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MONITORING AND ECO-FRIENDLY MANAGEMENT OF COFFEE WHITE STEM BORER, *Xylotrechus quadripes* CHEVROLAT (COLEOPTERA: CERAMBYCIDAE) IN *Coffea arabica*

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ABSTRACT

Coffee, the most widely consumed beverage and important cash crop, is cultivated in more than 70 countries in the world. Coffee white stem borer (CWSB) is one of the major problems in organic arabica coffee production in Nepal. Hence, a study was carried out for eco-friendly management of CWSB by understanding its habitat and ecology. Pest monitoring using CWSB lure in three different locations of Gulmi district showed that late May and early June was the peak emergence period of the beetles. Their population was significantly higher in coffee orchards without shade as compared to shaded coffee orchards. Effects of four different eco-friendly management practices namely red soil plus cow dung, Bordeaux paste, stem scrubbing plus 20% kerosene, stem scrubbing plus 30% neem oil was studied on pest population and plant health. Effect of those treatments on the number of adults, larvae, exit holes and cracks was studied. Stem scrubbing plus 30% neem oil reduced the number of adults, larvae and cracks by 90%, 95% and 31% respectively in late May and early June. Red soil plus cow dung was most effective against exit holes, reducing it by 91% compared to control.

Keywords:

Coffee, coffee white stem borer, eco-friendly, monitoring, shade

1. INTRODUCTION

Coffee is the most important cash crop and popular beverage consumed worldwide because of its pleasant taste, aroma, stimulant effect and health benefits. Coffee beans are grown along the equatorial zone called “The Bean Belt”, in over 70 countries. In Nepal, coffee is grown from 700 to 1500 m above sea level (Paudel et al., 2021). It is usually grown by marginalized farmers in upland, and is commercially grown only in 20-22 hilly districts. Nepalese coffee is widely recognized as organic and specialty coffee due to its peculiar aroma and flavor (Paudel & Parajuli, 2020). The specialty coffee of Nepal has high demand in the international market because of its reduced caffeine amount (Tuladhar & Khanal, 2020). Despite high demand for Nepalese coffee in the international market, the country is not in position to meet this demand because of the low national coffee production (Karki, Regmi, & Thapa, 2018). Coffee is a

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shade-loving plant. Shade in coffee orchard provides optimum condition for its growth. With proper shade, coffee plants are not exposed to excessive light. Shade providing trees host natural enemies to pests of coffee and shade also delays berries maturation enhancing the coffee quality (Bote & Struik, 2011). In Nepal, multipurpose trees like moringa, banana, guava are grown in coffee orchard to provide shade (K. C., Shrestha, & Dhimal, 2016).

An increase in coffee white stem borer (CWSB) infestation is questioning the sustainability of coffee production in most of the coffee growing areas of Asia and Africa (Thapa & Lantinga, 2016). Stem borers are the major enemies of coffee. Coffee white stem borer (*Xylotrechus quadripes*) (Coleoptera: Cerambycidae) is native to southeast Asia and is a major constraint for coffee production (Seetharama et al., 2005). It is considered as the major pest of Arabica coffee (Thapa & Lantinga, 2016). It was first recorded in India in 1838 AD and now is a major coffee pest in other Asian countries including Nepal, China, Sri Lanka, Vietnam and Myanmar (Venkatesha & Dinesh, 2012). The female beetle lays eggs on the rough surfaces of the main stem of coffee plant. These eggs hatch into larvae which is the most dangerous stage of the pest. Larva on hatching enters the stem making tunnels that make ridges on the stem of the plant which indicates the infestation (Vega et al., 2006). When larva feeds inside the stem, stem starts swelling (Kumar et al., 2019). The tunnels result in wilting and yellowing of leaves (Cristancho et al., 2016). Larva feeding creates larval galleries which are continuously filled with the larval frass (Rhainds et al., 2009). After completion of larval stage of about 10 months, the larva changes into the resting pupal stage which lasts for about one month. Pupae change to adults, and under favorable environmental conditions, adults emerge out of the stem by cutting an exit hole of about 0.01 m in diameter (Liebig, et al., 2018).

CWSB infestation is the major constraint for the coffee production which fetches a loss up to 70% in Nepal (Bajracharya et al., 2015). Lack of ecofriendly management practices for the control of CWSB is increasing the threat that Nepalese coffee will lose its international organic trade. Therefore, this study was carried out with the objective of understanding the population dynamics of CWSB by regularly monitoring their population in various sites of Gulmi district and evaluating the locally available management practices for CWSB. In this study, we hypothesized that the neem oil application on scrubbed stem will decrease the adult and larval population and the number of exit holes and cracks in the stem.

2. METHODOLOGY

2.1. STUDY SITE:

The research was conducted in Reeptole (1240 masl), Panitanki and Coffee Research Program, Bhandari Dada of Gulmi district, Nepal (Figure 1) from January to July 2020. The field research was conducted in completely randomized block design (RCBD) with five treatments and four replications. Under each treatment, five plants were sampled. So, in total, 100 plants were taken under observation. Healthy, non-border plants in the center of the orchard were randomly selected for the study.

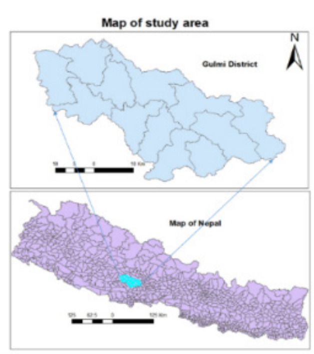

Figure 1: Map of study area.

2.2. CWSB ADULT MONITORING USING CROSS VANE TRAPS

Multi location monitoring of CWSB was carried out by the installation of cross vane pheromone traps in mid-March 2020. The CWSB pheromone lure, 2-hydroxy-3-decanone, which was loaded into a small, sealed vial of 2.5 cm length and 0.75 cm thickness, was used as bait. Five traps were pre-installed at Coffee Research Program, Bhandari Dada, and five traps each was installed at other two locations: Reeptole and Panitanki. Traps were kept for three and half months, and they were monitored at an interval of five days. The beetle collection data from April to June were analyzed.

2.3. DETAILS OF TREATMENTS

Treatments included red soil plus cow dung (T1), Bordeaux paste (T2), stem scrubbing with jute bag and applying kerosene at 20% concentration (T3), stem scrubbing with jute bag and applying neem oil at 30% concentration (T4) and control (T5). Equal amount of red soil and cow dung were mixed properly and then applied to the plant stem. 200ml of kerosene was mixed in 800 ml of water and 300 ml of commercially available neem oil was mixed in 700 ml of water. All treatments were applied 4 times at an interval of 15 days from last week of February to mid-April. Treatments were applied in the main stem and thick branches.

2.4. DATA COLLECTION AND ANALYSIS

Cross vane traps were observed every 5 days and the number of insects trapped was noted down. CWSB infested plants in each experimental unit were observed. Larvae were counted by cutting and longitudinally splitting the stem. This helped us to know the effect of treatment on the larval population. Similarly, other research parameters included were number of exit holes, number of cracked signs and number of adults.

Quantitative and qualitative data obtained from research were analyzed and interpreted by using RStudio and MS-Excel. Count data were square root transformed to normalize the data before conducting analysis of variance (ANOVA). Treatment means were separated by using Duncan's Multiple Range Test (DMRT) at 5% level of significance.

3. RESULTS

3.1. MONITORING OF CWSB AT DIFFERENT LOCATIONS

Cross-vane pheromone traps loaded with lure were installed at the height of 180 cm (average plant height) at different locations for monitoring of beetle population. The monitoring of CWSB was done in three time points: i) April and early May, ii) late May and early June and iii) June 15-30. These three time points were considered to cover pre-monsoon and monsoon season to find the peak beetle emergence time of the year. CWSBs were not recorded in any of traps in any locations for April and early May. A paired t-test was done for the analysis of beetle population in late May and early June and June 15-30. The results showed that in late May and early June, an average of 7.6 adult beetles were found, which was significantly higher as compared to an average of 2.2 adults in June 15-30 (Table 1).

Table 1. Paired t-test between late May plus early June and June 15-30 for monitoring of *Xylotrechus quadripes* in *Coffea arabica* in Gulmi, Nepal, 2020

	Late May and early June	June 15-30
Mean	7.6 ± 0.6	2.2 ± 0.2
Variance	2.74	0.48
P(T<=t) two-tail	0.002**	

** represents level of significance at 1%

For comparing the beetle population between shaded and non-shaded coffee orchard, a paired t-test analysis was done. An average of 13 CWSB adults were found in coffee orchard with no shade providing trees. This value was significantly higher in comparison to the adults' mean of 8.1 in the coffee orchard with shade (Table 2).

Table 2. Paired t-test (between the shaded and non-shaded locations) for monitoring of *Xylotrechus quadripes* in *Coffea arabica* in Gulmi, Nepal, 2020

	Shaded	Non-shaded
Mean	8.1 ± 0.5	13 ± 0.8
Variance	3.68	8.5
P(T<=t) two-tail	0.007**	

** represents level of significance at 1%

3.2. NUMBER OF ADULT COFFEE WHITE STEM BORER

Regardless of the treatments, the maximum number of adults were found in late May and early June compared to the other two sampling periods. After control, maximum adult beetles were found in plants treated with cow dung plus red soil for all the sampling periods. Stem scrubbing plus 30% neem oil was the most effective treatment as significantly low adults were found in plants with this treatment. In major adult emergence period i.e. late May and early June, there were significantly lower adults in plants treated with stem scrubbing plus 30% neem oil with an average of 0.50 beetles than other treatments (Table 3).

Table 3: Effect of different ecofriendly management practices on the mean number of adults *Xylotrechus quadripes* from April to June in *Coffea arabica* in Gulmi, Nepal, 2020.

Treatments	Adult (April and early May)	Adult (late May and early June)	Adult (June 15-30)
Red soil plus cow dung	1.25(1.31)[a]	4.00(2.11)[ab]	1.50(1.40)[ab]
Bordeaux paste	0.75(1.09)[a]	3.00(1.86)[bc]	1.00(1.22)[b]

Stem scrubbing plus 20% kerosene	0.50(0.97)[a]	2.00(1.58)[c]	0.25(0.84)[c]
Stem scrubbing plus 30% neem oil	0.25(0.84)[a]	0.50(0.96)[d]	0.00(0.70)[c]
Control	1.00(1.18)[a]	5.25(2.39)[a]	2.00(1.58)[a]
LSD (α=0.05)	0.46	0.302	0.211
P value	0.243	0.000	0.000

LSD: least significant difference, S: significant, values with same letter on columns are not significantly different at 5% level of significance using DMRT (Duncan's Multiple Range Test) and figure in parenthesis indicate square root transformation (sqrt (x+0.5)).

Stem scrubbing with 20% kerosene also recorded significantly lower adults after neem oil in late May and early June. Bordeaux paste was effective compared to control but was not as effective as neem oil (Table 3).

3.3. NUMBER OF LARVAE OF COFFEE WHITE STEM BORER

All treatments were effective in controlling larval population as compared to control. Within treatments, larval population was significantly lower in stem scrubbing plus 30% neem oil followed by cow dung plus red soil. The average larval population was 0.50, 0.25 and 0.50 for stem scrubbing plus 30% neem oil and 0, 1.75 and 2.25 for cow dung plus red soil in April and early May, late May and early June and June 15-30 respectively (Table 4).

Table 4: Effect of different ecofriendly management practices on the mean number (square root transformed) of larva *Xylotrechus quadripes* from April to June in *Coffea arabica* in Gulmi, Nepal, 2020

Treatments	Larva (April and early May)	Larva (late May and early June)	Larva (June 15-30)
Red soil plus cow dung	0.00(0.96)[b]	1.75(1.47)[c]	2.25(1.64)[d]
Bordeaux paste	0.50(0.96)[b]	2.75(1.77)[b]	3.25(1.92)[c]
Stem scrubbing plus 20% kerosene	0.50(0.96)[b]	3.00(1.87)[b]	4.00(2.11)[b]
Stem scrubbing plus 30% neem oil	0.50(0.71)[b]	0.25(0.84)[d]	0.50(0.97)[e]
Control	1.75(1.49)[a]	5.00(2.35)[a]	6.00(2.55)[a]
LSD (α=0.05)	0.413	0.230	0.177
P value	0.000	0.000	0.000

LSD: least significant difference, S: significant, values with same letter on columns are not significantly different at 5% level of significance using DMRT (Duncan's Multiple Range Test) and figure in parenthesis indicate square root transformation (sqrt(x+0.5).

In late May and early June, Bordeaux paste and kerosene were equally effective against larval population but in June 15-30, the number of larvae was significantly lower in plants treated with Bordeaux paste than with kerosene (Table 4).

3.4. NUMBER OF EXIT HOLES

The exit holes in the main stem and the thick primaries were counted before the application of treatment and up to120 days after the application of treatments (DAT). The result was non-significant up to 60 days after the application of treatment. On 75 DAT, the number of exit holes varied from 0.21 to 1.39 (Table 5), making all the three treatments significantly different from the control plot except for the stem scrubbing plus 20% kerosene. Similar was the case on 90 DAT where the number of exit holes ranged from 0.19 to 1.36 but only red soil plus cow dung and Bordeaux paste was found to be significantly different from the control.

On 105 DAT, the number of exit holes varied from 0.21 to 2.31 and all the four treatments were significantly different from the control. The Bordeaux paste and red soil plus cow dung were found to be the most effective on 105 DAT, but there was no significant difference between these treatments. On 120 DAT, which was almost 4 months after the first application of treatments, the number of exit holes ranged from 0.21 to 2.83 with the lowest number in red soil plus cow dung and the highest in control (Table 5).

Table 5. Effect of different practices on the number of exit holes (square root transformed) of *Xylotrechus quadripes* over 120 days in *Coffea arabica* in Gulmi, Nepal, 2020

Treatments	Before trt application	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	105 DAT	120 DAT
Red soil plus cow dung	0.05 (0.74)^{a}	0.06 (0.75)^{a}	0.06 (0.75)^{a}	0.13 (0.78)^{a}	0.13 (0.78)^{b}	0.21 (0.84)^{b}	0.21 (0.83)^{c}	0.21 (0.84)^{d}	0.21 (0.84)^{e}
Bordeaux paste	0.13 (0.79)^{a}	0.19 (0.82)^{a}	0.19 (0.82)^{a}	0.21 (0.86)^{a}	0.25 (0.86)^{ab}	0.25 (0.86)^{b}	0.25 (0.85)^{c}	0.30 (0.89) ^{d}	0.48 (0.99)^{d}
Stem scrubbing plus 20% kerosene	0.08 (0.76)^{a}	0.27 (0.86)^{a}	0.27 (0.86)^{a}	0.45 (0.96)^{a}	0.45 (0.96)^{ab}	0.68 (1.06)^{ab}	0.79 (1.12)^{b}	1.70 (1.48)^{b}	2.12 (1.62)^{b}
Stem scrubbing plus 30% neem oil	0.28 (0.88)^{a}	0.20 (0.82)^{a}	0.25 (0.86)^{a}	0.25 (0.86)^{a}	0.78 (0.87)^{ab}	0.45 (0.96)^{b}	0.48 (0.99)^{bc}	0.73 (1.11)^{c}	1.15 (1.28)^{c}
Control	0.25 (0.86)^{a}	0.38 (0.93)^{a}	0.60 (1.03)^{a}	0.53 (1.00)^{a}	0.77 (0.12)^{a}	1.39 (1.36)^{a}	1.67 (1.47)^{a}	2.39 (1.70)^{a}	2.83 (1.82)^{a}
LSD (α=0.05)	0.196	0.235	0.258	0.245	0.257	0.315	0.228	0.182	0.142
P value	0.528	0.571	0.262	0.323	0.112	0.021	0.000	0.000	0.000

LSD: least significant difference, S: significant, values with same letter on columns are not significantly different at 5% level of significance using DMRT (Duncan's Multiple Range Test) and figure in parenthesis indicate square root transformation (sqrt(x+0.5)). Here DAT is the date after the first application of treatments.

3.5. NUMBER OF CRACKS/ RIDGES

The number of cracks was non-significant for up to 30 DAT. On 45, 60 and 75 DAT, red soil plus cow dung had significantly lower cracks as compared to control. On 90 and 105 DAT, both cow dung plus red soil and stem scrubbing plus 30% neem oil recorded significantly lower cracks. On 120 DAT, the average lowest cracks of 4.50 were found in stem scrubbing plus 30% neem oil followed by 6.00 in red soil plus cow dung. Stem scrubbing plus 20% kerosene was effective only at 120 DAT while Bordeaux paste showed lower cracks from 105 DAT (Table 6).

Table 6. Effect of different practices on the number of cracks (square root transformed) of *Xylotrechus quadripes* over 120 days in *Coffea arabica* in Gulmi, Nepal, 2020

Treatments	Before trt application	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	105 DAT	120 DAT
Red soil plus cow dung	0.59 (1.02)^{b}	0.64 (1.05)^{b}	1.14 (1.23)^{a}	1.30 (1.30)^{b}	1.86 (1.49)^{b}	2.68 (1.75)^{c}	3.71 (2.04)^{b}	3.79 (2.06)^{c}	6.00 (2.55)^{c}
Bordeaux paste	1.00 (1.21)^{ab}	1.00 (1.21)^{ab}	1.50 (1.38)^{a}	3.60 (1.99)^{a}	4.13 (2.14)^{a}	5.25 (2.40)^{ab}	5.25 (2.40)^{a}	5.50 (2.45)^{b}	6.88 (2.71)^{bc}
Stem scrubbing plus 20% kerosene	1.33 (1.34)^{a}	1.33 (1.35)^{a}	1.88 (1.54)^{a}	3.83 (2.06)^{a}	5.35 (2.41)^{a}	5.93 (2.53)^{a}	6.01 (2.55)^{a}	6.45 (2.63)^{a}	7.25 (2.78)^{b}
Stem scrubbing plus 30% neem oil	1.55 (1.42)^{a}	1.60 (1.44)^{a}	2.25 (1.65)^{a}	2.90 (1.84)^{ab}	3.95 (2.10)^{a}	3.75 (2.06)^{bc}	4.33 (2.20)^{b}	4.50 (2.24)^{c}	4.50 (2.24)^{d}
Control	1.04 (1.21)^{ab}	1.16 (1.27)^{ab}	1.71 (1.47)^{a}	3.25 (1.91)^{a}	4.19 (2.13)^{a}	4.46 (2.22)^{ab}	5.33 (2.41)^{a}	6.53 (2.64)^{a}	9.13 (3.10)^{a}
LSD (α=0.05)	0.258	0.240	0.407	0.552	0.495	0.360	0.163	0.175	0.207
P value	0.049	0.038	0.283	0.072	0.020	0.002	0.000	0.000	0.000

LSD: least significant difference, S: significant, values with same letter on columns are not significantly different at 5% level of significance using DMRT (Duncan's Multiple Range Test) and figure in parenthesis indicate square root transformation (sqrt(x+0.5)). Here DAT is the date after the first application of treatments.

4. DISCUSSION

The maximum adults were seen in late May and early June because of the bright and sunny weather while very few numbers of adults were seen in April and early May and at the end of June. Stem scrubbing plus 30% neem oil and stem scrubbing plus 20 % kerosene were found most effective against adults. Despite having the least exit holes in plants treated with red soil plus cow dung and Bordeaux paste, more adults were observed in the plants treated with red soil and cow dung. Very fewer CWSB adults were observed in the shaded garden because of the shade providing plants. Similar observations were also found in the study done by Thapa and Lantinga (2016).

Stem scrubbing controlled the oviposition of coffee white stem borers. Smoothening of the stem of the plant removed the crevices and cracks in stem which were the major egg laying sites for CWSB. As a result, insects did not prefer those scrubbed plants and hence less adults were seen in the scrubbed plants. The result goes in line with the findings of Venkatesha and Dinesh (2012). Scrubbing would have been even more effective if it was done during the egg laying period or before the larvae bore into the stem. As the number of larva increases, the more cracks or ridges appear in the stem. Since the larval population was lower in stem scrubbing plus 30% neem oil and cow dung plus red soil, the lower cracks in those treatments were obvious. Among the scrubbed plants, less adults were seen in neem oil treated plants than kerosene treated plants. Neem, being a very effective bio-pesticide (Panthi, 2015), the extract of its seeds and leaves were found effective against CWSB. The effect of Neem was long-lasting than kerosene. The more the application of neem oil, the more the repellency against feeding and oviposition (Jilani & Saxena, 1990) and hence very few adults were seen in the neem oil treated plants.

The adult of CWSB lays eggs in the batches of 1-10 and the white creamy eggs hatch and change to larva after 8-15 days (NTCDB, 2018b). Larval stage lasts for about 10 months in which larvae go through five instars. Very few larvae were seen in April and early May which might be because larva from previous season had already changed into pupal stage and the eggs laid on studied year were not ready to hatch and bore into the stem. Similarly, the maximum number of larvae was seen on June 15-30 which explains that eggs laid on that year changed into larvae and were boring inside the stem. Despite having fewer adults in plants scrubbed and treated with 20% kerosene, the larval population was found more. This may be due to the short-term repellent effect of kerosene. Its volatile nature couldn't resist oviposition which resulted in even small number of hatched larvae to easily bore inside the stem. The larval population in plants treated with red soil plus cow dung was also found less in number. This was because the clay in soil helped in sticking cow dung to the plant stem and the stems treated with cow dung somehow might have increased the width of stem (NTCDB, 2018). The newly hatched larvae could not bore into the thicker stem and hence larvae inside the plant were less. While cutting the stem of plant scrubbed and treated with neem oil, some of the larvae were found dead which indicated that neem oil had inhibitory action against the larva of insect pests (Isman et al., 1990).

Exit holes are the emergence holes through which the adult borers come out of the stem during flight season (Rhainds et al., 2009). Fifth instar larva make exit holes before pupating so to ease the adult to emerge through the holes. Different treatments were applied from February when the borer inside the stem was almost at the end of the larval period. The least number of exit holes was observed with the paste of red soil plus cow dung followed by Bordeaux paste. This might be because these treatments were long-lasting and remained in stem for a longer time.

Soil in mid hills of Nepal is haplustalfs and rhodustalfs which contain clay in different proportions (Gurung S.B., 2020; Soil survey staff, 2014). The porous property of clay helps in the evaporative cooling (Katsuki et al., 2018). Agricultural residues made with 40% of cow dung have the lowest thermal conductivity (Onjefu et al., 2019). The evaporative cooling character of clay and thermal insulating behavior of cow dung might be the possible reason behind the minimum exit holes in the plant treated with the red soil plus cow dung. Clay evaporated the hot water in the mixture and red soil insulated the flow of heat from outside to inside of the stem. This might have prevented the adults from emerging through exit holes. The dead adults seen inside the stem also indicated that adults couldn't come out, which ultimately lowered the number of exit holes.

5. CONCLUSION

Based on the field visit, farmer's response, literature review and research conducted from among all the constraints for coffee production, coffee white stem borer was found to be the major problem for arabica coffee cultivation in Nepal. Since Nepalese coffee is popular as organic coffee, the use of any chemical pesticides is forbidden which directly demands the need of eco-friendly management practices for the pest control. The research conducted showed that coffee, being shade-loving plant, the provision of shade in coffee orchard proved to be the most effective against adult population of CWSB even in the peak emergence period i.e., late May and early June. Very few adults were found in scrubbed plants because of the absence of egg laying crevices. Stem scrubbing was very effective in itself to reduce the pest and application of any biopesticide having the repellent action like neem oil provided the synergistic result. Stem scrubbing plus 30% neem oil was found to be very effective against the larval population of coffee white stem borer that automatically resulted to a smaller number of cracks. The treatments like cow dung and red soil, stem scrubbing, and neem oil are locally available and affordable. Although these eco-friendly management practices might not have a quick effect on the pests, the adoption of these practices could control the pest slowly without causing any harm to the environment and human health. Therefore, these are affordable, accessible and environmentally friendly practices which can be easily adopted by farmers at a local level. Repetition of the experiment in different geographical locations in multiple years might provide clearer picture on the behavior of CWSB and effectiveness of treatments. Likewise, weather parameters like rainfall and temperature directly influence beetle behavior and hence, incorporating these data in future studies could enhance the robustness of the study.

DECLARATION

The authors declare no conflict of interests.

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