic fluid fortification. Bivoltine silkworms produced highest shell ratio of 23.53 per cent in 15 per cent fortification, followed by 50 per cent (23.04 %), 10 per cent (20.99 %), treated control (20.72 %), 25 per cent (20.00 %) and five per cent (19.80 %) and all were on par. While, it was 19.33 per cent in unfortified leaves (Table 13).

#### 4.3.2.4 Cocoon yield (g/dfl)

The cocoon yield in Kolar Gold was significantly enhanced by fortifying 15 per cent vermicoelomic fluid (700 g). It was followed by 10 per cent (660 g), five per cent (640 g), 25 per cent (640 g), treated control (640 g) and 50 per cent (600 g) as compared to 580 g in unfortified treatment. The Bivoltine hybrid produced highest cocoon yield by fortifying vermicoelomic fluid 15 per cent (742 g), 10 per cent (725 g) and 25 per cent (720 g) which were on par to each other (Table 13).

### 4.3.3 Silk parameters

#### 4.3.3.1 Silk filament length (m)

The data presented in the Table 14 indicate significant difference in vermicoelomic fluid fortification. In Kolar Gold, vermicoelomic fluid 15 per cent fortification gave 923.61 m of silk, it was followed by 10 per cent (897.62 m), five per cent (882.63 m), 25 per cent (854.76 m) and 50 per cent (840.50 m) and were on par with each other. The bivoltine hybrid silkworms spun longer silk filament of 1265.64 m when fortified with 15 per cent vermicoelomic fluid. It was followed by 10 per cent (1262.75 m), 25 per cent (1205.88 m), five per cent (1185.38 m), 50 per cent (1133.56 m) and treated control (1117.18 m) and were on par with 15 per cent fortification.

#### 4.3.3.2 Denier

The Kolar Gold and Bivoltine hybrid silkworms fed with vermicoelomic fluid fortified mulberry leaves produced a significant effect on denier. Fortification of 15 per cent vermicoelomic fluid produced finer denier (2.24) in Kolar Gold, followed by 25 per cent (3.10), 10 per cent (3.27), five per cent (3.40) and 50 per cent (3.54). In Bivoltine hybrid finer denier was found in 15 per cent (1.82) fortification, followed by 10 per cent (2.01), five per cent (2.06), 50 per cent (2.17), 25 per cent (2.30) and treated control (2.33) and all were on par with each other (Table 14).

#### 4.3.3.3 Fibroin (%)

Improvement in fibroin of silk filament was exhibited by fortifying vermicoelomic fluid to Kolar Gold and Bivoltine hybrid silkworms as compared to untreated control Kolar Gold silkworms produced highest fibroin in 15 per cent (76.30 %) fortification, followed by five per cent (74.71 %), 25 per cent (74.53 %), treated control (73.45 %), 10 per cent (72.25 %) and 50 per cent (71.64 %) fortification.

While, it was 70.96 per cent in untreated control. Bivoltine hybrid also produced high fibroin in 15 per cent (87.05 %) fortification, followed by 10 per cent (83.52 %), 25 per cent (82.28 %), water fortification (79.48 %), 50 per cent (78.00 %) and five per cent (78.60 %).While, the untreated control produced 77.07 per cent of fibroin in bivoltine hybrid (Table 15).

4.3.3.4 Sericin (%)

Kolar Gold produced lowest sericin when fed on 15 per cent (23.76 %), followed by 25 per cent (25.46 %), treated control (25.46 %), five per cent (25.8 %), 10 per cent (27.74 %) and 50 per cent (28.35 %). Bivoltine hybrid at 15 per cent (12.94 %) fortification gave least sericin, followed by 10 per cent (16.47 %), 25 per cent (17.71 %), treated control (20.15 %), 50 per cent (22.00 %), untreated control (22.92 %) and five per cent (21.39 %) (Table 15).

# 4.4 Effect of fortification of mulberry leaves with vermimeal on mulberry silkworm, *Bombyx mori* L.

## 4.4.1 Growth and development

4.4.1.1 Fifth instar duration (hr)

Fortification of mulberry leaves with vermimeal had a significant influence on fifth instar larval duration. Vermimeal at 15 per cent fortification significantly reduced the fifth instar larval duration in Kolar Gold (158.30 hr). It was followed by 10 per cent (160.50 hr) and 50 per cent (162.33 hr) and were on par with untreated control (162.37 hr) and treated control (164.33 hr). The larval duration was maximum in 5 per cent (168.30 hr) and 25 per cent (170.40 hr) fortification. Bivoltine hybrid also recorded shorter larval duration of 160.37 hr by fortifying 15 per cent vermimeal. It was followed by 10 per cent (162.43 hr), five per cent (164.00 hr), 25 per cent (165.40 hr) and 50 per cent (165.17 hr). While, untreated control and treated control recorded 170.10 hr and 173.73 hr of larval duration (Table16)

4.4.1.2 Mature larval weight (g/ 10 larvae)

The full grown larval weight was significantly increased by vermimeal fortification in both silkworm hybrids. Kolar Gold silkworms fed with 15 per cent vermimeal recorded highest weight of 40.67 g/ 10. It was followed by 10 per cent (39.53 g/ 10), 25 per cent (39.16 g/ 10) and 50 per cent (37.00 g/ 10) and were on par with vermiwash 15 per cent. While, feeding silkworms with 5 per cent vermimeal recorded 34.33 g/ 10 of larval weight, treated and untreated control recorded 34.23 g/ 10 and 34.24 g/ 10 and were on par with 5 per cent fortification. Bivoltine hybrid silkworms recorded 36.40 g/ 10 of larval weight by feeding 15 per cent vermimeal fortified leaves which was highest among all the treatments. While, vermimeal 10 per cent (35.78 g/ 10) and 50 per cent (34.62 g/ 10) were on par with15 per cent. Fortification of vermimeal at 5 and 25 per cent recorded uniform weight of bivoltine silkworms (33.94 g/ 10) and treated control recorded (31.79 g / 10) of larval weight as compared to silkworms fed with unfortified leaves (27.90 g/ 10) (Table17).

**Table 14: Effect of fortification of mulberry leaves with vermicoelomic fluid on silk filament length and denier of mulberry silkworm**

| Treatments | Silk filament length (m) | | Denier | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermicoelomic fluid -5% | 882.63 $^{ab}$ | 1185.38 $^{ab}$ | 3.40 $^{b}$ | 2.06 $^{a}$ |
| Vermicoelomic fluid -10% | 897.62 $^{ab}$ | 1262.75 $^{a}$ | 3.27 $^{b}$ | 2.01 $^{a}$ |
| Vermicoelomic fluid -15% | 923.61 $^{a}$ | 1265.64 $^{a}$ | 2.24 $^{a}$ | 1.82 $^{a}$ |
| Vermicoelomic fluid -25% | 854.76 $^{ab}$ | 1205.88 $^{a}$ | 3.10 $^{b}$ | 2.30 $^{ab}$ |
| Vermicoelomic fluid -50% | 840.50 $^{ab}$ | 1133.56 $^{ab}$ | 3.54 $^{b}$ | 2.17 $^{ab}$ |
| Treated control | 770.13 $^{b}$ | 1117.18 $^{ab}$ | 3.59 $^{b}$ | 2.33 $^{ab}$ |
| Control | 556.38 $^{c}$ | 1004.69 $^{b}$ | 3.55 $^{b}$ | 2.67 $^{b}$ |
| **S.Em±** | **43.51** | **59.98** | **0.26** | **0.19** |
| **CD at 5%** | **127.01** | **175.09** | **0.75** | **0.54** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

**Table 15: Effect of fortification of mulberry leaves with vermicoelomic fluid on fibroin and sericin of mulberry silk**

| Treatments | Fibroin (%) | | Sericin (%) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermicoelomic fluid -5% | 74.71 [b]<br>(59.80)* | 78.60 [e]<br>(62.44)* | 25.80 [d]<br>(30.53)* | 21.39 [b]<br>(27.56)* |
| Vermicoelomic fluid -10% | 72.25 [e]<br>(58.18)* | 83.52 [b]<br>(66.03)* | 27.74 [c]<br>(31.76)* | 16.47 [e]<br>(23.97)* |
| Vermicoelomic fluid -15% | 76.30 [a]<br>(60.87)* | 87.05 [a]<br>(68.87)* | 23.76 [f]<br>(29.20)* | 12.94 [f]<br>(20.96)* |
| Vermicoelomic fluid -25% | 74.53 [c]<br>(59.67)* | 82.28 [c]<br>(65.12)* | 25.46 [e]<br>(30.26)* | 17.71 [d]<br>(24.88)* |
| Vermicoelomic fluid -50% | 71.64 [f]<br>(57.80)* | 78.00 [f]<br>(62.03)* | 28.35 [b]<br>(32.20)* | 22.00 [b]<br>(27.97)* |
| Treated control | 73.45 [d]<br>(58.95)* | 79.48 [d]<br>(63.08)* | 25.46 [e]<br>(30.26)* | 20.15 [c]<br>(26.71)* |
| Control | 70.96 [g]<br>(57.42)* | 77.07 [g]<br>(61.41)* | 29.04 [a]<br>(32.58)* | 22.92 [a]<br>(28.59)* |
| **S.Em ±** | **0.02** | **0.03** | **0.02** | **0.22** |
| **CD at 5%** | **0.07** | **0.09** | **0.07** | **0.64** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
*Figures in parentheses are angular transformed values.

**Table 16: Effect of fortification of mulberry leaves with vermimeal on fifth instar larval duration of mulberry silkworm**

| Treatments | Fifth instar larval duration (hr) | |
|---|---|---|
| | Kolar gold | Bivoltine hybrid |
| Vermimeal -5% | 168.30[e] | 164.00 [c] |
| Vermimeal -10% | 160.50[b] | 162.43 [b] |
| Vermimeal -15% | 158.30[a] | 160.37 [a] |
| Vermimeal -25% | 170.40[f] | 165.40 [d] |
| Vermimeal -50% | 162.33[c] | 165.17 [d] |
| Treated control | 164.33[d] | 173.73 [f] |
| Control | 162.37[c] | 170.10 [e] |
| **S.Em±** | **0.17** | **0.20** |
| **CD at 5%** | **0.51** | **0.59** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

4.4.1.3 Silk productivity (cg/day)

Silk productivity was significantly enhanced by feeding silkworms of Kolar Gold and Bivoltine hybrid with vermimeal fortification. Kolar Gold silkworms exhibited highest silk productivity of 4.80 cg/day when fed with 15 per cent vermimeal, while 10 per cent (4.34 cg/day), 25 per cent (4.13 cg /day), 50 per cent (4.15 cg/day) and five per cent (4.11 cg/day) were the next best treatments. However, untreated treatment recorded 3.94 cg/day and on par with treated control (3.65 cg/ day). Bivoltine hybrid silkworms showed highest and on par silk productivity in 15 per cent (5.65 cg/ day), 10 per cent (5.63 cg/day), 5 per cent (5.42 cg/day) and treated control (5.40 cg/day). They were followed by vermimeal 50 per cent (4.87 cg/day). While it was least in untreated control (3.76 cg/day) (Table 17).

4.4.1.4 Pupal weight (g/ 10 pupae)

Data presented in the Table 18 reveals that mulberry leaves fortification with vermimeal had a significant effect on pupal weight. Fortification of vermimeal at 15 per cent showed highest pupal weight (13.28 g/ 10) in Kolar Gold hybrid, followed by 10 per cent (12.49 g/ 10) and both were on par as compared to untreated control (12.34 g/ 10), 50 per cent (12.31 g/ 10), five per cent (12.19 g/ 10) and 25 per cent (11.92 g/ 10). While, treated control recorded 11.49 g/ 10 of pupal weight in Kolar Gold. Bivoltine hybrid pupal weight was significantly high in 15 per cent (13.77 g/ 10) fortification. While, 10 per cent (13.42 g/ 10) fortification was on par with 15 per cent, followed by 50 per cent (12.82 g/ 10), 25 per cent (12.67 g/ 10) and five percent (12.28 g/ 10) fortification and were on par.

4.4.1.5 Effective rate of rearing (ERR %)

The effective rate of rearing in Kolar Gold silkworms was significant and high when fed with vermimeal 15 percent (99.67 %). It was followed by 10 per cent (99.00 %) and 25 per cent (98.00 %) and were on par with 15 per cent. Fortification of 5 per cent and 50 per cent vermimeal produced 96.00 % of rearing rate as compared to treated control (86.00 %). The bivoltine hybrid silkworms recorded 100 per cent effective rate of rearing in untreated control, followed by vermimeal 15 per cent (97.33 %) , 10 per cent (96.00 %) 5 per cent (94.67 %), 50 per cent (89.67 %) and treated control (95.00 per cent) (Table 18).

## 4.4.2 Cocoon parameters

4.4.2.1 Cocoon weight (g/ 10 cocoons)

Cocoon weight varied significantly due to vermimeal fortification at different concentration in Kolar Gold and Bivoltine hybrid. In Kolar Gold highest cocoon weight of 16.88 g was recorded with 15 per cent vermimeal as compared to 15.82 g in untreated control. It was followed by 10 per cent (16.06 g) and similar with untreated control (15.82 g). While, 50, 25 and 5 per cent yielded 15.37 g, 15.51g and 14.98 g of cocoons (Plate 6). In Bivoltine hybrid, 15 per cent vermimeal fortification recorded highest cocoon weight (17.85 g), followed by 50 per cent (17.47 g) and 10 per cent (17.25 g) and all were on par with each other. Vermimeal 25 per cent (16.26 g) and five per cent (16.22 g) were the next best treatments and on par with treated control (13.82 g) (Table 19 and Plate 7).

**Table 17: Effect of fortification of mulberry leaves with vermimeal on mature larval weight and silk productivity of mulberry silkworm**

| Treatments | Mature larval weight (g/10 larvae) | | Silk productivity (cg/ day) | |
|---|---|---|---|---|
| | **Kolar gold** | **Bivoltine hybrid** | **Kolar gold** | **Bivoltine hybrid** |
| Vermimeal -5% | 34.33 [b] | 33.94 [b] | 4.11 [b] | 5.42 [ab] |
| Vermimeal -10% | 39.53 [ab] | 35.78 [ab] | 4.34 [b] | 5.63 [a] |
| Vermimeal -15% | 40.67 [a] | 36.40 [a] | 4.80 [a] | 5.65 [a] |
| Vermimeal -25% | 39.16 [ab] | 33.94 [b] | 4.13 [b] | 5.09 [ab] |
| Vermimeal -50% | 37.00 [ab] | 34.62 [ab] | 4.15 [b] | 4.87 [b] |
| Treated control | 34.23 [b] | 31.79 [c] | 3.65 [c] | 5.40 [ab] |
| Control | 34.24 [b] | 27.90 [d] | 3.94 [bc] | 3.76 [c] |
| **S.Em±** | **1.86** | **0.66** | **0.12** | **0.19** |
| **CD at 5%** | **5.41** | **1.92** | **0.36** | **0.54** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

4.4.2.2 Cocoon shell weight (g/10 shells)

The shell weight was highest in Kolar Gold fed with 15 per cent vermimeal (3.16 g/ 10), followed by 25 per cent (2.95 g/ 10) and 50 per cent (2.94 g/ 10) and were at par. Bivoltine hybrid fortification with vermimeal from 5 to 50 per cent recorded uniform shell weight. However, highest shell weight of 3.96 g/ 10 was recorded in 15 per cent, followed by 50 per cent (3.89 g/ 10), treated control (3.78 g/ 10), 10 per cent (3.71 g/ 10), 5 and 25 per cent (3.51 g/ 10) (Table 19).

4.4.2.3 Cocoon shell ratio (%)

Mulberry leaves fortified with vermimeal resulted in significant increase in shell ratio in Kolar Gold and Bivoltine hybrids (Table 20). In Kolar Gold, 15 per cent vermimeal fortification (23.92 %) significantly increased the shell ratio. While, 10 and 25 per cent recorded 22.85 per cent of shell ratio and were on par with 15 per cent. Vermimeal 50 per cent (21.91 %) and treated control (21.61 %) were on par. Bivoltine hybrid fed with vermimeal 15 per cent fortified leaves produced significantly high shell ratio of 19.23 per cent followed by 50 per cent ( 18.74 %), 5 per cent (18.60 %), 10 per cent (18.50 %), 25 per cent (18.35 %) which were on par to each other.

4.4.2.4 Cocoon yield (g/dfl)

Kolar Gold fed with 15 per cent vermimeal fortified leaves produced 743 g/ dfl, followed by five per cent (711 g/ dfl), 50 per cent (708 g/ dfl) and 25 per cent (707 g/ dfl) and were on par with each other. The untreated treatment recorded 670 g of cocoons/dfl. Fortification of vermimeal 15 per cent (640 g/ dfl) has significantly enhanced the cocoon yield in Bivoltine hybrid over rest of the treatments. It was followed by 10 and 25 per cent and both gave 600 g/ dfl of yield. 50 per cent (580 g/ dfl) and untreated control (580 g/ dfl) and 5 per cent 540 g/ dfl and 520 g/ dfl in treated control.

### 4.4.3 Silk parameters

4.4.3.1 Silk filament length (m)

Silk filament was significantly longer in Kolar Gold cocoons obtained by 15 per cent (923.60 m) vermimeal fortification. It was followed by 10 per cent (813.63 m), 50 per cent (803.75 m) and 25 per cent (800.00 m) and were on par with 15 per cent. Bivoltine hybrid produced longest filament of 1167.25 m when fortified with 15 per cent vermimeal, followed by five per cent (1129.13 m), 10 per cent (1118.88 m), 25 per cent (1110.04 m), 50 per cent (1106.88 m) and all were on par with each other (Table 21).

4.4.3.2 Denier

The silk filament of Kolar Gold was finer due to 15 per cent vermimeal fortification (2.80), followed by ten per cent (2.91), 50 per cent (3.23) , treated control (3.32), 25 per cent (3.37) and were on par with 15 per cent. Five per cent (3.48) and untreated control gave coarser denier (3.55). The Bivoltine hybrid silk was finer in 15 per cent (1.99), 10 per cent (2.04), 50 per cent (2.12), five per cent (2.38), 25 per cent (2.48) fortification as compared to treated (2.52) and untreated control (2.67) (Table 21).

**Table 18: Effect of fortification of mulberry leaves with vermimeal on pupal weight and effective rate of rearing of silkworm**

| Treatments | Pupal weight (g/10 pupae) | | Effective rate of rearing (%) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermimeal -5% | 12.19 [bc] | 12.28 [b] | 96.00 **[b]**<br>(78.49) * | 94.67 **[b]**<br>(77.60) * |
| Vermimeal -10% | 12.49 [abc] | 13.42 [a] | 99.00 **[ab]**<br>(85.34) * | 96.00 **[b]**<br>(79.02) * |
| Vermimeal -15% | 13.28[a] | 13.77 [a] | 99.67 [a]<br>(88.05) * | 97.33 **[b]**<br>(80.88) * |
| Vermimeal -25% | 11.92[c] | 12.67 [b] | 98.00 **[ab]**<br>(82.02) * | 96.67 **[b]**<br>(79.90) * |
| Vermimeal -50% | 12.31 [bc] | 12.82 [b] | 96.00 **[b]**<br>(78.49) * | 89.67 **[b]**<br>(72.87) * |
| Treated control | 11.49[d] | 11.37 [c] | 86.00 **[c]**<br>(68.01) * | 95.00 **[b]**<br>(77.09) * |
| Control | 12.34[b] | 10.49 [d] | 99.67 **[a]**<br>(88.05) * | 100.00 [a]<br>(89.96) * |
| **S.Em±** | **0.14** | **0.20** | **1.50** | **2.45** |
| **CD at 5%** | **0.42** | **0.57** | **4.38** | **7.14** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
*Figures in parentheses are angular transformed values

**Table 19: Effect of fortification of mulberry leaves with vermimeal on cocoon and shell weight of mulberry silkworm**

| Treatments | Cocoon weight (g/10 cocoons) | | Cocoon shell weight (g/10 shells) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermimeal -5% | 14.98[ef] | 16.22 [b] | 2.76[bc] | 3.51 [a] |
| Vermimeal -10% | 16.06[b] | 17.25 [a] | 2.88[bc] | 3.71 [a] |
| Vermimeal -15% | 16.88[a] | 17.85 [a] | 3.16[a] | 3.96 [a] |
| Vermimeal -25% | 15.51[cd] | 16.26 [b] | 2.95[ab] | 3.51 [a] |
| Vermimeal -50% | 15.37[de] | 17.47 [a] | 2.94[ab] | 3.89 [a] |
| Treated control | 14.53[f] | 15.78 [b] | 2.30[d] | 3.78 [a] |
| Control | 15.82[bc] | 13.82 [c] | 2.66[cd] | 2.67 [b] |
| **S.Em±** | **0.15** | **0.17** | **0.08** | **0.14** |
| **CD at 5%** | **0.45** | **0.49** | **0.24** | **0.41** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

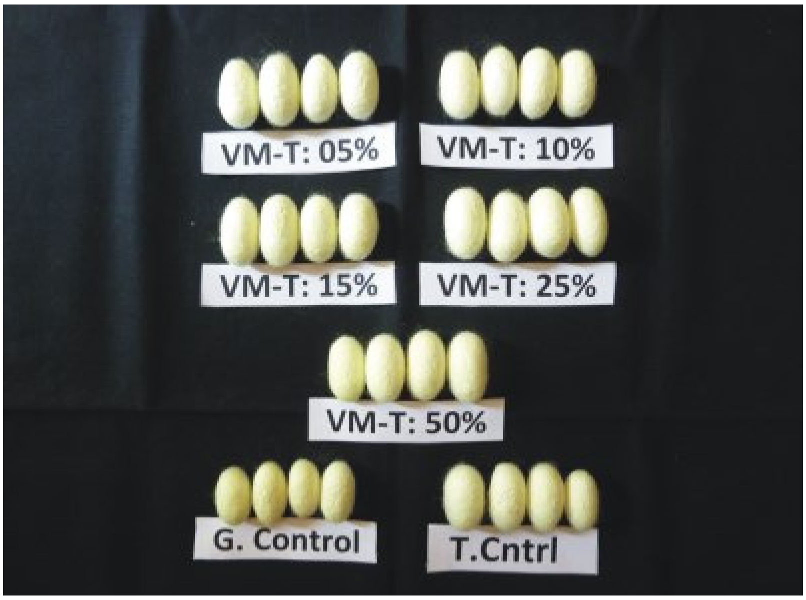


**Plate 6: Cocoons of Kolar Gold obtained by fortifying mulberry leaves with vernimeal**

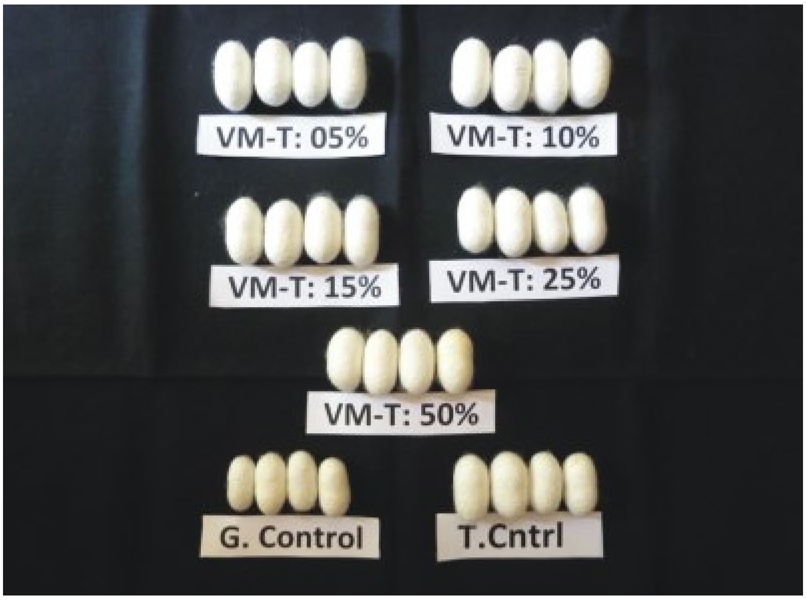


**Plate 7: Cocoons of Bivoltine hybrid obtained by fortifying mulberry leaves with vermimeal**

**Table 20: Effect of fortification of mulberry leaves with vermimeal on cocoon shell ratio and cocoon yield of silkworm**

| Treatments | Cocoon shell ratio (%) | | Cocoon yield (g/dfl) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermimeal -5% | 18.60$^{ab}$ (25.53)* | 20.33$^{bc}$ (26.7)* | 540$^{d}$ | 711$^{b}$ |
| Vermimeal -10% | 18.50$^{ab}$ (25.47)* | 22.85$^{ab}$ (28.54)* | 600$^{b}$ | 684$^{c}$ |
| Vermimeal -15% | 19.23$^{a}$ (25.99)* | 23.92$^{a}$ (29.26)* | 640$^{a}$ | 743$^{a}$ |
| Vermimeal -25% | 18.35$^{abc}$ (25.35)* | 22.85$^{ab}$ (28.54)* | 600$^{b}$ | 707$^{b}$ |
| Vermimeal -50% | 18.74$^{ab}$ (25.64)* | 21.91$^{abc}$ (27.90)* | 580$^{c}$ | 708$^{b}$ |
| Treated control | 17.19$^{bc}$ (24.47)* | 21.61$^{abc}$ (27.69)* | 520$^{e}$ | 700$^{bc}$ |
| Control | 16.83$^{c}$ (24.21)* | 19.33$^{c}$ (26.03)* | 580$^{c}$ | 670$^{d}$ |
| **S.Em±** | **0.37** | **0.64** | **2.89** | **3.09** |
| **CD at 5%** | **1.09** | **1.85** | **8.43** | **9.01** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
* Figures in parentheses are angular transformed values.

**Table 21: Effect of fortification of mulberry leaves with vermimeal on cocoon filament length and denier of mulberry silkworm**

| Treatments | Silk filament length (m) | | Denier | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermimeal -5% | 752.75[b] | 1129.13[ab] | 3.48 [bc] | 2.38 [abc] |
| Vermimeal -10% | 813.63[ab] | 1118.88 [ab] | 2.91 [ab] | 2.04 [ab] |
| Vermimeal -15% | 923.60[a] | 1167.25 [a] | 2.80 [a] | 1.99 [a] |
| Vermimeal -25% | 800.00[ab] | 1110.04 [ab] | 3.37 [abc] | 2.48 [abc] |
| Vermimeal -50% | 803.75[ab] | 1106.88[ab] | 3.23 [abc] | 2.12 [ab] |
| Treated control | 759.53[b] | 979.21 [c] | 3.32 [abc] | 2.52 [bc] |
| Control | 556.38[c] | 1004.69 [bc] | 3.55 [c] | 2.67 [c] |
| **S.Em±** | **39.85** | **38.64** | **0.18** | **0.15** |
| **CD at 5%** | **116.35** | **112.80** | **0.54** | **0.43** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT

**Table 22: Effect of fortification of mulberry leaves with vermimeal on fibroin and sericin composition of mulberry silk**

| Treatments | Fibroin (%) | | Sericin (%) | |
|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| Vermimeal -5% | 76.22 [d] (60.80) * | 73.77 [e] (59.21) * | 23.77 [d] (29.20) * | 26.22 [c] (30.79) * |
| Vermimeal -10% | 81.34 [b] (64.38) * | 75.67 [c] (60.47) * | 18.66 [f] (25.62) * | 24.32 [e] (29.53) * |
| Vermimeal -15% | 82.83 [a] (65.50) * | 79.09 [a] (62.80) * | 17.77 [g] (24.95) * | 20.90 [g] (27.20) * |
| Vermimeal -25% | 72.60 [f] (58.44) * | 74.38 [d] (59.60) * | 27.39 [b] (31.56) * | 25.61 [d] (30.40) * |
| Vermimeal -50% | 77.77 [c] (61.89) * | 71.17 [g] (57.54) * | 22.22 [e] (28.11) * | 28.82 [a] (32.46) * |
| Treated control | 75.17 [e] (60.13) * | 73.33 [f] (58.89) * | 24.82 [c] (29.87) * | 26.66 [b] (31.11) * |
| Control | 70.96 [g] (57.42) * | 77.07 [b] (61.41) * | 29.04 [a] (32.58) * | 22.92 [f] (28.59) * |
| **S.Em±** | **0.02** | **0.01** | **0.01** | **0.02** |
| **CD at 5%** | **0.07** | **0.02** | **0.02** | **0.07** |

In vertical columns means followed by similar letters are not different statistically (CD = 0.05) by DMRT
*Figures in parentheses are angular transformed values.

**Table 23: Benefit cost ratio of fortification of mulberry leaves with vermiproducts on mulberry silkwor**

| Treatments | Vermiwash | | Vermicoelomic fluid | | Vermimeal | |
|---|---|---|---|---|---|---|
| | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid | Kolar gold | Bivoltine hybrid |
| T1- 5% | 2.92 | 1.36 | 1.41 | 1.35 | 0.66 | 0.95 |
| T2- 10% | 3.33 | 3.00 | 1.77 | 1.71 | 0.25 | 0.17 |
| T3- 15% | 3.72 | 2.93 | 2.52 | 2.12 | 0.60 | 0.73 |
| T4- 25% | 1.87 | 1.96 | 1.14 | 1.33 | 0.14 | 0.26 |
| T5-50% | 2.40 | 0.84 | 0.30 | 0.64 | 0.30 | 0.19 |

#### 4.4.3.3 Fibroin (%)

Improvement in fibroin content of silk filament was exhibited by silkworms reared with vermimeal supplemented mulberry leaves as compared to unsupplemented leaves. Among the five concentrations fortified to fifth instar silkworms of Kolar Gold and Bivoltine hybrid, maximum fibroin in silk was evident with 15 per cent (82.83 and 79.09 %) and ten per cent (81.34 and 75.67 %) as compared to untreated control (70.96 and 77.07 %) in both the hybrids (Table 22).

#### 4.4.3.4 Sericin (%)

Lesser sericin content was apparent in silk filament of cocoon spun by silkworms reared on mulberry leaf supplemented with 15 per cent vermimeal in Kolar Gold (17.77 %) and Bivoltine hybrids (20.90 %). Whereas, increased sericin was seen in untreated control (29.04 %) of Kolar Gold and 50 per cent (28.82 %) fortification in Bivoltine hybrid (Table 22).

# 5. DISCUSSION

Silkworm being a monophagous insect derives almost all the required nutrients for its growth from mulberry leaves. Though mulberry leaves provides almost all the nutrients required for its development, the variation in quantity of nutrients in the leaves limits the balanced supplementation of nutrients. Hence, supplementation of nutrients through mulberry is one of the remedy to balance the nutritional requirements of silkworm and to enhance the silk production. Hence, results of the experiment on fortification of mulberry leaves with vermiproducts on mulberry silkworm growth, cocoon and silk parameters are discussed here under.

## 5.1 Effect of fortification of mulberry leaves with vermiwash on mulberry silkworm *Bombyx mori* L.

### 5.1.1 Silkworm growth and development

Vermiwash fortification to mulberry leaves at 5, 10, 15, 25 and 50 per cent showed significant improvement in silkworm growth and development. The fifth instar larval duration varied significantly between vermiwash fortification at different concentration and untreated treatment. Vermiwash 15 per cent fortification significantly reduced the fifth instar larval duration (160.23 hr). The silkworms in treated control showed on par larval duration (160.37 hr) with 15 per cent fortification. The mature larval weight was significant and high in vermiwash 15 per cent (40.15 g/ 10 larvae), 10 per cent (39.09 g/ 10 larvae), 25 per cent (38.36 g/ 10 larvae), 50 per cent (36.95 g/ 10 larvae) and treated control (36.93 g/ 10 larvae) and were on par with 15 per cent as compared to 34.24 g / 10 larvae recorded in untreated control (Fig. 1). The silk productivity was significantly enhanced by fortifying vermiwash 15 per cent (6.04 cg/ day) as compared to treated control (4.12 cg/ day) and untreated control (3.94 cg/ day). The effective rate of rearing varied significantly between different concentrations of vermiwash, but vermiwash 10 per cent (99.67 %) and 15 per cent (99.00 %) were on par with untreated control (99.67 %). The vermiwash 15 per cent (15.02 g /10 pupae) recorded highest pupal weight, followed by 10 per cent (14.63 g/10 pupae), 50 per cent (14.37 g/10 pupae) and 25 per cent (14.27 g/10 pupae) which were on par as compared to untreated treatment (12.34 g/10 pupae).

In Bivoltine hybrid, fortification of vermiwash had a significant influence on fifth instar larval duration, vermiwash 15 per cent (158.63 hr) significantly reduced the larval duration as compared to unfortified control (170.10 hr). The mature larval weight was significantly higher in silkworms fed with 15 per cent (39.29 g/ 10 larvae) vermiwash, 10 per cent (38.27 g/ 10 larvae) and 25 per cent (38.15 g/ 10 larvae) which were on par as compared to untreated control (27.90 g/ 10 larvae) (Fig. 1). Fortification of vermiwash had significantly influenced the silk productivity, 15 per cent vermiwash enhanced the silk productivity to 6.31 cg/ day as compared 3.76 cg/ day in unfortified treatment. Vermiwash 10 per cent (5.99 cg / day) and 25 per cent (5.75 cg/ day) were on par with 15 per cent. The effective rate rearing was significant and higher in untreated treatment (100 %), followed by vermiwash 15 per cent (99.67 %) and 10 per cent (99.67 %) and were on par with untreated control. The pupal weight was significant and high in 15 per cent fortification (14.28 g/10 pupae) as compared to untreated control (12.35 g/10 pupae) and it was 12.35 g/10 pupae in treated control.

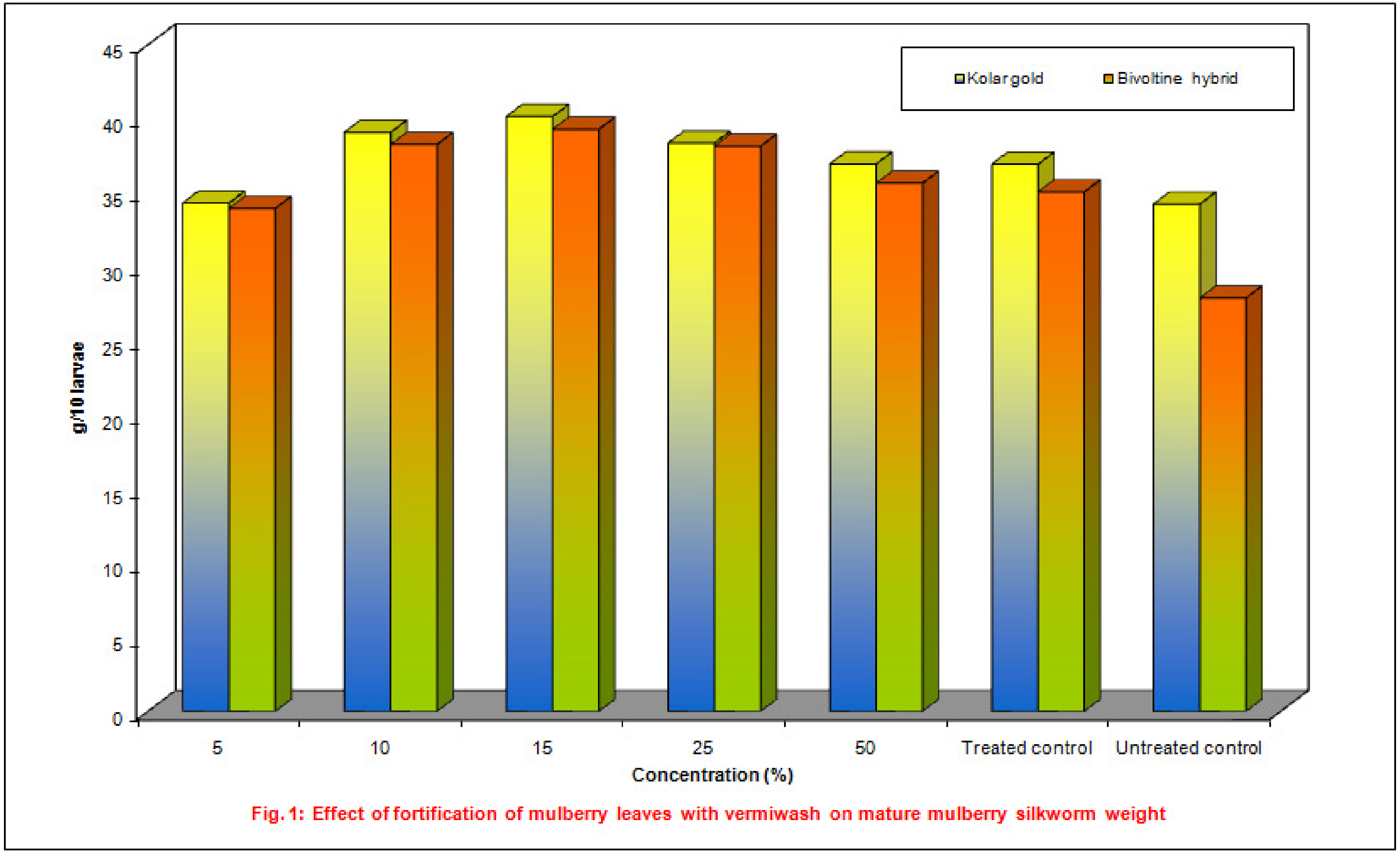


**Fig. 1: Effect of fortification of mulberry leaves with vermiwash on mature mulberry silkworm weight**

### 5.1.2 Cocoon parameters

Vermiwash fortification to mulberry silkworm significantly enhanced the cocoon parameters *viz.,* cocoon weight, shell weight, shell ratio and cocoon yield. Significant increase in cocoon weight was registered in Kolar Gold when fortified with 15 per cent (20.70 g/ 10) as compared to 15.82 g / 10 cocoons in untreated control and 17.06 g/ 10 in treated control (Fig. 2). The cocoon shell weight was significantly high in mulberry leaves fed with 15 per cent (4.03 g/ 10 shells) vermiwash fortification and less in untreated treatment (2.66 g/ 10 shells) (Fig. 3). Mulberry leaves fortified with vermiwash produced significant effect on shell ratio of Kolar Gold silkworms, 15 per cent ( 20.77 %), 10 per cent (20.07 %), 25 per cent (19.82 %), 5 per cent ( 18.87 %) and 50 per cent (18.59 %) recorded higher and on par shell ratio when compared to 17.16 and 16.80 per cent in treated and untreated control. Vermiwash 15 per cent fortification yielded 740 g/dfl cocoons in Kolar Gold as compared to untreated treatment (580 g/ dfl) and treated control (640 g/dfl) (Fig. 4).

Bivoltine hybrid silkworms also showed similar trend in cocoon traits. The cocoon weight was significantly enhanced by fortifying 15 per cent (18.65 g/ 10) vermiwash as compared to 16.45g/ 10 and 13.82 g/10 cocoons in treated and untreated control (Fig. 2). However, 15 per cent vermiwash yielded higher shell weight of 3.96 g / 10 shells, followed by 10 per cent (3.92 g/ 10 shells), 5 per cent (3.90 g/ 10 shells), 50 per cent (3.87 g/ 10 shells) and 25 per cent (3.60 g/ 10 shells) as compared to 3.41 g/ 10 shells in water treated and 2.67 g/ 10 shells in untreated control (Fig. 3). Shell ratio was significantly more in 15 per cent vermiwash (22.70 %) fortification, 5 per cent (21.25 %), 10 per cent (22.14 %), 25 per cent (22.10 %), 50 per cent (20.49 %) vermiwash fortification and treated control (20.72 %) as compared to 19.33 per cent in untreated control. Vermiwash 15 per cent fortification yielded 760 g/dfl of uniform cocoon yield and both were significantly superior over treated (700 g/dfl) and untreated control (670 g/dfl) (Fig. 4).

### 5.1.3 Silk parameters

The silk traits were significantly enhanced by vermiwash fortification. Kolar Gold produced longer silk filament at all concentrations of vermiwash fortification and on par with treated control that varied from 855.50 m (15 per cent) to 766.88 m (50 per cent) as compared to 556.38 m in untreated silkworms (Fig. 5). The finer denier of 2.71 was observed in 15 per cent vermiwash fortification, followed by 10 per cent (3.11) and it was 3.55 in untreated and 3.59 in treated control. The fibroin in silk was significantly enhanced in 15 per cent (79.50 %) vermiwash fortification as compared to 70.96 per cent in untreated control. Significant decrease in sericin was apparent in silkworms fed with 15 per cent (20.49 %) vermiwash than compared with untreated control (29.04 %).

The silk filament in Bivoltine hybrid was longer in 15 per cent (1275.25 m) and 10 per cent (1275.25 m) fortification over treated (1117.18 m) and untreated control (1004.69 m) (Fig.5). Denier was finer at all concentrations of vermiwash fortification and varied from 1.90 (15 %) vermiwash to 2.14 (50 %) vermiwash and coarser in untreated treatment (2.67). The fibroin in silk was significantly enhanced by 15 per cent (83.52 %) vermiwash fortification as against 77.07 per cent in untreated treatment. The same treatment showed reduction in sericin (16.47 %) as compared to untreated control (22.92%).

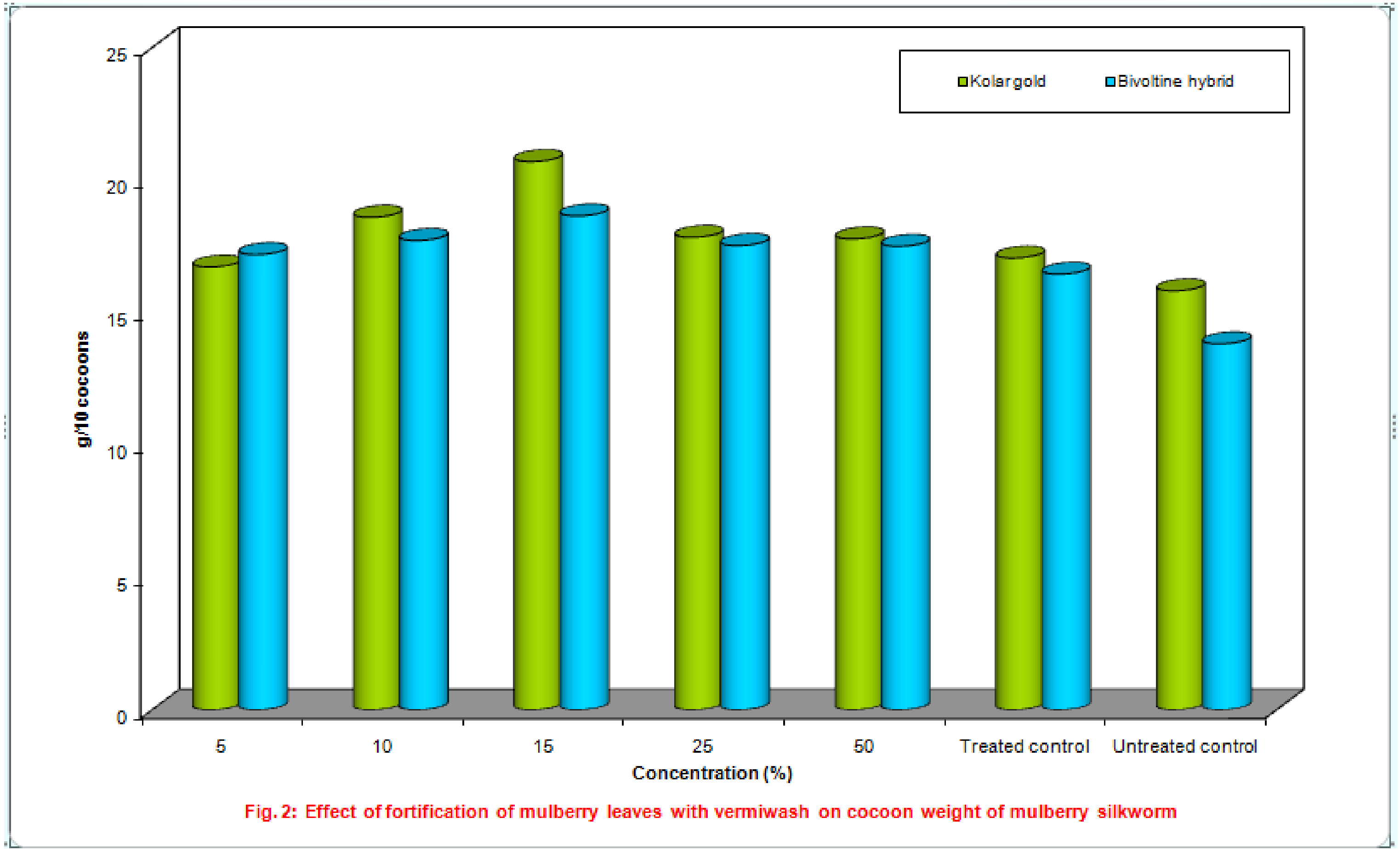


**Fig. 2: Effect of fortification of mulberry leaves with vermiwash on cocoon weight of mulberry silkworm**

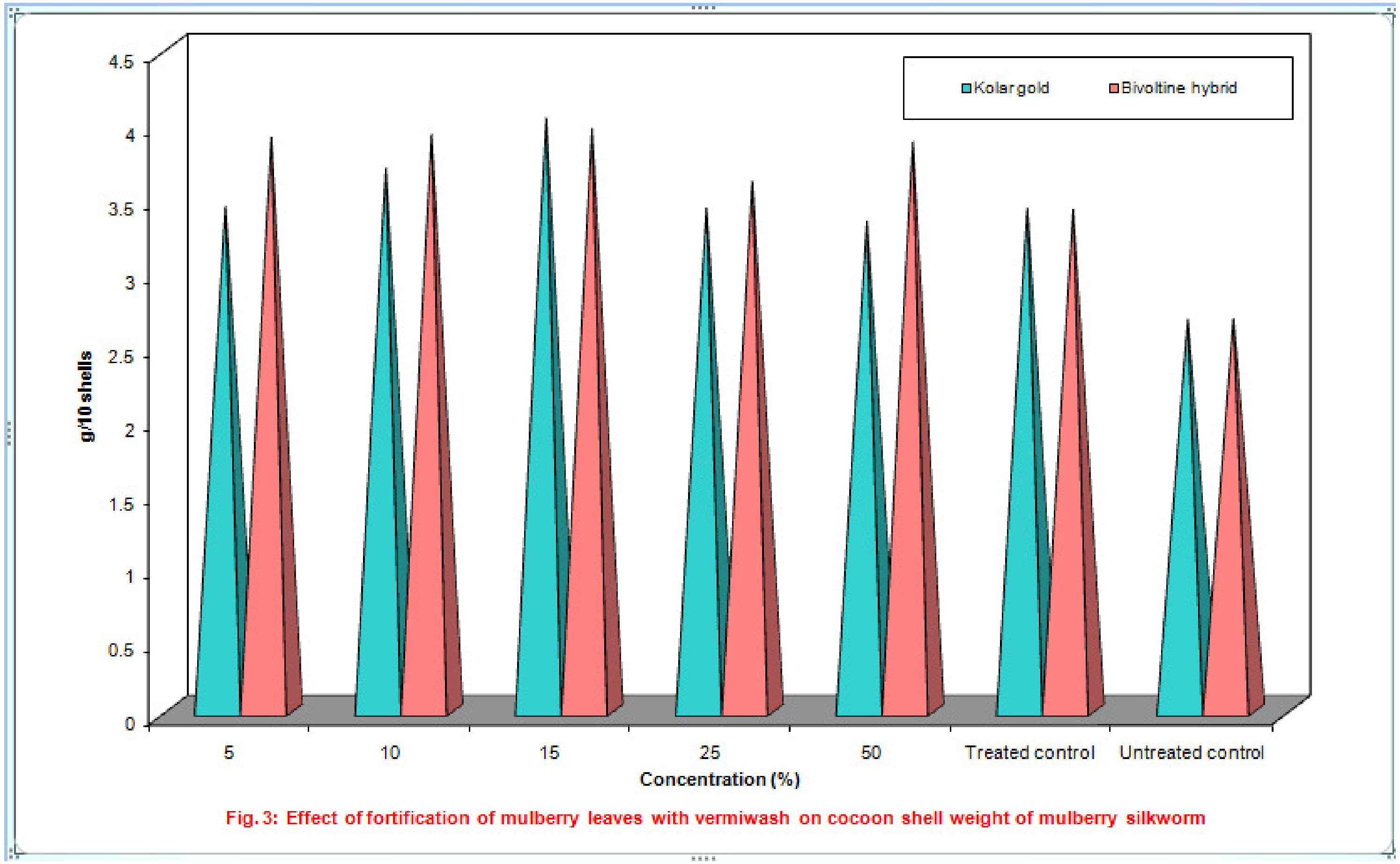


**Fig. 3: Effect of fortification of mulberry leaves with vermiwash on cocoon shell weight of mulberry silkworm**

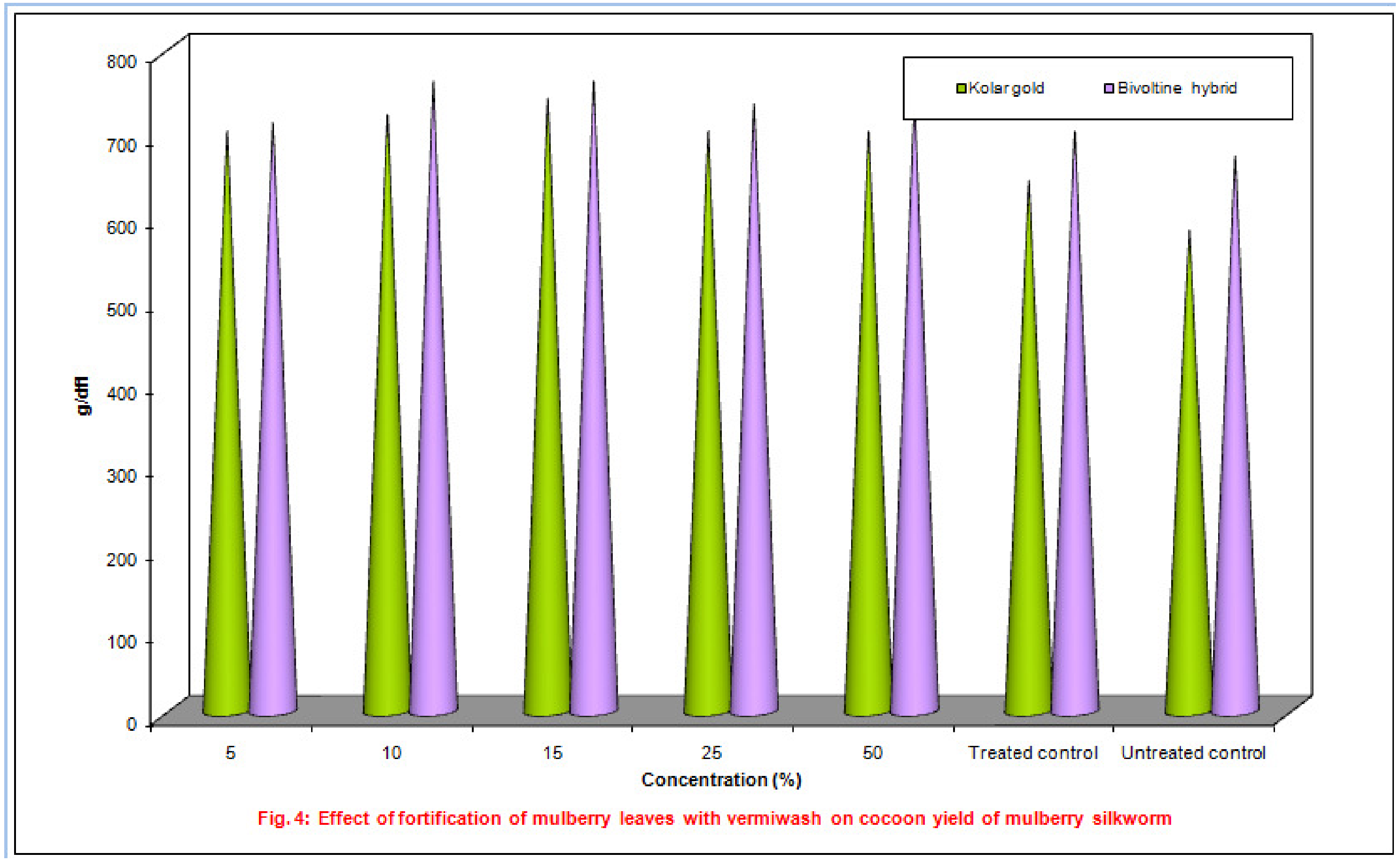


**Fig. 4: Effect of fortification of mulberry leaves with vermiwash on cocoon yield of mulberry silkworm**

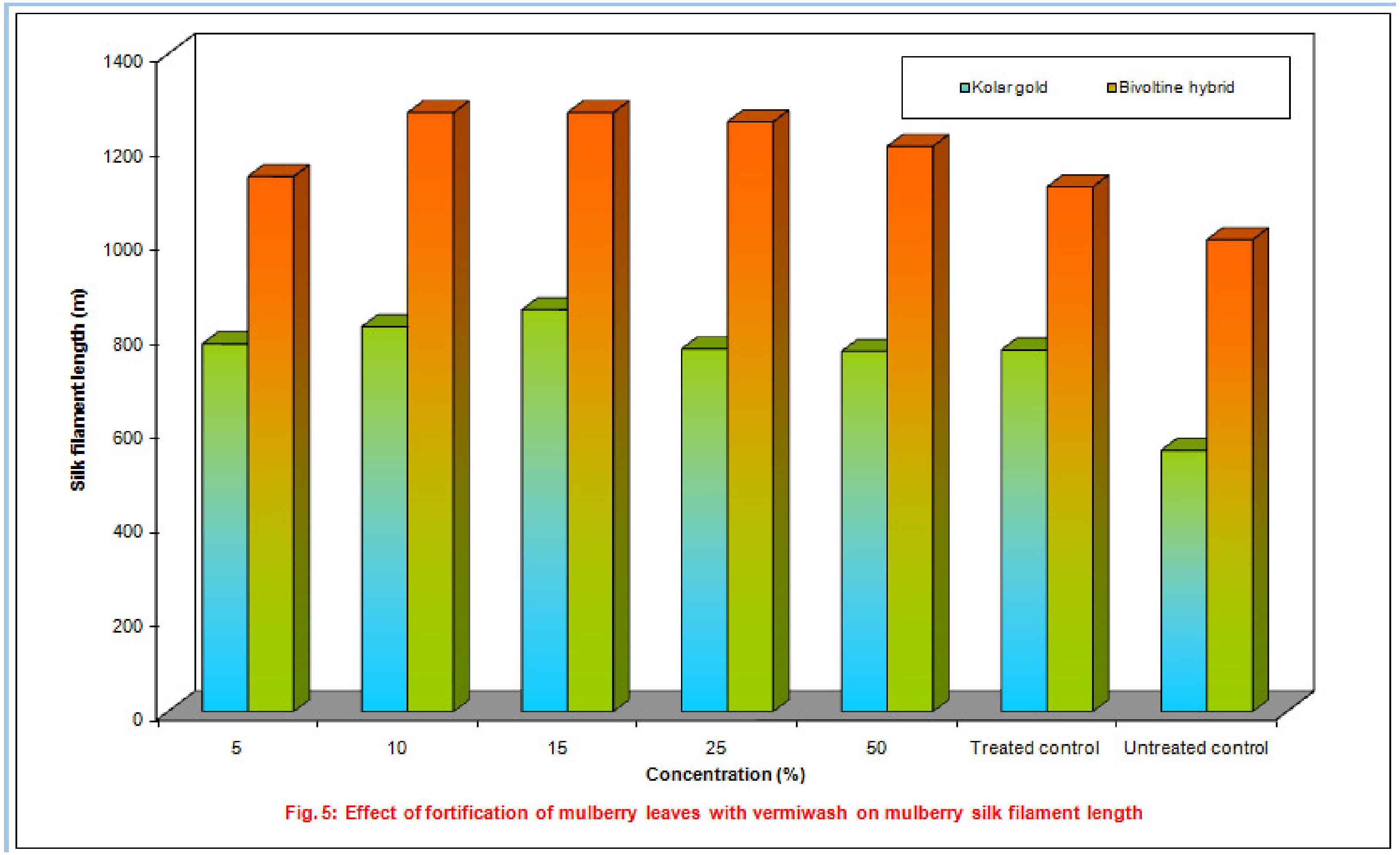


**Fig. 5: Effect of fortification of mulberry leaves with vermiwash on mulberry silk filament length**

Vermiwash fortification to Kolar Gold and Bivoltine hybrid silkworms showed significant reduction in larval duration and enhanced growth, cocoon traits and silk traits and higher fibroin in silk. Though, silkworms derive most of the required nutritional elements from mulberry leaves. However, extra supplementation of nutrients through vermiwash might have balanced the nutritional requirements of silkworms, resulting in increase in productivity. Among the concentrations tried, 15 per cent vermiwash fortification was found to be optimum as it has yielded higher growth, cocoon and silk traits and recorded high benefit cost ratio in both the hybrids studied. Purushothaman *et al.* (2012) observed significant improvement in silkworms by vermiwash fortification at 50 per cent and partially agrees with the present findings as traits showed improvement up to 50 per cent fortification. The nutrient composition of vermiwash varies with ingredients used for vermicomposting. The vermiwash used in the present study may be having higher amount of nutrients and at 15 per cent fortification yielded good response in silkworms, besides the B:C ratio was high. The biochemical analysis of mulberry silkworm fed with vermiwash enriched leaves by Venkataramana *et al.* (2009) showed increase in carbohydrates, protein and lipid content in the total body tissue of fifth instar larva and supports the present observations.

Vermiwash, a liquid wash collected from a vermitank by washing the body of earthworms and casting. It contains all the nutrients in soluble form and is being normally used as foliar spray and is known to provide crop nourishment and resistance in plant v/s pests and diseases (Giraddi; 2001; 2004; Thangard *et al.,* 2003; Kale, 2006; Biradar *et al.,* 2007; Soumya *et al.,* 2007). However, limited study has been made on the use of vermiwash as foliar spray on mulberry or fortification with leaves to enhance the cocoon production.

## 5.2 Effect of fortification of mulberry leaves with vermicoelomic fluid on mulberry silkworm, *Bombyx mori* L.

### 5.2.1 Silkworm growth and development

The fifth instar larval duration was significantly shorter in vermicoelomic fluid 15 per cent (158.63 hr) fortification as compared to treated control (160.37 hr) and untreated control (162.3 hr). While, larval duration was prolonged in 50 per cent vermicoelomic fluid (172.23 hr) fortification. Irrespective of the concentrations used vermicoelomic fluid fortification has significantly increased the mature larval weight over unfortified treatment. At, 15 per cent vermicoelomic fluid fortification gave maximum weight (39.36 g/ 10 larvae), followed by 10 per cent (39.21 g/ 10 larvae), 25 per cent (39.02 g/ 10 larvae) 5 per cent (38.75 g/ 10 larvae) and 50 per cent (38.70 g/ 10 larvae) and all were on par (Fig.6). High and significant silk productivity was recorded in 15 per cent (5.26 cg/day), 10 per cent (5.13 cg/ day), 25 per cent (4.91 cg/day) and 5 per cent (4.82 cg/ day) vermicoelomic fluid fortification over unfortified treatment (3.94 cg/ day). Effective rate rearing did not vary between vermicoelomic fluid 15 per cent (99.67 %) and 5 per cent (97.00 %) fortification with untreated treatment (99.67 %). The highest pupal weight was recorded in silkworms which received 15 per cent (15.63 g/ 10) vermicoelomic fluid as compared to unfortified treatment (12.34 g/ 10).

In Bivoltine hybrid, the fifth instar larval duration was significantly reduced by fortifying 15 per cent (160.23 hr) vermicoelomic fluid when compared to unfortified treatment (170.10 hr). Larval weight was significantly enhanced at 15 per cent (40.95 g/10 larvae) and 10 per cent (40.58 g/ 10 larvae) vermicoelomic fluid fortification as compared to unfortified treatment (27.90 g/ 10 larvae) (Fig.6). The silk productivity was significantly higher in 15 per cent (6.38 cg/day) and 10 per cent (5.81 cg/day) vermicoelomic fluid than treated control (4.97 cg/day) and untreated treatment (3.76 cg/day). The effective rate of rearing was significantly highest in untreated control (100 %), followed by 10, 15 and 25 per cent vermicoelomic fluid fortification and they were on par with each other. The pupal weight in Bivoltine hybrid was significantly more in 15 per cent (14.18 g/ 10) vermicoelomic fluid as compared to unfortified treatment (10.49 g).

### 5.2.2 Cocoon parameters

Fortification of vermicoelomic fluid at 15 per cent recorded highest cocoon weight of 20.77 g/ 10 in Kolar Gold (Fig.7). Cocoon shell weight varied significantly between different concentrations of vermicoelomic fluid, 15 per cent (3.57 g/ 10 shells) recorded maximum weight, followed by treated control (3.42 g/ 10 shells) and 25 per cent (3.29 g/ 10 shells) as compared to untreated treatment (Fig.8). The significant increase in the shell ratio was recorded at all concentrations of vermicoelomic fluid studied and varied from 20.07 per cent (15 %) to 18.11 per cent (50 %) as compared to unfortified treatment (16.83 %). The cocoon yield was significantly influenced by vermicoelomic fluid fortification at 15 per cent (700 g/dfl) gave highest yield as compared to untreated control (580 g /dfl) (Fig. 9).

In Bivoltine hybrid the cocoon weight was significant and more in 15 per cent (18.79 g/ 10) vermicoelomic fluid fortification as compared to untreated treatment (13.82 g/10 cocoons) (Fig.7). The shell weight varied significantly due to the fortification of vermicoelomic fluid and was highest in 15 per cent (4.15 g/ 10 shells), 10 per cent (3.91 g/10 shells) and 25 per cent (3.76 g/10 shells) which were at par and superior to untreated control (2.67 g/ 10 shells) (Fig.8). Cocoon shell ratio was significant at all concentrations of vermicoelomic fluid studied including treated control and varied from 23.53 per cent (15 %) to 19.80 per cent (5 %) over untreated control (19.33 %). The highest cocoon yield was produced from the silkworms which were fed with 15 per cent vermicoelomic fluid (742 g/dfl), 10 per cent (725 g/dfl) and 25 per cent (720 g/dfl) vermicoelomic fluid fortification and were on par as compared to untreated control (670g/dfl) (Fig. 9).

### 5.2.3 Silk parameters

Kolar Gold produced longer silk filament when fed with vermicoelomic fluid fortified leaves. The silk filament length was on par at 15 per cent (923.61 m), 10 per cent (897.62 m), 5 per cent (882.63 m), 25 per cent (854.76 m) and 50 per cent (840.50 m) as compared to treated control (770.13 m) and untreated control (556.38 m) (Fig.10). Further, finer silk filament was obtained in 15 per cent (2.24) vermicoelomic fluid fortification over rest of the concentrations, treated control (3.59) and untreated treatment (3.55). The silk obtained out of 15 per cent vermicoelomic fluid fortification accumulated highest percentage of fibroin (76.30 %) and lowest percentage of sericin (23.76 %) over untreated treatment that had 70.96 per cent of fibroin and 29.04 per cent of sericin.

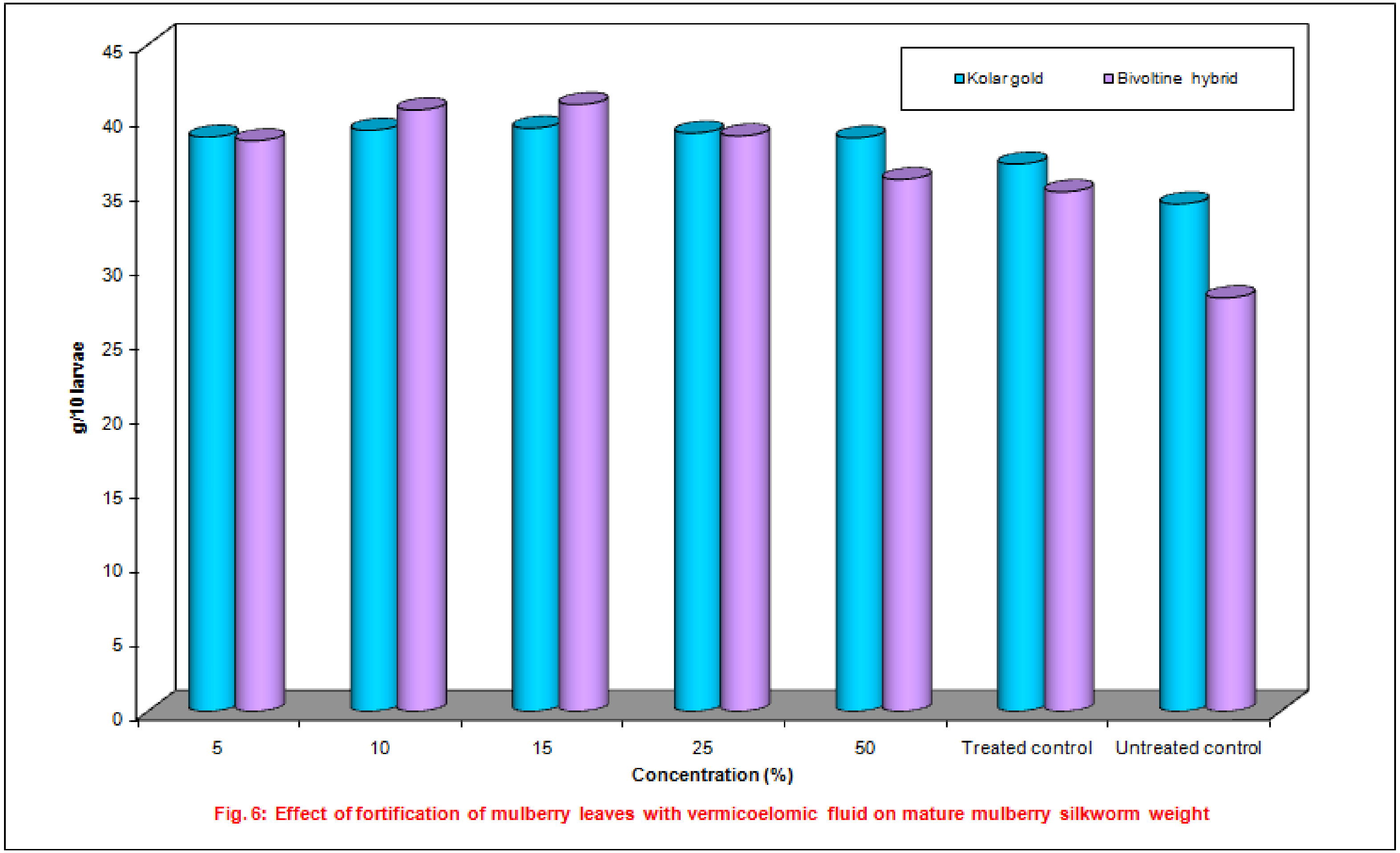


**Fig. 6: Effect of fortification of mulberry leaves with vermicoelomic fluid on mature mulberry silkworm weight**

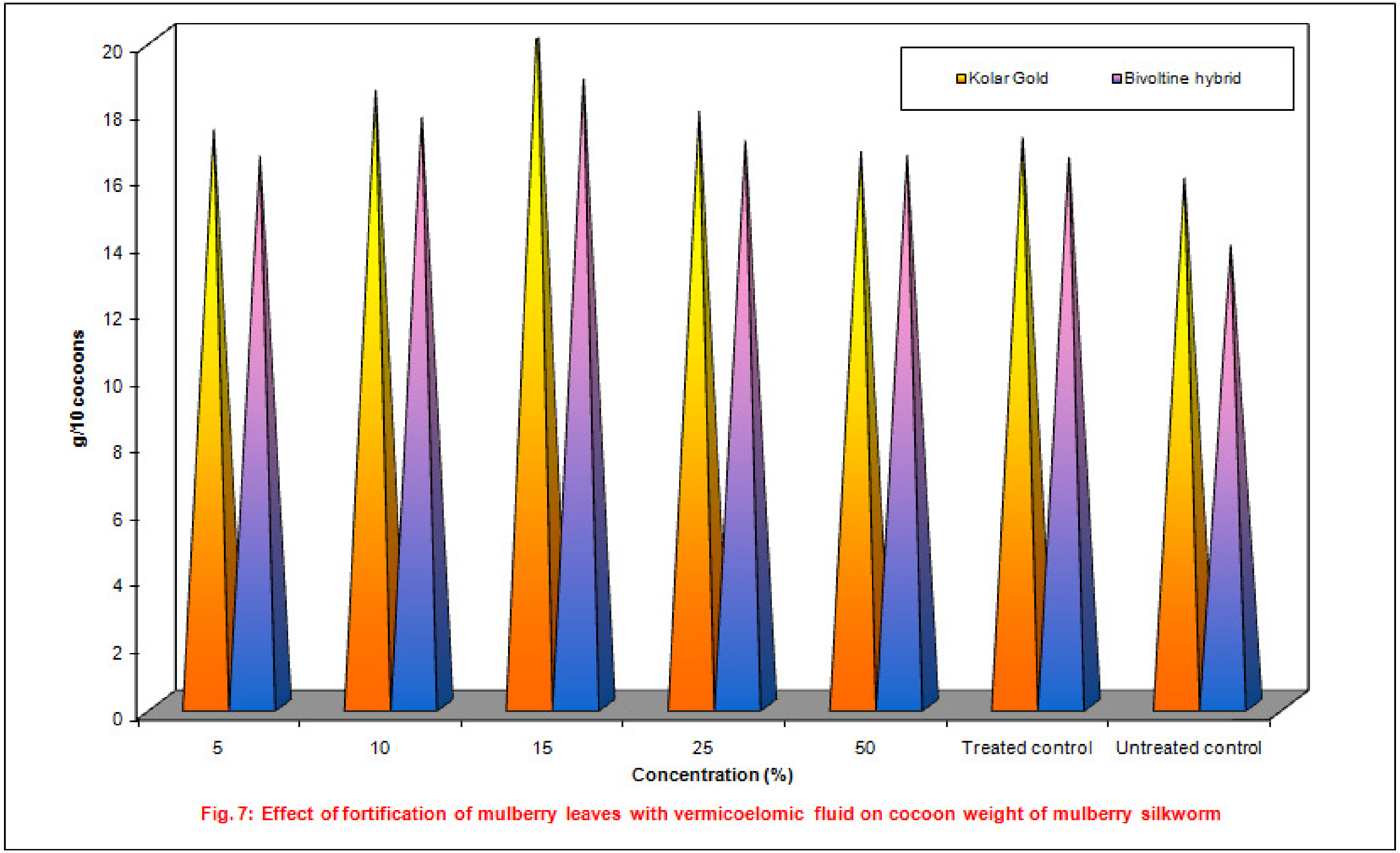


**Fig. 7: Effect of fortification of mulberry leaves with vermicoelomic fluid on cocoon weight of mulberry silkworm**

Bivoltine hybrid also showed significant enhancement in silk traits. The longest silk filament was produced by the silkworms that were fed with 15 per cent (1265.64 m), 10 per cent (1262.75 m), 25 per cent (1205.88 m), 5 per cent (1185.38 m) 50 per cent (1133.56 m) and treated control (1117.18 m) and were on par with each other as compared to unfortified treatment (1004.69 m) (Fig.10). The denier was finer and on par in 15 per cent (1.82), 50 per cent (2.17), 25 per cent (2.30) and treated control (2.33) and was coarser in untreated control (2.67). The supplementation of vermicoelomic fluid at 15 per cent yielded less sericin content (12.94 %), while it was higher in controlled treatment (22.92 %). The fibroin protein in silk was maximum in 15 per cent (87.05 %) vermicoelomic fluid fortification as compared with unfortified treatment (77.07 %). The benefit cost ratio (B:C) of Kolar Gold silkworms was highest in 15 per cent (2.52) vermicoelomic fluid fortification. While, 10, 25 and 5 per cent recorded 1.77, 1.14, 1.41 of B:C ratio. The benefit cost ratio of Bivoltine hybrid was 2.12 in 15 per cent vermicoelomic fluid fortification than compared to untreated control (1.67) and treated control (1.05).

The vermicoelomic fluid of earthworms is reported to have growth stimulating agents and a variety of polypeptides and other micronutrients. For silkworms, protein plays an important role in silk production. In the present study mulberry leaves were fortified with vermicoelomic fluid from 5 to 50 per cent to improve the economic traits. The result revealed the positive effects of vermicoelomic fluid in improving the growth of silkworms resulting in higher values for cocoon and silk traits. It is known that vermiwash is a rich source of low molecular weight peptides with amino acid sequence F1-alanine –methionine – valine –serine and F2- alanine –methionine-glycosine –thiamine with molecular weight F1-535.27 Da and F2- 519.27 Da (Zi hong Xi-chun, 2003) and fortification through leaves might have enhanced the silkworm growth and silk protein synthesis, resulting good larval growth and higher values of cocoon and silk traits. Doss *et al.*(2011) observed positive effect of vermicoelomic fluid on silkworms when fortified at rate of 1 ml/ 10 mg of leaves and strengthen the present findings. In present study vermicoelomic fluid fortification was found effective from 5 to 50 per cent, however considering the benefit cost ratio, 15 per cent fortification was found to be best to realise higher returns.

The positive effects of vermicoelomic fluid on plant propagation and growth has been well documented (Karuna *et al.,* 1999; Mahale *et al.,* 2002; Shobha and Kale, 2007). Improvement in silkworm cocoon traits fed with treated leaves has been reported by Rawgul *et al.* (2010 and 2011) and supports the present findings.

## 5.3 Effect of fortification of mulberry leaves with vermimeal on mulberry silkworm, *Bombyx mori* L.

### 5.3.1 Silkworm growth and development

The fortification of vermimeal through mulberry leaves made a significant improvement in silkworm growth and development. The fifth instar larval duration of Kolar Gold was significantly reduced in 15 per cent (158.30 hr) vermimeal fortification as compared to unfortified treatment (162.37 hr). The mature larval weight was significantly enhanced in 15 per cent (40.67 g/ 10), 10 per cent (39.53 g/ 10), 25 per cent (39.16 g/ 10) and 50 per cent (37.00 g/ 10) fortification which were on par as compared to unfortified treatment (34.24 g/ 10). The results revealed that the silkworms fed with 15 per cent vermimeal fortified mulberry leaves significantly enhanced the silk productivity (4.80 cg/day) over unfortified treatment (3.94 cg/day). The effective rate of rearing was significantly more in Kolar Gold that were fed with 15 per cent (99.67 %), 10 per cent (99.00 %) and 25 per cent (98.00 %) vermimeal fortified leaves and were on par with untreated treatment (99.67 %). The pupal weight was significant and maximum in 15 per cent (13.28 g/ 10) vermimeal fortification as compared to 12.34 g in unfortified treatment and was least in treated control (11.49 g/ 10).

In Bivoltine hybrid the fifth instar larval duration was significantly reduced by fortifying 15 per cent (160.37 hr) vermimeal when compared to unfortified treatment (170.10 hr). Mature larval weight was significantly enhanced at 15 per cent (36.40 g/10 larvae) and 10 per cent (35.78 g/ 10) vermimeal fortification as compared to unfortified treatment (27.90 g/ 10). The silk productivity was significantly higher in 15 per cent (5.65 cg/ day) and 10 per cent (5.63 cg/day) vermimeal over untreated treatment (3.76 cg/ day) and treated control (5.40 cg/ day). The effective rate of rearing was significantly highest in untreated control (100 %) and 15 per cent (97.33 %), followed by 25 (96.67 %), 10 (96.00 %), treated control (95.00 %), 5 (94.67 %) and 50 per cent (89.67 %) vermimeal fortification and were on par with each other. The pupal weight in Bivoltine hybrid was significantly more in 15 per cent (13.77 g/ 10) vermimeal as compared to unfortified treatment (10.49 g/ 10).

### 5.3.2 Cocoon parameters

The fortification of 5, 10, 15, 25 and 50 per cent vermimeal to mulberry silkworm made a significant impact on cocoon traits of Kolar Gold. The cocoon yield was significantly more in 15 per cent (640 g/dfl) vermimeal fortified silkworms as compared to untreated control (580 g/dfl) and treated control (520 g/dfl). Cocoon weight was significantly more in a treatment that received 15 per cent (16.88 g/ 10) vermimeal fortification compared to treated control (15.82 g/ 10). The cocoon shell weight was significantly more in 15 per cent (3.16 g/ 10) vermimeal fortification, followed by 25 (2.95 g/ 10) and 50 per cent (2.94 g/ 10) as compared to unfortified treatment (2.66 g/ 10) and treated control (2.30 g/ 10). The shell ratio was significantly enhanced at all concentrations of vermimeal fortification and varied from 18.60 per cent (5 %) to 19.23 per cent (15 %) as compared to treated (17.19 %) and untreated control (16.83 %).

The Bivoltine hybrid fed with 15 per cent vermimeal fortified leaves yielded significantly more cocoons (743 g/dfl) as compared to 670 g/ dfl in silkworms fed with unfortified leaves. A significant increase in cocoon weight was observed in silkworms fortified with 15 per cent (17.85 g/ 10) vermimeal, followed by 50 per cent (17.47 g/ 10) and 10 per cent (17.25 g/ 10) and it was least in unfortified treatment (13.82 g/ 10). Vermimeal fortification at 15 per cent concentration (3.96 g/10 shells), 50 per cent (3.89 g/10 shells), 10 per cent (3.71 g/ 10), 5 and 25 per cent (3.51 g/ 10) recorded higher shell weight over unfortified treatment (2.67 g/ 10). Vermimeal fortification had a significant positive effect on shell ratio and higher shell ratio was observed in 15 per cent (23.92 %), 50 per cent ( 21.91 %), 10 and 25 per cent (22.85 %) and treated control (21.61 %) which were on par as compared to untreated control (19.33 %).

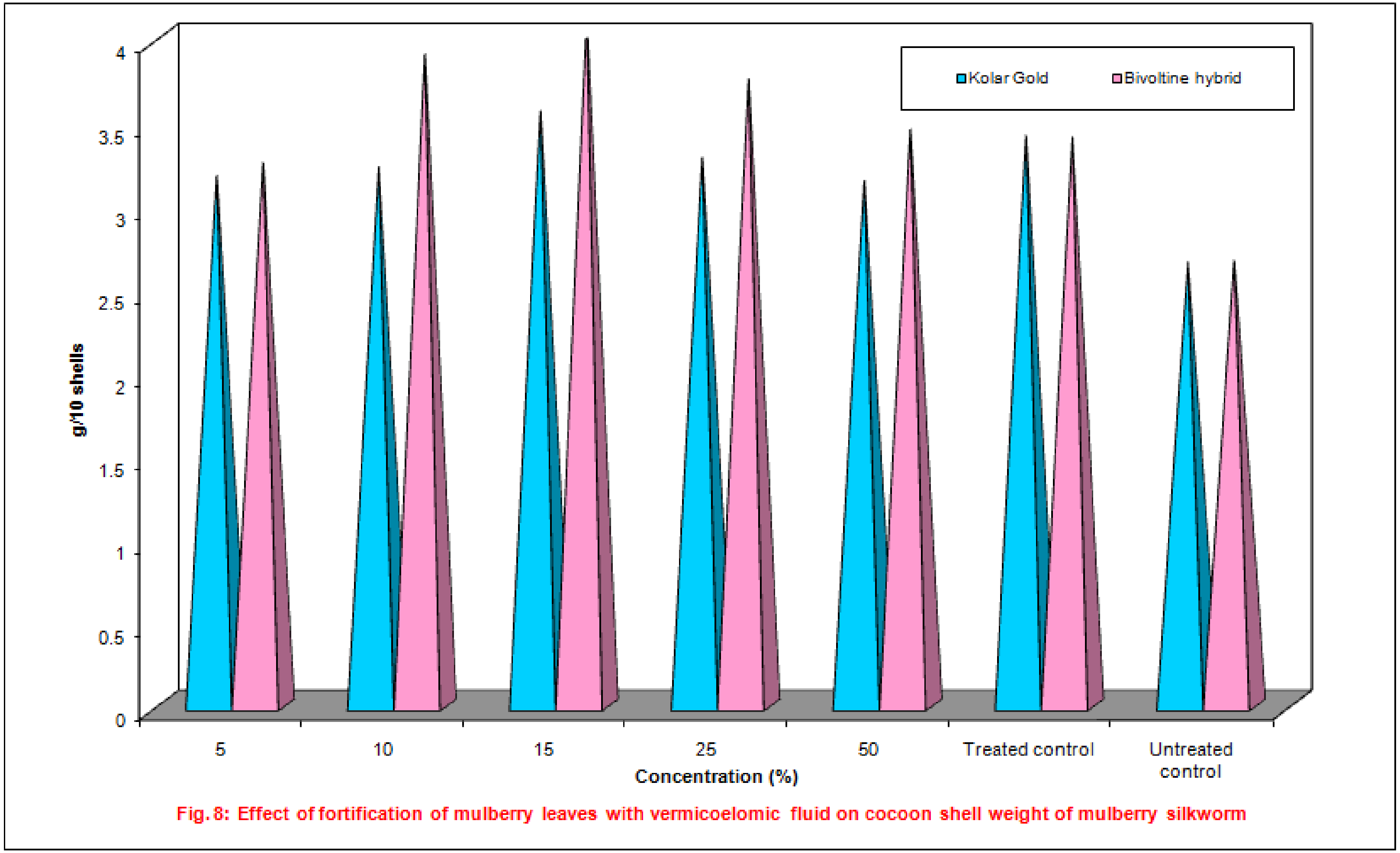


**Fig. 8: Effect of fortification of mulberry leaves with vermicoelomic fluid on cocoon shell weight of mulberry silkworm**

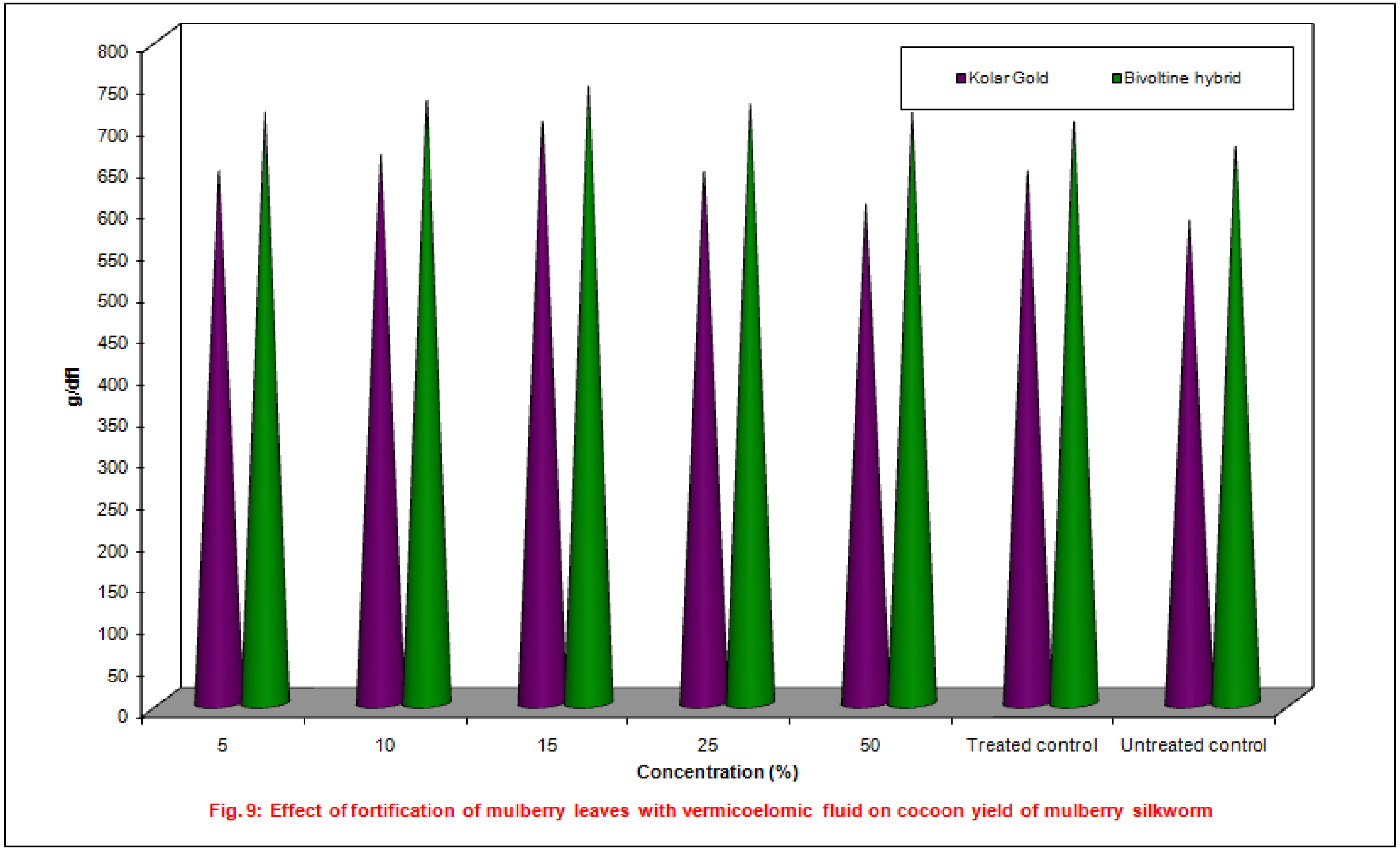


**Fig. 9: Effect of fortification of mulberry leaves with vermicoelomic fluid on cocoon yield of mulberry silkworm**

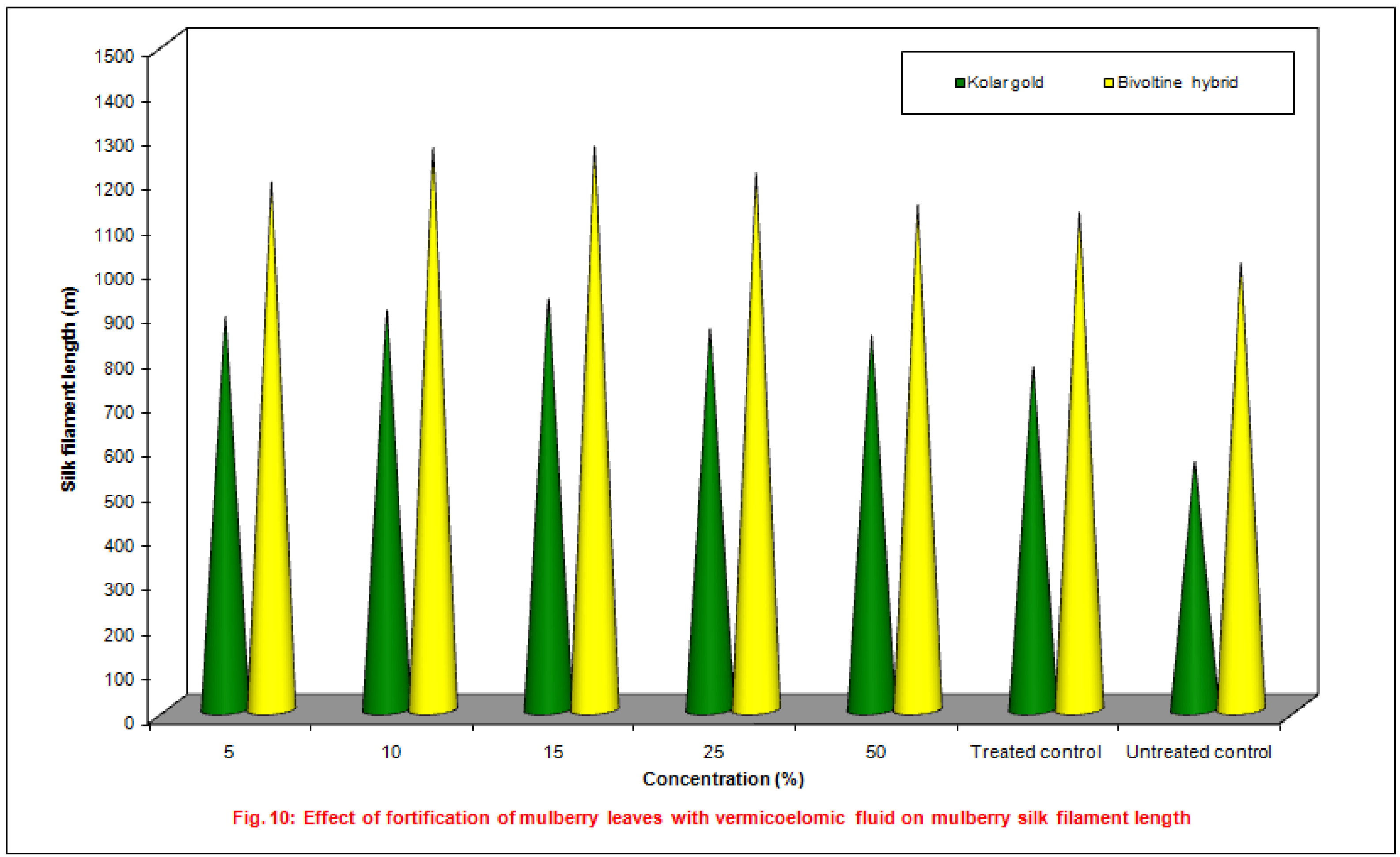


**Fig. 10: Effect of fortification of mulberry leaves with vermicoelomic fluid on mulberry silk filament length**

### 5.3.3 Silk parameters

The silk filament of Kolar Gold cocoons were significantly increased by fortifying vermimeal 15 per cent (923. 60 m), 10 per cent (813.63 m), 50 per cent (803.75 m) and 25 per cent (800.00 m) which were on par as compared to unfortified treatment (556.38 m). Similar trend was observed in silk thickness and finer being in 15 per cent (2.80), 10 per cent (2.91), 50 per cent (3.23) and 25 per cent (3.37), 5 per cent (3.48) fortification and coarser denier of 3.55 was obtained in unfortified treatment. The silk of Kolar Gold had high fibroin in 15 per cent (82.83 %) vermimeal fortified treatment as compared to 70.96 per cent in unfortified treatment, correspondingly 15 per cent vermimeal fortification recorded lowest sericin of 17.77 % as compared to 29.04 per cent in unfortified treatment.

The Bivoltine hybrid fortified with vermimeal produced longer silk filament at 15 per cent (1167.25 m), 5 per cent (1129.13 m), 10 per cent (1118.88 m), 25 per cent (1110.04 m ) and 50 per cent (1106.88 m) which were all on par and significantly superior over treated control (979.21 m) and unfortified treatment (1004.69 m). The mulberry leaves fortified with 15 per cent vermimeal gave finer silk of 1.99 denier, followed by 10 per cent (2.04), 50 per cent (2.12), 5 per cent (2.38) and 25 per cent (2.48) which were on par with 15 per cent and coarser in unfortified treatment (2.67). Maximum fibroin in silk was observed in 15 per cent vermimeal treated treatment (79.09 %) and the same treatment accumulated lesser sericin (20.90 %) as compared to unfortified treatment which recorded 77.07 per cent of fibroin and 22.92 per cent of sericin. The benefit cost ratio showed the negative trend at all concentrations of vermimeal fortification.

Vermimeal, a feed consisting of processed earthworm biomass is a rich source of protein (54 %) (Barcelo, 1988), fortification of vermimeal to silkworms through leaves resulted significant improvement in the growth, cocoon and silk traits. Supplementation of extra protein source through leaves to the silkworms might have satisfied the dietary protein requirement of silkworms and helped in increased synthesis of proteins. As such vermimeal fortification to silkworms has not been studied to support or contradict the present findings. Barcelo (1988) used vermimeal as feed additive to broilers, 14 per cent vermimeal resulted in significant gain in broiler weight. In present study vermimeal fortification registered significant improvement of economic traits of silkworms. But, considering the benefit cost ratio vermimeal fortification has yielded negative returns owing to cost involved in vermimeal preparation.

The results of the study clearly revealed that the fortification of mulberry leaves with vermiwash and vermicoelomic fluid at 15 per cent and feeding such leaves to silkworms daily once during fifth instar significantly improves the silkworm growth, cocoon and silk traits.

## Future line of work

1. Large scale evaluation of vermiwash and vermicoelomic fluid at 15 per cent on cocoon yield of mulberry silkworm growth.
2. Effect of vermiwash and vermicoelomic fluid for stimulating the egg production in parental silkworms.

# 6. SUMMARY AND CONCLUSIONS

The vermiproducts *viz.,* vermiwash, vermicoelomic fluid and vermimeal obtained in the process of vermicompost production. These vermiproducts serves as a good source of nutrients, enzymes and hormones and found to enhance the growth of plants and in poultry and aquaculture. Few studies were also made to enhance the silkworm growth and cocoon production in sericulture. A study was made to know the effect of vermiproducts on mulberry silkworms through fortification of mulberry leaves. The results of the study have been summarised below.

The vermiwash and vermicoelomic fluid were found safe to Kolar Gold and Bivoltine hybrid silkworms up to 10 per cent. While, vermimeal was found safe up to 50 per cent fortification to mulberry.

The growth and development of Kolar Gold and Bivoltine hybrid were significantly influenced by feeding vermiwash fortified leaves. In Kolar Gold, 15 per cent vermiwash fortification has significantly reduced the fifth instar larval duration (160.23 hr) and enhanced the mature larval weight (40.15 g/ 10), silk productivity (6.04 cg/day), effective rate of rearing (99.00 %), pupal weight (15.02 g/ 10). The cocoon traits *viz.,* cocoon weight (20.70 g/ 10), cocoon shell weight (4.03 g/10shells), cocoon shell ratio (20.77 %) and cocoon yield (740 g/dfl) were also significantly improved by 15 per cent vermiwash fortification. Vermiwash 15 per cent further increased the cocoon filament length (855.50 m), denier (2.71) and fibroin (79.50 %).

In Bivoltine hybrid, vermiwash 15 per cent fortification has significantly reduced fifth instar larval duration (158.63 h) and increased the mature larval weight (38.15 g/ 10), silk productivity (5.75 cg/ day), effective rate of rearing (99.67 %) and pupal weight (14.28 g/ 10). The same concentration of vermiwash also enhanced the cocoon weight (18.65 g/ 10), cocoon shell weight (3.96 g/10shells), cocoon shell ratio (22.70 %) and cocoon yield (760 g/dfl), cocoon filament length (1275.25 m), denier (1.90) and fibroin (83.52 %). Vermiwash 15 per cent fortification had high B:C ratio of 3.72 and 2.93 in Kolar Gold and Bivoltine hybrid silkworms.

The fifth instar larval duration in Kolar Gold was also significantly shorter in 15 per cent vermicoelomic fluid fortification (158.63 hr) as compared to silkworms fed with untreated leaves (162.37 hr). The mature larval weight was increased by fortifying vermicoelomic fluid and on 5 to 50 per cent were on par and varied from 38.75 g/10 larvae (5 %) to 39.36 g/10 larvae (15 %). The silk productivity was highest in 15 per cent (5.26 cg/ day) vermicoelomic fluid fortification. While, 5 per cent (4.82 cg/day), 10 (5.13 cg/ day) and 25 per cent (4.91 cg/day) were on par with 15 per cent. The effective rate of rearing was maximum and on par in 15 per cent (99.67 %) vermicoelomic fluid fortification, 5 per cent (97.00 %) and untreated control (99.67 %). The pupae obtained by silkworms fed with 15 per cent vermicoelomic fluid fortified leaves yield highest weight of 15.63 g/ 10 and it was 12.34 g/10 pupae in unfortified treatment. Higher benefit cost ratio of 2.52 was obtained by fortifying 15 per cent vermicoelomic fluid to Kolar Gold silkworms. The cocoon traits *viz.,* cocoon weight (20.77 g/ 10), cocoon shell weight (3.57 g/10shells), cocoon shell ratio (20.07 %) and cocoon yield (700 g/dfl) were also significantly improved by 15 per cent by vermicoelomic fluid fortification. Vermicoelomic fluid 15 per cent fortification further increased the silk filament length (923.61 m), finer denier (2.24) and fibroin (76.30 %).

Bivoltine hybrid exhibited a significant difference in growth and development by feeding vermicoelomic fluid fortified leaves. The fifth instar larval duration (160.23 hr) was significantly reduced by 15 per cent vermicoelomic fluid fortification. Further, the mature larval weight (40.95 g/10 larvae), silk productivity (6.35 cg/day), effective rate of rearing (99.67 %) and pupal weight (14.18 g/ 10) were significantly enhanced by 15 per cent vermicoelomic fluid fortification. The cocoon yield was significantly increased to 742 g/dfl by fortifying 15 per cent vermicoelomic fluid. The cocoon weight was significantly more in 15 per cent (18.27 g/10 cocoons) vermicoelomic fluid fortification. While, cocoon shell ratio was maximum and on par in 15 (4.15 g/ 10 shells), 10 (3.91 g/ 10 shells) and 25 per cent (3.76 g/10) vermicoelomic fluid fortification. The silk filament length was longer in 15 (1265.64 m), 10 (1262.75 m), 25 (1205.88 m), 5 (1185.38 m) and 50 per cent (1133.56 m) and in treated control (1117.18 m) and were on par with each other. The denier was finer at 15 (1.82), 10 (2.01), 5 (2.06), 50 (2.17), 25 (2.30) vermicoelomic fluid and treated control (2.33) and were on par with each other. Higher benefit cost ratio of 2.12 was obtained by fortifying 15 per cent vermicoelomic fluid to bivoltine hybrid silkworms.

The silkworms of Kolar Gold responded positively to vermimeal fortification. Vermimeal 15 per cent fortification significantly reduced the fifth instar larval duration (158.30 hr). The mature larval weight was significantly high in 15 per cent (40.67 g/ 10) vermimeal fortification, 10 per cent (39.53 g/ 10), 25 per cent (39.16 g/ 10) and 50 per cent (37.00 g/ 10) were on par with 15 per cent. The silk productivity of 4.80 cg/day was noticed in silkworms fortified with 15 per cent vermimeal and the same treatment registered higher effective rate of rearing (99.67 %) and pupal weight (13.28 g/10 pupae).Vermimeal fortification at 15 per cent to Kolar Gold has significantly increased the cocoon weight (16.88 g/10), cocoon shell weight (3.16 g/ 10 shells), cocoon shell ratio (23.92 %) and cocoon yield (640 g/dfl). Further, longest silk filament length was observed by the cocoons spun by silkworms fortified with 15 per cent vermimeal (923.60 m) and the same treatment produced finer denier (2.80) and high fibroin (81.34 %).

The Bivoltine hybrid shown to have significant difference by fortifying mulberry leaves with vermimeal fortification. Shorter larval duration was observed in 15 per cent (582.00 hr) fortification. The mature larval weight was significantly high in 15 per cent (36.40 g/ 10) vermimeal fortification, 10 per cent (35.78 g/ 10), 25 per cent (33.94 g/ 10) and 50 per cent (34.62 g/ 10). The silk productivity of 5.65 cg/day was noticed in silkworms fortified with 15 per cent vermimeal and the same treatment registered higher effective rate of rearing (97.33 %) and pupal weight (13.77 g/10 pupae) than compared to untreated control. Vermimeal fortification at 15 per cent to Bivoltine hybrid has significantly increased the cocoon weight (17.85 g/10 cocoons), cocoon shell weight (3.96 g/ 10 shells), cocoon shell ratio (19.23 %) and cocoon yield (743 g/dfl). The silk filament length was longer in 15 (1167.25 m), 5 (1129.13m), 10 (1118.88 m), 25 (1110.04 m) and 50 per cent (1106.88 m) and were on par with each other. The denier was finer at 15 (1.99), 10 (2.04), 50 (2.12), 5 (2.38) and 25 per cent (2.48) vermimeal fortification and were on par with each other. Fibroin in silk was maximum in 15 per cent vermimeal fortification (82.83 %).

It is summarized that fortification of vermiwash and vermicoelomic fluid at 15 per cent daily once during fifth instar to silkworms of Kolar Gold showed the superiority in all the quantitative parameters and was found to be best to enhance the silk yield and obtained higher returns. Fortification of vermiwash and vermicoelomic fluid at 10 per cent to bivoltine hybrid was best to increase the growth, cocoon yield and to obtain higher returns with respect to cost benefit. Hence fortification of nutrient and amino acid rich organics like vermiwash and vermicoelomic fluid can be utilized for increasing the silk production.

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**Appendix I: The nutrient composition of vermiwash and vermicoelomic fluid used for the study**

| Parameter | Vermiwash | Vermicoelomic fluid |
|---|---|---|
| Total Nitrogen (%) | 0.49 | 0.35 |
| Total Phosphorous (%) | 0.005 | 0.00625 |
| Total potassium (%) | 1.425 | 3.25 |
| Total sulphur (%) | 0.020 | 0.031 |
| Iron (ppm) | 3.55 | 3.76 |
| Manganese (ppm) | 0.47 | 0.31 |
| Copper (ppm) | 0.14 | 0.047 |
| Zinc (ppm) | 0.081 | 0.11 |

# EFFECT OF FORTIFICATION OF MULBERRY LEAVES WITH VERMIPRODUCTS ON MULBERRY SILKWORM, *Bombyx mori* L.

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## ABSTRACT

A study was carried out to know the effect of fortification of mulberry leaves with vermiproducts *viz.,* vermiwash, vermicoelomic fluid and vermimeal to mulberry silkworms. The vermiproducts fortified mulberry leaves were fed to Kolar Gold and Bivoltine hybrid silkworms daily once in the morning and other two feeds fed with normal leaves during fifth instar. Fortification of vermiwash at 15 per cent to Kolar Gold silkworms has significantly reduced fifth instar larval duration (160.23 hr), and enhanced mature larval weight (40.15 g/ 10 larvae), silk productivity (6.04 cg/ day), cocoon yield (740 g/ dfl), cocoon shell ratio (20.77 %) over unfortified silkworms. Similarly, in bivoltine hybrid also 15 per cent vermiwash fortification has reduced the larval duration (158.63 hr) and enhanced the mature larval weight (39.29 g/ 10 larvae), silk productivity (6.31 cg/ day), cocoon yield (760 g/ dfl) and shell ratio (22.70 %) were significantly highest over unfortified silkworms.

Vermicoelomic fluid fortification at 15 per cent to Kolar Gold silkworms has significantly reduced the fifth instar larval duration (156.63 h) and increased mature larval weight (39.36 g/ 10 larvae), silk productivity (5.26 cg / day), cocoon yield (700 g/ dfl), cocoon weight (20.77 g/ 10 cocoons), cocoon shell weight (3.57 g/ 10 shells), shell ratio (20.07 %), silk filament length (923.61m), fibroin protein in silk (76.30 %). In Bivoltine hybrid silkworms, fortification of vermicoelomic fluid 15 per cent has reduced the fifth instar larval duration (160.23 hr) and increased the mature larval weight (40.95 g/ 10 larvae), silk productivity (6.38 cg/ day), cocoon yield (742 g/ dfl) and cocoon shell ratio (23.53 %) over untreated control.

Vermimeal fortification through mulberry leaves made a significant improvement in silkworm growth and development. The fifth instar larval duration of Kolar Gold was significantly reduced in 15 per cent (158.30 hr), increased mature larval weight (40.67 g/ 10 larvae), silk productivity (4.80 cg/ day), cocoon yield (640 g/ dfl) and cocoon shell ratio (19.23 %). Similarly in Bivoltine hybrid silkworms fortification of vermimeal 15 per cent has reduced the fifth instar larval duration (160.37 hr) and increased the mature larval weight (36.40 g/ 10 larvae), silk productivity (5.65 cg/ day), cocoon yield (743 g/ dfl) and cocoon shell ratio (23.92 %) over untreated control.