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Factors Constraining the Natural Regeneration of Alibangbang (*Bauhinia malabarica* Roxb.) in Carranglan Watershed, Nueva Ecija, Philippines

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ABSTRACT

Field experiments on insect infestation, rodent predation and seed viability were conducted to determine the causes of natural regeneration failure of Bauhinia malabarica Roxb. in Carranglan Watershed. The larva of Caryedon serratus (Olivier) infested the pods and seeds of Bauhinia malabarica with a mean infestation rate of 78.32 % and 73.23 %, respectively. Other experimental trees recorded a mean infestation rate of 75.00 % on pods and 71.19 % on seeds. Examination conducted in different parts of the watershed obtained a mean infestation rate of 65.00 % and 67.80 % on pods and seeds, respectively. On the other hand, rodents were not eating ripened seeds of the species since no predation was observed. On viability test, only 47.50 % germination was obtained in seeds soaked in tap water for 24 hours. This treatment had the earliest germination period (7.75 days), longest total germination period (52 days) and highest germination value (3.32). Similarly, it recorded the highest root length (5.73 cm), total length (12.34 cm) and seedling vigor index (585.62).On the other hand, seeds alternately soaked in tap water and hot for 30 seconds had the highest germination energy (40.75 %). Therefore, serious infestation on Bauhinia malabarica seeds and low viability limits the regeneration of the species in the watershed.

Key words:*Bauhinia malabarica Roxb.,Caryedon serratus (Olivier), natural regeneration, watershed*

INTRODUCTION

Natural regeneration of forest ecosystem across the Philippines was slow and ecological succession hardly takes its course. Decades of deforestation resulted in the establishment of grassland in most watershed in the country. The Philippines has about 3.9 M ha of grassland areas (*Philippine Forestry Statistic 2006*). It comprises nearly eight percent of the country's total land area. Carranglan Watershed in Nueva Ecija is covered with more than 70 % of its total land area with grassland (*Department of Environment and Natural Resources* (*DENR*) *and Department of Agriculture-Bureau of Agricultural Research* (*DA-BAR*) *2003*). In response, the government implemented massive rehabilitation of degraded watershed using exotic and fast growing species. Only few indigenous species is being utilized. The government had already spent PhP 1.5 B for the restoration of Pantabangan-Carranglan Watershed (*Master Plan of the Municipality of Pantabangan 1980-2000*). However, satisfactory results have not been achieved because species survival was very low. Survival rate of seedlings planted in the reforestation program from 1978 to 1982 was only 50 %, way below the standard survival rate of 80 % (*Florece 1996*).Today, forest cover of the Philippines is approximately 7.2 M ha (*Philippine Forestry Statistics 2009*), and Carranglan Watershed remains a bastion of grass-dominated communities.

Alibangbang (*Bauhinia malabarica* Roxb.), a lesser-known species, is a prospective pioneer forest tree for restoring open areas of watersheds. It grows well in Carranglan Watershed, can also survive in open and shaded conditions Aside from its potential to use during drought period especially in El Niño years (*PCARRD 2001*). What is intriguing about the species is that despite numerous mature trees that could be sources of seeds to propel natural regeneration, wildlings could hardly be observed under clumps or isolated individuals. Had there been wildlings just like some forest tree species that are invasive, then colonization by *B. malabarica* could have already resolve the rehabilitation problem of grasslands in the country, since *B. malabarica* could resist regular fire (*Florece 1996*). Thus, this study aimed to determine the causes of natural regeneration failure of *B. malabarica* in Carranglan Watershed. Specifically, it sought to determine the biotic factors affecting the regeneration of the species and its germination potential.

MATERIALS AND METHODS

The Study Area

The study was conducted in Carranglan Watershed in the municipality of Carranglan (**Figure 1**) in the northern portion of Nueva Ecija where Alibangbang is naturally growing. It is geographically situated between 120°52' and 121° 12' longitude and 15° 51' and 16° 09' latitude (*Development Master Plan of Carranglan 2003-2007*).

Likewise, the study area has an elevation ranging from

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200 to 1,400 masl (*Development Master Plan of Carranglan 2003-2007*). According to Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), the area has an average rainfall of 194.78 mm, with peak reaching up to 717 mm while temperature ranges from 22°C to 34°C with an average of 28.1°C. On the other hand, predominant type soil in the area are Annam clay loam, Umingan sand and Annam sandy clay loam and more than 80% of the total land area is classified as Annam clay loam is suitable for growing crops like rice, banana, sweet potato and corn (*Development Master Plan of Carranglan 2003-2007*).

The study area is also part of the Pantabangan-Carranglan Watershed, which supports multi-purpose dam for irrigation and hydroelectric generation. The field experiment on insect infestation and rodent predation was conducted in the Model Site No. 1 of the former Philippine-Japan Forestry Development Project-Watershed Management (RP-JFDP-WM) of the DENR and is located in barangay R.A. Padilla. Model Site No. 1 is a 10-ha demonstration area consisting of 2-ha Mango orchard (*Mangifera indica* L.), a mixed plantation of various forest tree species and natural stand of *Bauhinia malabarica*. The experiment was conducted for 11 months, from July 2010 to May 2011. On the other hand, viability test was conducted in the Forest Nursery of Institute of Renewable Natural Resources (IRNR) of the College of Forestry and Natural Resources (CFNR), University of the Philippines Los Baňos (UPLB).

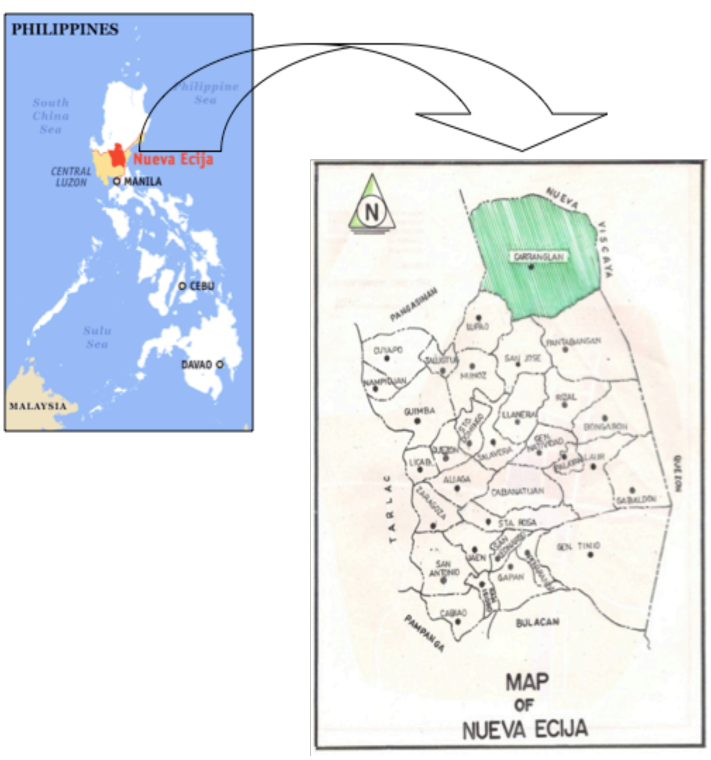

Figure 1. Location of the study area (Adapted from Development Master Plan of Carranglan, Nueva Ecija 2003-2007) and http://www.teachersparadise.com

Field Layout on Insect Infestation on Pod and Seed

The study consisted of ten randomly selected *B. malabarica* trees in the model site to determine insect infestation on pods and seeds. Trees selected were those that flowered every year and are found in patches or in group in the model site. It also facilitates ease in recording and monitoring. It was difficult to find other experimental trees that flowers since not all *B. malabarica* produce flower and fruit every year in the watershed. The average height of trees is 8.96 m with an average diameter of 22.81 cm while the mean crown radius is 4.52 m.

Only trees that produced fruits were selected. The experiment involves enclosing of branches with 1.0 mm mesh and exposing the others (not covered with net). Upon emergence of fruit, two branches per tree were enclosed with net to protect the pods against insect attack and to determine their growth and development. Another two exposed branches were randomly selected two served as control and for comparison against those enclosed with mesh. Sixteen replicates were established for each treatment.

Matured fruits from the treatments were harvested manually. Each pod was examined for any sign of insect attack. The infested pods were separated and stored in a rice sack for 36 days to determine infestation rate on seeds. Ten samples of larvae were randomly collected from the pods and were cultured in a glass bottle. The adult insects are collected and placed separately in a vial with 70 % alcohol. These were brought to the Museum of Natural History UPLB for identification.

Another ten ripened pods on the branches of *B. malabarica* trees outside the experimental area were randomly collected and inspected for larvae or insect attack. In addition, another ten *B. malabarica* trees were randomly sampled in different parts of the watershed like in Barangay Joson and R.A Padilla. Ten matured pods were randomly collected in each tree and were examined for insect attack on the seeds. The infested pods were likewise placed in a sack for 36 days to determine infestation rate on seeds. Infestation rate on pod and seed was computed.

Rodent Injestion of Ripened Pods

This study was done to determine rodent injestion on *B. malabarica* seed using “catch and release” technique. Thirty (30) rodent cage traps of normal size were set up strategically (three traps per trees) in the experimental site with ripened pods of *B. malabarica* as bait. The trunk of *B. malabarica* experimental trees were wrapped with galvanized iron sheet to prevent climbing of rodents, which may feed on ripe fruits at the branches. Likewise, fallen matured fruits on the ground and surroundings of the experimental trees were cleared and collected. In addition, leaning branches of trees on *Bauhinia malabarica* were pruned to prevent climbing of rodents and reaching the fruits. This study was conducted for two months from April to May 2011 when fruits of Alibangbang were already matured.

Germination and Viability Test

Research design. The experiment was laid out in Completely Randomized Design (CRD) with three treatments and four replicates each. One hundred seeds were tested for each replication in separate seed boxes, thus, a total of four hundred seeds per treatment. The pre-sowing treatments used include: (a) control (T1), (b) seed soaked in tap water for 24 hours (T2), and (c) seed alternately soaked in tap and hot water for 30 seconds (T3).

Prior to germination test, physical and color assessment method were done to determine the status of seed maturity. Those seeds with deformed shape, immature and discolored were discarded for uniformity. Likewise, water floatation method was used to separate the floater and sinker seeds and further determination of seed vigor. Sinker seeds were considered viable and were used in the germination test. Floater seeds were also subjected to germination to validate their viability.

Ripened fruits collected from the branches enclosed with 1.0 mm mesh in experiment number 1 were used in this study. This ensures that the seeds were free from insect infestation. Magnifying lens was used to further check for larval attack. On the other hand, the soil medium composition was 3:1:1 ratio of garden soil, sand and compost. The soil was sterilized with boiling water to prevent growth of harmful microorganisms, fungi and other soil borne pathogens. Watering was done twice a day, early in the morning and late in the afternoon.

Computation. The germination period, percentage of germination, germination value and energy were determined and computed. Likewise, growth performance and seedling vigor index were also determined. Seedling vigor index was computed using the formula of *Abdul-Baki and Anderson* (*1973*) as:

Seedling vigor index = % germination X (total shoot length + total root length).

On the other hand, germination value (GV) was computed using the formula of *Djavanshir and Pourbeik* (*1976*) as:

Germination Value (GV) = Final $\sum$ (DGS) (N) (Final Cumulative Germination %/10)

Where, DGS = daily germination speed and N= number of daily counts.

Further, germination energy was determined as the peak day of germination where mean daily germination percentage is highest (*Hossain et al. 2005*). This study was conducted for two months from April to May 2011.

Data Analysis

The data were analyzed using Analysis of Variance (ANOVA) for mean comparison in insect infestation on pods and seeds and in germination and viability test. Tukey High Significance Difference (HSD) test was also used for pairwise mean comparison.

RESULTS AND DISCUSSION

Insect Infestation on Pod and Seed

The length of matured pods ranges from 19.50-26.00 cm with a mean of 23.33 cm (**Figure 2**) while width ranges from 1.40-2.00 cm with a mean of 1.51 cm. The number of seeds per pod ranges from 14-30 with a mean of 17.58 (**Figure 2**). Examination of ripened fruits revealed that pods and seeds of the enclosed branches with 1.0 mm mesh were not infested. Only the pods and seeds of the exposed branches (not covered with net) in the experimental area were infested with larva of *Caryedonn serratus* (Olivier) locally known as seed borer/beetle (**Figure 2**). This was significantly different (at 5 % level) from the other treatment.

The insect belongs to family Bruchidae under Order Coleoptera. The larva that damaged the cotyledon of the seed (**Figure 3**) measured about 2-7 mm long and 3 mm wide. The number of larva inside the pods ranged from three to nine. **Table 1** presents the percentage of *B. malabarica* infested pods and seeds with the insect larva.

Figure 2. Left photo shows ripe (brown) and immature (green) pods of Alibangbang. Healthy and mature seeds of *Bauhinia malabarica* with a radius of 4-5 mm (right photo).

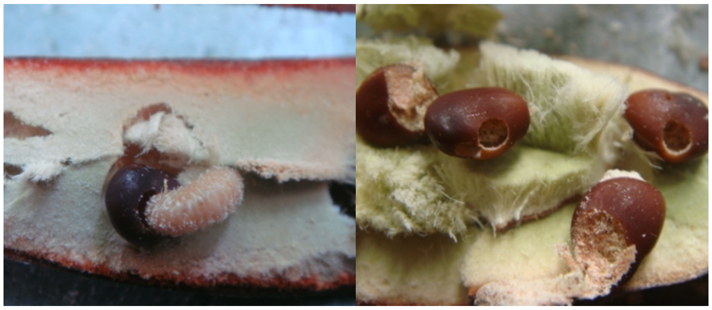

Figure 3. Caryedon serratus larva, the seed predator of Alibangbang (right). Damaged *Bauhinia malabarica* seeds with embryo eaten by the larva of *Caryedon serratus* (left)

Table 1. Percentage of infested *Bauhinia malabarica* pods and seeds with *Caryedonserratus* in the different replicates of enclosed and control branches.

Tree Number	Replicates (branch no.)	Treatment			
		Exposed branches (control)		Enclosed branches*	
		Infested Pod	Infested Seed	Infested Pod	Infested Seed
1	1	77.09	66.86	0.00	0.00
	2	75.29	65.92	0.00	0.00
2	3	85.28	78.93	0.00	0.00
	4	84.98	80.26	0.00	0.00
3	5	85.71	81.36	0.00	0.00
4	6	62.96	63.55	0.00	0.00
5	7	100.00	91.97	0.00	0.00
	8	100.00	93.91	0.00	0.00
6	9	58.23	56.56	0.00	0.00
	10	72.21	72.66	0.00	0.00
7	11	88.79	66.02	0.00	0.00
	12	88.47	78.03	0.00	0.00
8	13	63.05	80.21	0.00	0.00
	14	69.02	76.45	0.00	0.00
9	15	72.73	60.61	0.00	0.00
10	16	80.81	71.91	0.00	0.00

*With 1.00 mm mesh, ±0.00 standard error of mean

As observed from the exposed branches, the mean infestation rate of 78.32 % on pods and 73.23 % on seeds were obtained (**Table 2**). This was significantly different from the other treatment. The range of pod and seed infestation was high. Pod infestation ranged from 62.96 % - 100 %, while seed infestation ranged from 60.61 % - 92.94 %.

Noticeably, 100 % of the pods in the enclosed branches were not infested while only 21.68 % remained undamaged in the control branches. This was significantly different (at 5 % level) from each other (**Table 2**). Similarly, 100 % of the seeds in the enclosed branches were undamaged, while 26.77 % were uninfested on the exposed or control branches. This was also significantly different (p=0.05 %) from each other.

The high infestation rate obtained implies that *C. serratus* is a serious pest of *B. malabarica* as it attacks viable seeds. Seed predation occurs while mature pods are still attached to the branches. When the mature pods fall on the ground, only few potential viable seeds are left for germination. This suggests that infestation on seeds has lowered the regeneration potential of the species. In addition, the different treatments had significant effects on the infestation rate of pods and seeds. Moreover, this study is the first report of the *C. serratus* larva infestation on *B. malabarica* seeds, which is contrary to other reports and literature that the tree species has no pest infestation (*Research Information Series on Ecosystem 1994*).

On the other hand, inspection of 100 pods randomly sampled from other branches of the experimental trees obtained a mean infestation rate of 75 % (**Table 3**). The mean infestation rate on seeds was 71.19 %. The range of pod and seed infestation was relatively wide, varying from 60 - 90 % and 62.07 - 83.86 %, respectively. This implied that ripe fruits and seeds of *B. malabarica* on other branches not subjected to experiment were also infested with the larvae of *C. serratus*.

Other *B. malabarica* trees from different parts of the watershed, like in barangays Joson and R.A. Padilla, were also infested with the larvae of *C. serratus*. The examination of randomly collected 100 pods from the branches of ten (10) trees obtained a mean infestation rate of 65.00 % (**Table 3**). Likewise, the mean infestation rate on seed was 67.80 %. Pod infestation ranged from 50 90 %, while seed infestation ranged from 58.89 - 77.14 %. This implied that infestation was not only confined to the experimental site, but also to other *B. malabarica* trees found in other parts of the Watershed.

Caryedon serratus has been reported to attack seeds of other plants. In Sudan, the mean infestation rate of *C. serratus* in *Acacia nilotica* (L. Willd. ex Del.) was

Table 2. Mean percentage of infested and uninfested *Bauhinia malabarica* pods and seeds with *Caryedon serratus* in the enclosed and controlled branches.

Treatments	Infested pod	Uninfested pod (undamaged)	Infested seed	Uninfested seed (undamaged)
Enclosed Branches*	0.00^{b}	100.00^{a}	0.00^{b}	100.00^{a}
Exposed (Control)	78.32^{a}	21.68^{b}	73.23^{a}	26.77^{b}

Means across row with same superscript are not significantly different at 5 % level (Tukey HSD Test)
*With 1.00 mm mesh

Table 3. Percentage of *Bauhinia malabarica* pods and seeds infested with *Caryedonserratus* in the different areas of the Watershed.

Location	Pods	Seeds
Experimental area (in other branches of same Bauhinia malabarica trees not subject to experiment)*	75.00	71.19
Other areas (Barangay Joson and R.A. Padilla)*	65.00	67.80

*10 pods were sampled tree^{-1}

extremely high in stored seeds (80–90 %), moderate in pods on the forest floor (20 %) and least in pods from the standing trees (10%) (*El Atta 1993*). Examination of stored seeds revealed extremely higher infestation rates of 87.8 %, 87.6 % and 90 % of the total number of sampled seeds stored in Sennar, Singa and Wad Medani, respectively (*El Atta 1993*).

Other host plants of the insect pest include *Arachishypogaea* L. (groundnut), *Elaeis guineensis* (African oil palm), *Gossypium* (cotton), *Phaseolus* (beans), and *Theobroma cacao* (cocoa) (http://www.cropgenebank.sgrp.cgiar.org). In Senegal, the native hosts of *C. serratus* include *Bauhinia rufescens*, *Cassia sieberiana*, *Piliostigma reticulatum* and *Tamarindus indica*, which are all leguminous species (*Sembene 2006*). The insect species is of Asian origin, especially prevalent in the warm and hot parts of the region (*Southgate 1979*). It is also distributed to many tropical and subtropical regions of the world like Northeastern and West Africa, the West Indies, Hawaii, and parts of South and Central America as far north as Mexico.

The seeds of *B. malabarica* were found to be the food material of the larva needed for growth and development. According to *Vijayakumari et al.* (*1993*), the seeds of *B. malabarica* contained higher amount of crude lipid and rich in minerals like Calcium (Ca), Magnesium (Mg) and Iron (Fe). It also contains 45 % of gluteins, which constituted the major seed protein fraction followed by globulins, accounted for about 34% (*Vijayakumari et al. 1993*). Such chemical and mineral compositions were also essential to human nutrition. In addition, amino acids tyrosine and phenylalanine are high while the major seed anti-nutritional substances are phenols, tannins, L-Dopa and haemagglutinins (*Vijayakumari et al. 1993*).

Control of *Caryedon serratus*

Important biological and chemical controls are necessary in the prevention of *C. serratus* infestation. Dichloromethane (DCM) extract showed deterrent activity on oviposition of *C. serratus* (20 eggs mL^{-1}) with only 23 % to 57 % of eggs hatched (*Latwal et al. 2010*). Ovipositional deterrent activity of DCM egg extract may be due to some chemical components (such as phthalates and oleicacid) present in this extract and the chemical components responsible for it may be used to control this insect along with other control measures (*Latwal et al. 2010*).

Damage to seeds upon storage can also be prevented. Fumigation with 32 g m^{-3} methyl bromide for four hours followed by seed treatment with chlorpyriphos 3g kg^{-1} should be done before storing the seeds (*Ghanekar et al. 1996*).

Practically, enclosing *B. malabarica* branches with a 1.0 mm mesh net can be a useful tool in controlling seed beetle infestation since no infestation was observed on pods enclosed with these nets. This protects the pod from the insect to lay egg in the surface of the pods. It may also allow the normal growth and development of the pods to produce viable seeds.

Life History and Description of *Caryedon serratus*

Egg. The eggs of *C. serratus* are translucent, white, approximately 1 mm long and 0.5 mm wide (*Davey 1958*). In the field, the egg of *C. serratus* is attached at the surface of Alibangbang pods nearing maturity (**Figure 4**) in the branches of the tree. Breeding is suspected to occur in November to December and January to February, or during dry season in Carranglan Watershed. It was observed that egg development occurs from seven to 17 days, often which larva emerges.

Larva. The larva is white to orange and about 2-7 mm long and 2-3 mm wide. Fully-grown larva reaches up to 7 mm before pupation.When hatched, the larva digs a hole in the wall of the pod directly to the seeds where predation starts. This exit or entry hole is the first sign of infestation on the pods (**Figure 4**). The hole serves as an exit of the adult insect from the pods after pupation. Based on insect culture technique, the larva was fully grown after 17 days, where voracious predation on the seed took place. Larval stage and pupation overlapped, which occurred from February to April and coincided with the abundance pod and seeds of *B.malabarica* in the watershed.

Pupa. Pupa, on the other hand, is also white to orange, oval in shape, approximately 5 mm long and 3 mm wide (**Figure 4**). One *Caryedon* species occurring in Southern Africa has larvae that enter the soil to pupate (*Skaife 1926 as cited in http://www.fao.org*).The length of time spent in the pupal cells or cocoons is variable while the greater proportion of adults emerges as soon as they are fully developed, others may stay within the cell or cocoon for several months as in *C. serratus* spp. *palaestinicus* Southgate (*Donahaye,*

Figure 4. Eggs of *Caryedon serratus* attached on the surface of the pod and a hole (encircled in white) created by the larva that serve as exit way for the adult (right).The pupa of *Caryedon serratus* (left).

Navarro and Calderon 1966 as cited in http://www.fao.org). This adult diapause is designed to carry the species over to the next season when pods are available (*http://www.fao.org*).Insect culture revealed that pupal stage took about 15 days before the adult emerges from the cocoon.

Adult.The adult insect (**Figure 5**) has a reddish-brown cuticle, densely clothed with grey-brown setae, but with dark, irregular markings on the elytra while the pygidium in the female is fully visible from above (*http://www.cropgenebank.sgrp.cgiar.org*).It has a body length of 5-6 mm and 3 mm wide. Almost entirely covered dorsally by golden scale-like setae (*http://www.cropgenebank.sgrp.cgiar.org*).The antennae are 5 to 10 serrate with 2-4 segments impressed basally while the head is with prominent and median carina (*http://www.cropgenebank.sgrp.cgiar.org*). Pronotum is subconical, evenly convex dorsally, reddish-fuscous to testaceous, irregularly punctured, with fine bead around all margins, except for anterior angles (*http://www.cropgenebank.sgrp.cgiar.org*).

In addition, the elytra is one-and-a-half times as long as broad, punctate-striate, testaceous to dark reddish-fuscous usually with darker maculatron (*http//:www.cropgenebank.sgrp.cgiar.org*). The metafemora strongly thickened, with ventral, comb-like row of one large, sub median tooth followed by 8-12 small teeth (*http://www.cropgenebank.sgrp.cgiar.org*).On the other hand, the metatibiaeis strongly curved, but simple, without either ventral, sub basal tubercle or two small, unequal, ventroapicalcalceriae (*Prevett, 1967 as cited in www.cropgenebank.sgrp.cgiar.org*).

The optimum conditions for development are 30-33°C and 70-90% RH, under which conditions the development period is 41-42 days (*http://www.cropgenebank.sgrp.cgiar.org*). Breeding can take place between 23 and 35°C (*Davey 1958*), a climatic characteristic of Carranglan Watershed.

It was further suspected that the beetle might breed again from July to October where there are still fallen *B. malabarica* pods on the ground as food source of larvae.

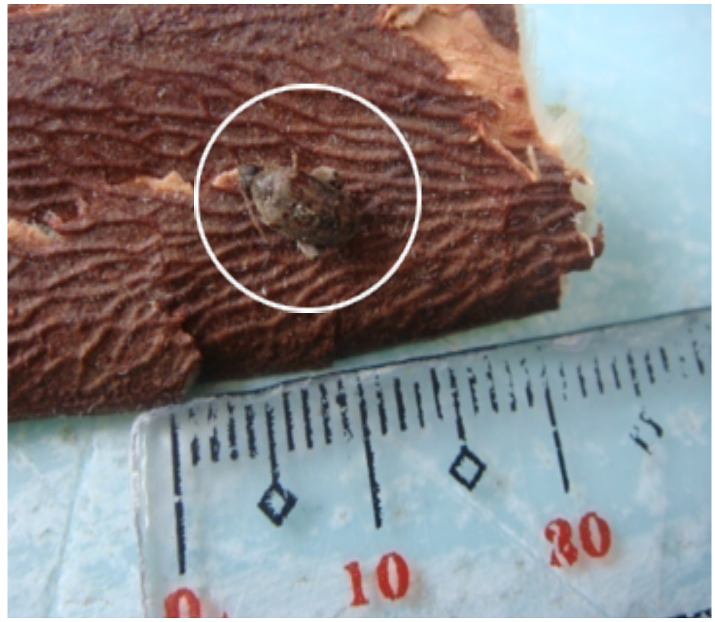

Figure 5. The adult of *Caryedon serratus*.

These beetles, according to *Sembene* (2006) feed on pollen or nectar during the rainy season. In the presence of adequate food, beetles can survive 80–90 days in the laboratory (*Delobel 1989 as cited by Sembene 2006*), hence, in nature it may also live 3 months or even longer (*Sembene 2006*). In periods of intense heat or strong rains (factors enhancing mortality of *Caryedonserratus*), the beetles find shelter, by negative phototropism, under the trees in litter (*Sembene 2006*).

The pollen from *B. malabarica* flowers may provide food for the beetle and the insect is possibly a pollinator of *B. malabarica*. In July, *B. malabarica* begins to produce flower and fruits. Adult insects are attracted to flowers of Acacia and related trees and to extra-floral nectaries which brings the sexes together for mating (*http://www.fao.org*). The feeding stimulus may also trigger the release of sex pheromone while the intake of pollen or nectar is not essential for the maturation of the ovaries but such feeding by the female would undoubtedly increase fecundity and possibly extend the life of the insect (http://www.fao.org). **Table 4** summarizes the life history of *C. serratus* and the phenology of Alibangbang in Carranglan Watershed.

Rodent Injestion of Ripened Seeds and Wildlings

This study coincided with matured fruits of *B. malabarica*. After two months of monitoring and observation, no rodents were captured in the established 30 traps around the ten *B. malabarica* trees. The trapping incidentally coincided also with the post-harvesting season of rice in the area. This limits the available food for rodents but still no injestion was observed. Thus, it was concluded that the seeds of *B. malabarica* are not preferred food of rodents. There was also no predation on surviving wildlings of *B. malabarica*. Further, all *B. malabarica* experimental trees were infested with a species of termite under Family Rhinotermitidae. The pods of *B. malabarica* is indehiscent that prevents the release of seeds to the ground. It was observed that termites were important agents in releasing seeds from the pods. This termite species attacks the pulp of the pods and in the process released the seeds to the soil. Thus, it allows germination of *B. malabarica* in the experimental area. This also explains the presence of wildlings of the species in the site.

Germination and Viability Test

Germination Period and Percentage

The different pre-sowing treatments significantly influenced the germination percentage, germination period and total germination period of *B. malabarica* seeds (**Table 5**). Seeds sown in the nursery germinated after seven days and continued up to 52 days. The earliest mean germination period (7.75 days) was obtained in seed soaked in cold water for 24 hours (T2) (**Table 5**). Seed germination significantly occurred earlier by 3.75 and 1.75 days compared to the control (T1) and to seed alternately soaked in tap and hot water for 30 seconds (T3), respectively. Second earliest germination period (9.50 days) was obtained in T3 while the latest (11.50 days) was observed in T1.

Total germination period was significantly different (at 5 % level) among the three treatments (**Table 5**). The longest mean total germination period (52 days) was recorded in T2. It was longer by eight and 4.25 days compared to T3 (44 days) and T1 (47.75 days), respectively. These results contradicted to the report of *Wilan* (*1985*) where germination period in the nursery was 30 days. It also contradicted to the findings of *Orwa et al.* (*2009*) where germination took 55 to 123 days.

Similarly, the highest mean germination percentage was obtained in T2 with 47.50 % followed by T3 with 43.74 %, which was not significantly different at 5 % level (**Table 5**). The lowest germination percentage was obtained in T1 (38 %) and was significantly different (at 5 % level) from the rest. The results conformed with the findings of *Orwa et al.* (*2009*) which attained a germination rate of 45 % on seeds stored for two weeks but decline to 25 % for three months of storage. Findings of *Wilan* (*1985*) revealed that *B. malabarica* had 14 to 18% germination, which was also low. Although pre-sowing treatments had significant effects on germination percentage, the values were still low to produce adequate number of planting stock in the nursery to be used in any restoration program in Carranglan Watershed. The result suggests that seed of *B. malabarica* has low germination potential. This can be attributed to the high dormancy of *B. malabarica* seed and apparently less effective pre-sowing treatments used in the experiment.

On the other hand, no germination was recorded on floater seed of *B. malabarica*. This validated that floater seeds are no longer viable. Likewise, water floatation method was confirmed to be an effective measure to determine viable seed for germination.

Germination Energy and Value

Determination of germination energy is important in seed viability testing. It determines the peak and speed of germination. Therefore, it is a measure of the vigor of seedling that it produced (*Hossain et al. 2005*). Likewise, germination value, which is a composite value of germination

Table 4. Summary of the life history of *Caryedon serratus* in comparison to the phenology of *Bauhinia malabarica* in Carranglan Watershed.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A. Life history of C.serratus												
Breeding	■	■										
Egg laying/hatching (7-17 days)*		■	■									
Larvae (17 days)*		■	■	■								
Pupae (15 days to several months)*		■	■	■	■							
Adult (80-90 days)**				■	■	■	■	may exhibit adult diapause				
B. Phenology of *Bauhinia malabarica*												
Flowering							■	■	■	■		
Fruiting								■	■	■	■	
Leaf dropping	■											■
Fruit ripening		■	■	■								
Leaf flushing	■	■	■	■	■							

*Based on insect culture technique

**Delobel 1989 as cited by Sembene 2006

Table 5. Germination percentage, period, value, energy and total germination period of Bauhinia malabarica under various pre-sowing treatments.

Variables	Control T1	Soaked in tap water for 24 hours (T2)	Alternately soaked in tap water and hot water for 30 seconds (T3)
Germination (%)	38.00[b]	47.50[a]	43.75[a]
Germination period (day)	11.50[a]	7.75[c]	9.50[b]
Total germination period (day)	47.75[b]	52.00[a]	44.00[c]
Germination Energy (%)	32.50	35.50	40.75
Germination Value	2.28	3.32	2.93

Means across column with the same superscript are not significantly different at 5% level (Tukey HSD Test);

speed and total germination, provides an objective means of evaluating the results of germination test (*Hossain et al. 2005*).

B. malabarica seeds in T3 obtained the highest germination energy of 40.75 % followed by T2 with 35.50 % (**Table 5**). The least germination energy was recorded in T1 with 32.50 %. On the other hand, the longest (or slower) energy period (40 days elapsed since time of sowing) was obtained in T3. It was followed by T2 (35 days) while the shortest (or faster) energy period was recorded in T1 (35 days). Germination value, on the other hand, ranges from 2.28 to 3.32. The highest germination value was obtained in T2 (3.32) followed by T3 (2.93). The lowest was recorded in T1 with 2.28.

Results on germination energy and value were low. The mean energy period of Alibangbang was 37 days, which implies that a longer time is required to reach germination peak. It likewise suggests that *B. malabarica* seed in Carranglan Watershed have low or poor germinability or capacity to produce seedling. This again can be attributed to the high dormancy period of the seed and the pre-sowing treatments used.

Germination Pattern

The highest mean daily germination percentage was obtained 40 days after sowing in T3 (1.01 %), 36 days in T2 (0.99 %) and 35 days in T1 (0.93 %) (**Figures 6** and **7**). There were days where all treatments have no germination. Both T2 and T3 had two days with zero germination while T3 had three days. Germination peaked on the 31st up to the 35th day in T1. Germination increased rapidly on the 32nd to 36th day in T2 (**Figures 6** and **7**). Similarly, germination peaked on the 40th to 45th day in T3. The observed mean germination peak was five days. In these periods, the cumulative germination percentages rose sharply then declined gradually until the end of the test (**Figure 7**). At the end of the test, the seeds that did not germinate were inspected and most of the seeds were found to be decayed and rotten. This may be the reason for the gradual decline of daily germination totals, as well as to the mean and cumulative germination.

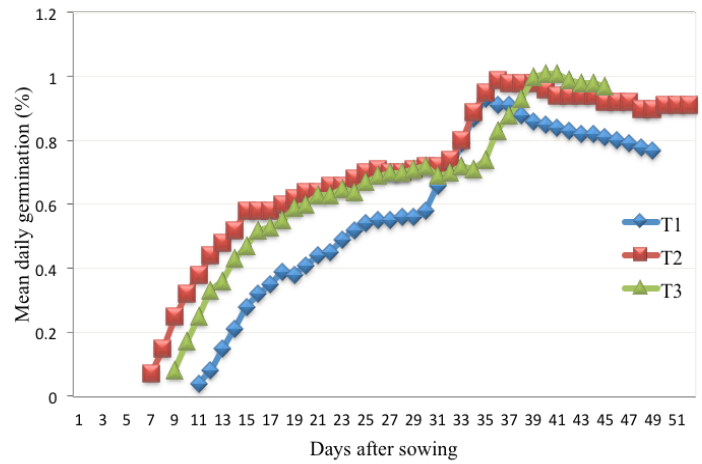

Figure 6. Mean daily germination percentage of *Bauhinia malabarica* under different treatments.

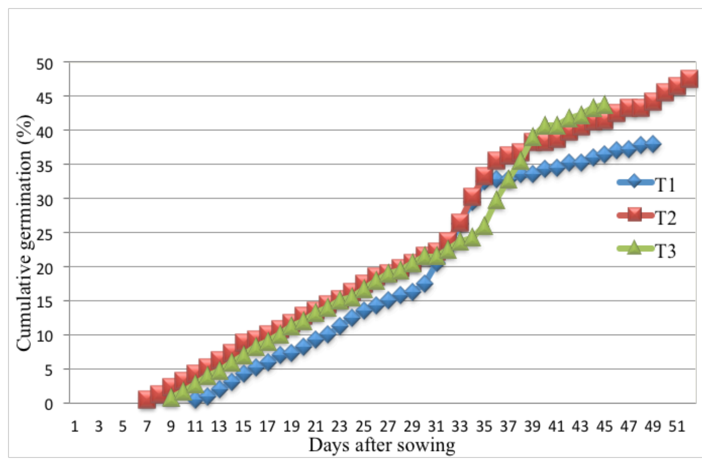

Figure 7. Cumulative germination percentage of *Bauhinia malabarica* under different treatments.

Growth Performance of Seedlings

Pre-germination treatments had significant effects on the growth and development of root length, collar diameter, total length and vigor of *B. malabarica* seedlings. However, the treatments had no significant effects on shoot development and number of leaves.

The highest mean root length was obtained in T2 with 5.73 cm (Table 6). This was significantly higher by 2.22 cm and 1.95 cm in T3 and T1, respectively. The lowest root length was recorded in T3 (3.51 cm). The mean shoot length

Table 6. Root, shoot and total length and collar diameter, number of leaves and seedling vigor index of *Bauhinia malabarica* under various pre-germination treatments.

Variables	Control T1	Soaked in tap water for 24 hours (T2)	Alternately soaked in tap water and hot water for 30 seconds (T3)
Root length (cm)	3.78[b]	5.73[a]	3.51[b]
Shoot length (cm)	5.38[a]	6.61[a]	5.87[a]
Total length (cm)	9.16[b]	12.34[a]	9.38[b]
Collar diameter (mm)	2.35[b]	2.79[a]	2.43[ab]
Number of leaves	3.08[a]	3.88[a]	3.37[a]
Seedling vigor index	344.54[b]	585.62[a]	409.94[b]

Means across column with same superscript are not significantly different at 5% level (Tukey HSD Test);

obtained was not significantly different at 6.60 cm (T2), 5.87 cm (T3) and 5.37 cm (T1). In terms of mean seedling total length, the longest was obtained in T2 (12.34 cm). It was significantly higher by 2.96 cm and 3.18 cm in T3 and T1, respectively. The shortest mean total length was recorded in T1 (9.16 cm).

Similarly, the highest mean collar diameter was found in T2 (2.79 mm), followed by T3 (2.43 mm) and was not significantly different from T1 (2.35 mm). However, mean collar diameter of T2 and T3 was significantly different from each other. Effects of pre-sowing treatments were not significantly different in the mean number of leaves of the seedlings at 3.88 (T2), 3.37 (T3) and 3.08 (T1). In addition, the highest seedling vigor index (585.62) was obtained in T2; this was significantly higher (at 5 % level) by 175.68 and 241.08 in T3 and T1, respectively. The second highest seedling vigor index was obtained in T3 (409.69), while the lowest was recorded in T1 (344.54), which were not significantly different (at 5 % level) with each other. The results revealed that seed soaked in tap water for 24 hours (T2) had better effects on the growth and development of *B. malabarica* seedlings as compared to other treatments since majority of the variables were significantly enhanced by this treatment.

CONCLUSION

The low natural regeneration of *B. malabarica* in Carranglan Watershed was mainly attributed to the serious infestation of the larva of *C. serratus* on pods and seeds. A high mean rate of infestation on pods and seeds were obtained in the exposed branches of the trees in the experimental area. Infestation of larva was also observed in other branches of the same experimental trees as well as in different location of the watershed. Rodents were not eating ripened seeds of the species since no predation was observed. In addition, the low seed viability also contributed to the low regeneration of the tree species in the watershed.Pre-sowing treatments significantly influenced seed germination and seedling growth of *B. malabarica* however, values obtained were low.This study likewise proved that seed soaked in tap water for 24 hours resulted to higher germination percentage, earliest germination period, and higher seedling vigor index and seedling growth compared to other treatments. In addition, the treatments applied were practical and cost-effective. It can be easily adopted by local residents of Carranglan for large-scale nursery propagation. Further, this study had opened future research on seed technology of Alibangbang and other pre-germination treatment that would further increase the germination potential and performance of *B. malabarica* in Carranglan Watershed.

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