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IMPACT OF ABIOTIC FACTORS ON THE SEED PRODUCTION OF DABA (TV) TASAR SILKWORM DURING FIRST CROP GRAINAGE

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ABSTRACT

Tasar silkworm quality seed in adequate quantity is vital for raw silk production and BSM&TCs cater the need of basic seeds in the country. In recent years, environmental rigors like very high summer temperature have hampered seed production especially during first crop. The present study deals with the impact of abiotic factors viz. temperature, humidity and rainfall on the seed production of Daba (trivoltine) tasar silkworm at BSM&TC, Pali during 1st crop grainage taking into account last five years data. The year 2022 was very harsh for diapausing cocoons as the highest temperature from 1st April to 23rd May was above 40^0C and average was above 35^0C accompanied with humidity much below threshold lower limit as the rainfall was scarce. The preservation loss calculated before sorting of cocoons for processing was 19.22%. Again out of 1,52,432 cocoons processed dfls production was 21,450 @ 7.11 cocoons required for production of one dfl although 45,469 couplings were obtained. Out of the couplings 3,652 (8.03%) did not lay eggs and 4,332 (9.53%) were rejected due to very less eggs laid. A total of 1,23,119 (80.7%) moths emerged thus with a tally of about 20% death of pupae. Average realized fecundity was only 123 and depression in eggs was observed. So, the number of unfertilized eggs was determined on the basis of froth floatation during washing immediate after moth testing and also on 6th day of coupling. It was found that about 39 % of eggs were unfertilized. More number of female moths emerged in first phase in comparison to males indicating towards the death of male cocoons. The grainage data of last five years were superimposed with the atmospheric data. It was found that the high average temperature (33 to 36^0C) with continuous highest temperature above 40^0C with average humidity (30% or below) over a period of 40 days preceding the grainage operation result in adverse impact on egg production. The lethality or death of sperm is also suspected which need to be studied further. The intermittent rain fall during four preceding months is beneficial for diapausing cocoons.

Key words: Grainage, Humidity, Seed production, Tasar silkworm, Temperature.

Introduction

In Tasar industry, three factors "breed, seed and feed" are crucial for achieving the targeted goal of raw silk production. Among them quality seed or silkworm egg production is one of the challenging tasks which require systematic and methodical approach that involves seed cocoon production, selection, grainage operation, disease management and finally the seed. Basic Seed Multiplication and Training Centres (BSM & TCs) of Central Silk Board play important role in production of basic and nuclear seeds which are further multiplied at state PPCs and subsequently at farmers' level (Kapila *et al*., 1992). Tropical tasar silkworm is wild in nature and it has two to three life cycles in a calendar before entering into pupal diapause. These diapausing seed cocoons are preserved in different types of grainage houses in BSM & TCs located at different geographical areas, thus they are often influenced by biotic and abiotic factors resulting into pupal mortality, erratic and un-seasonal and unsynchronized moth emergence that affects seed recovery.

In recent years climate change is visible globally with increase in optimum temperature called as global warming (Walther *et al*., 2002). This has resulted in alteration of life history traits in many fauna and flora (Karthik *et al*., 2021). Due to their specificity in ecological requirements such as temperature, humidity, food plants and egg laying habitats, Lepidopterans are most likely to get affected by global climate change (Forister and Shapiro 2003; González-Megías *et al*. 2008). The diapausing seed cocoons of both Daba (bivoltine) and Daba (trivoltine) have to tide over the stress of high temperature and associated abiotic factors (Chakrabarty *et al.*, 2003). The year 2022 experienced some unprecedented events during grainage operation of diapausing seed cocoons with pupal mortality, faulty emergence of male and female moths and the timings, poor fecundity, case of improper fertilization and ultimately low seed production. So the present work was taken up to compare the seed production parameters vis-a-vis weather data of last five years in order to find out the impact of different parameters.

Materials and Methods

The study was carried out at BSM&TC, Pali, Chhattisgarh ($22^0$22'4''N, $82^0$19'45''E and 325 mASL) from 2018 to 2022. Daba (TV) seed cocoons of tasar silkworm were consigned in the grainage during 2nd week of December in the traditional mud wall grainage houses with country tile roofs. Care was taken uniform hanging of cocoons consisting of 100 cocoons in each garland. All other recommended

packages of practice for preservation of seed cocoons were followed. By the 1st April, sorting of cocoons was over for dead and pierced ones and only live cocoons were preserved. All the grainage parameters viz. emergence of male and female moths, couplings etc. were recorded. Oviposition was carried out in earthen cups where mated female moths were kept for three days followed by mother moth examination. Moths having pebrine and/or bacteria were rejected. Number of moths with either no laid eggs as well as poor fecundity was also recorded. Surface sterilization of eggs was done with Depuratex and after drying, disease free layings (Dfls) were prepared. In each lot, the hatching% was also recorded. During 2022, the climatic conditions were harsh where depression of eggs was noticed. On 6th day of coupling, the eggs were again washed with water where unfertilized eggs floated on the surface and through froth floatation their number was recorded. The weather data viz. temperature and relative humidity were recorded both inside and outside grainage house. Similarly the rainfall data as well as the cloudy conditions were also recorded. Cloudiness was described as percent depending on the period of cloud cover in 24 hours. Data were analysed for mean, percentage besides comparison of proportions with Z test. One way Analysis of Variance (ANOVA) was also performed to compare the means.

Results

The details of grainage parameters from the year 2018 to 2022 are presented in Table 1. It may be seen that the period of active grainage operation varies in each year. During 2018, 2018 and 2019 it was initiated from mid-June and continued till 1st week of July, shortest grainage span was observed during the year 2019. On the other hand 2021 and 2022 had long grainage spell beginning from late May that continued till 1st week of July. Initial preservation loss till 1st April was significantly differed among years ($P < 0.05$) lowest being the year 2020 (17%) and highest in 2018 (23.32%). Cocoons preserved for grainage operation was not uniform, hence the emergence and coupling etc. were calculated as percentage of the cocoons. Male moth emergence percentage was significantly lowest (37.51%) during 2022 while it was at par for other years. Female moth emergence was identical for all the years. However, total emergence percentage was very low in 2022 while it was more than 95% in other years. The total coupling percentage was also significantly very less in 2022 (68.95%), while it was highest in 2018 (94.27%) while at par in other years. The dead cocoons were also sorted out after the grainage which was significantly highest (19.23%) during 2022 and 0.95% to 3.5% in other years. Rejection due to pebrine was negligible in all the years while bacteria containing samples was high in 2019 to 2021. Loss due poor fecundity was significantly high in 2019 and 2022 so also the percentage of moths that did not lay eggs. Total loss was less in 2018, but significantly high in 2019, 2020 and 2022. In the seed sector 200 or 2 gram eggs are considered as one Dfl and Cocoon : Dfl ratio is an important parameter that decides the efficiency or egg recovery in a grainage. This ratio was significantly highest (7.11 : 1) in 2022 and lowest in 2018 (2.8 : 1). The mean fecundity was also significantly less (123) in 2022 while at par (173 to 186) in other years, however, the hatching% was identical in all years.

Table 1 : Details of grainage parameters of Daba (TV) race of tasar silkworm at BSM&TC, Pali over five years (Figures in parentheses indicate percentage, NS – Not significant).

Parameters	2018	2019	2020	2021	2022	P <
Grainage period	14 June to 4 July	18 June to 8 July	16 June to 3 July	28 May to 3 July	26 May to 1 July	--
Cocoons preserved	106000	140000	85500	166000	188700	--
Preservation loss	24721 [a] (23.32)	29180 [b] (20.84)	14535 [c] (17)	29800 [c] (17.95)	36268 [b] (19.22)	0.05
Cocoons processed	81279	110820	70965	136200	152432	--
Male moths emerged	43122 [a] (53.05)	60450 [a] (54.55)	39032 [a] (55)	73548 [a] (54)	57170 [b] (37.51)	0.01
Female moths emerged	37388 (46)	47496 (42.86)	29450 (41.5)	60742 (44.6)	65949 (43.26)	NS
Total emergence	80510 [a] (99.05)	107946 [a] (97.41)	68482 [a] (96.5)	134290 [a] (98.6)	123119 [b] (80.77)	0.01
Total couplings obtained	35244 [a] (94.27)	42281 [b] (89.02)	25327 [b] (86)	53844 [b] (88.64)	45469 [c] (68.95)	0.001
Dead cocoons	769 [a] (0.95)	2874 [a] (2.59)	2483 [a] (3.5)	1910 [a] (1.4)	29313 [a] (19.23)	0.001
Rejection due to pebrine	266 (0.75)	634 (1.5)	461 (1.82)	641 (1.19)	570 (1.25)	NS
Rejection due to bacteria	699 [a] (1.98)	1270 [b] (3)	886 [b] (3.5)	1732 [b] (3.22)	598 [a] (1.32)	0.05
Loss due to poor fecundity	810 [a] (2.3)	4267 [c] (10.09)	2107 [bc] (8.32)	2160 [b] (4.01)	4332 [c] (9.53)	0.001
Loss due to no eggs laid	1170 [a] (3.32)	5651 [c] (13.37)	1761 [b] (6.95)	2603 [a] (4.83)	3652 [b] (8.03)	0.001
Total loss	2945 [a] (8.36)	12456 [d] (29.46)	5215 [c] (20.59)	7136 [b] (13.25)	9152 [c] (20.13)	0.001
Actual Dfls prepared	32299	30459	20112	46708	36317	--
Weight of total eggs	58150	52900	35800	86150	42900	--

Dfls prepared as per norm @ 2 g/Dfl	29075	26450	17900	43075	21450	--
Cocoons required for one dfl (Cocoon : Dfl)	2.80 [a]	4.19 [b]	3.96 [b]	3.16 [b]	7.11 [c]	0.001
Mean fecundity	180 [a]	173 [a]	178 [a]	186 [a]	123 [b]	0.001
Hatching %	81.12	87.34	83.24	85.15	80.22	NS

The male and female silk moth emergence percentages as well as coupling percentage are presented in Figure 1 to 5 respectively for year 2018 through 2022. It may be noted that, the pattern is not uniform for all the years. One uncommon pattern was notice during 2022 where female silk moths outnumber the males whereas males were more in all other years. Multiple peaks were observed in 2018, 2021 and 2022, however, 2018 had fruitful couplings in early lots of emergence. The year 2021 and 2022 recorded prolonged emergence span, but during 2022 effective coupling percentage was very less, might be due to unavailability of male to copulate.

It was noticed that there was depression of eggs during initial phase of grainage up to 12 days in 2022, probably due to improper fertilization or death of embryo. So, the number of unfertilized eggs was determined on the basis of froth floatation during washing immediate after moth testing and also on 6th day of coupling. It was found that about 39 % of eggs were unfertilized which floated on water surface. Due to very high temperature, there was also discoloration of silk moth wings during 1st half of grainage period accompanied with abnormal emergence behaviour.

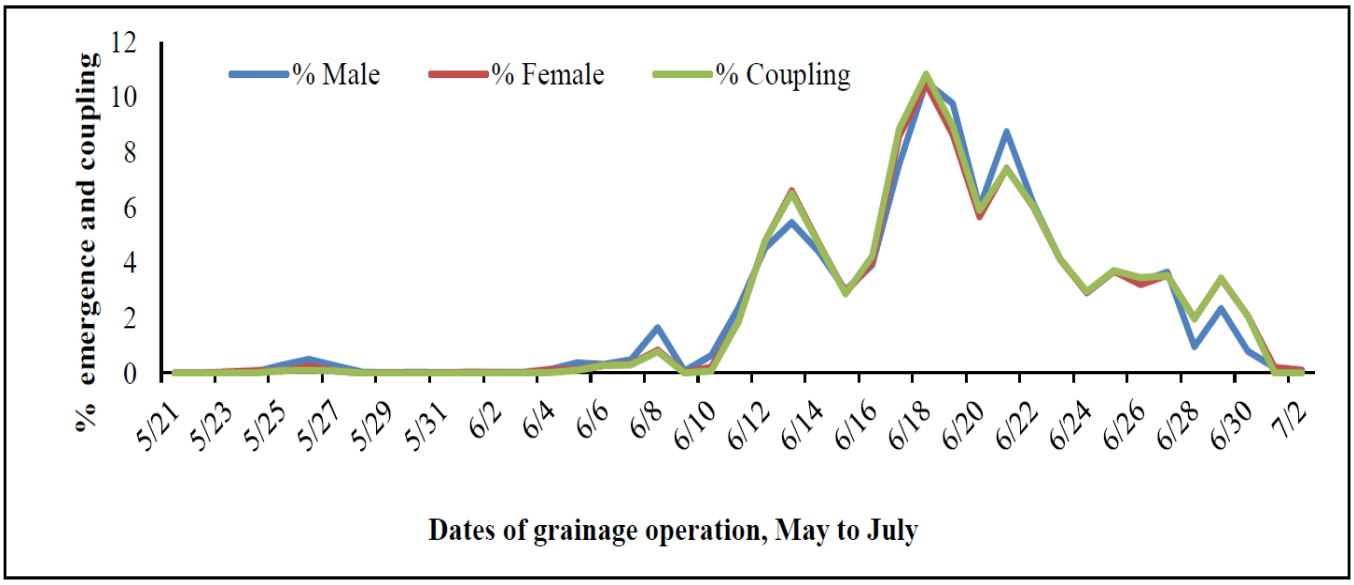

Fig. 1: Percentage of male and female moth emergence and coupling during the year 2018

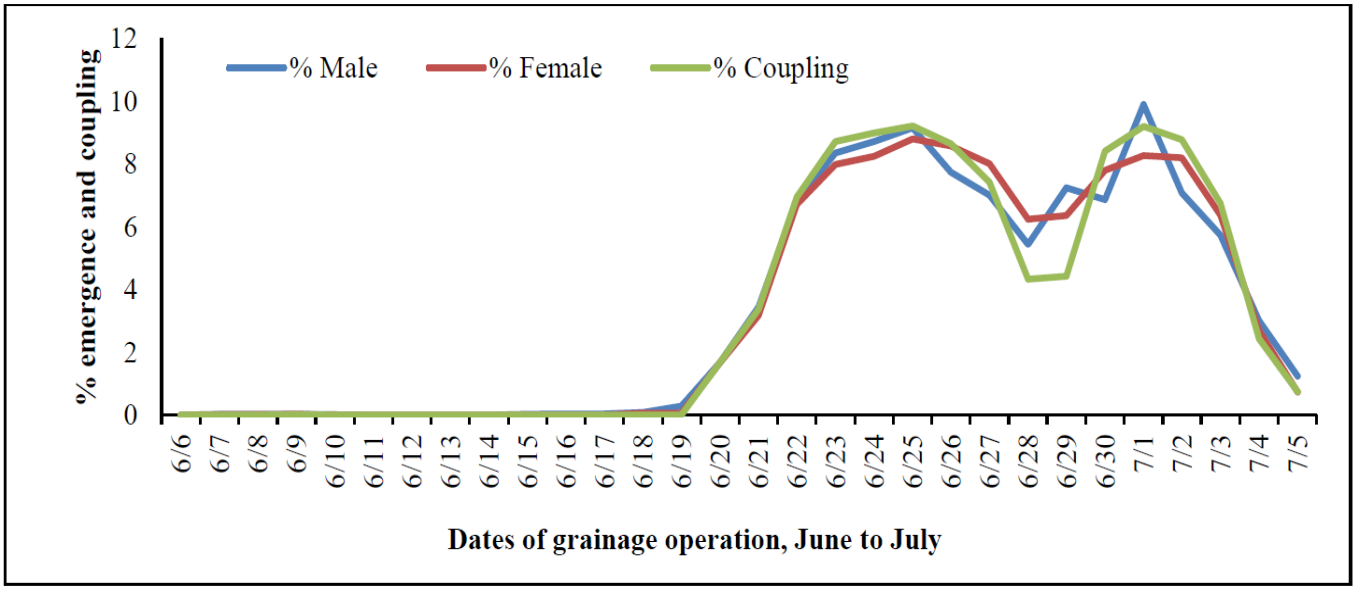

Fig. 2: Percentage of male and female moth emergence and coupling during the year 2019

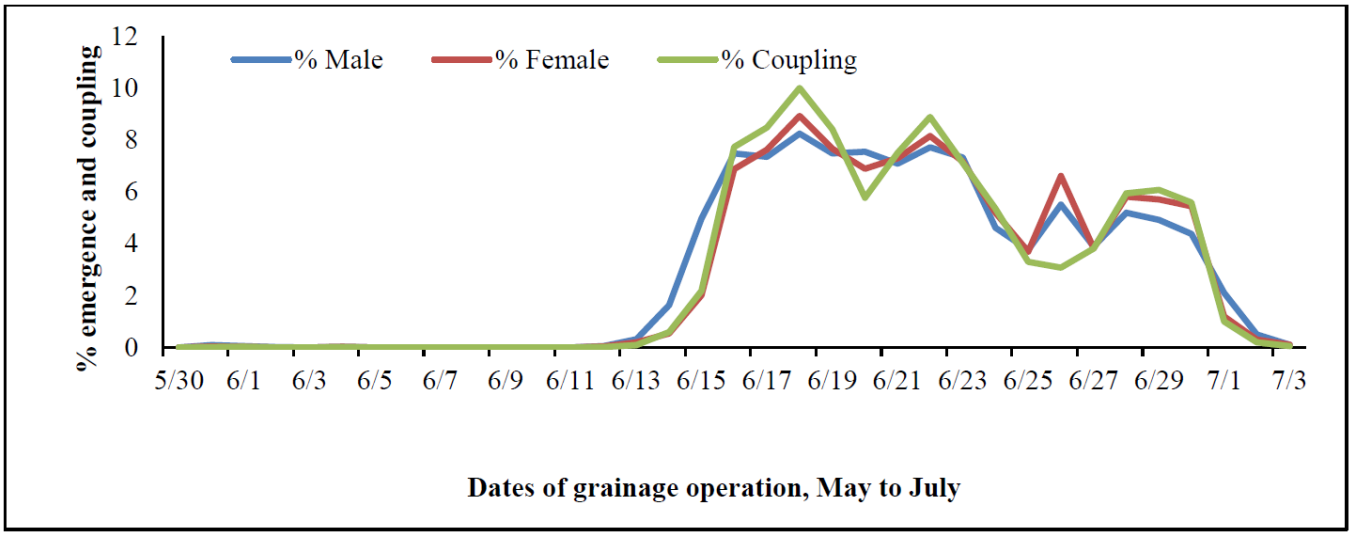

Fig. 3: Percentage of male and female moth emergence and coupling during the year 2020

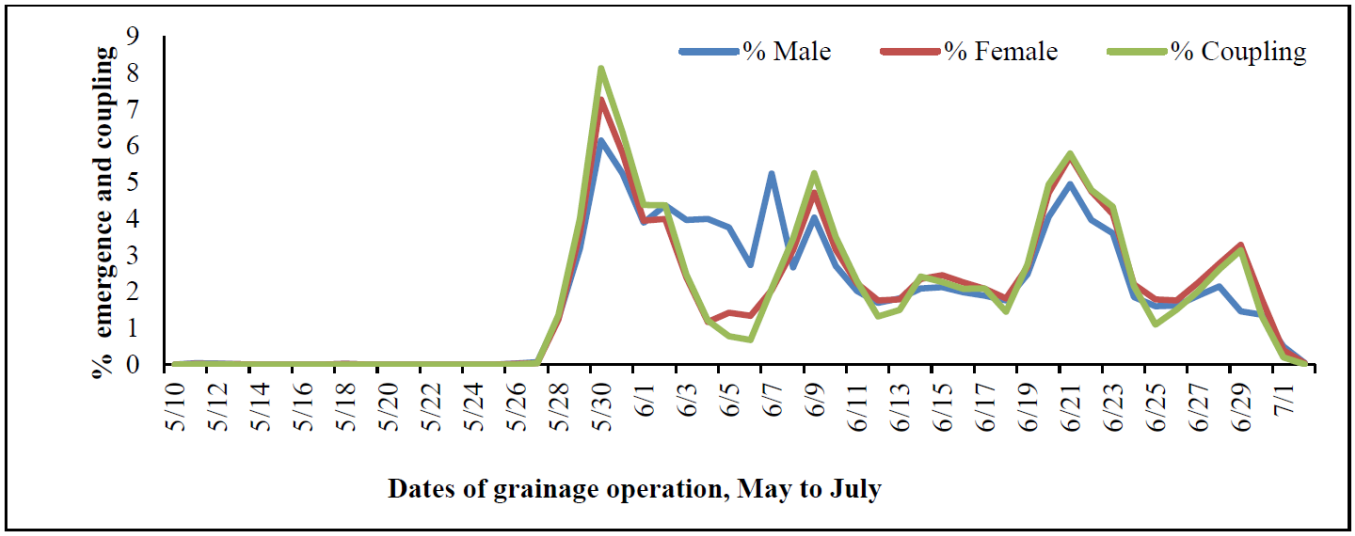

Fig. 4: Percentage of male and female moth emergence and coupling during the year 2021

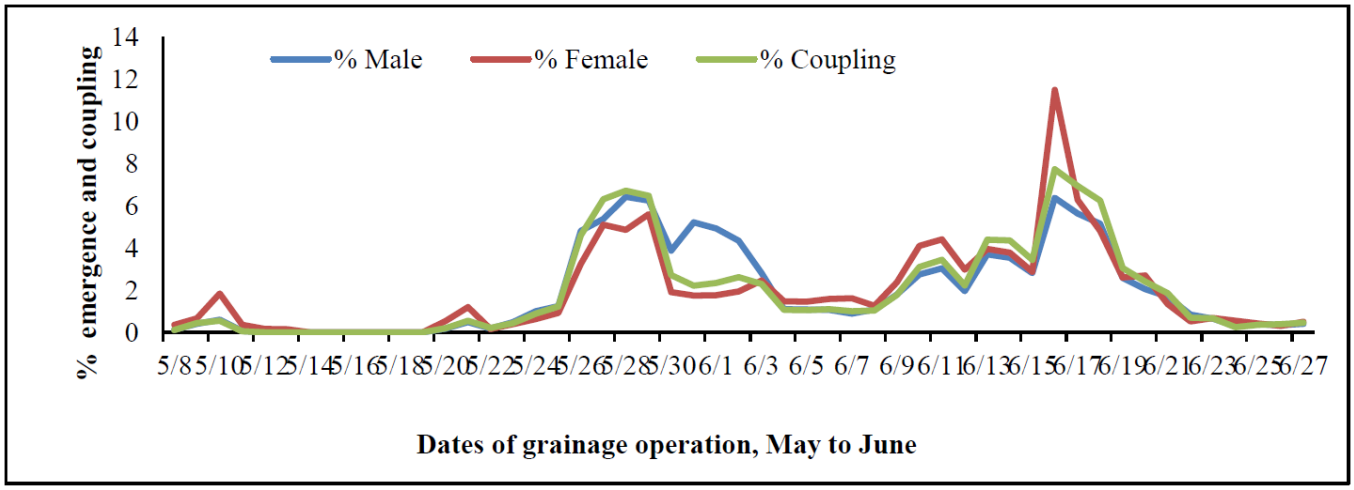

Fig. 5: Percentage of male and female moth emergence and coupling during the year 2022.

It is well known that the environmental factors influence the life history traits of insects. So the maximum and minimum temperature both inside as well as outside the grainage house during 2018 to 2022 has been presented at Figure 6 to 10 respectively. The maximum and minimum relative humidity, indoor and outdoor is presented in Figure 11 to 15 respectively. Average weekly rainfall as well as mean cloudiness percentages from 1st April to 30th June during 2018 to 2022 are presented in Figure 16 and 17 respectively. Total rainfall was very less in 2022 (112.1 mm), while 2021 and 2020 received adequate rainfall, 529.5 mm and 356.4 mm respectively. On the other hand during the same period 131 mm and 178.4 mm was experienced in 2019 and 2018 respectively. Although during the period maximum

temperature went beyond 40^{0}C from 2018 to 2020 but it was not continuous with showers occasionally associated with number of cloudy days with good cloudiness percentage. However, the same period in 2022 was very harsh. The highest temperature remained above 40^{0}C from 1st April till 17th June baring a few days in between with negligible or no rainfall till 21st May. The number of cloudy days and so also the cloudiness percentage was very less in 2022. This is also reflected in the relative humidity percentage during the same period in 2022 where inside humidity remained very low below 30% (20 to 40%) while outside humidity hovered around 50%. Only after rainfall, there was improvement of situation. On the other hand, in other years in spite of high outside temperature, relative humidity was above 40% in pre grainage period.

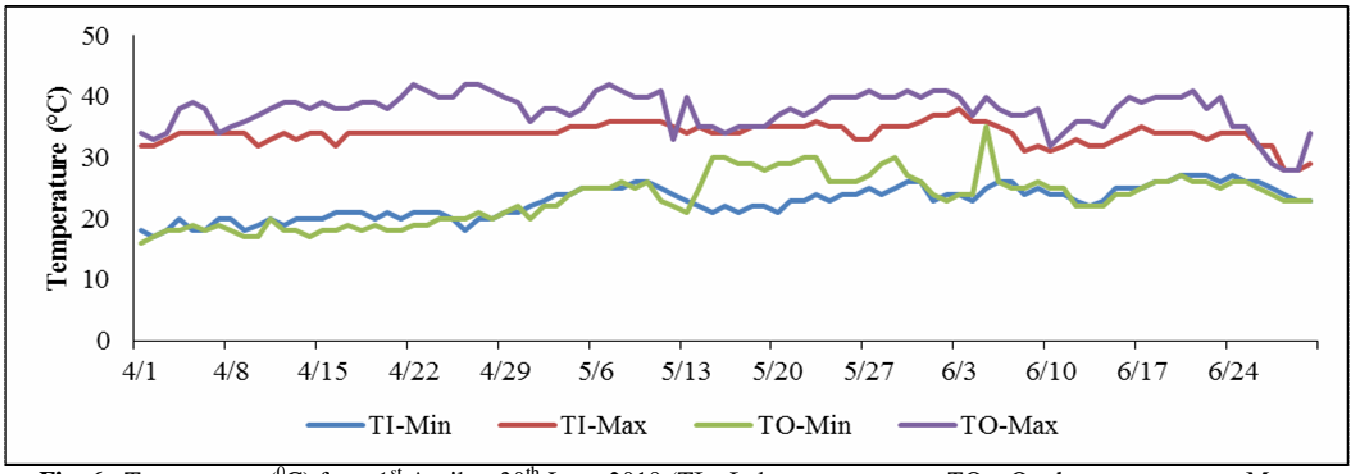

Fig. 6 : Temperature (^{0}C) from 1st April to 30th June, 2018 (TI – Indoor temperature, TO – Outdoor temperature, Max – Maximum, Min – Minimum).

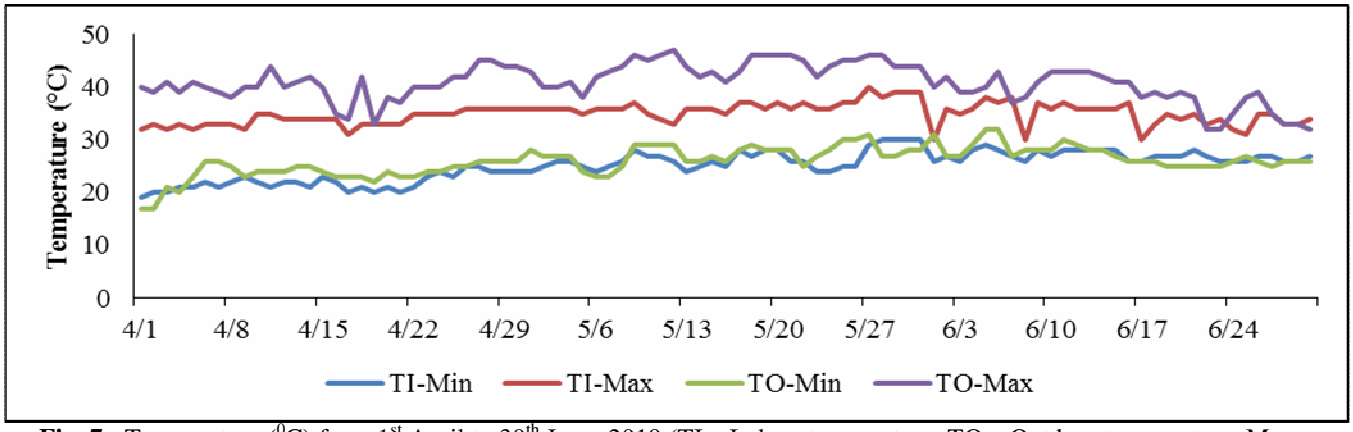

Fig. 7 : Temperature (^{0}C) from 1st April to 30th June, 2019 (TI – Indoor temperature, TO – Outdoor temperature, Max – Maximum, Min – Minimum).

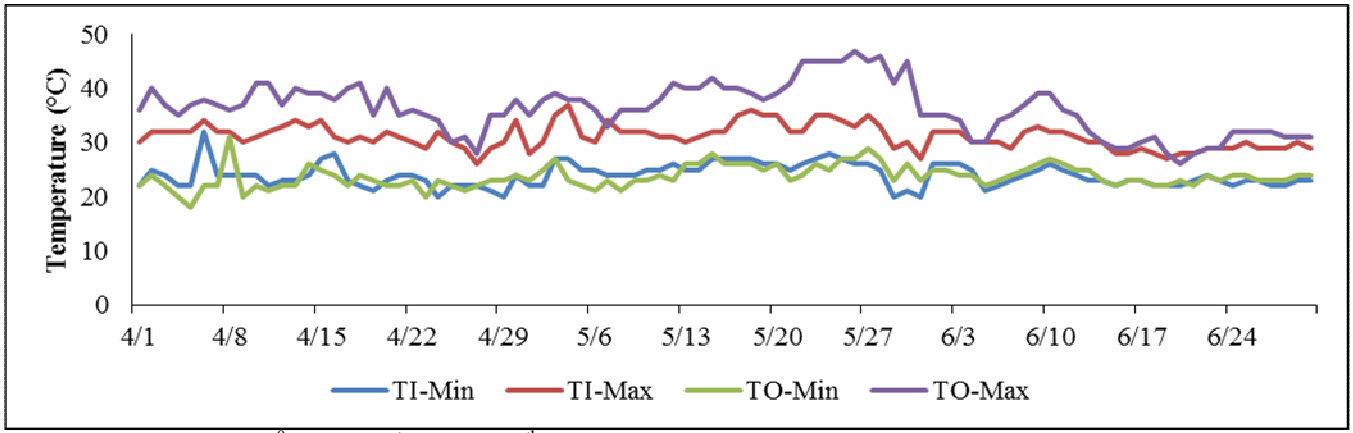

Fig. 8 : Temperature (^{0}C) from 1st April to 30th June, 2020 (TI – Indoor temperature, TO – Outdoor temperature, Max – Maximum, Min – Minimum).

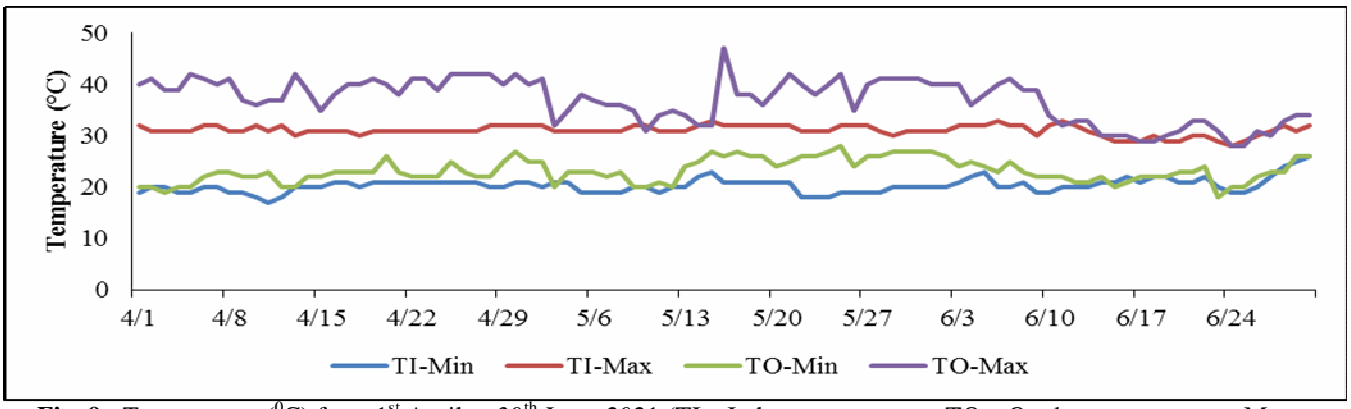

Fig. 9 : Temperature (^{0}C) from 1st April to 30th June, 2021 (TI – Indoor temperature, TO – Outdoor temperature, Max – Maximum, Min – Minimum).

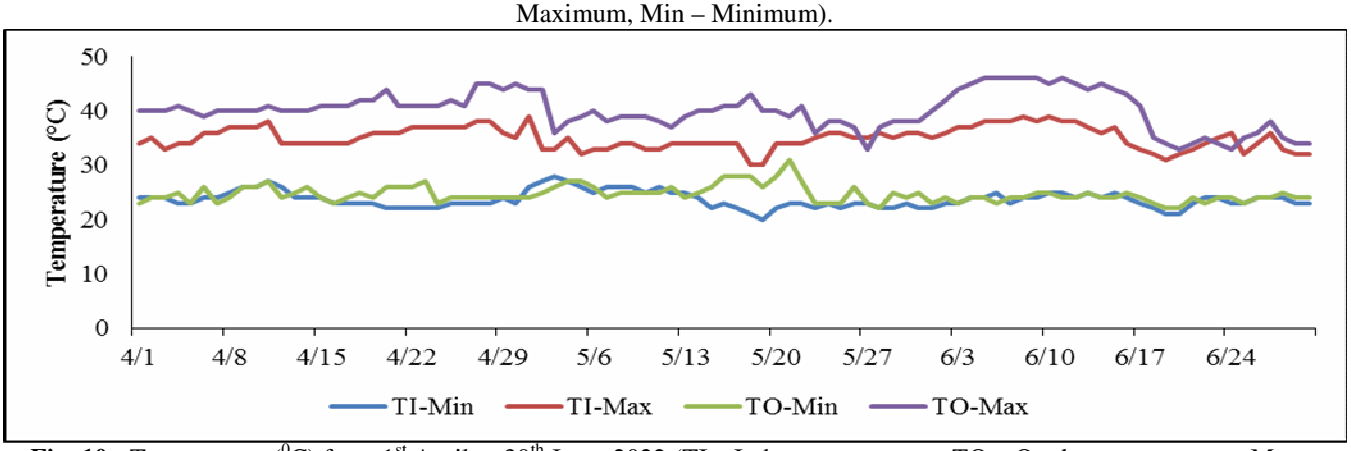

Fig. 10 : Temperature (^{0}C) from 1st April to 30th June, 2022 (TI – Indoor temperature, TO – Outdoor temperature, Max – Maximum, Min – Minimum).

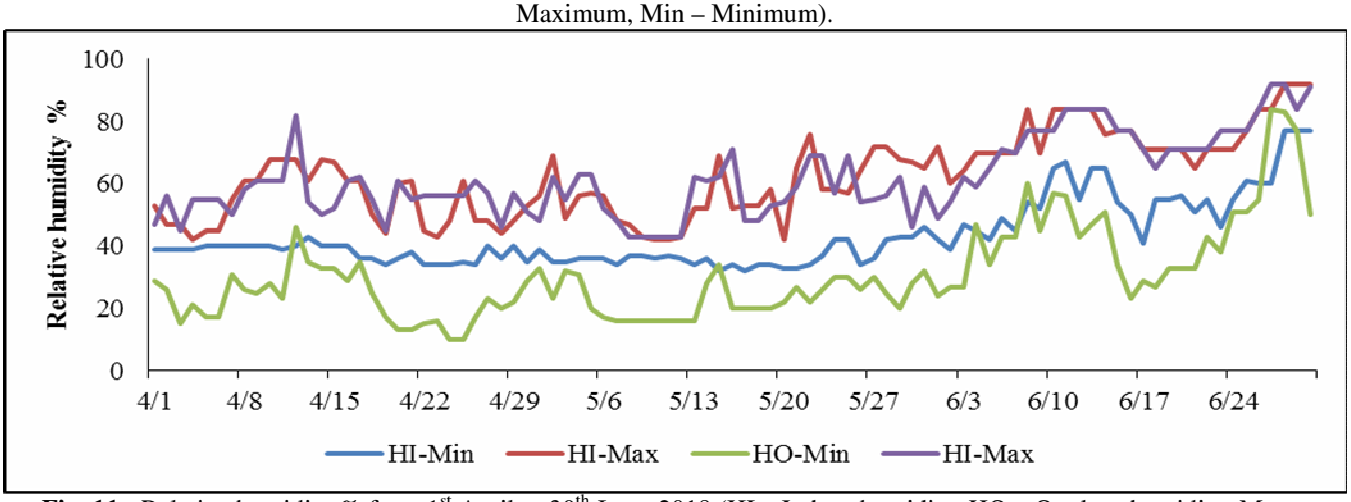

Fig. 11 : Relative humidity % from 1st April to 30th June, 2018 (HI – Indoor humidity, HO – Outdoor humidity, Max – Maximum, Min – Minimum).

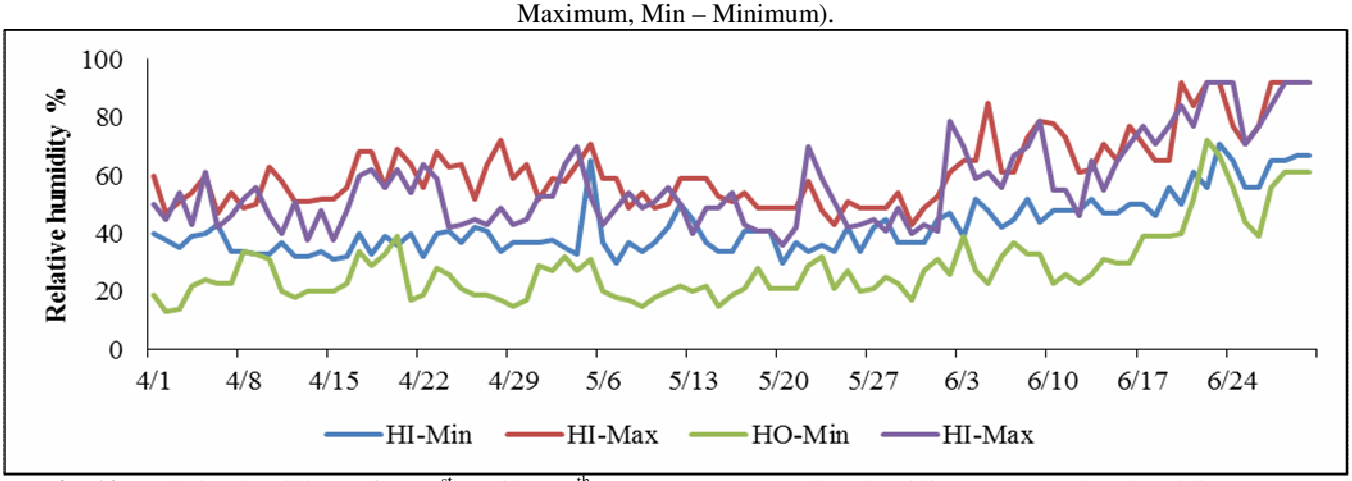

Fig. 12 : Relative humidity % from 1st April to 30th June, 2019 (HI – Indoor humidity, HO – Outdoor humidity, Max – Maximum, Min – Minimum).

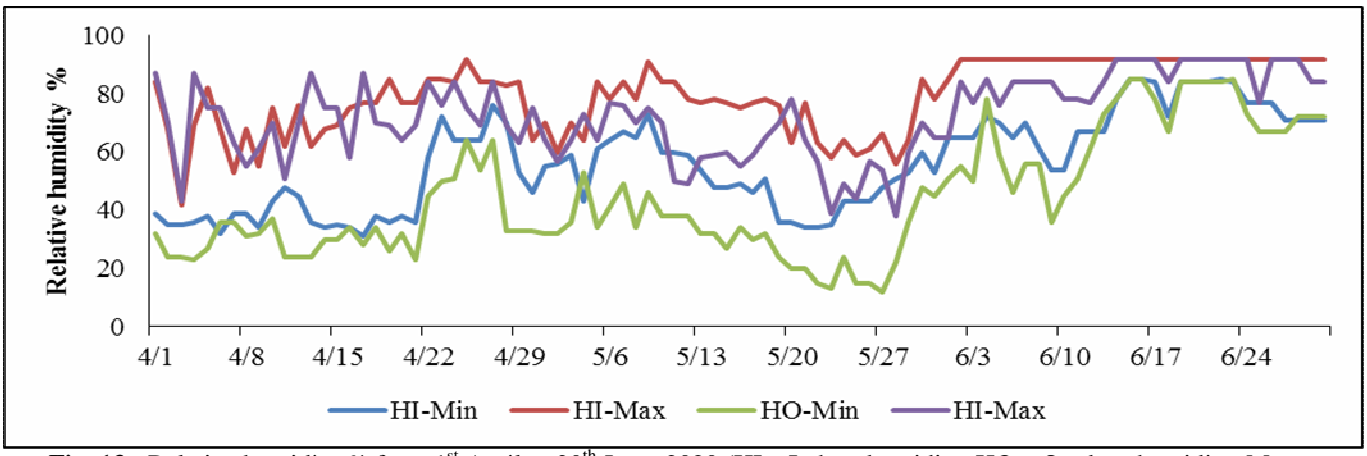

Fig. 13 : Relative humidity % from 1st April to 30th June, 2020 (HI – Indoor humidity, HO – Outdoor humidity, Max – Maximum, Min – Minimum).

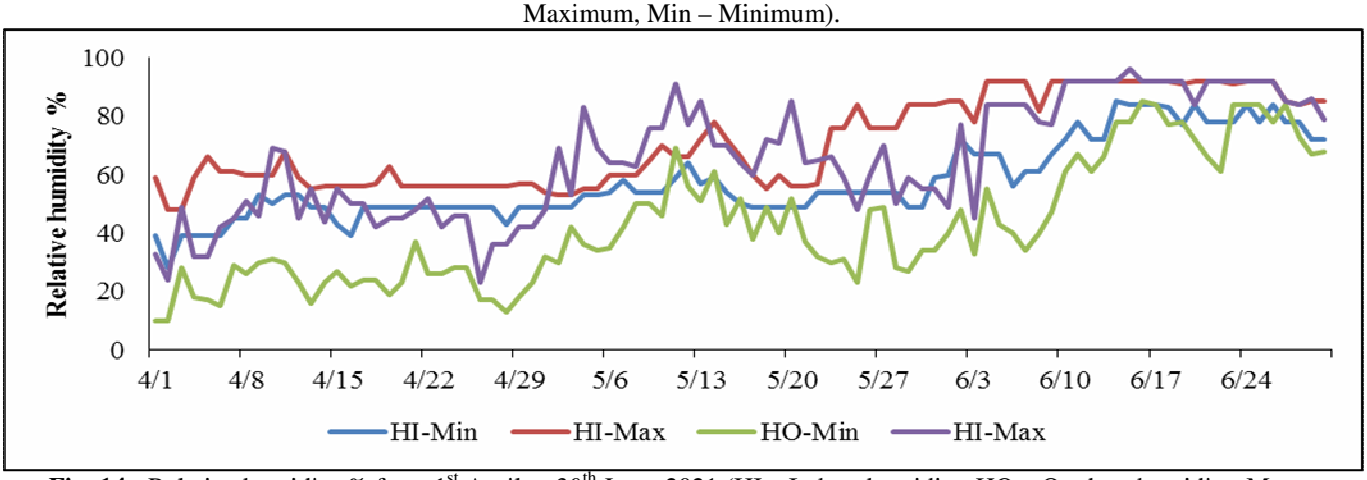

Fig. 14 : Relative humidity % from 1st April to 30th June, 2021 (HI – Indoor humidity, HO – Outdoor humidity, Max – Maximum, Min – Minimum).

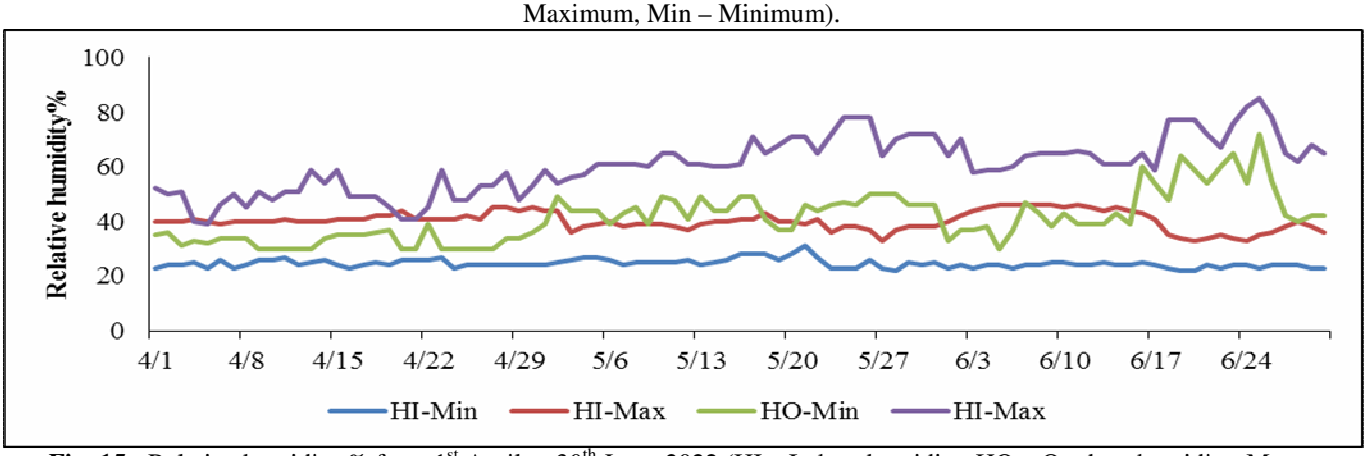

Fig. 15 : Relative humidity % from 1st April to 30th June, 2022 (HI – Indoor humidity, HO – Outdoor humidity, Max – Maximum, Min – Minimum).

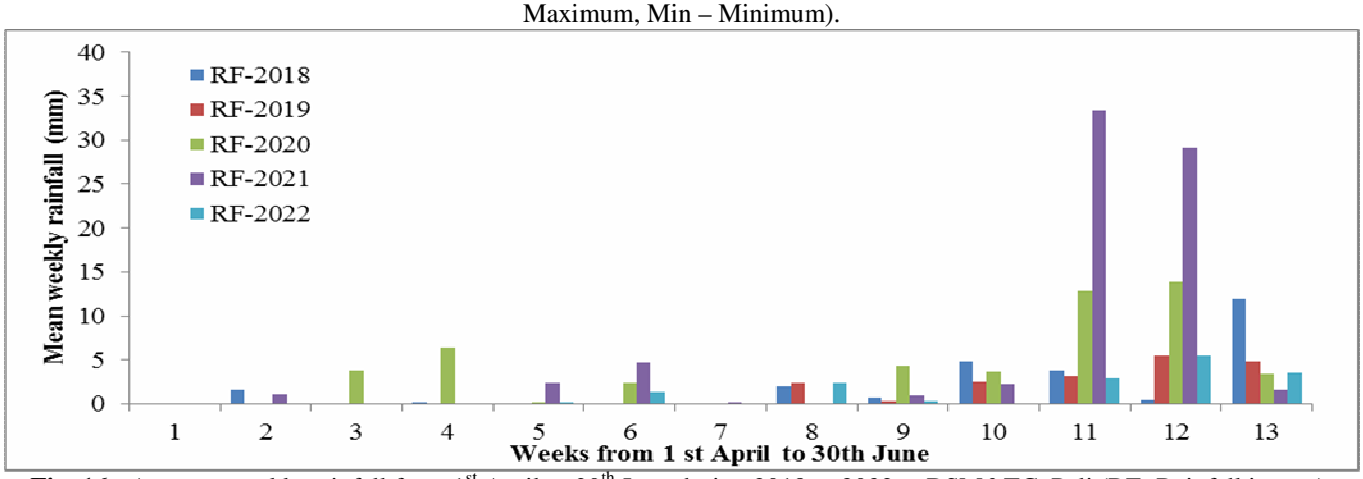

Fig. 16 : Average weekly rainfall from 1st April to 30th June during 2018 to 2022 at BSM&TC, Pali (RF- Rainfall in mm).

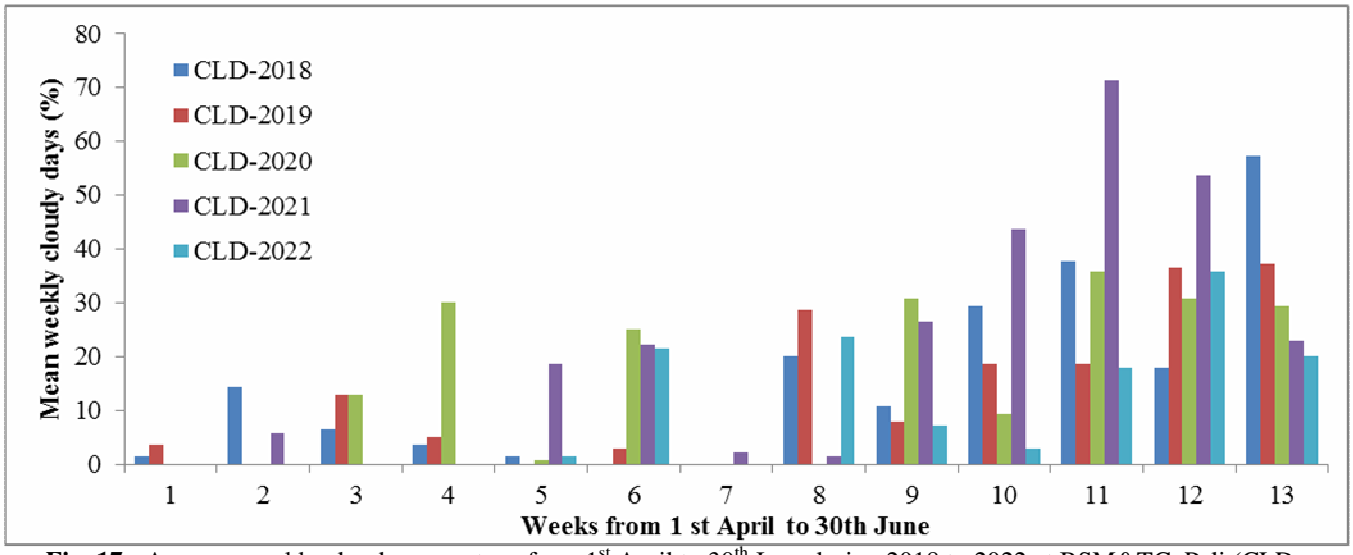

Fig. 17 : Average weekly cloudy percentage from 1st April to 30th June during 2018 to 2022 at BSM&TC, Pali (CLD-Cloudiness %).

Discussion

The study was planned to compare the tasar silk moth emergence pattern, coupling percentage, fecundity and other grainage parameters from 2018 for five years as the year 2022 was very harsh on seed production of Daba (TV) at BSM&TC levels in states like Chhattisgarh and Madhya Pradesh, Andhra Pradesh and Telengana. Climate change has influenced the life history traits of many flora and fauna globally. Adverse effects of climate change on insect-plant interaction have been also described (Karthik *et al*., 2021). Hence, this study also involved the weather parameters and their plausible impact on tasar silkworm seed production.

The year 2018 was very good for seed production as almost all the moths and couplings could be utilized for seed production which is indicated by very less number of cocoons required for the production of Dfls. The years 2019, 2020 and 2021 also comparatively good for seed production. In these four years, intermittent rainfall although in small quantity was recorded in April as well as May which are the hottest months otherwise. This was associated with number of cloudy days and both contributed to the maintenance of humidity inside the grainage house. On the other hand, very high temperature with least and no rainfall along with heat waves might have resulted in the reduction of relative humidity inside and outside the grainage house. Mud walled grainage houses are supposed to be the best in maintaining temperature and humidity, but in this case continuous high temperature above 40^0C to 45-46^0C created such conditions.

Daba (TV) produces small cocoons in comparison to Daba (BV) and also enters late into diapause after the third crop. The energy in tasar pupae is preserved for maintenance of diapause besides contributing to reproductive processes. Continuous high temperature might have affected the homeostasis of the pupae, may be using more energy for maintenance. High temperature is also known to adversely affect the spermatogenesis and oogenesis in insects, which might have led into lethality of sperm, which is a further matter of investigation. In our study 39% of eggs were depressed either with no or dead embryo suggests the improper fertilization of female moths. It was noticed that female moths emerged early which outnumbered the males. This is indicative of the fact that males being small in size many might have died due to high temperature associated with less humidity. With the commencing of proper rainfall the temperature came down with increase in humidity above 50%, where coupling, fertilization and egg laying became normal. But before that adverse climatic conditions took a heavy toll so that overall grainage performance was poor. Temperature regimes and different levels of relative humidity are known to play an important role in the life cycle of insect and its adaptability to the local climate (Tamiru *et al.,* 2012). But, if it goes beyond threshold level, adverse effects are seen at physiological level. All the insect species has their own choice of temperatures for usual growth and very high temperature slows down the growth that may leads to developmental malfunction (Chapman, 2002). Atmospheric temperature and relative humidity, the most important abiotic factors directly influence the body temperature of poikilothermic caterpillars affecting the feeding, fecundity, and also mortality (Casey, 1981; Wellington *et al.*, 1999). Temperature is probably the single most important environmental factor that influences behaviour, development, survival, reproduction, and geographical distribution of insects (Shiva Kumar *et al.,* 1997; Petzoldt and Seaman, 2013).

In the present study the grainage span was prolonged in 2021 and 2022 with early emergence during May. This also resulted an early brood of Daba-TV although with low population size. This may be taken as indication of adjustment of life cycle of tasar silkworm in response to high temperature. Yamamura and Kiritani (1998) have observed that with a 2^0C rise in temperature, insects might experience one to five additional life cycles per season, and this hypotheses need to be verified in tasar silkworm too.

Conclusion

The study compared the seed production of Daba (TV) race of tasar silkworm from 2018 to 2022 along with climatological data. It was found that the high average temperature (33 to 36^0C) with continuous highest outside temperature above 40^0C with average humidity (30% or below) over a period of 40 days preceding the grainage operation result in adverse impact on tasar egg production

with improper emergence behaviour, low coupling, low fecundity, and may be with embryonic death. The lethality or death of sperm is also suspected which need further studies. The intermittent rain fall during four preceding months to grainage operation is beneficial for diapausing cocoons. In future, care must be taken for maintenance of temperature and humidity inside the grainage with automatic humidity monitoring system so that precious seed materials could be properly utilized.

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