Original Research Article

Topical Application of Acetone Solution of Ferruginol, Meroterpene Compound to the Fifth Instar Larvae of Silkworm Bombyx mori (L.) (Race: PM x CSR2) for Quality Improvement in Silk

Mansi Avinash Adagale¹, Apurva Baban Tamhane¹ and Vitthalrao B. Khyade²*

¹Shardabai Pawar Mahila Mahavidyalaya Shandanagar, Malegaon (Baramati), Pune 413115, Maharashtra, India
²Sericulture Unit, Malegaon Sheti Farm, Agricultural Development Trust Baramati, Shandanagar, (Malegaon Khurd) Post Box No - 35, Baramati, Pune 413 115, Maharashtra, India

*Corresponding author

ABSTRACT

The principle of efficient use of available system for quality improvement is tried to utilize in the present study. The present attempt was undertaken to study the influence of acetone solution of Ferruginol, a natural phenol and a meroterpene compound, on the cocoon characters and silk filament parameters of silk worm Bombyx mori (L.) (Race: PM x CSR2). Three concentrations (5ppm; 10ppm and 20ppm) of Ferruginol were prepared. The fifth instar larvae were utilized for the experimentation. Soon after the fourth moult, the fifth instar larvae were grouped into five groups (each with hundred individuals) (Untreated control; Acetone treated control; 5ppm Ferruginol; 10ppm Ferruginol and 20ppm Ferruginol). Ten microliters of each concentration of Ferruginol solution were topically applied to respective group to the individual larva at 48 hours after the fourth moult. The larvae were maintained through standard schedule. Acetone solution of Ferruginol at 5 ppm, 10 ppm and 20 ppm concentrations recorded maximum cocoon weight (2.046; 2.387; 2.924 gm), shell weight (0.438, 0.541, 0.673 gm), pupal weight (1.613; 1.846; 2.252 gm). All three concentrations of Ferruginol recorded significant weight of cocoon, shell, and pupal weight in comparison with the control (untreated and acetone treated). There was a gradual increase in the silk yield with an increase in the concentrations of Ferruginol (in acetone) from 5 ppm, 10 ppm and 20 ppm. Shell ratio of the cocoons harvested from the treated group were found with most significant (** P < 0.005, ***P < 0.01) influence. Similar type of effect was observed for the silk filament parameters. Efficient use of acetone solution of Ferruginol may open a new avenue in the field of sericulture.

Keywords
Bombyx mori, Ferruginol, Meroterpene, Silk yield.

Article Info
Accepted: 02 March 2017
Available Online: 10 April 2017

Introduction

The titer of ecdysone and juvenile hormone serves a lot for metamorphosis in insects, like silkworm, Bombyx mori (L). The ecdysone and juvenile hormone (JH) are the two major circulating hormones in insects, which control majority of the growth and developmental activities of the insects. The Juvenile Hormone (JH) has been considered to be an exclusive insect hormone and thus has attracted much attention also in plant and grain protection oriented research. The Juvenile Hormone (JH) is clearly a pleiotropic
master hormone of insects, which governs most aspects of their integration with the ecosystem and affects decisive life history parameters during their entire life cycles (Hartfelder, 2000). The Juvenile Hormone (JH) also regulates diverse traits in insects such as the synthesis of yolk protein, uptake of the molecule into the developing egg, diapause, flight, development, reproductive features and dispersal polymorphisms (Denlinger, 1985; Nijhout, 1999; Wyatt and Davey, 1996; Era and Cisper, 2001; Wheeler and Nijhout, 2003). The juvenile hormone reportedly alters physiological processes essential for insect development and appears to act especially on insects (Siddall, 1976; Ravindra Chaudhari and Vitthalrao Khyade, 1997).

Juvenile Hormone Analogues (JHAs) are a group of terpenoids that regulate many aspects of insect physiology. They regulate development, reproduction, diapause and polyphenisms (Riddiford, 1994; Nijhout, 1994; Wyatt and Davey, 1996; Khyade and Slama, 2014). The insect Juvenile Hormone Analogues (JHAs) are terpenes and their analogue. The terpenes are a large and diverse class of organic compounds, produced by a number of plants. The terpenes are also produced by some insects, which emit from their osmeteria. The papilionid larvae are distinguished by presence of osmeteria. The osmeterium is a defensive organ found in all Papilionid larvae, in all stages (Chattopadhyay, 2011). The osmeterium is situated in the prothoracic segment. It can be averted when the larva feels threatened. In averted condition, osmeterium resembles a fleshy forked tongue not unlike a snake tongue and this along with the large eye like spots on the body might be used to startle birds and small reptiles. The osmeterial organ remains inside the body in the thoracic region in an inverted position and is averted when the larva is disturbed in any way emitting a foul, disagreeable odour which serves to repel ants (Eisner and Meinwald, 1965); small spiders (Damman, 1986) and mantids (Chow and Tsai, 1989). The composition of secretion from osmeteria varies from species to species. It contains monoterpenic hydrocarbons, sesquiterpenic compounds or a mixture of aliphatic acids and esters. Crossley and Waterhouse (1969) studied the fine structure of the osmeterium of Papiliodemoleus libanius Fruhstorfer and found to contain 3 types of specialised cells for synthesis, acid secretion. Lu et al., (1991) confirmed the storage of the osmeterial secretion (VitthalraoKhyade, Edvard Moser and May – Britt Moser, 2015; Madhuri Anil Shivpuje et al., 2016).

A meroterpene is a chemical compound having a partial terpenoid structure. The meroterpene compounds are also called as Terpeno-phenolics. The Terpeno-phenolics are compounds that are partly terpenes and partly natural phenols. Plants in the genus Humulus and Cannabis produce terpeno-phenolic metabolites (Page, 2006). Examples of terpeno-phenolics are:Bakuchiol; Ferruginol; Mutisianthol and Totarol. They can also be isolated from animals. The methoxyconidiol, epiconic, and didehydroconic, isolated from the ascidian Aplidium aff. densum, show anti-proliferative activity (Simon-Levert et al., 2010).
Ferruginol is a natural phenol and a meroterpenoid (a chemical compound containing a terpenoid substructure) that has been isolated from the needles of the redwood *Sequoia sempervirens*. The terpenoid part is a diterpene of the abietane chemical class. Research published in 2005 found that this and other compound of the class from *Sequoia* have anti-tumor properties, and showed in vitro human colon, breast, and lung tumor reduction and reduction in oncogene transformed cells as well. Specific activity of tumorgrowth inhibition (GI) is 2-5 micrograms/milliliter (Son et al., 2005). The Ferruginol has also been found to have antibacterial activity (Smith et al., 2007; Flores, 2001). Gastroprotective effects of ferruginol have also been noted (Areche Carlos, 2008). The totarol is synthesized biologically from ferruginol. The Totarol motivates research in drug discovery due to its ability to inhibit numerous microorganisms. The Totarol exhibits antimicrobial properties in numerous species including gram-positive bacteria, nematodes, crustacean foulers. In addition to inhibiting microorganisms by itself, totarol exhibits inhibitory synergy with currently used antimicrobial drugs, totarol potentiates isonicotinic acid hydrazide against various microbials. There are no reports on use of acetone solution of Ferruginol in rearing the larvae of silkworm for commercial silk yield. In view of to determine the effects of the topical application of acetone solution of Ferruginol on cocoon characters and silk filament parameters, the present study has been planned.

**Materials and Methods**

The experimentation was divided into the parts like: Preparation of Acetone solution of Ferruginol; Rearing of silkworm larvae; Topical application of Acetone solution of Ferruginol to the fifth instar larvae Analysis of economic parameters and statistical analysis of the data.

Preparation of Acetone Solution of Ferruginol: The Ferruginol powder (Commercially with trade name: Totarol) was procured through the local dealer. According to instructions (Vitthalrao Khyade and Bhunjé, 2015), the acetone solution of Ferruginol was prepared. It was dissolved in acetone solvent. Three different concentrations (5 ppm; 10 ppm and 20 ppm) of acetone solutions of Ferruginol were freshly prepared before use.

Rearing of silkworm larvae: The rearing of silkworm larvae has been carried out through standard methods suggested by Krishnaswami et al., (1992) and explained by Khyade (2004) and Vitthalrao Khyade et al., (2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2016). The disease free layoffs of multivoltine cross breed race (PM x CSR2) of silkworm, *Bombyxmori* (L) were procured through the “Dr. APIS” Laboratory and processed for black boxing, rearing of early instars, rearing of late age instars, provision of mountage for spinning the cocoon and cocoon harvesting through the standard methods of Krishnaswami et al., (1992) and Sharad Jagtap (2012).

Topical application of Acetone solution of Ferruginol to the fifth instar larvae: The fifth instar larvae were utilized for the experimentation. Soon after the fourth moult,
the fifth in star larvae were grouped into five groups (each with hundred individuals). The groups include: Untreated control; Acetone treated control; 5 ppm Ferruginol; 10 ppm Ferruginol and 20 ppm Ferruginol. Ten microliters of each concentration of Acetone solution of Ferruginol were topically applied to respective group to the individual larva at 48 hours after the fourth moult. The larvae were maintained through standard schedule. Rearing was conducted in wooden trays with four feedings per day. The provision of mountage was made to the mature fifth larvae for spinning their cocoons (Khyade, 2004 and Vitthalrao Khyade et al., (2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2016).

Analysis of economic parameters: The cocoons from the mountage were harvested on fifth day after the provision of mountage for spinning. Twenty cocoons from each group were selected randomly, deflossed and used for recording the weight of entire cocoon. Each cocoon was cut vertically using the blade. Weight of entire cocoon; weight of shell of cocoon and weight of pupa were noted. Through the use of readings of weight of entire cocoon and weight of shell of cocoon, the shell ratio was calculated. The reading of weight of shell was divided with reading of weight of entire cocoon. The quotient thus obtained was multiplied with hundred for getting the shell ratio of individual cocoon. Ten cocoons per replication were reeled and length in meter (A) of unbroken silk filament was obtained by using eprouvate. Weight in gram of silk filament (B) from individual cocoon was recorded. Length (A) and weight (B) of silk filament were accounted for the calculation of Denier scale. The reading of weight of silk filament (B) was divided by the reading of length of silk filament (A). Quotient thus obtained was multiplied by 9000 for the purpose to get the denier scale of silk filament Vitthalrao Khyade and Abhilasha Bhunje, 2015 and 2016).

Statistical analysis of the data

The experimentation was repeated for thrice for the purpose of consistency in the results. The data was subjected for analysis. The statistical methods were employed to calculate the mean, standard deviation, percent variation and student “t” - test (Norman and Bailey, 1955).

Results and Discussion

The results on the topical application of acetone solution of Ferruginol to the individual fifth in star larvae of silkworm, *Bombyx mori* (L) are presented table-1. The cocoon weight (gm); shell weight (gm); Pupal weight (gm); Shell Ratio; Silk Filament Length (SFL in meters); Silk Filament Weight (SFW in grams) of the Untreated Control group and Acetone Treated group were measured 1.795 (±0.084); 00.347 (±0.009);1.448; 19.331; 758.81 (±9.159); 0.183 (±0.035) and 2.170 respectively. Topical application of 5 ppm acetone solution of Ferruginol to the fifth instar larvae at 48 hours after the fourth moult was found increasing in the entire cocoon weight (13.983 percent); Cocoon Shell Weight (26.224 percent); Pupal weight (11.395 percent). The shell ratio of the cocoon harvested from the 5 ppm acetone solution of Ferruginol group was found measured 21.407. It was significant (P < 0.05) over the control. The denier scale of silk filament reeled from the 5 ppm acetone solution of Ferruginol group was found measured 2.404, which was also significant (P < 0.05) over the control group.

Topical application of 10 ppm acetone solution of Ferruginol to the fifth instar larvae at 48 hours after the fourth moult was found increasing in the entire cocoon weight (32.980
percent); Cocoon Shell Weight (55.907 percent); Pupal weight (27.486 percent). The shell ratio of the cocoon harvested from the 10 ppm acetone solution of Ferruginol group was found measured 22.664. It was significant over the control. The denier scale of silk filament reeled from the 10 ppm acetone solution of Ferruginol group was found measured 3.165, which was also significant (P < 0.005) over the control group.

Topical application of 20 ppm acetone solution of Ferruginol to the fifth instar larvae at 48 hours after the fourth moult was found increasing (P < 0.01) in the entire cocoon weight (62.896 percent); Cocoon Shell Weight (93.948 percent); Pupal weight (55.524 percent). The shell ratio of the cocoon harvested from the 20 ppm acetone solution of Ferruginol group was found measured 22.948. It was significant (P < 0.01) over the control. The denier scale of silk filament reeled from the 20 ppm acetone solution of Ferruginol group was found measured 3.171, which was also significant (P < 0.01) over the control group.

Table.1 The economic parameters of the cocoons (and silk filament) spinned by mature fifth instar larvae of silkworm, *Bombyx mori* (L) (Race PM x CSR2) received topical application of acetone solution of Ferruginol at 48 hours after the fourth moult

| Parameters | Cocoon Weight (gm) | Shell Weight (gm) | Pupal Weight (gm) | Shell Ratio | SFL (m) (A) | SFW (gm) (B) | Denier Scale of SF = (B÷A) x 9000 |
|------------|-------------------|-------------------|-------------------|-------------|-------------|-------------|-----------------------------------|
| UTC        | 1.795 (±0.084)    | 0.000             | 0.347 (±0.009)    | 19.331      | 758.81      | 0.183       | 2.1700.00                         |
| ATC        | 1.795 (±0.089)    | 0.000             | 0.000             | 19.331      | 758.81      | 0.183       | 2.1700.00                         |
| 5 ppm      | 2.046 (±0.013)    | 13.983            | 0.0438 (±0.022)   | 1.613       | 21.407      | 0.281       | 2.404**                           |
| 10 ppm     | 2.387 (±0.018)    | 32.980            | 0.0541 (±0.094)   | 1.846       | 22.664      | 0.478       | 3.165**                           |
| 20 ppm     | 2.924 (±0.187)    | 62.896            | 0.0671 (±0.103)   | 2.252       | 22.948      | 0.491       | 3.171***                          |

- Each figure is the mean of the three replications.
- Figure with ± sign in the bracket is standard deviation.
- Figure below the standard deviation is the increase for calculated parameter and percent increase for the others over the control.

UTC= Untreated Control; ATC = Acetone Treated Control; SFL= Silk Filament Length; SFW= Silk Filament Weight
* : P < 0.05; ** : P < 0.005; ***: P < 0.01
**Fig.1** The Shell Ratio of the cocoons spinned by mature fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: ) received topical application of acetone solution of Ferruginol at 48 hours after the fourth moult

![Graph showing shell ratios at different concentrations of Ferruginol](image1)

UTC=Untreated Control; ATC =Acetone Treated Control

**Fig.2** The Denier Scale of the silk filament from the cocoons spinned by mature fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: ) received topical application of acetone solution of Ferruginol at 48 hours after the fourth moult

![Graph showing denier scale at different concentrations of Ferruginol](image2)

UTC=Untreated Control; ATC =Acetone Treated Control

The economic parameter in sericulture is the cocoon spinned by the mature fifth instar larvae of silkworm, *Bombyx mori* (L). Cocoon is the most important aspect in sericulture as it is used for reeling the commercial silk fibre. Cocoon weight, shell weight and thereby the shell ratio was found influenced by the topical application of acetone solution of Ferruginol to the fifth instar larvae of silkworm, *Bombyx mori* (L). The range of percent increase in the cocoon weight and shell weight in the experimental (treated) groups was 13.983 to 62.896 and 26.224 to 93.948 respectively. Shell ratio of the cocoons was found
improved in the corresponding groups of treatment. Most significant (p<0.001) shell ratio belonged to cocoons harvested from the group of larvae treated with twenty ppm acetone solution of Ferruginol at 48 hours after the fourth moult.

Most of the terpene compounds used for topical application to the larval instars of silkworm are the Juvenoids (Vitthalrao Khyade and Dhanashri Gaikawad, 2016). Being member of terpene group, the Ferruginol may have Juvenile activity in silkworm. The Ferruginol received by larvae through the acetone topically, may influence the appetite, nutrition and absorption of digested food. This may be responsible for accelerated growth of silk glands. Cocoon is the material used for reeling the commercial silk fibre. It is in fact, a protective shell made up of a continuous and long proteinaceous silk filament spun by mature silkworm prior to pupation for self protection from adverse climatic situations and natural enemies. The juvenoid titre (endogenous and / or exogenous) in the body of larvae stimulate hypermetabolism (Slama, 1971). Use of Ferruginol through the acetone for topical application, thus chiefly reflected into the improvement of cocoon quality, shell ratio and silk filament quality (Vitthalrao Khyade, et al., (2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2016). Ferruginol topically applied may be utilized
by the silkworm larvae for the extra synthesis of silk. The Ferruginol is one of the most popular meroterpenic supplement. Use of Ferruginol through acetone for rearing of silkworm larvae is much more easy method. Use of Ferruginol, a meroterpenic may open a new avenue in sericulture for the qualitative cocoon and silk filament.

Acknowledgement

Academic support and inspiration received from Shardabai Pawar Mahila Mahavidyalaya Shardanagar, Malegaon (Baramati) Dist. Pune.PIN – 413115 (India) deserve appreciations and exert a grand salutary influence. The work is part of submission of project under Environmental Sciences for S. Y. B. Sci. (2016 – 2017).

References

Ajami, A.M., Riddiford, L.M. 1973. Comparative metabolism of the cecropia juvenile hormone, *J. Insect Physiol.*, 19: 635–646.

Akai, H., Kimur, K., Kiuchi, M. and Shibukawa, A. 1985. Increase in silk production by repeated treatments with a Juvenile Hormone Analogue. *J. Sericulture Sci. Japan*, 54: 297-299.

Baishya, R.L. and Hazarika, L.R. 1996. Effect of methoprene and diflubenzuron on water, lipid, protein and chitin of Dicladispa armigera (Coleoptera: Chrysomelidae). *Entomon.*, 91(1): 7-11.

Balaraman Manohar, Soundar Divakar and Kadimi Udaya Sankar. 2009. Amyloglucosidase Catalyzed Syntheses of Bakuchiol Glycosides in Supercritical Carbon Dioxide. *Bull. Korean Chem. Soc.*, Vol. 30, No. 8, pp. 1760-1766, INIST:22343814

Banerji Asok and Chintalwar, G. 1983. Biosynthesis of bakuchiol, a meroterpenic from *Psoralea corylifolia*. *Phytochem.*, 1983, vol. 22, no9, pp. 1945-1947, INIST:9311490

Calvez, B., Hirn, M. and Reggi, M. 1976. Progress of development programme during the last larval instar of *Bombyx mori* (L. Relationship with food intake, ecdyosteroids and juvenile hormone, *J. Insect Physiol.*, 24(4): 233–239.

Cappellozza, L., Ianne, P. and Cappellozza, S. 1997. Effect of body weight on effectiveness of the insect growth regulator (I.G.R.) fenoxycarb applied to the male and female silkworm (*Bombyx mori*) (Lepidoptera: Bombycidae. Sericologia, 37: 443-452.

Chatterjee, S.N. and Datta, R.K. 1992. Hierarchical clustering of 54 races and strains of the mulberry silkworm, *Bombyx mori* L. significance of biochemical parameters. *Theor. Appl. Genet.*, 85: 394-402.

Chattopadhyay, J. 2011. The structure and defensive efficacy of glandular secretion of the larval osmeterium in Graphium agamemnon agamemnon Linnaeus, 1758 (Lepidoptera: Papilionidae).

Chengamma, C., Rajesekhar, R. and Govindappa, S. 2000) Influence of methoprene on *Bombyx mori*. L. *Indian J. Seric.*, 39: 135-138.

Chow, Y.S. and Tsai, R.S. 1989. Protective chemicals in caterpillar survival, *Experientia (Basel)*, 45(4): 390-392.

Chowdharay, S.K., Raju, R.S. and Ogra, R.K. 1990) Effect of JH analogues on silkworm, *Bombyx mori* L., growth and development of silk gland. Sericologia, 30: 155-165.

Chowdharay, S.K., Sehgal, F., Raj, S.K., Raju, P.S. and Mathu, S. 1986. Giant cocoon formation in *Bombyx mori* L. topically treated with juvenile hormone SJ-42-F. Sericologia, 26: 455-459.

Crossley, A.C. and Waterhouse, D.F. 1969. The infrastructure of osmeterium and the nature of its secretion in Papilio larvae (Lepidoptera; Papilionidae. *Tissue and Cell*, 1: 525-554.

Damman, H. 1986. The osmeterial glands of the swallowtail butterfly Eurytides Marcellus as a defense against natural enemies. *Ecol. Entomol.*, 11: 261-265.

Denlinger, D.L. 1985. Hormonal control of diapause. In: Comprehensive Insect Physiology, Biochemistry and Pharmacology, G.A.Kerkut and L.I. Gilbert (Eds. Pergamon Press, Oxford. pp 353-412.
Deshmukh Rajkumar Bapurao and Vitthalrao B. Khyade. 2013. Utilization of Aloe vera (L) herbal tonic for treating mulberry leaves before feeding the fifth instar Larvae of silkworm, Bombyx mori (L)(Race: PM x CSR2. Int. J. Bioassays, 02(01): 281 – 285. www.ijbio.com ISSN: 2278 – 778X.

Eisner, T. and Meinwald, Y.C. 1965. The defensive secretions of a caterpillar (Papilio), Sci., 150: 1733-1735.

Era, A.J. and Cisper, G. 2001. Genetic and diurnal variation in the juvenile Hormone Titer in a Wing-Polymorphic Cricket: Implications for the Evolution of Life Histories and dispersal. Physio Biochem Zool., 74: 293-306.

Gabboub, I.A., El-Helay, M.S. and Mostafa, S.M. 1985) Food utilization, rate of larval growth, and fecundity of Bombyx mori L. Lepidoptera: Bombycidae) fed mulberry leaves treated with methoprene, triprene and diflubenzuron. J. Econ. Entomol., 78: 1182-1186.

Garg, R.C. and Donahue, W.A. 1989. Pharmacologic profile of methoprene, an insect growth regulator, in cattle, dogs, and cats. J. American Vet. Med. Assoc., 194: 410-412.

Gauri, U., Kadam and Vitthalrao B. Khyade. 2013. Effect of age and sex on the activity of protease in the mid gut and integument of fifth instar silk worm, Bombyx mori (L) (Race: PM x CSR2. Int. J. Adv. Biol. Res., (Society for Science and Nature.Vol. 3 (2) 2013: 188 - 190 ISSN 2250 – 357.www.scienceandnature.org

Gopakumar, B., Ambika, B. and Prabhu, V.K.K. 1977. Juvennimimetic activity in some south Indian plants and their probable cause of this activity in Morus alba (L. Entomon, 2: 259 – 261.

Gordon, R. and Burford, I.R. 1984. Effects of methoprene, a juvenile hormone analogue, on the larval and pupal stages of the yellow fever mosquito, Aedes aegypti. J. Insect. Physiol., 30: 279-286.

Grenier and Grenier. 1983. Fenoxycarb, a fairly new growth regulator: a review of its effects on insects. Ann. App. Biol., 122: 369–403.

Hyun Cho, Jung-Yang Jun, Eun-Kyoung Song, Ki-Hong Kang, Hum-Young Baek, Yong-Suk Ko and Youn-Chul Kim. 2001. Bakuchiol: A Hepatoprotective Compound of Psoralea corylifolia on Tacrine-Induced Cytotoxicity in Hep G2 Cells. Planta Med., 67(8), pp. 750-751, doi:10.1055/s-2001-18347

Inagaki, S. and Yamashita, O. 1986. Metabolic shift from lipogenesis to glycogenesis in the last instar larval fat body of the silkworm, Bombyx mori. Insect. Biochem., 16: 327-332.

Jadhav, G. and Kallapur, V. L. 1989. Contribution of tissue protein to the cocoon shell in the fifth instar silk worm, Bombyx mori (L).

Jagtap, S.G. and Khyade, V.B. 2012. The pattern of chitin deposition in the body wall / Integument of fifth instar larvae of silkworm, Bombyx mori (L) (Race: PM x CSR2) recipient of acetone extractives of some non – mulberry plants. Biodiversity; Biotechnology and Climate Change (Editor: Dr. A. R. Tuwar and Dr. M. J. Shaikh Dept. of Life Sciences, Arts and Science College, Sonai Tal. Newasa, Dist. Ahmednagar – 414105 India): 105 – 109. www.sonaicollege.com.

Jagtap, S.G. and V.B. Khyade. 2011. Influence of Manta Through Topical Application to the Larval Instars of Silkworm, Bombyx mori (L) (PM x CSR2) and feeding them Insulin Treated mulberry leaves. J. Assoc. Zool. India, Vol. 4(1): 124 – 130.

Judy, K.J., Schooley, D.A., Dunham, L.L., Hall, M.S., Bergot, B.J., Siddall, J.B., 1973. Proc. Natl. Acad. Sci. U.S.A. 70: 1509-1513.

Kajiura, Z. and Yamashita, O. 1989. Super growth of silkglands in the dauer larvae of the silkworm, Bombyx mori, induced by a juvenile hormone analogue. J. Seric. Sci. Japan, 58: 39-46.

Kamimura, M. and Kiguchi. 1980. Effect of juvenile hormone analogue on fifth stadium larvae of silk worm, Bombyx mori (L) (Lepidoptera: Bombycidae. Appl. Entomol. Zool., 33(2): 333 – 338.

Khyade, V.B., Gaikwad ,D.R. and Thakare, U.G. 2012. Utilization of Aloe vera (L) Herbal Tonic for Treating Mulberry Leaves before feeding the Fifth Instar Larvae of Silkworm, Bombyx mori (L) (Race: PM x CSR2) (Editor: Dr. A. R. Tuwar and Dr. M. J. Shaikh Dept. of Life Sciences, Arts and
Science College, Sonai Tal. Newasa, Dist. Ahmednagar – 414105 (India): 37 – 40.
Khyade, V.B. 2004. Influence of juvenoids on silk worm, *Bombyx mori* (L. Ph.D. Thesis, Shivaji University, Kolhapur, India, 2004.

Khyade, V.B.; Ganga V. Mhamane. 2005. Vividh Vanaspati Arkancha Tuti Reshim Kitak Sangopanasathi Upyojana, *Krishi Vdyan*, 2005, 4, 18-22.
Khyade, V.B., Patil, S.B. Khyade, S.V. and Bhawane, G.P. 2002. Influence of acetone maceratives of *Vitis vinifera* on the larval parameters of silk worm, *Bombyx mori* (L), *Indian J. Comparative Animal Physiol.*, 20, 14-18.
Khyade, V.B., Patil, S.B., Khyade, S.V. and Bhawane, G. P. 2003. Influence of acetone maceratives of *Vitis vinifera* on the economic parameters of silk worm, *Bombyx mori* (L. *Indian J. Comparative Animal Physiol.*, 21: 28–32.
Khyade, V.B., Poonam B. Patil, M. Jaybhay, Rasika R. Gaikwad; Ghantalo, U. S., Vandana D. Shinde; Kavita H. Nimballkar and J.P. Sarwade. 2007. Use of digoxin for improvement of economic parameters in silk worm, *Bombyx mori* (L. *Bioinformatics (Zoological Society of India), 2007.*
Khyade, V. B., Sonali S. Machale; J. P. Sarwade; S.B. Patil and Sadhana D. Heshpande. 2006. Screening of plant extractives for juvenile activity in silk worm, *Bombyx mori*(L. *J. Zool. Soc. India, Environment and Development*: 61 – 77.) (Editors: B. N. Pandey and G. K. Kulkarni) (Publisher: A P H Publishing Corporation, New Delhi) (ISBN: 81-313-004-8 / 97881315300497.
Kochi, S.C. and Kaliwal, B.B. 2006. The effects of potassium bromide on biochemical contents of the fat body and haemolymph of cross breed races of the silkworm, *Bombyx mori* L. *Caspian J. Environ. Sci.*, 4: 17-24.
Kotikal, Y. and Devaiah, M.C. 1986. Juvenile hormones in sericulture. *Indian Silk*, 25: 19-20.
Krishnaswami, S., Narasimhana, M.N., Suryanarayana, S. K. and Kumaraj, S. 1978. Sericulture Manual –II: Silk worm rearing. F A O, United Nation’s Rome, 1978, 131.
Lauber, H., Borst, D., Baker, F.C., Carasco, C., Sinkus, M., Reuter, C.C., Tsai, L.W., and Schooley, D.A. 1987. Identification of a juvenile hormone-like compound in a crustacean. *Sci.*, 235: 202-205.
Lu, Chow-Chin; Yien Shing Chow. 1991. Fine structure of the larval osmterium of *Papilio demoleus libanius* (Lepidoptera: papilionidae. *Ann. Entomol. Soc. Am.*, 84(3), 294-302.
Mali, S.G. and Khyade, V.B. 2010. Influence of Juvenile Hormone Analogue and Insulin applied at third and fourth instar on some larval and cocoon characters in silk worm, *Bombyx mori* (L. *J. Bio – Sci.*, Vol. 18: 49 – 52 (http://www.banglajol.php/JBS/index. ISSN: 1023 – 8654.
Mamatha, D.N., Nagalakshmma, K.M. and Rajeshwara Rao. 1999. Impact of selected Juvenile Hormone Mimics on the organic constituents of silk worm, *Bombyx mori* (L).
Mamatha, D.M., Cohly, H.P.P., Raju, A.H.H. and Rajeswara Rao, M. 2006. Studies on the quantitative and qualitative characters of cocoons and silk from methoprene and fenoxycarb treated *Bombyx mori* (L) larvae. *African J. Biotech.,* 5: 1422-1426.
Mamatha, D.M., Vijaya, K., Cohly, H.P.P. and Rajeswara Rao, M. 2008. Juvenile Hormone Analogues, Methoprene and Fenoxycarb Dose- Dependentlly Enhance Certain Enzyme Activities in the Silkworm *Bombyx mori* (L). *Int. J. Environ. Res. Public Health*, 5: 120-124.
Miranda, J.E., De Bortoli, S.A. and Takahashi, R. 2002. Development and Silk Production by Silkworm Larvae after Tropical Application of Methoprene. *Sci. Agri.*, 59: 585-588.
Montogomery, R. 1957. Determination of glycogen. *Archives of Biochemistry and Biophysics*, 67: 378-386.
Nair, K.S., Kariappa, B.K. and Kamble, C.K. 2008. Impact of Individual and Co-Administrations of Juvenile Hormone Analogue and Phytoecdysteoid on the Crop Management and Performance of Silkworm, *Bombyx mori* L. *J. Biol. Sci.*, 8: 470-473.
Nair, K.S., Vijayan, V.A., Nair, J.S. and Trivedy, K. 1999. Juvenilomimic compounds for enhanced productivity in silkworm, *Bombyx mori* L. – A screening. *Ind. J. Seric.*, 38: 119- 124.
Nijhout, H.F. 1994. Insect Hormones (Princeton Univ. Press, Princeton)
Nijhout, H.F. 1999. Control mechanisms of polyphenolic development in insects. Bio. Sci., 49: 181-192.
Page, J.E., Nagel, J. 2006. "Chapter eight Biosynthesis of terpenophenolic metabolites in hop and cannabis". Integrative Plant Biochemistry. Recent Adv. Phytochem., 40, p. 179. doi:10.1016/S0079-9920(06)80042-0. ISBN 9780080451251.
Ravindra, D. Chaudhari and Vitthalrao B. Khyade. 1997. Changes in protein profile in silk work, Bombyx mori (L) caused by CMV and NPV. Bull. Assoc. Zool., 4(3): 33 – 37.
Richard, D.S., Applebaum, S.W., Sliter, T.J., Baker, F.C., Schooley, D.A., Reuter, C.C., Henrich, V.C., Gilbert, L.I. 1989. Juvenile Hormone Bisepoxide Biosynthesis in vitro by the Ring Gland of Drosophila melanogaster: A Putative Juvenile Hormone in the Higher Diptera. Proc. Natl. Acad. Sci., USA 86: 1421-1425
Riddiford, L.M. 1994. Adv. Insect Physiol., 24: 213–274.
Roe, J.H. 1955. The determination of sugar in blood and spinal fluid with anthrone reagent. J. Biol. Chem., 242: 424-428.
Rogers., I.H., J.F. Manville; T. Sahot. 1974. "Juvenile Hormone Analogons in Conifers. II. Isolation, Identification, and Biological Activity of cis-[1′(R)-5′-Dimethyl-3′-oxohexy]-cyclohexane-1-carboxylic Acid and (+)-(R)-[1′(R)-5′-Dimethyl-3′-oxohexy]-1-cyclohexene-1-carboxylic Acid from Douglas-fir Wood". Canadian J. Chem., 52(7): 1192–1199. doi:10.1139/v74-187. Retrieved 22 March 2014.
Röller, H., Dahm, K.H., Sweeley, C.C., Trost, B.M. 1967. Angew. Chem. Internat., Edit. 6, 179-180.
Sharad G. Jagtap; Vitthalrao B. Khyade and Santoshrao G. Mali. 2015. Influence of Treating the mulberry leaves with aqueous maceratives of seed powder of Syzigium cumini(L) on the activities of digestive enzyme in the fifth instar larvae of silkworm, Bombyx mori(L) (Race: PM x CSR2. Elixir Int. J. Appl. Zool. Elixir Appl. Zoology 85 (2015) 34140-34144.
www.elixirpublishers.com(Elixir.International Journal.Aplied.Zoology
Sharad Ganpat Jagtap. 2012. Influence of plant extractives on silkworm, Bombyx mori (L. Ph. D. Thesis, Shri jagdish prasad jhabarmal tibrewala university, vidyanagari, jhunjhunu, rajasthan – 333001 India.
Shivpuje Madhuri Anil, Wanve Hanumant V. and Belpatre Sadashiv, N. 2016. Influence of magnetic energy on protein contents in the fifth instar larvae of silkworm, Bombyx mori (L) (Race: PM x CSR2. World Scientific news 42: 73-86. www.worldscientificnews.com.
Siddall. 1976. Insect growth regulators and insect control. A critical approach. Envt. Health. Perspectives, 14: 119-126.
Simon-Levert, A., Menniti, C., Soulère, L., Genevière, A. M., Barthomeuf, C., Banaigs, B., Witzczak, A. 2010. "Marine Natural Meroterpenes: Synthesis and Antiproliferative Activity". Marine Drugs, 8(2): 347–358. doi:10.3390/md8020347. PMC 2852842. PMID 20390109.
Smith, W. and Nijhout. H.F. 1981. Effects of a juvenile hormone analogue on duration of the fifth instar in the milkweed bug Oncopeltus fasciatus. J. Insect Physiol., 27: 169–173.
Sucheta S. Doshi, Anil N., Shendage and Vitthalrao B. Khyade. 2014. Utilization of Digixin the herbal product for treating the mulberry leaves and feeding the fifth instar larvae of silkworm, Bombyx mori (L) (Race: PM x CSR2. Standard Global J. Scientific Res., Vol. 1 (2): 020 – 024 March 2014.http://www.standardglobaljournals.com/journals/SGJSR/2014/march/Doshi%20et%20al.html
Sucheta S. Doshi; Anil N. Shendage and Vitthalrao B. Khyade. 2016. The monoterpenes compounds for juvenile hormone activity through changes in pattern of chitin deposition in the integument of fifth instar larvae of silkworm, Bombyx mori (L) (PM x CSR2. World Scientific news, 37: 179-201. www.worldscientificnews.com.
Thyagaraja, B.S., Kelly, T.J, Masler, E.P. and Borkovec, A.B. 1991. Thyroid Induced Haemolymph Protein and Ecdysteroid Increases in the Silkworm, Bombyx mori L.:
Effect of Larva Growth and Silk Production. *J. Insect Physiol.*, 37: 153-159.

Vishakha S. Chape, Abhilasha C. Bhunje and Vitthalrao B. Khyade. 2016. Efficient Use of Extractive of *Oroxyllum indicum* for the improvement of Quality of Silk in Silkworm, *Bombyx mori* (L) (Race: PM x CSR2). International Conference on “Plant Research and Resource Management” And 25th APSI Silver Jubilee Meet 2016 at T. C. College Baramati 11, 12 and 13 February, 2016. Pages: 304 – 308.

Vitthalrao B. Khyade and Vivekanand V. Khyade. 2013. The Phytoconstituents of Animal Hormone Analogues. *Annals of Plant Sci.*, Vol. 2(5): 125 – 137. http://annalsofplantsciences.com/index.php/apsissue/view/10 ISSN: 2287 – 688X

Vitthalrao B. Khyade. 2005. Vividh Vanaspatisi Arkancha Tuti Reshim Kitak Sangopanasath Upyojan. Influence of mealy bug infestation on mulberry leaves on the silkworm, *Bombyx mori* (L). Krishi Vidnyan 4: 18-22.

Vitthalrao B. Khyade. 2014. The activity of protease in the fifth instar silkworm, *Bombyx mori* (L) (Race: PM X CSR2). Biolife April – June Vol. 2 (2) 2014:

Vitthalrao B. Khyade. 2014. Influence of Lanoxin Treated Mulberry Leaves on the contents of proteins in the fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2. 2014. Page: 8 – 17. Proceeding, Two day UGC sponsored National seminar on, “Recent Trends in Cell Biology, Biotechnology and Bioinformatics”, Organized by Department of Zoology, Balwant College, Vita Tal. Khanapur, Dist. Sangli 415311 (India) (6 and 7 September, 2013. Editor: Prof. Smt.) U. H. Shah (Department of Zoology, Balwant College, Vita. ISBN 978 – 81 – 927211 – 3 – 2.

Vitthalrao B. Khyade. 2016. Utilization of mulberry leaves treated with seed powder of cowpea, *Vigna unguiculata* (L) for feeding the fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2. *J. Med. Plants Studies*, 4(3): 182 - 188. http://www.plantsjournal.com/archives/2016/vol4issue3/PartC/4--2-33-339.pdf

Vitthalrao B. Khyade and Abhilasha C. Bhunje. 2015. Efficient use of acetone extractive of *Oroxyllum indicum* for the improvement of quality of silk in silkworm *Bombyx mori* (L.) (Race: PM x CSR2. *Malaya J. Biosci.*, 2(4): 185-190 ISSN 2348-6236 print /2348-3075 online http://www.malayabiosciences.com/

Vitthalrao B. Khyade and Anil N. Shendage. 2012. Influence of Aloe vera (L) Herbal formulation on Larval Characters and Economic Parameters of silkworm, *Bombyx mori* (L)(Race: PM x CSR2. *The Ecoscan*, Special Issue Vol. 1 (121): 321 – 326. www.theecoscan.in ISSN: 0974 – 0376.

Vitthalrao B. Khyade and Atharv Atul Gosavi. 2016. Utilization of mulberry leaves treated with seed powder cowpea, *Vigna unguiculata* (L) for feeding the fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2. *World Scientific news*, 40: 147-162.

Vitthalrao B. Khyade and Dhanashri R. Gaikawad. 2016. Insect Juvenile Hormone. *World Scientific News*, 44: 216-239.

Vitthalrao B. Khyade and Jiwan P. Sarwade. 2009. Influence of acetone extractives selected plants on the body wall chitin of fifth instars of silkworm, *Bombyx mori* (L) (Race: PM x CSR2. *J. Association of Zoologists, India*. Vol. 2 (1): 39 – 47.

Vitthalrao B. Khyade and Jiwan P. Sarwade. 2009. Influence of methanolic extractives of roots of *Achyranthus aspera* (L) on the body wall chitin in fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2. *J. Association of Zoologists, India*. Vol. 2 (1): 11 – 21.

Vitthalrao B. Khyade and Jiwan P. Sarwade. 2009. Protein profiles in the fifth instar larvae of silkworm, *Bombyx mori*(L) (Race: PM x CSR2),fed with Digoxin treated mulberry leaves. *The Bioscan*, Vol.4, No.1: 41 – 44.

Vitthalrao B. Khyade and Jiwan P. Sarwade. 2013. Utilization of Digoxin, the herbal product for treating the mulberry leaves and feeding the fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2. 2013 *Int. J. Multidisciplinary Res.*, *(IJMR)* Vol. I / Issue 12 (III): 38-42. ISSN: 2277 – 9302.
Vitthalrao B. Khyade and Jiwan P. Sarwade. 2013. Utilization of Retinol through the topical application to the fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2) for qualitative improvement of the economic parameters. *Int. J. Adv. Life Sci.*, Vol. 6 Issue 5 November, 2013.Pages: 532 – 537.

Vitthalrao B. Khyade and Jyoti A. Kulkarni. 2011. Effect of Digoxin treated mulberry leaves on protein profiles in fifth instar larvae of *Silkworm, Bombyx mori* (L) (PM x CSR2). *Res. J. Chem. Sci.*, Vol.1(1): 2–6. www.isca. ISSN 2231.

Vitthalrao B. Khyade and K. Slama. 2014. Changes in the Pattern of Chitin Deposition in The Integument of Fifth Instar Larvae of Silkworm, *Bombyx mori* (L) (Pm X Cs2) Topically Applied With Various Concentrations Of Acetone Solution Of Retinol. *J. Biodiversity and Ecol. Sci.*, Vol. 4, Issue 4: 159 – 167.ISSN: 2008-9287.

Vitthalrao B. Khyade and Karel Slama. 2015. Screening of acetone solution of fme and selected monoterpenic compounds for juvenile hormone activity through changes in pattern of chitin deposition in the integument of fifth instar larvae of silkworm, *Bombyx mori* (L) (PM x CSR2). IJBRIITISH Vol. 2 Issue 3 (May – June 2015): 68 – 90. ISSN 2349-9419 www.ijbritish.com

Vitthalrao B. Khyade and M. B. Deshmukh. 2004. Evaluation of plant extracts for juvenoid activity against red cotton bug, *Dysdercus cingulatus* (L).Influence of mealy bug infestation on mulberry leaves on the silkworm, *Bombyx mori*(L). The Proceeding of International Symposium, (23 – 25 November, 2004); University of Agricultural Sciences, Dharwad, Karnataka (India) on strategies for sustainable cotton production: A global vision/ 3. crop protection: 97 – 99.

Vitthalrao B. Khyade and Rajkumar B. Deshmukh. 2015. Mid gut protease and amylase activity in the fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2) fed with mulberry leaves treated with aqueous solution of stevia inulin powder. Proceedings, U G C Sponsored National Conference on Recent Trends in Life Sciences (10 - 11, July, 2015), organized by Department of Zoology, S. M. Joshi College, Pune. Page: 95 – 106. ISBN 978-93-5235-362-0.

Vitthalrao B. Khyade and Sucheta S. Doshi. 2012. Protein Contents and activity of enzymes in the mid gut homogenate of fifth instar larvae of silk worm, *Bombyx mori*(L) (Race: PM x CSR2) fed with herbal drug (Kho Go) treated mulberry leaves. *Res. J. Recent Sci.*, Vol. 1 (2): 49 – 55. www.isca.in ISSN 2227–2502.

Vitthalrao B. Khyade and Vivekanand V. Khyade. 2013. Plants: The Source of Animal Hormones. “Frontiers in Life sciences”, the book published by Science Impact Publication, Ahmedpur (Latur) – 413515 (India): 151 – 168. Editor: Dr. Sayyed Iliyas Usman (Poona College, Camp Pune. ISBN: 978 – 93 – 5067 – 394 – 2.

Vitthalrao B. Khyade, Kajal D. Gokule, Sunanda Rajendra Pawar, Rajkumar B. Deshmukh. 2016. Utilization of the Retinol and Phytol for the quality improvement of cocoon and silk fibre spun by fifth instar larvae of silkworm, *Bombyx mori* (L) (Race: PM x CSR2. World Scientific News 42 (2016): 167-181. www.worldscientificnews.com.

Vitthalrao B. Khyade, Sivani C. Bhosale, Vishakha R. Kakade and Jiwan P. Sarwade. 2015. Pattern of Chitin Deposition in The Integument of Fifth Instar Larvae of Silkworm, Bombyx mori (L) (PM x CSR2) Treated with Acetone Solution of Selected Monoterpenic Compounds and Fernasol Methyl Ether (Fme). *J. Basic Sci.,* Special Issue on BioIPPF, 34-40. www.skpubs.com

Vitthalrao B. Khyade, Vivekanand V. Khyade and Amar H. Kadare. 2014. Influence of Acetone Extractive of *Oroxylum indicum* Cocoon characters; Silk Filament Characters and the Electrophoretic patterns of esterase activity of silk worm *Bombyx mori* (L.)(Race: PM x CSR2. *Res. J. Recent Sci.*, Vol. 3(IVC-2014), 1-5 (2014) ISSN 2277-2502. www.isca.in, www.isca

Vitthalrao B. Khyade; and Jiwan P. Sarawade. 2012. Contents of protein and activity of protease and amylase in the mid gut homogenate of fifth instar larvae of *Bombyx mori* L. PM x CSR2) fed with herbal
drug (Kho-Go) treated mulberry leaves. *Int. J. Sci. Nature*, Vol.3 (3): 526 – 530.

Vitthalrao B. Khyade, Kajal P. Shukla and Jeevan P. Sarawade. 2012. Juvenile Hormone activity of some non mulberry plant extractives through inhibition of chitin deposition in the integument of fifth instar larvae of silk worm, *Bombyx mori* (L) (Race: PM x CSR2). *Res. J. Recent Sci.*, Vol. 1 (Issue: ISC-2112): 1-6. www.isca.in ISSN 2277 – 2502.

Vitthalrao B. Khyade, Karel Slama; Rajendra D. Pawar and Sanjay V. Deshmukh. 2015. Influence of Various Concentrations of Acetone Solution of Retinol on Pattern of Chitin Deposition in the Integument of Fifth Instar Larvae of Silkworm, *Bombyx mori* (L) (PM X CSR2). *J. Applicable Chem.*, 4(5): 1434 – 1445.

Vitthalrao B. Khyade, Karel Slama, Rajendra D. Pawar and Sanjay V. Deshmukh. 2015. Influence of Various Concentrations of Acetone Solution of Retinol on Pattern of Chitin Deposition in the Integument of Fifth Instar Larvae of Silkworm, *Bombyx mori* (L) (PM X CSR2). *J. Med. Plants Studies*, Volume 3 Issue 5 Part C: 124 – 131.

Vitthalrao B. Khyade, Poonam M. Patil, Kalyani R. Jaybhay, Rasika G. Gaikwad, Ganga V. Mhamane, Vivekanand V. Khyade, Kavita H. Nimbalkar and Sneha G. Jagtap. 2007. Effect of digoxin on economic parameters of silk worm, *Bombyx mori* (L. Journal of Zoological Society of India: Bioinformatics: 23 – 31. Editors: B. N. Pandey, Sadhana Deshpande, A. K. Triphathi and A. D. Adsool) (Publisher: A P H Publishing Corporation, New Delhi) (ISBN 13: 9788131302200 / ISBN 10: 8131302202).

Vitthalrao B. Khyade, Poonam M. Patil, Kalyani R. Jaybhay, Rasika G. Gaikwad, Ganga V. Mhamane, Vivekanand V. Khyade, Kavita H. Nimbalkar and Sneha G. Jagtap. 2007. Effect of digoxin on mid gut glucosidase activity in silkworm, *Bombyx mori* (L. Journal of Zoological Society of India: Bioinformatics: 32 – 48. Editors: B. N. Pandey, Sadhana Deshpande, A. K. Triphathi and A. D. Adsool) (Publisher: A P H Publishing Corporation, New Delhi) (ISBN 13: 9788131302200 / ISBN 10: 8131302202).

Vitthalrao B. Khyade, Uma S. Ghantalo and Vandana D. Shinde. 2007. Various effects of anti-biotics on selected parameters of silkworm *Bombyx mori*(L. J. Zool. Society of India, Bioinformatics: 11 – 22. Editors: B. N. Pandey, Sadhana Deshpande, A. K. Triphathi and A. D. Adsool) (Publisher: A P H Publishing Corporation, New Delhi) (ISBN 13: 9788131302200 / ISBN 10: 8131302202).

Vitthalrao B. Khyade, Vivekanand V. Khyade and Rhidim D. Mote. 2014. Influence of Acetone extractive of *Oroxylum indicum* (L) on
coconut characters, silk filament character and electrophoretic patterns of esterase activity of silkworm, *Bombyx mori* (L) (Race: PM x CSR2). Recent Trends in Zoology(Pages: 12-22. Editor: Dr. R. K. Kasar, Publisher: Dr. L. S. Matkar (Principal, New Arts, Commerce and Science College, Shevgaon Dist. Ahmednagar – 414502 (M.S.) India. ISBN: 978-93-84916-68-8.

Vithalrao B. Khyade, Vrushali D. Shinde and Shraddha S. Maske. 2016. Influence of the diterpenoids (Retinol and Phytol) (Race: PM x CSR2) on the cocoons and silk parameters in silkworm, *Bombyx mori* (L) (Race: PM x CSR2). *World Scientific news*, 42: 1-12. www.worldscientificnews.com.

Vithalrao B. Khyade, Vivekanand V. Khyade and Randy Wayne Schekman. 2015. Utilization of the topical application of Limonene to the fifth instar larvae of the silkworm, *Bombyx mori* (L) (Race: PM X CSR2) for the parameters of Larvae, Cocoon and Silk filament. *Int. J. Bioassay*, 4(02): 3632 – 3635.ISSN: 2278-778X www.ijbio.com

Vithalrao Khyade, Edvard Moser and May – Britt Moser. 2015. Influence of aqueous maceratives of seed powder of syzigium cumini (l) on the mid gut enzyme activity in the fifth instar larvae of silk worm, *Bombyx mori* (L) (Race: PM x CSR2). *World J. Pharmaceutical Res.*, Volume 4, Issue 6:997 – 1008. ISSN 2277– 7105.

Wheeler, D.E. and Nijhout, H.F. 1983. Soldier determination in the ant, *Pheidole bicornata*: Hormonal control of caste and size within castes. *J. Insect Physiol.*, 29: 847-854.

Wheeler, D.E. and Nijhout, H.F. 2003. A perspective for understanding the modes of juvenile hormone action as a lipid signaling system. *Bio Essay*, 25: 994–1001.

Wyatt, G.R. and Davey, K.G. 1996. Cellular and molecular actions of juvenile hormone. II. Roles of juvenile hormone in adult insects. *Adv. Insect Physiol.*, 26: 1–155.

Zera, A.J. and Tiebel, K.C. 1988. Brachypterizing effect of group rearing, juvenile hormone-III, and methoprene on winglength development in the wing-dimorphic cricket, Gryllus rubens. *J. Insect Physiol.*, 34: 489–498.

Zera, A.J. and Zhao, Z. 2004. Effect of a juvenile hormone analogue on lipid metabolism in a wing polymorphic cricket: Implications for the endocrine-biochemical bases of life-history trade-offs. Papers in the Biological Sciences, University of Nebraska – Lincoln. Posted at Digital Commons @ University of Nebraska – Lincoln.

How to cite this article:

Mansi Avinash Adagale, Apurva Baban Tamhane and Vithalrao B. Khyade. 2017. Topical Application of Acetone Solution of Ferruginol, Meroterpene Compound to the Fifth Instar Larvae of Silkworm *Bombyx mori* (L.) (Race: PM x CSR2) for Quality Improvement in Silk. *Int.J.Curr.Microbiol.App.Sci.* 6(4): 144-158. doi: https://doi.org/10.20546/ijcmas.2017.604.017