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INTEGRATED MANAGEMENT OF MULTISTRATA PRODUCTION SYSTEMS UNDER NEWLY ESTABLISHED RAMPT MODELS OF ROADSIDE AND SLOPELAND AGROFORESTRY

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Abstract: The alarming food crisis of the world demands immediate necessary steps for the development of sustainable systems for more food production and food security in an overpopulated country like Bangladesh. There are presence of huge fallow and wastelands along the sides and slopelands of the network of roads, highways, railways, irrigation canals, embankments, farm and homestead boundaries etc. in plain lands, and also in the riparian and hilly areas of Bangladesh. With a view to bringing these fallowlands under planned development and integrated cultivation along with soil conservation, landscape development and environmental benefits, the newly developed models, commonly termed as Roadside Agroforest Multistoried Production Technologies (RAMPT), have been established at Bangladesh Agricultural University Campus, Mymensingh, Bangladesh. The models have been designed to utilize every inch of land, accommodate increased number of suitable species for higher economic return, encourage biodiversity with integration of various types of MPTS including *Azadirachta* and *Sesbania*, herbaceous crops, spices, medicine and oil, biodiesel yielding plants, increase soil fertility and check soil erosion, and finally to maintain healthy environment. The models are also replicable to other similar slopelands such as raised farmland, homestead, office premise or institutional boundary slopes, embankment and hill slopes, etc. and pond, lake, canal or river sides as well. The managed models have appeared as attractive and effective multistoried production and insect repellent systems, and are expected to be sustainable, since *Sesbania* is continuously adding leaf biomasses and N_2 to the systems along with regular yield of flower vegetables, forage and fuel wood.

Key Words: Sustainable, live fence, MPTS, Neem (*Azadirachta*), Bakphul (*Sesbania*), Biodisel (*Jatropha*), food (vegetable), pruning, pollarding

INTRODUCTION

The agricultural land of Bangladesh is being decreased day by day (Haque 1996) due to conversion of agricultural land into institutional and housing areas, industrial areas, roads and highways, railways etc. The losses due to decreasing condition of agricultural land can be compensated by increasing intensity of production per unit area following the agroforestry

technologies. This involves selection of suitable species, appropriate production technologies and effective management systems. In an overpopulated country like Bangladesh, the production of multipurpose trees and shrubs (MPTS) in suitable places following the principles of agroforestry is very effective to obtain maximum benefits from minimum land. Multipurpose trees including both fruit and non-fruit species yield timber, fuel wood, fruit and forage (Hossain 1996). Therefore, selection of suitable MPTS and herbaceous species as well as their effective management practices may enhance production by intensive utilization of every inch of land through judicial accommodation of increased number of species per unit area. Suitable management technologies should be followed to obtain the desired characters / structures of trees to suit a particular agroforestry system (Hossain 1994).

There remain huge fallowlands and wastelands and the sides of roads, highways, railways, embankments, homesteads, farm houses and farm boundaries, pond sides, lake and river sides, etc. These lands are needed to be brought under production systems (Hossain 2006, 2007).Again crop land 'ails' (bunds) as well as farm and homestead boundaries have to be used under specialized planting systems to reduce friction and / or negative effects on others' land (Hossain 1994, 1996, 2007). The large trees grown by commonly followed roadside plantation practices seriously affect the adjacent crop fields, hence demanding the modification of the existing systems. The sustainable multistoried production and agroforest management technologies in roadsides, embankment sides and in farmlands will be a breakthrough in these regards. With all these views, the relevant project works were undertaken to establish multistoried production technologies (Hossain 2007) along roadsides and farm slopelands to utilize every inch of land, to accommodate increased number of suitable species for higher economic return, to encourage biodiversity with various types of MPTS, herbaceous crops, spices, oil yielding and medicinal plants, to check soil erosion, and finally to maintain healthy environment. Some of the results of these studies have been outlined in this article.

METHODOLOGY

The field works were carried out along roadsides of Bangladesh Agricultural University Farm Areas, Mymensingh-2202, Bangladesh. The initial work was outlined for the establishment of the novel roadside agroforest models termed as RAMPT-1, RAMPT-2 and RAMPT-3 which were reported elsewhere (Hossain 2006, 2007). The models have also been adjusted in farmland boundaries. The training and pruning of growing plants have been done according to Hossain (1994, 1996). To achieve all the objectives stated above, soil working and leveling were done following clearing of roughages, gravels, brick parts etc. before stepwise development and plantation for multistoried production systems. The initial protection was given by living poles, thorny branches, bamboos and nylon net fencing, followed by the development of live fences through plantation of *Acalypha* cuttings and then by lemon stem cuttings leaving necessary distance from footpath / foot walk / side way (Hossain 2007). Both these live fences simultaneously resulting beautification, protection and / or production of fruits (citron). The 1st row of Neem/Mehogini were planted inner/outer side of the live fences having plant to plant distance of 5 m, followed by production of *Jatropha*, turmeric, chilli, tomato, stem amaranth, okra, sunflower, country bean, kidney bean *Eryngium*, Indian spinach etc. on first flat bed until the establishment of selected MPTS. Alternate to Neem/Mahogony plants Bakphul trees have been grown along the 1st slopes of RAMPT models at 5 m distances in combination with

alternate plantation of Jatropha (Biodiesel yielding plant) stem cuttings. Both the 1st and 2nd flat beds of RAMPT models were cultivated with turmeric, chillies, beans, lady's finger, sweet gourd, bitter gourd, tomato, stem amaranth etc. The above mentioned MPTS were included in this study for their high qualities and multipurpose uses as reported by Khan and Alam (1996), Openshaw (2000) and Hossain (2007).

All these plantations have appeared as effective multistoried production systems (Fig. 1 and Fig. 2) which are expected to be sustainable since Bakphul is adding a huge quantity of leaf biomasses and N_2 to the systems. In addition, the wind blown nutrients are being trapped by the multistoried plant canopies developed along roadsides / farm boundaries and added to the soil naturally by rain water. Therefore, during the 1st year and 2nd year at development of the system, none or low dose of manure was necessary. The Neem plants are now in the young tree stage along with the maturing Bakphul trees. No disease or insect infestation was noticed in the system probably due to insect repellent system developed by the growing Neem / Mahogony plants. Pruning and pollarding were done according to Hossain (1994, 2007). Other relevant methods and designs are mentioned with the following relevant experimental results.

RESULTS AND DISCUSSION

Roadside and soil management for RAMPT models at initial and subsequent stages

After the initial development of roadsides and plantation under RAMPT models (Hossain 2007), the structures of roadsides were again managed properly with soil working during March to April of each year following winter crop harvest. In Bangladesh, the roadsides are usually damaged and washed out during rainy season that result into small to big ditches (Fig. 3 and Fig. 4) and sometimes become the causal factor of accidents of the vehicles. The poor and illiterate farmers also cut their roadsides to expand the crop lands. The practices under RAMPT models remove these problems since the sides are well managed for additional and better crop harvest (Fig. 1 and Fig. 2) by the farmers.

Fig. 1. An established 'RAMPT' model (RAMPT-2) showing front live fence of *Acalypha* followed by lemon hedge cum fruit (citron) production line. Behind the live fence a pollarded and pruned Bakphul tree is seen in between the Neem trees with plenty of regenerated shoots.

Fig. 2. The outer side (towards crop fields and opposite to that of Fig. 1) of 'RAMPT'-2 model showing 3rd year's cultivation of sweet gourd and bitter gourd on ground and the beans trailing on Bakphul trees. Note that the managed trees cast less shades on crop fields.

Fig. 3. A village roadsides having unplanned plantation of banana by the farmers gradually reducing the road surface areas. Part of the roadside has also been damaged. The 'RAMPT-1' model can save this roadside as well as help the farmers with regular income generation throughout the year.

Fig. 4. The raised roadsides having no plantation is also being damaged due to formation of a hole and narrow ditch by rain water. This might cause the accident and damage of vehicles and lives which can be saved following 'RAMPT' plantation model as suggested by Hossain (2007).

Management and production of MPTS (Multipurpose trees and shrubs)

Neem (*Azadicrachta indica* A. Juss.) and Mahogony (*Swietenia macrophylla* King.) saplings and trees

Neem leaves are so much useful to the peoples (mostly for medicinal purposes) that they take away leaves and twigs, even the whole saplings. The branches and growing tops of larger saplings/young trees are also broken and taken away. That is why success of establishment of Neem trees is very low. Each year thousands of Neem sapling are planted of which only a few percentages are established and some times it tends to be zero. Hence, initially 'thorn protection technique' as we call it, was followed by enclosing the saplings with thorny branches of *Acacia albida*, *Zizyphus mauritiana*, *Perkinsonia aculeata* and *Citrus* spp. etc. This ensured almost a 100% survival rates grown under RAMPT models at Bangladesh Agricultural University, Mymensingh (Hossain 2006, 2007) as compared to very few success rate (Fig. 5A) under cage protection, because the cages were broken by cattle and taken away by the poor villagers for their fire purposes.

The mahogony saplings did not require such attention as that of Neem saplings for its growth and development. A 100% standing trees were recorded in the RAMPT model area with good growth (Fig. 5B). In this case, thorn protection at sapling stage and stick supporting at later stages led the plants standing with straight growing and healthy appearance.

Bakphul (*Sesbania grandiflora* (Linn.) Poir.) trees

Bakphul trees were found to grow naturally well and uniformly branched and appeared very nice looking increasing the beautification of the areas. This is a very fast growing trees which yielded flower vegetable and forage (pruned shoots) within one year of growth. But its branches are weak and are easily broken during flower collection by the outsiders. Hence, branch pruning and

pollarding were followed to make the plants stout. The pruned and pollarded trees along with regeneration of new shoots are seen in Fig. 1. Similar to that of Neem saplings, the survival rates of Bakphul trees are very poor when grown out side the RAMPT model areas (Fig. 5C).

Jatropha (*Jatropha curcas* L.)

Since these plants are not browsed by animals, very good growth having almost 100% survival rate with healthy appearance was obtained under RAMPT models (Fig. 5D).

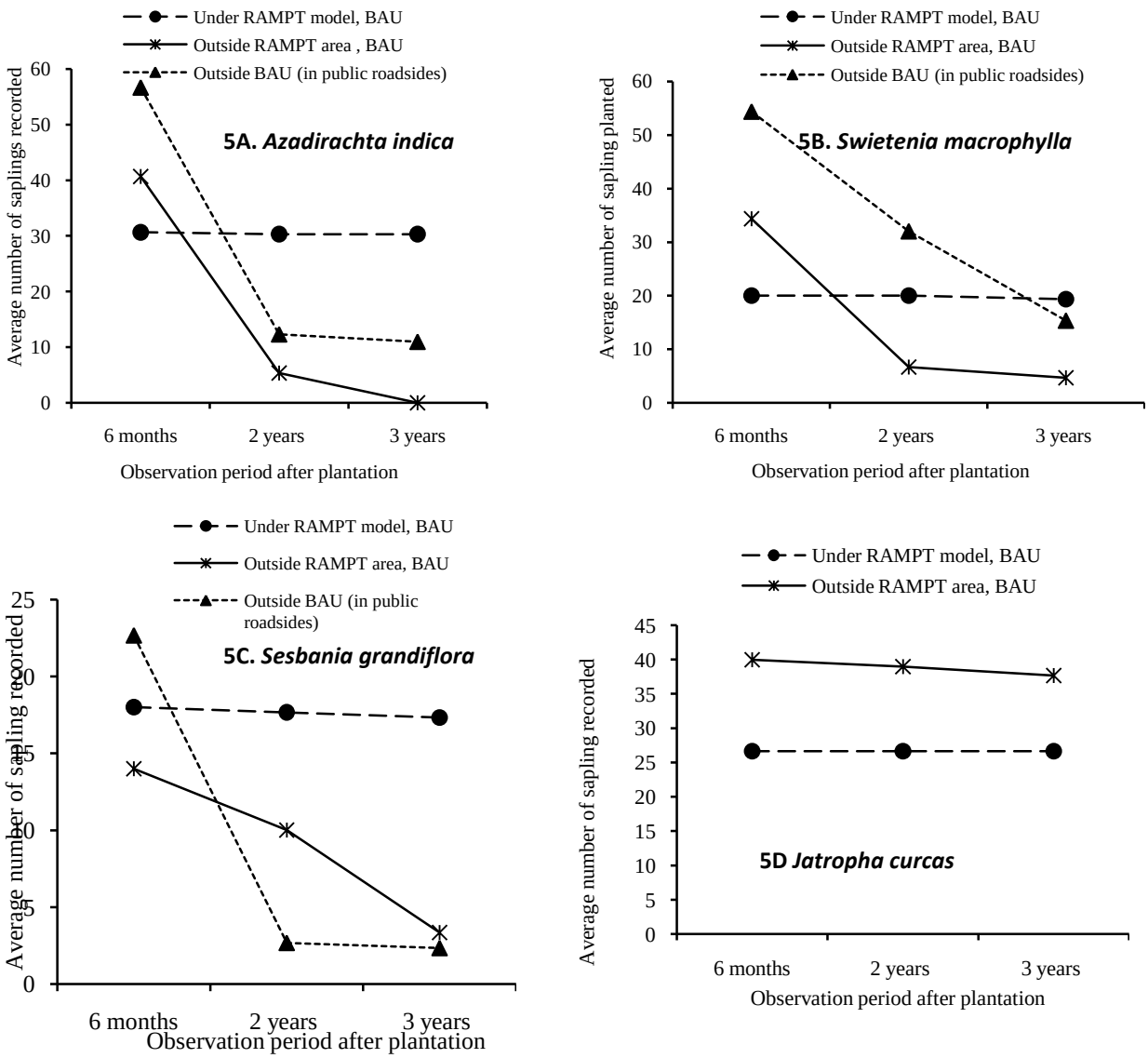

Fig. 5 (A-D). Showing survival rates of selected MPTS planted under different management practices

Pruning of the sapling/young tree branches and pollarding of MPTS

These practices made the plant stout with excessive shoot regeneration, hence increasing forage production. In fact, pruning and pollarding of Neem, Jatropha and Bakphul markedly influenced and enhanced shoot regeneration and made the plants stout and uniform in appearance. In all cases, pruning off all the branches at 1/3 to 2/3rd parts leaving 2/3 to 1/3rd basal area of branches showed better performances in regeneration, new shoot growth and higher shoot biomass production than those of severely pollarded or intact plants. This is in good conformity with report of Hossain (2007) on pruning of Neem, Bakphul and Jatropha plants.

Under-storied crop production with Neem, Mahogony and Bakphul trees

The tree species along with understoried crops and live fences (Fig. 1 and Fig. 2) formed a multistrata arrangement with simultaneous or intermittent yields throughout the year. Therefore, the farmers may receive regular incomes throughout the year along with environmental benefits and, in the long run, a huge quantity of quality timber for the nation. According to Hossain (2006) crop management encourages good growth of tree species (Fig. 6). Some of the experimental results are presented below.

Experiments with Mahogony (*Swietenia macrophylla*)

Crops such as okra, chilli, amaranth and Indian spinach were grown around Mahogony. Irrigation was given as and when found necessary. For this, soils around the saplings were prepared by spading, weeding, soil mulching etc. The interaction effect revealed that there was no significant difference in growth attributes of mahogony saplings due to the competition with crops (Fig. 7). Plant height and yield of different crops grown under *S. macrophylla* were found better under soil managed and manured conditions with poor result under unmanured condition. These results indicate that growth and yield of crops were not significantly affected by the competition of mahogony saplings at their early stages of growth.

Experiments with Neem (*Azadirachta indica*)

The results shown in Fig. 6 indicate that the growth and development of Neem sapling were significantly influenced by crop species and different soil management practices. The highest plant and branch length of Neem were found in soil managed with manure and both without crop and with crop condition.

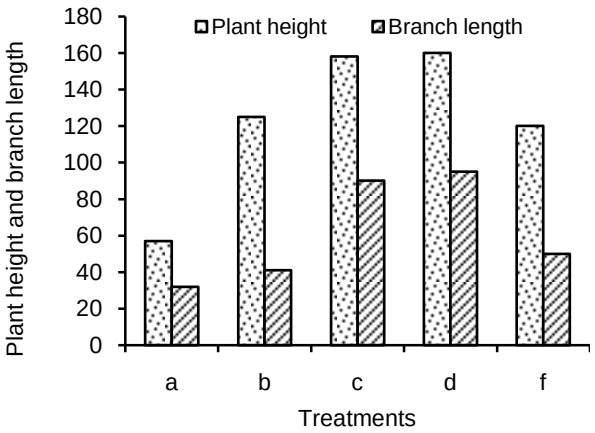

Fig. 6. Plant height and branch length of Neem grown with country bean (after Hossain 2006)

a = Unmanaged, b = + Soil management (- Manure , -Fertilizer, - Crop), c = + Soil Management (+ Manure, - Crop), d = + Soil Management , + Manure, + Crop, f = + Soil Management, - Manure, + Crop

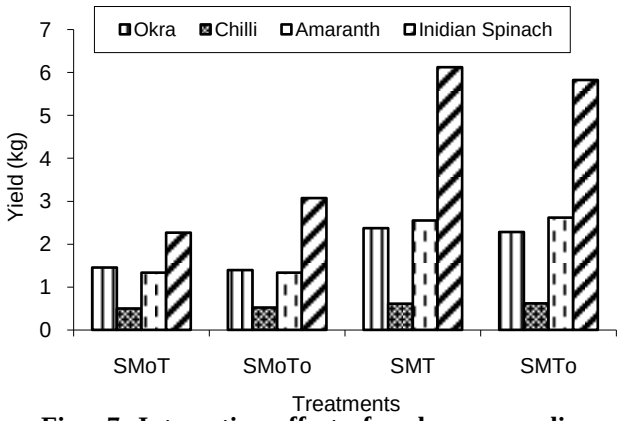

Fig. 7. Interaction effect of mahogany sapling on the yield of different crops

SMoT = Soil managed without manure with mahogany
SMoTo = Soil managed without manure without mahogany
SMT = Soil managed with manure with mahogany
SMTo = Soil managed with manure without mahogany

The results also showed that, in unmanaged soil condition without crop the growth of Neem was very poor, while better results were obtained when the soil around tree bases were managed. It was also revealed that, when Neem plants were grown in association with crops, no significant difference was observed in growth attributes due to the competition with crops. Plant height and yield of different crops grown under Neem plants also showed better results in soil managed condition (Table 1). These results encourage growing of vegetable crops along with Neem saplings at early stages of growth for mutual benefits in roadside agroforestry systems.

Table 1. Effect of Neem saplings on the plant height and yield per plot of different crops

Treatment	Okra		Chilli		Amaranth		Eryngium	
	Plant height (cm)	Yield (g)	Plant height (cm	Yield (g)	Plant height (cm)	Yield (g)	Plant height (cm)	Yield (g)
N = With Neem	134.33	1667.83	68.00	697.16	84.00 a	2385.16	26.33 a	33.33a
N_0= Without Neem	132.16	1661.66	65.16	694.33	81.16 b	2381.50	24.16 b	30.83 b
Level of Significance	NS	NS	NS	NS	*	NS	**	**
$LSD_{0.05}$					2.196		0.781	1.053

Mean values in a column having the similar letter (s) do not differ significantly whereas mean values having dissimilar letter (s) differ significantly as per (DMRT), ** Significant at 1% level of probability, * Significant at 5% level of probability, NS = Not significant

Experiments with Bakphul (*Sesbania grandiflora*)

The experimental results with *Sesbania grandiflora* (Figs. 8-11) clearly indicate that in case of shoot tip condition the development of new branches showed significant variation in intact and pollarded shoot tip. The number was 464.00 in pollarded shoot tip and 300.00 in intact shoot tip at 60 DAP. Again, in case of branch pruning condition, the maximum (513.17) number of new branches were observed in severely pruned stocks i.e. at lower + upper branch pruning levels at 60 DAP and minimum branch number (288.67) was recorded in no pruning condition at same DAP.

Similarly the number of leaves in new branches was significantly influenced by all pruning and pollarding treatments. The maximum leaf number was 975.78 in pollarded shoot tip and 633.67 in intact shoot tip at 60 DAP. Again, severe pruning levels produced the highest leaf number (1063.16) and no pruning level produced the lowest number of leaves (652.33) at 60 DAP. On the other hand the treatment of pollarded shoot tip with lower + upper branch pruned off condition produced the highest leaf number (1126.67) followed by the treatment of intact tip with lower + upper branch pruned off condition produced 999.224 leaves at 60 DAP. Whereas control treatment produced only 447.002 leaves at the same DAP.

The results presented in this study are in good conformity with other researchers. In this study it was observed that severe pruning/pollarding condition i.e. pollarded shoot tip with lower + upper branch pruning levels always produced higher number of buds, branches and leaves (resulting in increase in forage production) followed by the treatment of intact tip with lower + upper branch pruning level. According to Bisla *et al.* (1990) hard pruning resulted in significantly higher number of secondary and tertiary shoots and the largest leaf area. However, the results of the present study showed partial difference with the findings of Bisht *et al*. (1998) who observed that pollarding of *G. optiva* at 2 m height but leaving the main shoot intact produced maximum fuel and fodder.

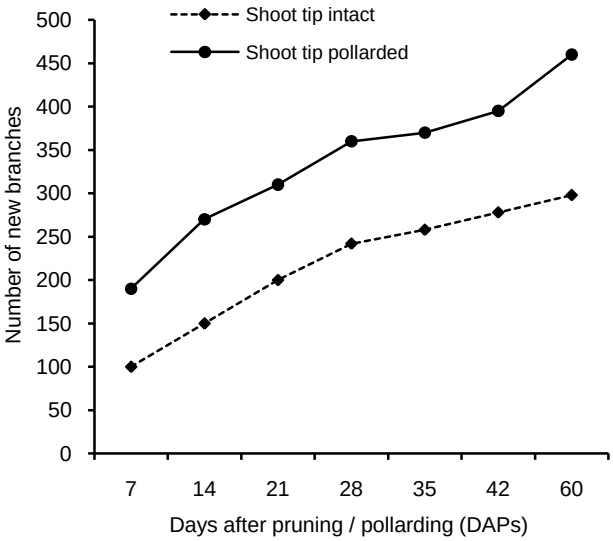

Fig. 8. Effect of shoot tip conditions on the number of new branches at different DAPs in *Sesbania grandiflora*

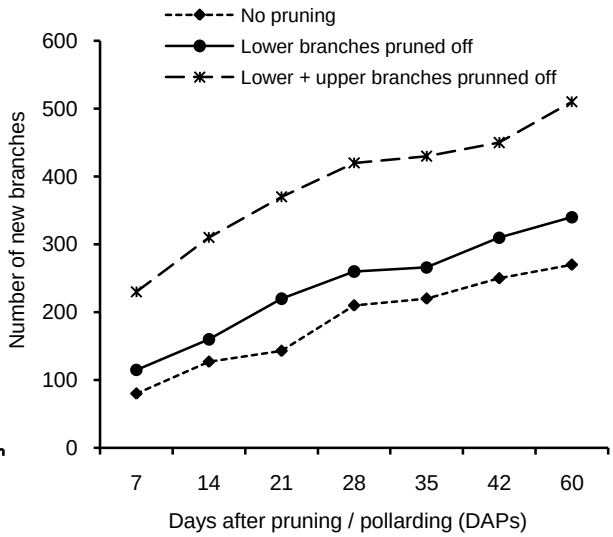

Fig. 9. Effect of branch pruning levels on the number of new branches at different DAPs in *Sesbania grandiflora*

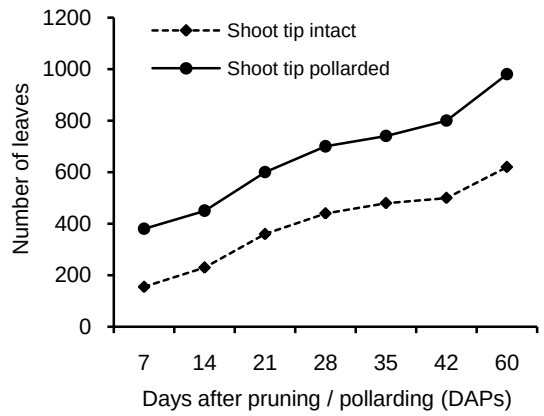

Fig. 10. Effect of shoot tip conditions on the number of leaves in new branches at different DAPs in *Sesbania grandiflora*

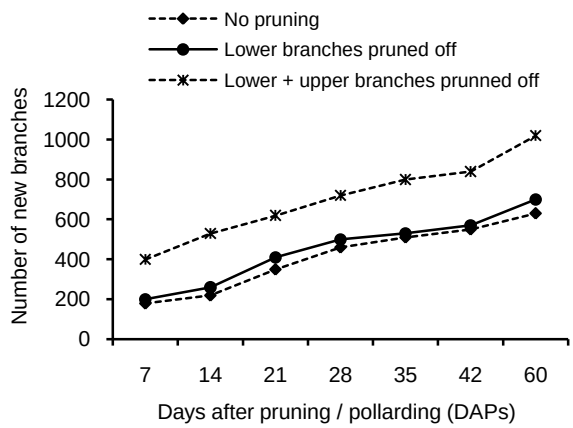

Fig. 11. Effect of branch pruning levels on the number of leaves in new branches at different DAPs in *Sesbania grandiflora*

Tipu *et al*. (2006) observed that the higher pruning height (150 cm) significantly had higher number of buds than that of lower pruning heights in the stocks of *Leucaena leucocephala*. Similarly the stocks with higher pruning height (150 cm) always produced higher number of branches as well as leaves than those with lower pruning heights (100 cm). These results along with other raw data clearly indicate that the pruning of branches and pollarding of upper levels of Neem, Jatropha and Bakphul markedly enhanced shoot regeneration resulting the plants into stout, good looking and uniform in appearance, as well as, higher production of shoot biomass compared to control plants.

Crop output and regular income generation under RAMPT models

After establishing the RAMPT-2 models along BAU farm roadsides, approximately 40 sq.meter (0.01 acre) land area under this model was intensively cultivated and protected approximately 30 m long roadsides was required for this model area. The standard crop management practices were followed according to Razzaque *et al*. (2000). The harvested crops were sold at retail prices and the total output and the sold price are shown in Table 2. Meanwhile, the vegetable prices have been increased by 10-15% and therefore, the total calculated income now might stand at approximately 2500/ taka instead of taka 2216.80. If a farmer possesses one acre of land near a medium or high way, he may get about 60-100 m of roadsides from his square to rectangular sized crop fields. Taking minimum (60 m) possible length of roadsides, he will get double income than that shown above. Hence, he might earn an additional income of taka 5000/- (2500/- × 2) annually without using his own lands.

According to Amin *et al*. (1996) Bangladesh has got approximately 7400 km of highways / railways which will be equivalent to a maximum of approximately 14,800 km roadsides suitable for 'RAMPT-2 and RAMPT-3' models. If, for example, 1/3rd of these roadsides are allowed to use for other purposes / system loss, then 2/3rd parts i.e. approximately 9,900 km roadsides could be brought under RAMPT-2 and RAMPT-3 models. If 60 m roadsides is given to one landless farmer, it will involve approximately 1.7 lac farmers for the said roadsides. However, if 16000

km district council roads (Amin et al. 1996) are used for RAMPT-1 model along with larger embankment sides, pond sides etc. for RAMPT-2 and 3, it will certainly exceeds 2 lac (0.2 million) farmers, who will earn 100 crore taka (2,00,000 × 5000/- = 100,00,00,000/- taka) annually creating job opportunities for 25000 farmers according to their existing per day income in Bangladesh. These figures are expected to be further increased since many more highways, railways and embankments have been established after the reports of Amin et al. (1996). As stated above, this is possible for vegetable and lemon (citron) production immediately without disturbing other existing systems in Bangladesh.

Table 2. Observed / calculated outputs of different MPTS and crops obtained from selected unit area (40 sqm (0.01 acre) of roadsides under RAMPT model during 2nd year of studies

Production periods	Crops grown (2-4 sqm area used per crop)	RAMPT beds	Total yield of each crop (kg)	Total price (Taka)
April–September	Chilli	1st flat bed	1.36	40.80
”	Okra	”	3.32	49.50
”	Amaranth	”	4.50	45.00
”	*Eryngium*	”	0.50	25.00
”	Lemon	”	0.50	20.00
”	Indian spinach	2nd flat bed	10.50	52.50
”	Papaya	”	36.00	540.00
October – March	Sweet guard	”	120.00	1200.00
”	Bitter gourd	”	2.20	44.00
”	Tomato	”	3.50	35.00
”	Bakphul (as vegetable)	”	5.50	165.00
”	Neem leaf	”	-	-
”	*Jatropha*	1st slope	-	-
”	Bakphul (as forage and fuel woods)	”	-	-
				Total = 2216.80

- Not recorded in 2nd year. This being done subsequently. Note that in addition to control of tree canopy, papaya, chilli, kakrol (*Momodica*) etc. shade tolerant species will be cultivated subsequently.

In addition to vegetable production, the system will yield very high value timber of Neem (*Azadirachta indica*) trees earning crores of taka in future. Their leaves will be utilized as insecticidal purposes in addition to its natural beautification and air purification (Tewari 1992). Similarly a huge quantify of forages will be produced from Bakphul trees that will enhance cattle (milk / meat food) production in this fodder crisis loaded country like Bangladesh. The systems will also yield fuel woods for the farmers and roughages for manure preparation at regular intervals. Therefore, large programs the said established and tested models may be started throughout this country without further delay for food security, environment benefits and reduction in unemployment problems of Bangladesh.

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LITERATURE CITED

Amin, S. M. R., Ahmed, F. U. and Fattah, I. M. 1996. Social forestry in Bangladesh: Concept and present status. *In*: Agroforestry in Bangladesh. M. A. Hqque (ed.). VFFP, SDC, Dhaka and BAU, Mymensingh. Pp. 30-37.

Bisht, J. K., Chandra, S., Jagpal Singh and Singh, R. D. 1998. Effect of cutting methods on the forage and fuel yield of bhimal (*Grewia optiva*) in mid hills of NW. Himalayas. Range Manage. Agroforest., 19(2): 206-207.

Bisla, S. S., Dhiman, B. K. and Daulta, B. S. 1990. Effect of pruning and spacing on vegetative growth of ber (*Zizyphus mauritiana* Lam). Haryana. J. Hort. Sci., 19(3-9): 256-262.

Haque, M. A. 1996. Prospect of Agroforestry in Bangladesh. *In*: Agroforestry in Bangladesh. Haque, M. A. (ed). VFFP, SDC, Dhaka. Bangladesh Agric. Univ., Mymensingh, Bangladesh. pp.64-70.

Hossain, M. A. 1994. Pruning, training and management in woody plants. *In*: Haque, M. A. (ed.). Village and Farm Forestry in Bangladesh (in Beng.), VFFP, BAU, Mymensingh and SDC, Dhaka.

Hossain, M. A. 1996. Propagation and management of multipurpose trees. *In*: Haque, M. A. (ed.). Agroforestry in Bangladesh. VFFP, SDC and BAU, Mymensingh.

Hossain, M. A. 2006. Development of models for sustainable multistoried production systems in roadside and farmland agroforestry. BAU Res. Prog. 17: 37-38.

Hossain, M. A. 2007. Structural development and establishment of RAMPT models in roadside, farmland and other slopeland agroforestry. Progress. Agric. 18(2): 99-107.

Khan, M. S. and Alam, M. K. 1996. Homeatead flora of Bangladesh, BARC, IDRC, SDC, Dhaka.

Openshaw, K. 2000. A review of *Jatropha curcas*: an oil plant of unfulfilled promise. Biomass and Bioenergy, 19(1): 1-15.

Razzaque, M. A., Sattar, M. A., Amin, M. S., Quium, M. A. and Alam, M. S. 2000. Krishi Projukti Hatboi (Handbook on Agro-technology), 2nd edn. Bangladesh Agric. Res. Inst., Gazipur.

Tewari, D. N. 1992. Monograph on Neem (*Azadirachta indica* A. Juss.). Intl. Book Distrib. Dehradun, India.

Tipu, S. U., Hosain, K. L., Islam, M. O. and Hossain, M. A. 2006. Effect of pruning height and shoot biomass yield of *Leucaena leucocephala.* Asian J. Plant Sci. 5(6): 1043-1046.