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Effect of Silkworm Larval Population Density on Quality of Cocoon Production

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Abstract: Larval population has a great impact on biology and physiology of insects including silkworm *Bombyx mori* L. The present study was conducted on hybrid $CSR_2 \times CSR_4$, comprising of seven treatments. Thepopulation density of silkworm larvae varied from 250 worms per plastic tray size (6ft.) to 550 wormsper tray to evaluate and recommend the optimum silkworm population number required to be reared under specific unit area commercially. Fourteen commercial characters were studied and evaluated by cumulative Mano's Evaluation Index (E.I.) method. The late age larval duration of the silkworm is directly proportional to the larval density, while as larval weight depicts relatively inverse relation. The highest E.I value of 56.30 was obtained for 250 population size. For population size of 300, 350, 400 silkworm the E.I values recorded were, 54.16, 52.42, 51.21 , respectively. The study also revealed that with the increase in larval population per square feet, the economic rearing parameters get reduced in metric traits. More density affects quantitative traits than qualitative traits. The larval population density 300 to 400 larvae/tray is economically and commercially optimum and advocated for field rearing.

Keywords: Silkworm*, Bombyx mori*, Population density, Cocoon production

The mulberry silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae) is a commercially important insect that spins 95-99 per cent of the valuable silk fibres for both textile and non-textile industry. As sericulture is increasingly becoming an income-generating activity in rural economies, improving the rearing environment can significantly boost both productivity and profitability. Rearing performance affects sharply in their ecological, biochemical, physiological and quantitative characters, which influence growth and development, and quantity and quality of silk produced in different geographical locations, and thus, varies under different ecological conditions to make silkworm rearing cost effective and more productive (Tilahun et al 2017).

The success of sericulture industry and cocoon productivity depends upon several factors of which the impact of the population density during the ultimate larval instar stadium is one of the crucial issues for successful cocoon crop production (Reddy et al 2015). Silkworm density play an important role in physiological programming of growth of different instars of larvae in relation to bed cleaning (Tilahun et al 2015) and optimum spacing to ensure good feeding appetite andto get quality cocoon production. Since the silkworm grow very fast particularly in the young age, the rearing seat is also to be proportionately increased. As the larvae progress through different developmental stages, growing exponentially from the initial instar to the point where they are ready to spin, the requirement for rearing space expands substantially by 80-100 times.

The overcrowding conditions developed during rearing create a suboptimal micro-environment which leads to insufficient space for silkworms to feed and move freely. The high population density increases humidity, produces excessive heat, and facilitates the fermentation of faecal matter. Krishna et al (2021) found that as the density of silkworms per rearing tray increases, larval weight and growth rate decrease significantly. The development of such type of condition can impair the metabolism of larvae, induced stress and hinder their growth, resulting in weak, underdeveloped larvae prone to disease outbreaks. As a result, this adversely affects key commercial traits, including cocoon weight, shell ratio, and the length and strength of the silk fibre.

Moreover, high-population larval density can delay the development cycle, reduce feed conversion efficiency and cause extended larval periods which elevate mortality rates, leading to a sharp decline in overall productivity. Consequently, this imbalance in nutritional uptake and physiological stress in an over- crowded environment weakens cocoon formation, resulting in the formation of defective cocoons with poor-quality silk filaments. Singh and Yadav (2023) concluded that silkworms spin cocoons with thinner shells, leading to a lower shell ratio when reared at higher densities. Thus, it is very important to avoid overcrowding in order to maintain a healthy and productive rearing environment. However, providing more space than optimal need can result in wastage of mulberry leaves, inefficient resource management and increased labour costs for feeding. Therefore, to achieve a sustainable sericulture rearing, it is essential that the density of population in the rearing bed should be regulated and ideal rearing bed conditions are ensured.

Considering the need to improve cocoon yield and silk quality and the economic significance of silkworm rearing as a source of income, this study was envisaged to assess the impact of larval population density on the production of high-quality cocoons.

MATERIAL AND METHODS

The present study was carried out during spring rearing season at Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu. Seed of $CSR_2 \times CSR_4$ was procured from RSRS, Dehradun and released from cold storage, incubated and reared as per the standard rearing techniques at silkworm research laboratory of Division of Sericulture at SKUAST-Jammu.(Krishanaswamy 1978). The number of larvae per rearing tray(2×3=6ft) were 250, 300, 350, 400, 450, 500, and 550 in such a way that each tray represents a single independent replicate in a completely randomized design. Each treatment was replicated 4 times. The rearing tray with 250 larvae served as control (standard). Following observations were made for different parameters:

Weight of 50 mature larvae (g): Fifty mature larvae were picked randomly from each replicate from 4 to 6 day of fifth instar and weighed using digital balance. The maximum larval weight was recorded in each replicate.

Larval survival percentage: The larval survival percentage represents the number of worms surviving during rearing up to pre spinning stageand was calculated by using the following formula:-

$$\frac{\text{Number of larvae surviving at pre-spinning stage}}{\text{Total number of larvae retained after III moult}} \times 100$$

Cocoon yield/10000 larvae

By weight (kg): This parameter was recorded as an average weight of cocoons harvested in kg converted for 10,000 larvae and was worked out by using the by following formulae:-

$$\text{By weight} = \frac{\text{Cocoon yield in kg}}{\text{Total number of larvae retained after III moult}} \times 10{,}000$$

By number: It was recorded as an average number of cocoons harvested and converted for 10,000 larvae and was worked out by using the by following formulae:-

$$\text{By number} = \frac{\text{Cocoon yield by number}}{\text{Total number of larvae retained after III moult}} \times 10{,}000$$

Single cocoon and shell weight (g): Twenty five male and twenty five female cocoons were randomly selected and weighed on digital balance to determine the average cocoon weight by using the following formula:

$$\frac{\text{Weight of 25 male (g)+25 female cocoon (g)}}{50}$$

Shell ratio percentage: Shell ratio was calculated is as:-

$$\frac{\text{Average weight (g) of 25cocoon shells of each sex}}{\text{Average weight of same cocoons of each sex}} \times 100$$

Total filament length (m): Filament length indicates the total reelable length of silk filament obtained from a single cocoon in meters. It is the average length of the silk reeled from a single cocoon.

$$\text{TFL} = \frac{\text{Length of raw silk reeled (m)} \times \text{No. of cocoons maintained per end}}{\text{No of reeling ends*}}$$

*Number of reeled cocoons = Number of cocoons taken for testing – Number of new unreelable cocoons/Number of converted carry over cocoons

Non-breakable filament length (m): It is a length at which cocoon filament breaks and is replaced by another cocoon. It was recorded as per the following formula:-

$$\text{NBFL} = \frac{\text{Length of silk filament reeled} \times \text{No. of cocoons maintained per end}}{\text{No of reeling ends*}}$$

*Indicates number of castings + Number of carry over cocoons – Number of converted carry over cocoon.

Filament size (d): It was determined by using filament reeled from ten cocoons from each replicate and it was calculated by using the following formula:-

$$\frac{\text{Weight (g) of raw silk reeled}}{\text{Length (m) of silk reeled} \times \text{No. of cocoons maintained per end}} \times 9000 \text{ (m)}$$

The observations were recorded on different parameters at larval, cocoon and the post cocoon parameters were evaluated by Evaluation Index method.

Evaluation index: Evaluation Index (E.I.) is the performance index which a single value measure of the multiple trait performance of a population Mano et al (1993).

$$\text{E.I.} = \frac{A-B}{C} \times 10 + 50$$

Where,

A = Value obtained for a particular trait of the hybrid combinations.

B = Mean value of a particular trait of all the hybrid combinations.

C = Standard deviation of a particular trait.

10 = Standard unit

50 = Fixed value gives

E.I. values for quantitative and qualitative characters surpassing the E.I. bench mark value >50 will be considered.

RESULTS AND DISCUSSION

Larval growth parameters: The observation made on the weight of fifty mature larvae and larval survival percentage depicted significant variation. The E.I. value greater than 50 was recorded in the population density of 250 larvae/6ft

(61.20) for the weight of 50 mature larvae, followed by 300 larvae (58.35) and 350 larvae (56.65) respectively, which clearly indicated that larval weight was favourably impacted by lower population densities (Table 1). This may be due to less number of worms in the rearing tray leads to robust growth and development and the competition for food is also less and the result collaborates with the findings of (Reddy et al 2015). In terms of larval survival percentage, a crucial parameter for maximizing cocoon yield, the E.I. value was higher in the 250 larvae/6ftpopulation (60.16). Densities above 450 larvae showed a significant drop in survival rates, likely due to increased disease incidence (Dutta et al 2013). High densities have been linked to a higher incidence of silkworm diseases like grasserie (Kumar et al 2014). Average E.I. for weight of 50 mature larvae and larval survival per cent was in 250 (60.68) followed by 300 and 350 population surpassing the benchmark of >50 (Table 1).

Cocoon parameters: The cocoon yield/10,000 larvae by weight and by number was significantly higher in the lower density populations (250-400 larvae) (Table 2) and this may be due to the fact that larval survival percentage was higher in less density population when compared to higher density population of larvae. Overcrowding of worms (450-550 larvae) resulted in more double and flimsy cocoons, which is considered to be negative and undesirable character for any breed/hybrid (Kamaraj et al 2016). Good cocoon and pupation percentage can be the attribute of rearing space, hygiene and appropriate time for picking mature larvae for seriposition. Maximum E.I. value for larval density was of 250 (61.18) followed by larval density of 300, 350 and 400. The spacing played a vital role in good cocoon percentage as well as the robustness of the breed. Current findings also provide evidence that spacing of worms is an important character and population density is directly correlated with good cocooning (Vemananda et al 2004). For pupation rate, maximum E.I. of 60.87 was scored by 250 larvae/tray followed by 300 (57.20), 350 (56.23) and 400 (53.16) while the population density of 550 larvae/6 ft² exhibited the lowest non-significant E.I. value (31.44), indicating reduced pupation success in denser populations.

The cocoon weight, shell weight and shell ratio are important commercial parameters of cocoon stage for quality reeling performance. The cocoon weight has a negative correlation with the shell ratio but positive correlation with shell weight. While single cocoon weight and single shell weight showed no significant differences across different densities, shell ratio important for silk reeling, revealed that the E.I. value > 50 was observed in population size of 250 (60.34), 300 (54.18) and 350 (50.93) respectively. Among selected seven populations size for all important commercial cocoon parameters, the average E.I. ranged between 42.04 (550) and 57.06 (250). Four out of seven population size 250 larvae (57.06), 300 (54.35), 350 (51.69) and 400 larvae per tray (50.09) crossed E.I. benchmark of >50 indicating that lower population densities generally yielded superior cocoon quality and productivity. The results are in accordance with the findings of Subramanian et al (2013) (Table 2).

Post cocoon characters have greater significance not only from reelers point of view but also from industrial point of view. Three post-cocoon parameters viz., total filament

Table 1. Evaluation Index values of silkworm hybrid on weight of mature larvae and larval survival percentage

Larval population/ tray	Weight of 50 mature larvae (g)	Larval survival (%)	Total	Average
250	61.20	60.16	121.36	60.68
300	58.35	58.99	117.34	58.67
350	56.65	56.39	113.04	56.52
400	49.81	51.46	101.27	50.63
450	47.72	50.00	97.72	48.86
500	39.36	38.01	77.37	38.68
550	36.89	34.92	71.81	35.90

Table 2. Evaluation index of bivoltine silkworm hybrid on different spacing for cocoon traits

Larval population/tray	Cocoon yield By Wt. (g)	Cocoon yield By No.	Good cocoon per cent	Pupation per cent	Double cocoon per cent	Flimsy cocoon Per cent	Single cocoon weight (g)	Single shell weight (g)	Shell ratio	Total	Avg. E.I.
250	58.79	58.82	61.18	60.87	39.58	42.37	60	70 .00	62 .00	513.61	57.06
300	61.56	54.84	57.36	57.20	41.65	42.61	55	60 .00	59 .00	489.22	54.35
350	51.48	53.52	56.23	56.25	42.06	42.71	53	60 .00	50 .00	465.25	51.69
400	52.76	55.43	53.16	53.28	49.5	47.76	49	50 .00	49 .00	459.89	51.09
450	47.80	53.31	49.12	49.12	57.93	50.99	45	50 .00	45 .00	448.27	49.80
500	45.88	40.01	41.76	41.76	54.87	54.15	45	50 .00	42 .00	415.43	46.15
550	30.78	34.05	31.44	31.44	64.38	69.30	36	40 .00	41 .00	378.39	42.04

Table 3. Evaluation index of bivoltine silkworm hybrid on different spacing for post cocoon traits

Larval population/tray	Total filament length (m)	Non-breakable filament length (m)	Filament size (d)	Total	Average
250	58.10	56.36	38.89	153.35	51.11
300	56.03	53.95	41.85	151.83	50.61
350	55.27	53.36	47.03	155.66	51.88
400	55.17	52.12	48.51	155.80	51.93
450	47.11	49.50	51.48	148.09	49.36
500	41.95	45.88	58.51	146.34	48.78
550	36.33	38.79	64.81	139.93	46.64

Table 4. Cumulative evaluation index of bivoltine silkworm hybrid on different spacing for commercial traits

Population size		250	300	350	400	450	500	550
Wt. of 50 mature larvae		61.20	58.35	56.65	49.81	47.72	39.36	36.89
Larval survival		60.16	58.99	56.39	51.46	50.00	38.01	34.92
Cocoon yield per 10,000 larvae	Wt.	58.79	61.56	51.48	52.76	47.80	45.88	30.78
	Nos.	58.82	54.84	53.52	55.43	53.31	40.01	34.05
Good cocoon		61.18	57.36	56.23	53.16	49.12	41.76	31.44
Double cocoon		39.58	41.65	42.06	49.5	57.93	54.87	64.38
Flimsy cocoon		42.37	42.61	42.71	47.76	50.99	54.15	69.3
Pupation		60.87	57.20	56.25	53.28	49.12	41.76	31.44
Single cocoon weight		60	55	53	49	45	45	36
Single shell weight		70	60	60	50	50	50	40
Shell ratio		62	59	50	49	45	42	41
Total filament length		58.10	56.03	55.27	55.17	47.11	41.95	36.33
Non-breakable filament length		56.36	53.95	53.36	52.12	49.50	45.88	38.79
Filament size		38.89	41.85	47.03	48.51	51.48	58.51	64.81
Total		788.32	758.34	733.95	716.96	694.08	639.14	590.13
Average E.I.		56.30	54.16	52.42	51.21	49.57	45.65	42.15
Rank		I	II	III	IV	-	-	-

length, non-breakable filament length and filament size contribute largely for silk, the end product. Population size 250 larvae scored maximum non- breakable filament length having E.I. value of 56.36 followed by 300, 350 and 400, while as the population 500 scored lowest E.I. value of 38.79 (Table 3). An inverse trend compared to other parameters was observed in filament size, with higher population densities yielding thicker filaments. The 550 larvaepopulation had the significant E.I. value (64.18), followed by 500 larvae and 450 larvae, and with non-significant differences observed in lower population densities, such as 250 larvae/6 ft.Among seven different population size the average E.I. values ranged between 46.64 (550) to 51.11 (250 larvae/tray). The result collaborates with the findings Kumari et al (2000).The fourteen commercial quantitative and qualitative traits revealed broad variability between different population densities. This may be attributed to the adaptability of silkworm larvae to different population size in the rearing space/environment. The cumulative results based on the E.I. values from the present investigation clearly indicates that rearing of silkworm with population size of 250 larvae with E.I. 56.30 expressed better results followed by larval population density of 300 , 350 and 400) (Table 4).

CONCLUSION

The population density of 300-400 per 6 ft allows the larvae to thrive due to reduced competition for food and space resulting in superior outcomes across commercial parameters such as larval survival, cocoon weight, shell weight, and post-cocoon traits and strike equilibrium between maintaining efficiency for commercial sericulture and ensuring optimal cocoon characteristics. This study can be highly optimum for field rearing and will be helpful for sericulturists to achieve better economic returns through improved cocoon yields and silk quality while minimizing the risk factors associated with higher densities.

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