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SPATIAL VARIATION IN COCOON YIELD IN TROPICAL TASAR SILKWORM: AN INFLUENCE OF INSECT-PREDATORS AND PATHOGENS

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ABSTRACT

Tropical tasar silkworm is a polyphagous silk spinning insect, endemic to India. The silkworms are commercially reared on field-raised host plants, which are geographically contiguous with the wild silkworm fauna. Ecologically, the silkworm is r-selected and evolved with complex survival strategies. Naturally, the population regulated by the interactions between host and natural enemies and their dynamics due to tri -trophic interactions. Hence, understanding the effect of biotic and abiotic factors on silkworm is most critical for increasing the productivity of the cocoons. The cocoon yield trends at different locations are an indication for local specific problems and requirements for specific technological interventions. Cocoon yield obtained at different locations during 2015 to 2017 was analysed for variation in cocoon yield. Further, predator dynamics and incidence of silkworm diseases were also measured to know their impact on silkworms. The results revealed that the highest cocoon yield was recorded in Chhattisgarh (59.97) and West Bengal (54.57) and lowest was in Maharashtra (34.92) and Madhya Pradesh (37.80). Average cocoon yield in Jharkhand and Odisha was 40.18 and 43.30, respectively. Based on the tukeys HSD test, the highest cocoon yield per dfl was recorded at Bilaspur and Pali. The next highest was recorded in Sundergarh, Boirdadar, Patelnaga and Bastar. The significant changes in the predator's population were recorded before and after brushing of the silkworm. Highest incidence was recorded during 1st, 2nd and 3rd instar silkworm and reduced in the subsequent stages. Correlation studies indicated that there was a strong positive linear relationship between silkworm mortality and predator population. Similarly, the silkworm mortality due to disease-causing pathogens was 53.70 %, 26.75 % and 10.90 % during the first crop and 29.27%, 12.10 % and 9.70 % during the second crop in Jharkhand, Madhya Pradesh and Chhattisgarh, respectively. The study showed that the spatial variation in cocoon yield wasinfluenced by the sporadic occurrence of insect-predators and disease-causing organisms at critical stages of rearing.

Keywords: Biotic factors, Polyphagous, r-selected, Tritrophic interaction.

Introduction

The tropical tasar silk-moth, *Anthereae mylitta* D., is a wild commercial silk moth cultured by the tribal on hosts plants i.e. *Terminalia arjuna* (L.) and *Terminalia tomentosa* Roxb (ex DC) Wight & Arn (Combretaceae). Tasar sericulture is a low investment profitable agro-industry sector. Therefore, the tribal farmers, rural youths and landless workers are practicing tasar sericulture for livelihood activity. Farmers can earn money through production of seed cocoons, DFLs (disease free layings) and commercial cocoons, as well as reeling & weaving activities. More than 3.5 lakh tribal and poor families are involved in this sector in Jharkhand, Bihar, West Bengal, Odisha, Chhattisgarh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Telangana and Uttar Pradesh states. The overall demand for tasar silk far exceeds its production in India. Therefore, India imports tasar silk from other countries to meet present domestic demand.

Ecologically, the saturniids are r-selected and evolved with complex survival strategies. Naturally, the herbivore populations are regulated by the interactions between host and natural due to tritrophic interactions. Tasar silkworm seed and commercial crop rearing activities conducted in exposed conditions close to the forest fringes. Further, the wild populations also feed and breed within the surrounding forest patches (Chakraborty *et al*., 2015). Eco-races like raily, laria, barafand Korbiare very popular in Chhattisgarh, Daba, Sarihan, Munga, Modia, Laria, Lodhma, Palma, Japla, Kowa and Barharwa in Jharkhand, Modal, Nalia, Sukinda, Boadh, Simlipal, Omarkote and Sukly in Odisha, Andhra local in

Telangana and Bhandara in Maharashtra (Mahendran *et al*., 2006; Saha and Kundu, 2006). Other Saturniidae like *Actiasselene* (Hübner), *Attacus taprobanis* Moore and *Loepaschintl meisteri* Brechlin (Shubhalaxmi, 2011) also distributed in association with *A. mylitta*. Therefore, complex ecological conditions exist in the tasar silkworm rearing fields across India. Hence, understanding the effect of biotic and abiotic factors on silkworm is most critical for understanding their dynamics in nature.

The dynamic equilibrium is a status of insect population revolved either above or below the mean level in the natural ecosystem. Similarly, spatial distribution of insect population is also an important aspect for understanding population regulation through ecological factors. Both the concepts are critical for understanding an organism and their interactions with biotic and abiotic factors. The biotic-pressure from predators, parasitoids, nematodes, fungi, protists, bacteria, viruses and non-insect predators on herbivores are not similar in all the places and it can be severe enough to cause extinctions or trivial impact on local population. Therefore, the impact of natural enemies needs to be studied to predict the spatial and temporal occurrence of herbivores and influence of natural enemies on insect population dynamics (Hawkins *et al*., 1997). Therefore, the present study was an attempt to understand the potentiality of tasar silkworm cocoon yield across the locations and effect of predators and disease-causing organisms at selected locations was evaluated.

Materials and Methods

The data on tasar silkworm seed (dfl) rearing and cocoon yield were collected regularly from the seed production units of tropical tasar silkworm located in the respective places and maintained at Basic Tasar Silkworm Seed Organisation (BTSSO). The available data was utilized for study the effect of rearing locations on cocoon yield. Average cocoon yield of DABA bivoltine (DBV) silkworm race during 2015, 2016 to 2017 in Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha and West Bengal was analysed. Further, State wise occurrence of preservation loss due to insects and non-insect pest was also computed and compared across the states. Loss of cocoons due to rat damage at different grainage houses was recorded at Bilaspur.

Occurrence of predators at different stages of silkworm were recorded at Bilaspur (22.2978° N, 82.0263° E) and Kharsawan (22.1492° N, 82.0447° E). Rearing of bivoltine dfls were conducted under exposed settings. The major predators attracted to the silkworm were collected from dusk and dawn throughout the rearing period, during regular watch and ward process during silkworm rearing. Similarly, the predator activities were also recorded three days preceding the silkworm rearing. Surveys were conducted during 2019-20 to assess the incidence of various tasar silkworm diseases on tasar silkworm under filed rearing conditions at Bilaspur, Chhattisgarh (22.0796° N, 82.1391°E 264 m AMSL) and Madhupur, Jharkhand (24.2654° N, 86.6480° E228 m AMSL) and Balaghat, Madhya Pradesh (21.8129° N, 80.1838° E 288 AMSL). Both the areas are traditional areas for tasar sericulture activities and fall under different agro-climatic zones. Observations like stage wise mortality of silkworms due to various types of disease were recorded during 1st and 2nd bivoltine crops. Total number of healthy and infected silkworms were recorded in the entire rearing patch and percentage disease incidence was calculated.

The field collected data on occurrence of predators at different silkworm stages and cocoon yield recorded at different zones and percentage data was transformed and analysed using Generalized Linear Models and Tukey's test employed for multiple comparisons (SPSS 16.0). Cocoon yields data from different experiment box-plot fitted using SPSS 16.0.

Results

State and unit wise cocoon yield

Cocoon yield per dfl among the different locations was varied significantly (F= 7.36; df=5,12; P=0.02; R2= 0.754) and higher yield was recorded in Chhattisgarh (59.97) and West Bengal (54.57) states and lowest was recorded in Maharashtra (34.92) and Madhya Pradesh (37.80). Average cocoon yield in Jharkhand was 40.18 and at par with other states except Chhattisgarh. However, cocoon yield in Odisha (43.30) was at par with all the states. However, cocoon yield was not varied significantly across the years in all the states(P=0.81). The Cocoon yield per dfl was also varied significantly across the different locations (F=9.08; df=14,30; P<0.01; R^2=0.809). Based on the tukeys HSD test, the homogeneous subsets having the cocoon yield between 34.92 to 54.79 are Bhandara, Balaghat, Nabarangpur, Kharsawan, Kathikund, Baripada, Madhupur, Keonjhar, Ambikapur, Sundergarh, Boirdadar, Patelnagar and Bastar. The next homogeneous subsets are Sundergarh, Boirdadar, Patelnagar, Bastar and Pali (49.12 to 68.88 cocoons per dfl). The homogeneous subsets having the highest cocoon yield per dfls are Pali and Bilaspur.

Predatorsand their impact on silkworm

The significant changes in the predator population were also recorded before and after brushing of the silkworm (P=0.01) within the same rearing field. The predator population was very few before brushing of the silkworm and its population significantly increased after brushing. Highest incidence was recorded during 1st, 2nd and 3rd instar silkworm and reduced in the subsequent stages (P<0.01). These predators were also recorded at lower rate during spinning to till harvesting of the cocoons. Similarly, the mortality of silkworm was considerably more during the early stages of silkworm compared to later stages (t=6.53; df=14; P<0.01). Correlation studies also indicated the positive linear relationship (r^2= 0.754) between silkworm mortality and predatorpopulation.Different types of wasps like *Polister sigma*, *Delta conoideum*, *Sceliphron madraspatanum*, *Vespa cinctaand*, *Polistes olivaceus* and *Chalybion bengalense*. Spiders like grass spider, yellow sac spiders, jumping spiders and wolf spiders were recorded during the study period. Another insect predator like *Hierodula membranacea* Burmeister (Mantodea: Mantidae) was also recorded in the tasar silkworm host plantation. The vertebrate predators like birds, snake, rat, squirrel, lizards, etc, were recorded during the study period in tasar host plantation. The rat damage on tasar cocoons was assessed at different grainage houses at Bilaspur (Fig. 4). The results revealed that the rat damage was significantly more in green shade net and tubular grainage structure compared to pucca grainage house (P<0.01).

Incidence of pathogens on silkworm

The silkworm mortality due to disease-causing pathogens was 53.70 %, 26.75 % and 10.90 % during the first crop and 29.27 %, 12.10 % and 9.70 % in the second crop in Jharkhand, Madhya Pradesh and Chhattisgarh, respectively. The silkworm mortality due to disease incidence between first to third instarg ranged from 0.01 to 2.75 %. However, silkworm mortality increased from fourth instar onwards ($P<0.01$). About 9.80 % and 6.63 % mortality was observed during the fourth instar first and second crop in Jharkhand, respectively. Similarly, 9.00 % and 4.10% in Madhya Pradesh and 2.80 % and 2.10 % in Chhattisgarh, respectively. Silkworm mortality increased to 42.37 % and 21.25 % in Jharkhand, 11.00 % and 4.25 % in Madhya Pradesh and 3.50 % and 3.80 % in Chhattisgarhduring the fifth instar infirst and second crop, respectively.

Discussion

Predators are the most crucial component in the ecosystem to keep the prey population under check. They are beneficial for crop plants, including tasar host plants, to keep the pest population under check or balanced conditions. Even though natural enemies are beneficial insects in the agriculture ecosystem, they are harmful to tasar silkworms. Forest-based rearing of silkworms resulted in 80-90% crop loss due to predators, parasitoids, pathogens and extreme climatic events (Hari and Seth, 1999).In certain locations, a drastic reduction in cocoon yield has also recorded due to the various diseases causing organisms (Sahay *et al*., 2000).Sen *et al*. (1970) reported the maximum incidence of diseases at later stages of silkworms. Mortality rate due to different natural enemies may vary with latitude. Studies revealed that the mortality factors like predators and pathogens are the dominant natural enemies in the tropics and subtropics (Elton, 1973; Hawkins *et al*., 1997). Jena *et al*. (2017) reported that the better growth of female larvae at higher altitude compared to lower altitude. Change of attitude influences the body size in many lepidopterans with positive relation (Bollingand Miller, 2007). The lifespan and growth of different stages of *A. Paphia* varies at different altitudes (Dey *et al*., 2010). The present study revealed that the cocoon yield was highest in Chhattisgarh related to favourable climatic conditions coupled with the farmers interest for adoption of latest technologies might be the reasons for enhanced cocoon yield. Also, ecological and biological differences could be the reasons for differences in cocoon yield.

Under outdoor rearing process, the larvae are being succumbed to various natural enemies and abiotic factors very often and subsequently affect the cocoon yield (Sen *et al*., 1970). The success of silkworm rearing and seed production depends on favourable conditions of both biotic and abiotic factors, including silkworm and host plants factors. Major predators and parasitoids like uzi fly, yellow fly, hemipteran bugs and wasps are inflicting severely on silkworm during the early stage of silkworm. (Selvaraj *et al*., 2020; Chandrashekharaiah *et al*., 2022). The vertebrate pests also feed silkworm larvae, pupae and moths during rearing and grainage period. Birds are serious predators on tasar silkworm and cause damage up to 10-25% (Reddy *et al*., 2020). Major vertebrate pests like 1) predatory birds - Owl, *Bubo nepalensis* (Strigidae: Strigiformes), House sparrow, *Passer domesticus* (Ploceidae: Passeriformes), Jungle crow, *Corvus splendens* (Corvidae: Passeriformes), Bulbul, *Phycnonotus jocosus* (Pycnonotidae: Passeriformes), Indian myna, *Acridotheres tristis* (Stumdae: Passeriformes) and Wagtail, *Motacilla alba* (Motacillidae: Passeriformes), 2) Reptiles - snake, *Ptyas mucosa* (Colubridae: Squamata) and Garden lizard, *Calotes versicolor* (Agamidae: Squamata) and 3) Mammalia - Rat, *Rattus rattus* (Muridae: Rodentia: Mammalia), Squirrel, *Funambulus palmarum* (Sciuridae: Rodentia) and Monkey, *Macaqa mulatta* (Ceropitheadae: Primate) are very problematic on larvae and cocoon under field conditions and incur severe loss to farmers (Jadhav *et al*., 2016).

Large numbers of silkworms released on to the host plants for rearing and cocoon production. A day after release of silkworm, the activities of the predators increased gradually up to the second instar stage. The parasitoids numbers decreased gradually and their activities were noticed till harvest of the cocoons. The initial increase in predator population related to defencelessness of the young age worms. The later stage silkworms feed avidly and gain weight and are capable of defending themselves from predators. Therefore, predators inflict huge losses during the beginning of the rearing (Mathur and Shkla, 1998; Gathalkar and Barsagade, 2016). The silkworms also succumb to entomo pathogens during third instar onwards and brings up to 40 % mortality (Sahay *et al*., 2000). *Antheraeamylitta* cytoplasmic polyhedrosis virus (AmCPV), Iflavirus, *Nosema mylittensis* (Microsporidia - Pebrine), *Penicillium citrinum* (fungus disease - mycosis), *Serratia nematodiphila* and *S. marcescens* (bacterial diseases causes anal lip sealing and rectal protrusion) are major diseases causing organisms on tasar silkworm (Sen*et al*., 1970; Singh *et al*., 2011; Ponnuvel *et al*., 2022). Plant feeding insect induced green plants volatile attract natural enemies of the herbivore from its surrounding ecosystem. However, predation or parasitisation success depends on the host or prey density and their defensive nature. Similarly, pathogen load and host density also determines the intensity of disease incidence. Therefore, the present study identified the spatial variation in the cocoon yield in tropical tasar silkworm in relation to local specific biotic factors. Further, influence of ecological settings at different locations on occurrence of natural enemies in relation to developmental stages of silkworm is need to be studied to enhance productivity.

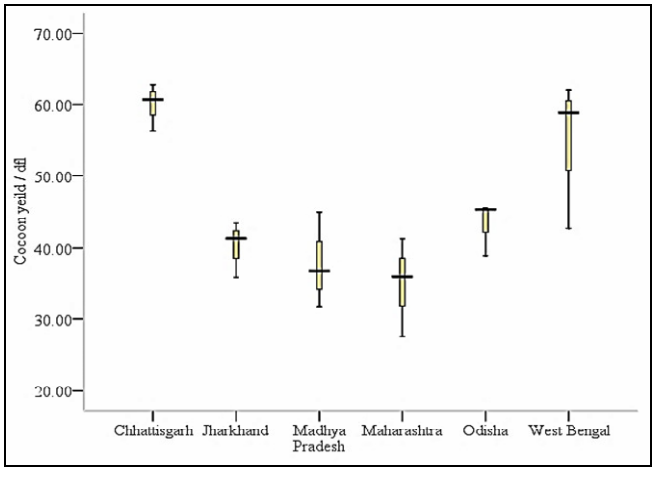

Fig. 1 : Average cocoon yield per dfl during 2015 to 2017 at different tasar sericulture practicing states in India using boxplot.

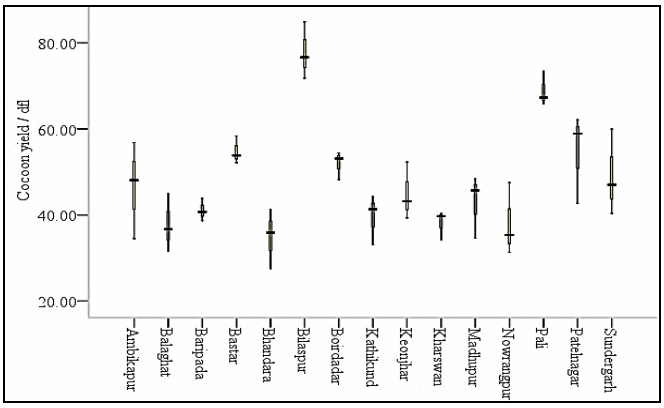

Fig. 2 : Average cocoon yield per dfl recorded during 2015 to 2017 at different locations having varied agro climatic conditions represented as boxplot.

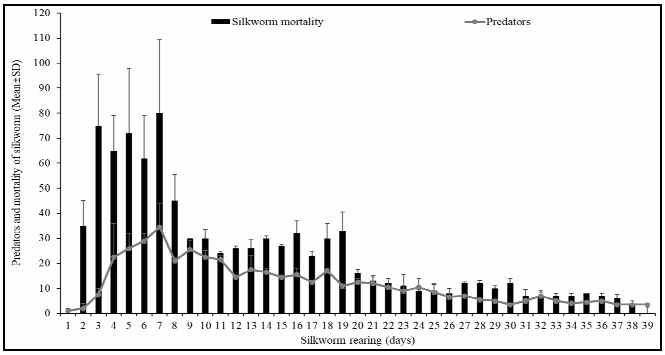

Fig. 3 : Population dynamics of predators before and after initiation of silkworm rearing.

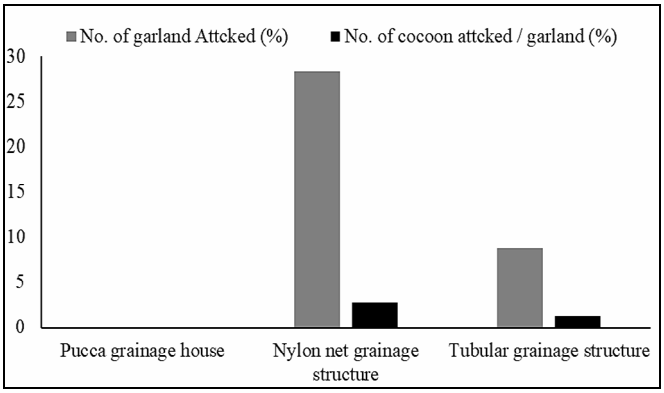

Fig. 4 : Loss of diapause seed cocoons preserved in different grainage housesat Bilaspur due to rats.

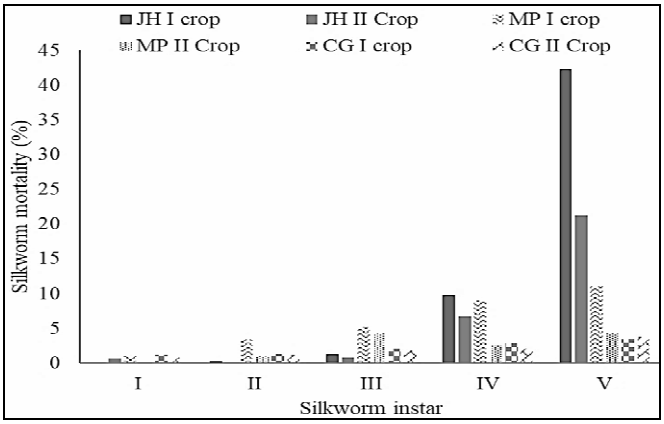

Fig. 5 : Silkworm moratlity due to incidence of disease causing pathogens at Jharkhand, Madhya Pradesh and Chhattisgarh

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