



Demonstration Models of Teak and Aonla based Agroforestry in Eastern UP

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Abstract— In view of importance and suitability of Teak and Aonla with different crop combinations, demonstration agroforestry models of these species were developed with the objectives to identify suitable seedling source of Teak and suitable variety of Aonla in different crop combinations for adoption by farmers of Eastern UP. Under model 1 of Aonla based agroforestry, it was found that increment in girth after two year of planting was highest (4.99 cm) for T₆ (N-7 + agriculture) followed by T₈ (chakaiya + agriculture, 4.70 cm) and other varieties with lowest (3.62 cm) value for T₁ (N6 control). On the basis of both height and girth data trends, variety N-7 performed well after two year of planting. Under model 2 in Teak based agroforestry, it was found that increment in girth after two year in T₄ (tissue culture + agri) performed well (4.96 cm) after two year of planting followed by other varieties with lowest (3.91 cm) value for T₁. It can be concluded from results of different trials that preliminary trends showed that for Aonla, N7 (Neelam) variety is performing superior compared to other varieties of Aonla with crop combinations of potato, mustard and wheat. In case of Teak, seedlings of tissue culture origin is performing superior as compared to other treatments in crop combinations of gram, barseem and barley. No significant effect of intercropping on trees and crops was experienced in early data of growth parameters of trees and production yield of intercrops.

Keywords— Demonstration model, agroforestry, Teak, Aonla, suitable seedlings, intercropping

I. INTRODUCTION

Agroforestry is the best means of sustainable agriculture, which not only meets our basic needs of food, fuel, fodder, fruit, etc. but also helps in providing better ecosystems to living being. Agroforestry is a low-input system which combines trees with crops in various combinations or sequences (Upadhyay, et al. 2021). Therefore, efforts have been made by the farmers, corporate and researchers for introducing tree based farming systems in the green belt of U.P. in the past two decades. Uttar Pradesh (U.P.), where every sixth Indian lives, contributes to 20.37 percent of the country's agricultural production. If Indian agriculture has to prosper, the situation in Uttar Pradesh has to improve in all sectors including crop diversification. Agroforestry can play a major role in bringing the desired level of diversification along with sustainability. India, with 329 million hectares of the geographical area, represents diverse agro-climatic conditions (Handa et al. 2019). Therefore, the production can be increased by choosing suitable tree species and agricultural crops. They have potential to fulfill

the social, economical and ecological goals of large populations and simultaneously improvement of land quality by soil fertility amelioration (Dollinger and Jose, 2018), enhancement of ecosystem services (Shem *et al.*, 2016) and mitigation of climate change impact (Ospina, 2017). An examination of the impact of agroforestry technology generation and adoption in different parts of the country highlights the major role of smallholders as agroforestry producers of the future. It is crucial that progressive legal and institutional policies are created to eschew the historical dichotomy between agriculture and forestry and encourage integrated land-use systems. Government policies hold the key to agroforestry adoption (Puri and Nair, 2004). In the state of Uttar Pradesh in India, agroforestry practices vary according to the agro-climatic zones and socioeconomic status of the farmer. It is now urgent need of time to adopt tree plantations in massive way in districts of Eastern Plain zone to achieve our national target of forest policy. Agroforestry is the only way for progress for farmers and rural people, leading to sustainable

development, food and nutritional security (Shukla et al. 2020).

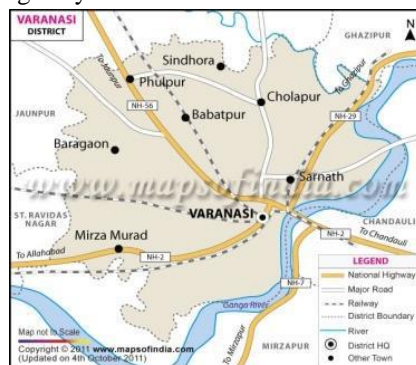
From Forest survey of India report (2021), it was recorded that forest cover including tree cover is only 1.11 % in Varanasi district. The cropping systems are different in rainfed and irrigated lands. Surveys of different parts of the eastern U. P. indicate that people have a progressive attitude towards agroforestry. Out of three zones lying under eastern part, tarai and vindhyan zones have comparatively rich resources of natural forest whereas the status of forest in eastern plain agro-climatic zone is in very primitive stage. Thus, Varanasi district was selected with a view to promote demonstration agroforestry models of *Tectona grandis* and *Emblia officinalis* in the region due to their high demand by tree growers. Eucalyptus sp., *Poplar deltoids*, *Tectona grandis*, *Moringa oleifera*, *Acacia nilotica*, *Dalbergia sissoo*, *Melia dubia* etc. are some of the important forest tree species which are suitable for different agroforestry systems in Eastern part of UP. Teak (*T. grandis*) for valuable timber and Aonla (*E. officinalis*) for fruits are important tree species in the world and is suitable for this region. Keeping in view the importance and suitability of Teak and Aonla with different crop combinations, demonstration agroforestry models of proposed species were developed with the objectives to identify suitable seedling source of Teak and suitable variety of Aonla in different crop combinations for adoption by farmers of the region and in other similar areas.

II. MATERIAL AND METHODS

Study Area

Varanasi district is located in the middle Ganges valley of North India, in the Eastern part of the state of Uttar Pradesh, bordering the districts of Jaunpur in the north, Ghazipur in the north-east, Chandauli in the east, Mirzapur in the south and Bhadhoi in the west. The total area of the district is 1,535 km² with population of 3.45 million persons. Varanasi, Pindra and Rajatalab are three tahsils in Varanasi district. The urban agglomeration lies between 25° 14' – 25° 23.5' N latitude and 82° 56' – 83° 03' E longitude. The soil is alluvial type formed by the deposition of sediments of Ganges River. Being located in the Indo-Gangetic Plains of North India the soil is very fertile as the low level floods continuously replenish the soil. Moreover, the soil is sandy loam in texture. The diurnal range of temperature ranges as average between 13°C and 14.5°C in the cold and hot months, respectively. The highest monthly temperature is recorded in May, varying between 32°C and 42°C. The annual rainfall is around 100 cm of which 90% occurs in rainy season. As per census 2011, there are 1277 revenue villages in Varanasi district. The agroforestry models of Teak and Aonla were established in Harhua block of

Varanasi located at 25 km from district HQ at Varanasi-Jaunpur Highway.



Map of district



Development block map

Fig 1. Map of district Varanasi

Establishment of Demonstration Plantation Models

The field trials were established in Harhua block of the Varanasi district. The following experimental trials of Aonla and Teak in different crop combinations were established:

Model – 1

Aonla + agri crop (Horti – agri system) in

Block

Design: RBD (Randomised Block Design)

Spacing: 8 M x 8 M

Replications: 03

Treatments: 11

T1	N -6 Control
T2	N-6 + agri
T3	N -10 Control
T4	N- 10 + agri
T5	N-7 Control
T6	N-7 + agri
T7	Chakaiya Control
T8	Chakaiya + agri
T9	Desi Control
T10	Desi + agri
T11	Sole crop

N- 6 (Amrit), N- 7(Neelam) and N- 10 (Balwant) and Chakaiya varieties of Aonla

Model-2

Teak + agri crop in block (Silvi- agri system)

Design: RBD

Spacing: 5 M x 5 M

Replications: 03

Treatments: 07

T1	Root shoot Control
T2	Root shoot+ agri crop
T3	Tissue culture Control
T4	Tissue culture + agri crop
T5	Seed control
T6	Seed + agri crop
T7	Sole crop

Data Collection, analysis and interpretation for trees and crops

The data on increment in girth and height were collected annually. The intercropping data were also recorded in block of 1x1 sq m and calculated per ha yield for each crop. The recorded data were analysed and interpreted for trials. Soil analysis (Jackson, 1985) of selected site was done by following standard methodologies for pH (7.6), EC (0.84 mm/cm), organic carbon (0.81 %), available N (199.15

kg/ha), available P (11.85 kg/ha) and available K (220.50 kg/ha) . The data analysed statistically by standard ANOVA technique using RBD. The statistical analysis was done by data analysis tool package of OPSTAT prepared by Statistical Software Package for Agricultural Research Workers, CCS HAU, Hisar, Haryana (Sheoran *et al.* 1998).

III. RESULTS AND DISCUSSION

The data were recorded annually for growth parameters (height and girth) for trials. Under model 1 of Aonla based agoforestry, it was found that increment in girth after one year of planting was highest (2.46 cm) for T₆ (N -7 + agriculture) followed by other varieties with lowest (1.84 cm) value for T₁ (N6 control). The data for height depicts that treatment T₈ (Chakaiya + agriculture) is performing well followed by T₆ and T₁₀ than other treatments whereas T₅ has lowest values. It was found that increment in girth after two year of planting was highest (4.99 cm) for T₆ (N -7 + agriculture) followed by T₈ (chakaiya + agriculture, 4.70 cm) and other varieties with lowest (3.62 cm) value for T₁ (N6 control). The data for height depicts that treatment T₆ (N -7 + agriculture, 1.51 m) performed well followed by T₈ (chakaiya +agriculture, 1.47 m) than other treatments whereas T₁ has lowest values (1.14 m). On the basis of both height and girth data trends, variety N-7 performed well after two year of planting (Table 1 & Fig.2).

Table 1. Growth performance of Aonla after two year

Treatments	Girth increment (cm)		Height increment (m)	
	After 1 yr	After 2 yr	After 1 yr	After 2 yr
T1	1.84	3.62	0.25	1.14
T2	2.31	4.08	0.27	1.15
T3	2.13	4.08	0.26	1.25
T4	2.41	4.67	0.28	1.38
T5	2.17	4.10	0.23	1.37
T6	2.46	4.99	0.30	1.51
T7	2.18	4.19	0.31	1.24
T8	2.39	4.70	0.33	1.47
T9	1.87	3.99	0.24	1.24
T10	2.17	4.25	0.26	1.35
F		S		S
SE(m)		0.09		0.03
CD (5%)		0.27		0.08

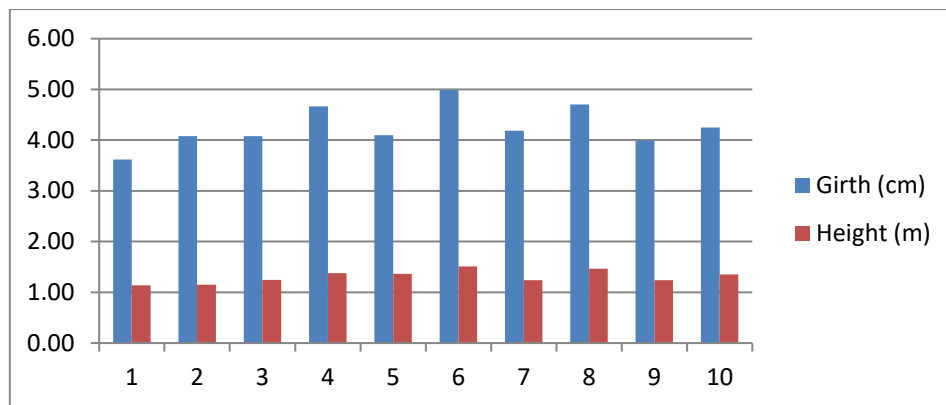


Fig. 2 Growth performance (girth & height) of Aonla after two year of planting

Intercropping yield

The intercropping of Potato in trial 1 (Aonla based agroforestry) revealed that highest (190.78 qt /ha) crop yield was recorded with T5 (N-7 with agriculture) whereas the sole crop was higher with 236.89 qt/ha (Table 2 & Fig.3).

Table 2: Potato yield (qt/ha)

Treatments	Potato yield (qt/ha)
T1	189.89
T3	187.34
T5	190.78
T7	188.89
T9	184.07
T11	236.89

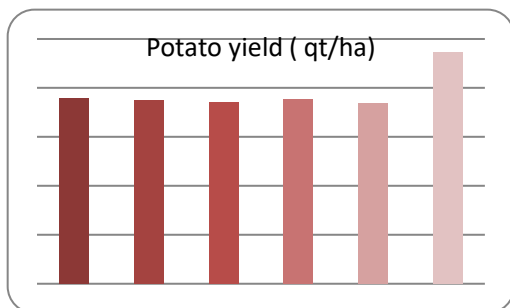


Fig. 3 Potato yield (qt/ha)

The intercropping of mustard in trial 1 (Aonla based agroforestry) revealed that highest (12.79 qt /ha) crop yield was recorded with T5 (N-7 with agriculture) whereas the sole crop was higher with 13.89 qt/ha (Table 3& Fig.4).

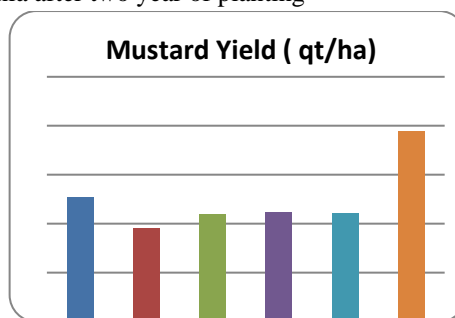


Fig. 4 Mustard yield (qt/ha)

Table 3: Mustard yield(qt/ha)

Treatments	Mustard Yield (qt/ha)
T1	12.23
T3	11.91
T5	12.79
T7	12.53
T9	12.22
T11	13.89

The intercropping of wheat revealed that highest (31.37 qt /ha) crop yield was recorded with T 5 (N-7 with agriculture) variety whereas the sole crop was higher with 34.18 qt/ha(Table 4 & Fig.5).

Fig. 5 Wheat yield (qt/ha)

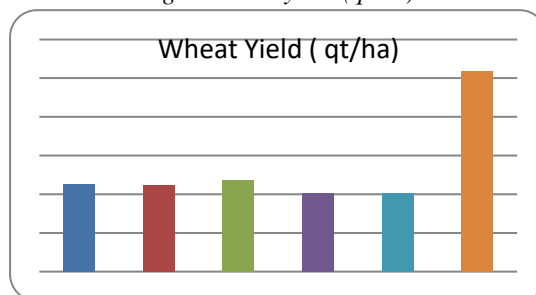


Table 4: Wheat yield (qt/ha)

Treatments	Wheat Yield (qt/ha)
T1	31.27
T3	31.23
T5	31.37
T7	31.04
T9	31.04
T11	34.18

In Varanasi district under Teak based agoforestry in model 2, it was found that increment in girth after one year of planting was highest (2.79 cm) for T 4 (tissue culture without agriculture) followed by other

varieties with lowest (1.99 cm) value for T5 (seed with agriculture). The data for height also depicts that treatment T4 (tissue culture without agriculture) is performing better (0.41 m) than other treatments whereas T1 (root shoot with agriculture) has lowest (0.39 cm) values.

On the basis of and girth data trends, T4 (tissue culture + agri) is performing well (4.96 cm) after two year of planting followed by other varieties with lowest (3.91 cm) value for T1 . The data for height also depicts that treatment T4 (tissue culture + agriculture) performed superior (2.45 m) than other treatments whereas T1 (root shoot control) has lowest (1.85 m) values. On the basis of both height and girth data trends, T4 (tissue culture+agri) performed well after two year of planting (Table 5 & Fig.6).

Table 5. Growth performance of Teak after two year of planting

S. No.	Treatments	Girth increment (cm)		Height (m)	
		After 1 yr	After 2 yr	After 1 yr	After 2yr
1.	T1	2.50	3.91	0.39	1.85
2.	T2	2.77	4.22	0.42	2.21
3.	T3	2.48	4.39	0.39	2.09
4.	T4	2.79	4.96	0.41	2.45
5.	T5	1.99	4.13	0.38	2.00
6.	T6	2.32	4.15	0.41	2.13
	F		S		S
	SE(m)		0.21		2.51
	CD (5%)		NA		NA

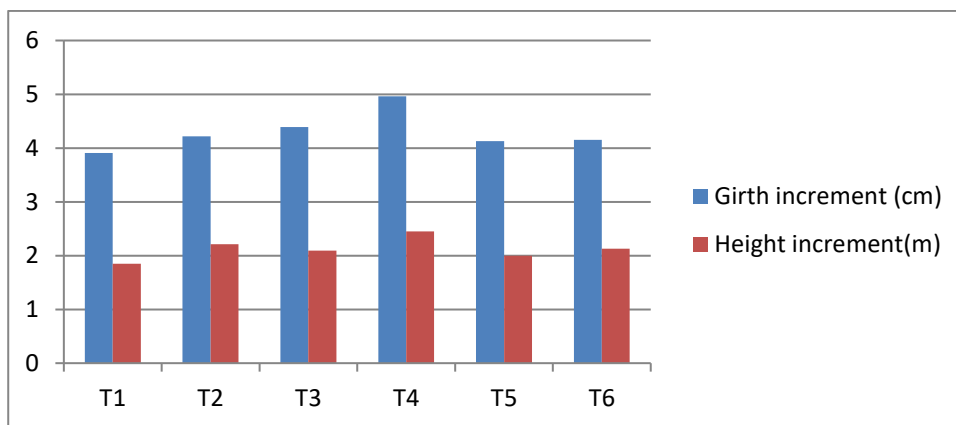


Fig. 6 Growth performance (girth & height) of Teak after two year of planting

The intercropping of Gram in Teak based agoforestry revealed that highest (13.07 qt /ha) crop yield was recorded with T3 (tissue culture + agriculture) whereas the sole crop was higher with 13.66 qt/ha (Table 6 & Fig. 7).

Table 6: Gram yield (qt/ha)

S. No.	Treatments	Gram Yield (qt/ha)
1	T1	9.44
2	T3	13.07
3	T5	10.24
6	T7	13.66

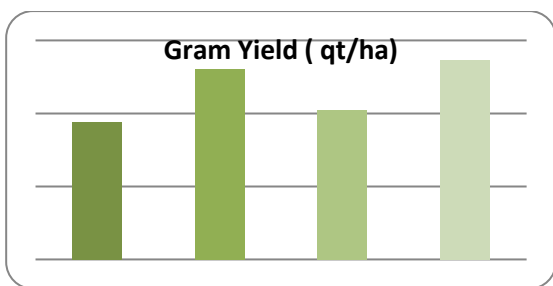


Fig.7 Gram yield (qt/ha)

The intercropping of Barseem in Trial 2 revealed that highest (857.78 qt /ha) crop yield was recorded with T5 variety whereas the sole crop was higher with 1040.56 qt/ha (Table 7 & Fig. 8).

Table 7: Barseem yield (qt/ha)

Treatments	Barseem Yield (qt/ha)
T1	763.44
T3	779.44
T5	857.78
T7	1040.56

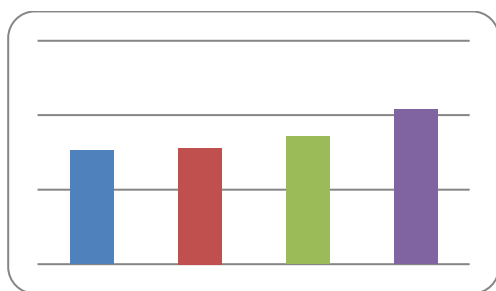


Fig. 8 Barseem yield (qt/ha)

The intercropping of Barley revealed that highest (22.36 qt /ha) crop yield was recorded with T 3 variety with approx. similar value with other treatments whereas the sole crop was higher with 24.49 qt/ha(Table 8 & Fig. 9).

Table 8: Barley yield (qt/ha)

Treatments	Barley Yield (qt/ha)
T1	21.90
T3	22.36
T5	21.91
T7	24.49

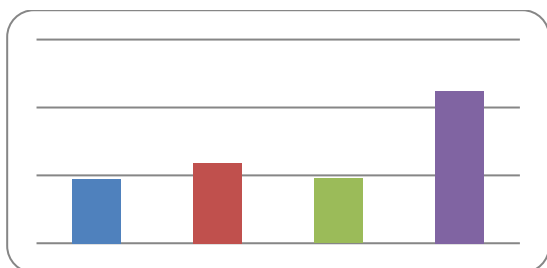


Fig. 9 Barley yield (qt/ha)

It can be concluded from results of different trials that preliminary trends showed that for Aonla, N7 (Neelam) variety is performing superior compared to other varieties of Aonla with crop combinations of potato, mustard and wheat . In case of Teak, seedlings of tissue culture origin is performing superior as compared to other treatments in crop combinations of gram, barseem and barley . No significant effect of intercropping on trees and crops was experienced in early data of growth parameters of trees and production yield of intercrops. The Aonla based agri-horticulture system has been proven to be one of the most profitable agroforestry systems in poor and marginal lands of drought-prone Bundelkhand region. It helps farmers to earn profits even in conditions of crop failure due to weather vagaries (Newaj et al. 2006).The foresters, researches, NGOs and tree growers and traders are needed to be coordinate on a common platform for successful implementation of agroforestry programme on massive level. Further, to enhance the efforts of farmers, sale of end products should be strengthened with the involvement of project planners and wood based industries (Srivastav et al. 2019).The yield of the associated agriculture crops varied in different combinations of the Teak and Aonla. In general, yield of the agri crops increased in combination of different treatment of trees. However, tree-crop interactions depend on the various associated factors; hence, this needs to be studied further at different age of the tree component. The findings revealed that in the harsh climatic conditions of the Bundelkhand region, teak-barley based agroforestry system may be a potential land-use system for adoption (Upadhyay et al. 2021). In the similar way, suggested combinations of agri crops with trees can be established in different regions of eastern UP.

IV. CONCLUSION

Technology has been transferred and demonstrated to farmers under agroforestry training programmes .The technology has been popularized through distribution of literature in extension programmes .Teak plantations are suitable for small/marginal farmers .The Aonla based agri-horticulture system may be one of the most profitable agroforestry systems in poor and marginal lands of Varanasi districts of UP region. It may help farmers to earn profits even in conditions of crop failure due to weather conditions. The Aonla based agri-horti system has been popularized through various farmers training programmes. Aonla based agri-horticulture system is one of the best with respect to alternate land use and economic returns for the region. However, better availability of market and storage facility may further improve the livelihood of practitioners of this system.

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