Management of Invasive Plants in Tropical Forest Ecosystems: Trials of Control Methods of *Azadirachta indica*

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Abstract: This study was conducted in Saadan National Park to establish the best control methods of Azadirachta indica in the tropical forests. Tested methods included; ring debarking, cutting, seedling uprroting and stem injection with glyphosate herbicide. Replanting of indigenous trees in some treated plots was also done. Shannon and Index of Dominance were used to assess tree and shrub species diversity. Results showed that there were 54 woody species with 2,300 stems ha⁻¹ in the study area for which 55% were A. indica. Distribution of the number of stems, basal area and volume ha⁻¹ showed a reversed 'J' shaped trend denoting an active recruitment. Regenerants were 11,236 with A. indica occupying 65%. Herbs coverage decreases with increasing canopy cover (R²= 81) while the neem saplings decrease with increasing herbs coverage (R²= 73). There was a positive correlation between the number neem saplings and the canopy cover of the neem trees. Treatment responses showed that of the 239 ring debarked trees, 3% died above the ring but sprouted just below it, 37% wilted without sprouting while 60% showed signs of wilting at the same time sprouting below the cut rings. All the cut steams sprouted into multiple shoots all chemical treated trees died. Stem injection with glyphosate was found to be more effective than other control methods tested.

Key words: Allien plants · Neem · Sanapa · Glyphosate · Mwarobaini · Tanzania

INTRODUCTION

General Information: Invasive alien plants (IAP) are nonnative plants species that have been introduced into a new location and spread beyond their natural range of occurrence with significant ecological, economical and even human health impacts [1,2]. Once in a new area, these species usually compete with the native plants in the new area for resources, such as light, water, nutrients and space, eventually out-competing the native species.

The absence of natural predators enhance the success of invasive species, but it is their strong vegetative growth, prolific seed production, long-lived seeds, a high seed germination rate, effective seed dispersal mechanisms and their rapid maturation to a seed-producing stage that most contribute to their success in new areas [3]. Impacts of invasive alien species have been documented. Aside from competing for resources IAPs replace indigenous vegetation thus

reducing biodiversity and distorting the general beauty of the environment e.g. by creating monoculture stands. This can lead to low tourism and loss of income.

Controlling invasive alien species is usually a costly undertaking; the longer they stay the more difficult it becomes to control them. The commonest methods of controlling invasive alien species include mechanical (e.g. uprooting, clear felling, ring-barking and slashing), chemical (e.g. application of herbicides), biological control (use of host-specific natural enemies to reduce their populations) and indirect methods such as the use of fire and ploughing. This project aimed at establishing the best control method for the neem tree (*Azadirachta indica*), an invasive alien tree species in Tanzania.

The Neem Characteristics: Neem (*Azadirachta indica*, syn. *Melia azadirachta* L. *Antelaea azadirachta* (L.) Adelb.) is a tree in the mahogany family *Meliaceae*. The trunk is relatively short, straight and may reach a diameter

of 1.2 m. The bark is hard, fissured or scaly and whitishgrey to reddish-brown. The sapwood is greyish-white and the heartwood reddish when first exposed to the air becoming reddish-brown after exposure. The root system consists of a strong taproot and well developed lateral roots. It is one of two species in the genus *Azadirachta* and is native to Burma, Nigeria, India and Pakistan, growing in tropical and semi-tropical regions. Other vernacular names include *Azad Dirakht* (Persian), DogonYaro (Nigerian), Margosa, Neeb (Arabic), Nimtree, Nimba (Sanskrit), Vepu, Vempu, Vepa (Telugu), Bevu in Kannada, Veppam in (Tamil) and Indian-lilac. In East Africa it is also known as *Mwarobaini* (Kiswahili), what means: *the tree of the 40*. It is said, that it treats 40 different diseases.

Neem is a fast-growing tree that can reach a height of 15-20 m, rarely to 35-40 m. It is evergreen but under severe drought it may shed most or nearly all of its leaves. The branches are wide spread. The fairly dense crown is roundish or oval and may reach the diameter of 15-20 m in old, free-standing specimens [4]. It was introduced to Eastern Africa in the 19th century by East Indian immigrants, who propagated the tree essentially for its medicine [5].

[6] citing Binggeli (undated) stated that neem is 'moderately invasive', but does not quantify its impact. However, [6] notes that on the Accra plains in Ghana native rodent populations have been reduced considerably in areas where large populations of neem occur. Similarly, [7] cited by [6] suggested that dense stands of neem in Ghana reduce diversity and abundance of small mammals in savanna thickets and riverine vegetation. Neem is widespread in Tanzania, but there are no records of when it was introduced.

The Introduction of a Neem Plant (Azadirachta Indica) in SANAPA: SANAPA constitutes what formerly were Mkwanja Ranch and the Saadani Game Reserve. The transition happened in 2002, two years after Mkwanja Ranch, then owned by a Swiss company (Amboni Ltd) closed down. The ranch was in existence since 1954. The neem plant and other alien plants were introduced as shade and ornamental plants in residential areas of the Mkwaja cattle ranch. The neem plant has since spread, becoming more abundant and widespread across the Park. Although the exact date for the neem introduction is not known, the abandonment of the ranch for some years facilitated its spread.

Today, neem and all other alien plants in the park, are an eyesore to visitors and a threat to the existence of native species. The plant has prolific seed production. The seeds can be dispersed by birds and people and can survive passage through the gut. It tolerates, or benefits from destructions such as natural damages, cutting and fire [8]. As such, a combination of control methods and a strong scientific approach are required to successfully control the species in Saadani National Park. Generally the study aimed at establishing the best control methods of *Azadirachta indica* (Neem). Specifically the study aimed to;

- To establish test different mehtos that can be used to control invasion of *Azadirachta indica*
- To determine regeneration potential of the A. indica
- To determine the relationship between herbs coverage, the seedlings and the neem tree
- Propose the best control method of the *A. indica* in the area

MATERIALS AND METHOD

Description of the Study Area: The project was carried out at the Saadani National Park about 100 km south of Tanga. The park is located in the centre of the historic triangle of Bagamoyo, Pangani and Zanzibar and covers an area of 1100 km². Much of park lies below 100m a.s.l. with higher ground to the south-west. The geology of the area is characterised by embedded sediments of sandy loams of low nutrient content and clay soils with a few isolated layers of pure sands or clay material. Gravel, mostly quartz and feldspar, are found scattered in the clay matrix [9].

The park's south east end is dominated by quaternary sediments due to alluvial and coastal depositions within the Wami river basin. Aside from Wami (the only perennial river in the area), other major but annual rivers include Msangazi, Madete, Mligaji and Mvave. Generally drainage in the park is poor and most rivers form swamps in the area adjacent to the sea. Ocean tides often flow up to 1.5km inland. While rainfall comes throughout the year [9], it shows a bi-modal pattern with the main peak between March and May and a smaller peak between October - December. The rainfall varies from 820mm to 1,000mm.

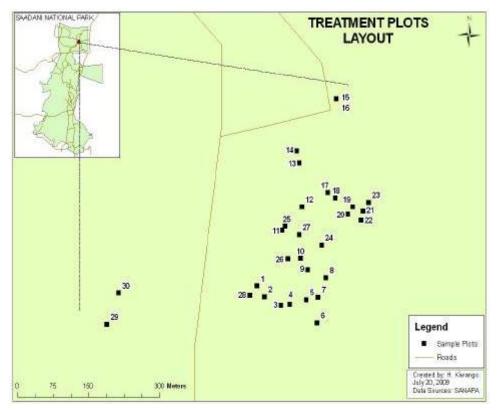


Fig. 1: A map of Saadani National Park showing a layout of treatment plots

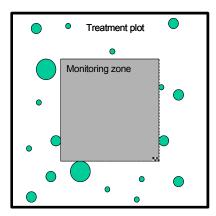


Fig. 2: A hypothetical example of the treatment plot with the monitoring plot in shaded area

Plot Layout: A total of 5 treatment plots of 20m x 20m were randomly established in an area of approximately 12,000m² (1.2ha) at Mkwaja headquarters (Figure 1) Each plot was replicated 6 times making a total of 30 treatment plots. In each plot a monitoring plot of 8m x 8m was established for baseline recording and future vegetation change (Figure 2). The treatment plan is summarized in Table 1.

Treatment Application: Three major treatment methods, ring debarking, tree cutting and stem injection with herbicide were applied including uprooting of seedlings.

Table 1: The treatment plan for the Azadirachta indica control pilot project at Saadani National Park

Treatments plots	nts plots Method (20mx20m) with 8mx8m monitoring plots	
Al	Cutting at base of all juveniles and adults, hand pulling of seedlings	
A2	Ring barking (50cm width ring) of all juveniles and adults, hand pulling of seedlings	
A3	Stem injection (100% glyphosate) of adults, cut and paint (100% glyphosate) juveniles, hand pulling seedlings	
A4	Treatment with replanting with native species (Khaya nyasica, Afzelia quanzensis and Melicia exelsa)	
A5	Control (no treatment applied)	

Ring Debarking: Ring debarking was applied to all *A. indica* with more than 3cm diameter measured at 1.3 above the ground. Debarking was done as between 0.3m and 1m above the ground depending on the stem size and shape. Ring width varied between 0.3m to 0.5m. In some cases rings were made even below these specifications depending on the branching of the tree. Seedlings were uprooted in all plots.

Tree Cutting: All juveniles and adult trees were cut at the base and seedlings uprooted.

Chemical Treatment: For stem injection, glyphosate (RONDOPLAZ 48% LC) herbicide was used. All stems were drilled with 60mm and 100m diameter bits at 1.3m above the ground; stems with Dbh less than 12 cm were drilled using the 60mm diameter bit, while larger ones with the 100mm diameter bit. The stems were drilled at an angle of 45° and 10cm deep along the sap wood to allow maximum retention and absorption of the chemical. Holes were made at an interval of 5cm around the stem and immediately filled with the herbicide. The dosage for each tree depended on the size (Dbh) of the tree hence number the of holes. The number of bit holes was determined as follows (e.g. for a 40 cm Dbh);

Volume (cc) = Area x length x No of holes =
$$\frac{\pi d^2}{4} x l = \frac{3.14x1^2}{4} x 10x26 = 205cc$$

If a hole was 1cm wide and 10cm long, then at tree drilled with 26 holes was be injected with the following amount of glyphosate herbicide;0

Volume (cc) = Area x length x No of holes
=
$$\frac{\pi d^2}{4} x l = \frac{3.14x1^2}{4} x 10x26 = 205cc$$

The stems were re-treated after 15 minutes with about 80% of the first dose. Therefore, an average treatment dose would be;

Total average dosage =
$$205cc \times \frac{80}{100} + 205 = 369cc$$

Since we used RONDOPAZ 48% LC with 360g/l of glyphosate (equivalent to 36% concentration) then the actual concentration of glyphosate injected in a tree of such size would be;

Actual concentration of Glyphosate injected

$$=\frac{36}{1000}x369=14cc$$

Planting: A total of 54 tree seedlings of three different indigenous species were planted. The species were Afzelia quanzensis, Mkongo (13 seedlings), *Milicia excelsa*, Mvule (17) and *Khaya nyasika*, Mkangazi (24 seedlings). These species were planted at a distance of 6m distance from each other. To prevent the plots from having similar species that would look like a plantation, these species were mixed in all plots and planted at random order.

Data Collection: During data collection plant species were identified in local vernacular names (Kizigua and Kizaramo) and their scientific names added later. Data collection was done in three phases i.e. during the baseline survey, treatment application and monitoring. Baseline survey was done in all plots. GPS points were taken. The vegetation of surrounding treatment plots was described including recording the number of all tree species as well as seedlings and saplings of all the tree species in the whole plot and separately for the monitoring zone. Dbh and height of all tree species were measured for whole plot and separately for the monitoring zone. Herbs were described and their ground coverage estimated in the monitoring zone only. Canopy cover for the whole plot and monitoring zone were also estimated.

Monitoring: The number of seedlings/saplings of all tree species for the whole plot and separately for the monitoring zone was recorded as well as number of seedlings of *A. indica* removed from the whole plot and separately for the monitoring plot. Also number of clearly dead individuals, re-growing trees and survivorship of native trees were recorded in order to know the state of treatment. Other parameters recorded were canopy cover, herbaceous cover and presence of herbaceous species in the whole plot.

Data Analysis

Stand Parameters: The following stand parameters were calculated; stems density (N), basal area (G) and volume per hectare (V) was performed. The total number of stems was computed based on the individual counts while the basal area was computed based on the diameter at breast height measured per individuals.

Stem Density (N) (Stem Count per Hectare): This was computed by using the following formula;

$$N = \frac{i}{A}$$
, Where; 'N' = Stem density (stem count/ha); 'i' =

Stem count and 'A' = Plot area (ha)

Basal Area (G) (m² per Hectare): This was calculated by using the following formula;

$$g_i = \frac{\pi Dbh^2}{4}$$

$$G = \sum \left(\frac{g_i}{A^* n}\right)$$
 Where; Dbh = Diameter at breast height

(cm); pi (= π = 3.14159265);.A = Plot area (ha) 'n' = Number of plots and 'g_i = Basal area of a tree/shrub (m²).

Volume: The volume of individual trees was calculated following Malimbwi *et al* (1994) which were found to give the same answer as when the form factor of 0.4 was used.

$$V_i = 0.0001 * d_i^{2.032} * h_i^{0.66}$$

Where; V_i = the volume of the ith tree (m³); d_i = the diameter at breast height (1.3m) for the ith tree (m) and h_i = the total height of the ith tree (m).

All stand parameters were distributed into diameter classes so as to assess the recruitment status of individual species. There were 4 diameter classes distributed as follows. Class 1 included parameters of individual species with Dbh < 10.1 while class 2 had Dbh < 20.1, class 3 with Dbh < 30.1 while class four included all individual with more than 30.1 Dbh. The analysis was performed for the overall as well as for individual treatments.

The target species (*A. indica*) was counted to determine the number of treated individuals for each treatment as shown in the treatment plan above (Table 1). The number of regenerants were analyzed first by determining the total counts followed by the analysis per ha for each tree and shrub species found in the sample plots. The student's t-tests were performed to check for any change in the stocking of regenerants in all plots. While the same test was performed to check changes in stand parameters estimated as described in section 2.7.1.1-3 for all the experimental plots. Correlation analysis was performed to determine the relationship between the canopy cover, number of regenerants and the

undergrowths (herbs cover). These analyses were performed for the baseline data through monitoring survey.

Indices of Diversity: Shannon Winner (H') and the Index of Dominance (ID) were used to assess tree and shrub species diversity while the relative frequencies, density and the relative dominance were analysed to determine the levels of species occupancy and dominancy in the area.

RESULTS

The Stand Parameters During Baseline Survey

Stand Density: A total of 2,317 stems per ha were found for all plots of which 1282 stems (55%) were of the *A. indica*. Assessment of the *A. indica* by diameter classes showed a reversed 'J' shape trend indicating active recruitment of this species in the area (Figure 3).

The number of *A. indica* counted for all treatment plots in relation to other species (individuals) is shown in Table 2.

Stand Basal Area and Wood Volume per Hectare:

The mean basal areas and volume per ha for all sample plots were $20.15\text{m}^2\text{ha}^{-1}$ and 106.01m^3 , respectively. These parameters showed a 'J'- shaped trend which indicates subsequent increase of the values with increase in tree sizes. This trend was also observed for the A. Indica. The distribution of these parameters for the best four dominant species is shown in Figure 4. The parameter values did not differ significantly (t- test, p < 0.05) before and after the study for all the plots which were not subjected into felling of the neems. Those which chemical was applied were also not compared on the understanding that they would eventually die in the process. Meanwhile, testing of all the plots by excluding the A. indica which was subject to treatments did not show any significant difference in above named parameters of other species.

Table 2: The number of A. indica counted for all treatment plots at Saadani National Park

SN	Treatment plots	A. indica	Others		
1	Cutting (A1)	76	66		
2	Ring debarking	161	180		
3	Herbicide	76	86		
4	Treated and planted				
	with natives	171	106		
5	Control	53	83		



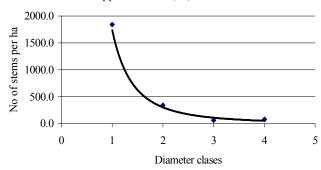


Fig. 3: Distribution of A. indica by diameter classes at the selected sites in Saadani National Park

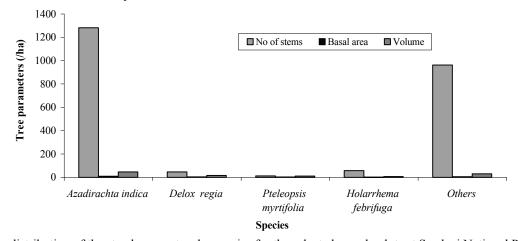


Fig. 4: The distribution of the stand parameters by species for the selected sample plots at Saadani National Park

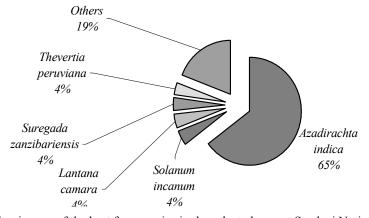


Fig. 5: Regeneration dominancy of the best four species in the selected area at Saadani National Park

Regeneration Potential: A total of 11,236 saplings for all species in the sample plots were counted, of which, 56% (6,283) accounted for *A. indica*. The analysis of these regenerants into ha basis also showed that *A. indica* had a higher proportion with the rest of the species accounting for insignificant proportions (Figure 5). The number of regenerants before and after the study did not differ significantly in all plots (t- test, P<0.05)

The distribution of regenerants by treatment plots is shown in Table 3.

Table 3: The number of *A. indica* regenerants counted for all treatment plots at Saadani National Park

SN	Treatment plots	A. indica	Others
1	Cutting (A1)	1 154	1 913
2	Ring debarking (A2)	1 436	2 998
3	Herbicide	1 449	2 259
4	Treated and replanted		
	with natives	921	1 697
5	Control	1 281	2 318

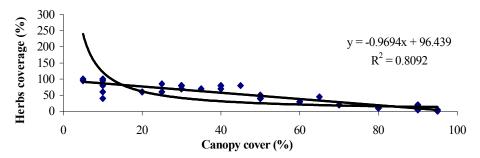


Fig. 6: The relationship between canopy cover and herbs coverage in the surveyed area in Saadani National Park

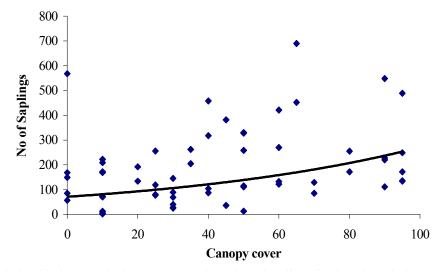


Fig. 7: The relationship between herbs coverage and number of saplings for the selected plots at Saadani National Park

The Relationship Between Canopy Cover and under Storey Vegetation: We found a significant negative correlation between canopy cover and the percentage coverage of herbs ($R^2 = 81$) (Figure 6). That means the herbs density decreases with increasing tree canopy cover. But, the number of all the tree saplings decrease with the increase of the percentage coverage of herbs ($R^2 = 73$).

However, there was relatively strong relationship (r = 51, p < 0.05) between canopy coverage and the number neem tree saplings in the area (Figure 7). Generally, most neem seedlings were found under the mother tree. However, experience showed that few seedlings survive to adulthood under the shade/cover based on the fact that neem is shade intolerant species.

Treatments Responses: A total of 239 individuals were ring debarked. Results further showed that 7 (3%) of the ringed individuals died above the ring but sprouted just below it. 88 (37%) individuals wilted without sprouting while 144 (60%) showed signs of wilting at the same time sprouting below the cut rings

All the 138 individuals cut down, had sprouted into multiple shoots after one year. There was no significant difference (t- test, p < 0.05) between the number of individuals that sprouted after the ring debarking and cutting treatment despite the differences in the proportions had shown in each treatment. For example, although the 239 stems that were ring barked, 151 sprouted while on the other hand 138 that were cut down all sprouted.

All the 105 individuals injected with glyphosate died and no signs of sprouting were observed. The monitoring data showed that injected individuals started wilting a week after the treatment.

Regenerants Response: About 12,971 *A. indica* regenerants were uprooted during treatment applications in all of the three categories. During monitoring, new regenerants were observed for each experiment. Figure 8 shows the number of seedlings observed in each quarter of the monitoring for each experiment.

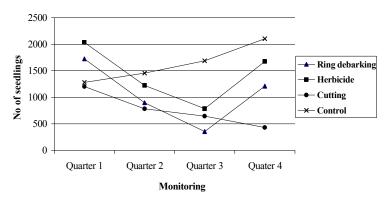


Fig. 8: The new regenerant counts as a response to treatments as observed during monitoring at Saadani National Park

Species Survival: There was neither death of mature trees in all the control plots nor death of non-target species in treatment plots. The number and diversity of tree seedlings observed during and after the baseline survey did not change significantly (t-test, p < 0.30, df = 4) during the last assessment. The numbers of other tree species seedlings were not disturbed during the treatment process unlike the neems seedlings which were constantly uprooted as per research protocol. In this case the numbers of the neem were expected to decrease with time especially in plots where mother trees were either cut or poisoned to death. However, the discussion with key informants revealed that neems keep larger soil seed banks where germination and spread of new seedlings occur in very wet seasons. Nevertheless, experience showed that some establishment occurs even under very low moisture seasons and that's why we were able to find new seedlings during every monitoring sessions. However, the trends differ between experiments as shown in figure 8. People believe that although few seedlings are seeing during dry season. Normally, a recurrence of above average seasonal rainfall results in a further massive increase in plant populations. The pattern of invasion has been exponential in nature but in a stepwise fashion associated with wet seasons. The occurrence of the seedlings is however expected to decrease with time as the seed bank diminishes.

Native Replanted Seedlings Survival: The planted seedlings performed very poor. Of the 54 seedling planted, 66% of them died recording a survival rate of only 34%.

Indices of Diversity: The Shannon-Wiener Index of Diversity 'H' and the Index of Diversity 'ID' for all the species were (6.17E-02) and (1.66E-05) and (0.020561) and (3437E-05) for *A. indica*, respectively.

DISCUSSION

Stand Parameters During and after the Baseline Survey:

The general assessment showed that *A. indica* has higher density as compared to other 53 woody species in the area. This trend may be due to research design (plots were laid in invaded area). However, apparent decay in sizeclass distribution denotes active recruitment and therefore the potential to of invade the rest of the ecosystem. [10]; [11]; [12] and[13] reported that a species and or a forest with an inverted '*J*' trend in distribution of its tree size classes is a good indicator of active regeneration and recruitment potential of such a species or species in that particular forest.

On the other hand the assessment of parameter values for other species measured remained the same as before and after the study because it could not be possible to realise for any increment in tree sizes in terms of girth size and or height for a period of one year. According to [14] different tree species have a different growth pattern over time. But a light demanding tree species tends to grow fast when it is young, but slow down in growth relatively fast when it is aging, while a shade tolerant tree species usually grow slow in the beginning but are relatively sustained in growth when it is aging. Therefore it is even difficult to realise a significant increase in size for trees in a mixed natural forest species in short intervals [15-17].

Species Regeneration Potential: The *A. indica* showed a high potential of self establishment in the area. Most of neem seedlings were found under the mother tree. Other species established outside the neem tree canopy shade area. This may be a good indicator that the *A. indica* has an allelopathic effect to other species. However, the neem seedlings were found in big numbers under relatively heavy canopy cover of the neem with decreasing in

increase of the herb coverage on the ground. This showed that the neem species being a pioneer its seedlings can easily be out-competed by the herbs layer. During monitoring, the number of new seedling was found increasing despite uprooting especially in those plots where there were no many disturbances on the canopy layer to allow overgrowth of the herbs layer. For the control plots the number of seedlings seemed to increase steadily due to the fact that not all the seedlings survive the natural competition based on the fact that the mother tree shades many seedlings under the canopy with few being dispersed far by other natural agents. So the competition grows high under the canopy. Generally neem showed ability to regenerate throughout the year from the seed bank that the mother tree shades during fruiting season.

Treatment Responses: Stem injection with glyphosate is more relatively efficient than other control methods tested (i.e. stem ring debarking and cutting) in killing both juveniles and mature *A. indica*. The chemical could induce stress to the tree and show signs of wilting a week later. This means if the tree is injected during fruiting, the chemical can weaken the process and hence kill the potential seed bank vital for its establishment. Another important observation is that the tree weakens at the point of injections and may fall down after an average of six months depending on the size of the tree stem.

This observation necessitates the need for changing the injecting behaviour from drilling the holes around the stem at the same level to drilling in alternate probably at a range of 1-1.5 m along the stem. This approach may ensure that treated individuals will not fall within a short period and open up for other possible pioneers and or cause unnecessary disturbances to the remaining species.

From these findings, it is clear that cutting or ring-debarking (girdling) of the *neem* stems does not provide a viable solution the control procedure. The methods seem to provide the opportunity for multiple sprouting of the stumps leading to the multiple stems in future which cannot be health to the ecosystem. Cutting down trees also results into serious disturbances or damages to the residual species while opening up the canopy for any possible invasion by other pioneer species or reoccupation by the *neem* in multiple numbers. On the other hand, cutting and girdling remains to be tedious and inefficient process. This is due to the fact that it may require a number of crews on site which reflects to the payments and required supervisory tasks. When supervision isn't optimum, crews may leave the inner-bark

membrane (phloem) on the stem which normally recruits the bark and hence the tree as a whole after sometimes. Our experience showed that the *neem* may recruit very easy and fast from micro left-overs of these membranes, from half-cut strips of a bark or from bark re-growth if cutting wasn't wide enough especially when debarking involves a multi-stem individuals. The cut back of the *neem* tree tends to grow towards both directions (down - upward direction).

Species Survival: The treatments were conducted carefully that they did not cause any serious damages which could lead into death of non targeted species. There was no new seedling recruitment observed for non targeted species probably due to the fact that the period that this project was implemented had poor weather of prolong droughts in the area which could not favour regeneration of non robust species like the neem. The droughts also affected the survival of the planted native species to the extent of recording a survival rate below 50% despites the efforts of watering. Although scheduled watering was done, death of these seedlings could also be attributed by other natural agents like termites which could take advantage of the dry soils but also the general poor performance of native species in competing environments could be the parallel reason for this.

Species Diversity Indices: The observed indices of diversity for this particular studied site showed a very low species diversity. For example the Shanon index which tells about species richness (number of species) and evenness (species distribution) [18] had very low values. [19] reported that the larger the value of H' the greater the species diversity and vice versa, while an ecosystem with H' value > 2 is regarded as medium to high diverse in terms of species.

CONCLUSION

To create and restore healthy native plant communities, the control of exotic and invasive plant species is critical. Experience from all over the world show that costs of controlling invasive plants is even higher and it varies between the methods used. This project was designed to test different methods that can be used to eradicate *A. indica* tree species from areas of invasion. Having tested three methods; ring debarking, cutting down of the individuals and application of herbicide, we conclude that application of RONDOPAZ 48% LC with 360g/l of glyphosate (equivalent to 36% concentration) injected into the stem is the best method that can be used

to kill the species. The other two methods seem to stimulate the species re-establishment and increase damage to the residual plants. They may also be cost ineffective since they involve a big work force and time consuming. The *neem* species establishes/anchors very well to the ground that uprooting of the seedlings can not be the best option after it has attained an average of 20cm tall.

Recommendations

- We recommend the following;
- The best, less expensive and effective method for controlling neem plants in SANAPA is stem injection with glyphosate herbicide.
- The same study to be conducted on other alien invasive plants in other ecosystems including other protected areas in Tanzania.
- Uprooting of the neem seedlings must be done during the early stages of germination.

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