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Economics and Yield Performance of Gamhar (G*melina arborea* roxb.) Under Agri-silvicultural System in East Singhbhum District in Jharkhand, India

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Abstract

The present experiment was conducted on the 'Economics and yield performance of Gamhar (*Gmelina arborea* Roxb.) under agrisilvicultural system in east Singhbhum District in Jharkhand' with the numerous objectives viz. to find out the growth of tree species of Gamhar planted in the boundary of agricultural field and to analyze the economic feasibility of Gamhar under agri-silvicultural system at Zonal Research Station, Darisai, BAU, Ranchi during 2011-12. The experiment was carried with tree species *Gmelina arborea* (Gamhar) along with the intention of growing agricultural crops namely Gram (*Cicer arietinum*), Pea (*Pisum sativum),* Indian mustard *(Brassica nigra)* and fruit crops namely Mango (*Magnifera indica*), Aonla (*Emblica officinalis*), Papaya (*Carica papaya*) and the experimental plots were arranged in fixed plot surveydesignwith three replications. The result data showed that the height of Gamhar was maximum found in agri-silviculture system (Gamhar + Gram) (11.79 m) while minimum in Gamhar + Pea (11.16 m). The diameter, basal area and volume of Gamhar less under sole plantation than agri-silvicultural system. The ascending order of increment were recorded as Gamhar + Indian mustard > Gamhar + Gram > Gamhar + Pea > Gamhar. Indeed, it observed that yield from horti-silvicultural system were highly significantly than the sole cropping

system. For instance, the yield of Papaya in hort-silvicultural system (553.11 q ha^{-1}) were statistically higher significantly than sole cropping of Papaya (476.53 q ha^{-1}) and similar trend followed in other crops also. In agroforestry system, highest financial yield of Gamhar (Rs. 72,972 of total boundary plants), Papaya (Rs. 7,19,043 ha^{-1}), Pea (Rs. 21,960 ha^{-1}), Gram (Rs. 45,000 ha^{-1}), and Indian mustard (Rs. 15,552 ha^{-1}) whereas in sole plantation, the financial yield of Gamhar (Rs. 21,406 of total boundary plants), Papaya (Rs. 6,19,493 ha^{-1}), Pea (Rs. 21,075 ha^{-1}), Gram (Rs. 37,160 ha^{-1}), and Indian mustard (Rs. 14,607 ha^{-1}).

Keywords: Growth parameters, Hort-silvicultural system, Economic performance, *Gmelina arborea*, Agri-silvicultural, Intercropping and Gamhar.

Introduction

The literatures and researcher data showed that there is negativeimpacts of agricultural expansion, landscape modification and deforestation on biodiversity, ecosystem services, alteringthe species composition and their ecological functions (Tscharntke *et al*. 2005; Priess *et al*., 2007; Flynn *et al*. 2009; Senior *et al*. 2013; Deguines *et al*., 2014; Kumar, 2016) which can lead to considerable changes in critical ecosystem processes. On the other hand, an increasingly industrialized global economy, rapid population growth, land degradation, land use pattern and role of various human activities have led to dramatically increased the pressure on the natural resources such as the available land for sustaining the livelihoods, and with over exploitation and extraction of the natural resources the ecosystems are becoming unsustainable and fragile since last century (Kumar 2017). Standardization of cultural practices is one of the primary objectives to make the system ecologically, sustainable and economically viable (Gill *et al*.. 2009). To avoid these circumstances, tree growing in combination to agriculture(agroforestry systems) as well as numerous vegetation managementregimes in cultural landscape (ethnoforestry systems) may improve soil fertility, carbon storage, provide fodder,produce tree fruits, expand fuel wood supplies and producea variety of wood products for farmers own use and salewithout demanding additional land (Kumar 2015; Kumar 2016). Agroforestry system reducing vulnerability, increasing resilience of farming systems and buffering households against climate related risk in addition to providing livelihood security (NRCAR 2013). For example, agri-silvicultural systems, where trees and crops are grown together, are net sinks while agri-silvipastoral systems are possible sources of GHGs (Kandji *et al.*, 2006). Agri-silvicultural systems are generally characterized by higher productivity on account of the vertical stratification of the shoot and roots systems of different components (Mathew *et al.,* 1992; Kumar *et al*., 2001), they areextremely dynamic with available resources andenvironmental conditions changing over time. In addition, trees in

managed species mixtures have a great potential to bring about 'micro-site enrichment' through processes such as efficient cycling of plant nutrients and nutrient pumping (Haines and DeBell 1979). Tree-crop compatibility trials in pursuit of identifying ideal combinations for understorey productivity improvements were conducted at several locations in India. Some of the reported combinations include rubber-banana (Rodrigo *et al*. 2001), *Hardwickia binata*-based agri-silvicultural system involving sorghum-pearl millet, pigeon pea, soybean and cotton (Khadse and Bharad 1996), coconut-based crop combinations for humid tropics such as coffee-banana, banana with ginger turmeric pineapple, papaya-pineapple, coffee-MPTs-pepper (Nair 1983; Lyiange *et al*. 1985).

Gamhar (*Gmelina arborea* Roxb) (Family- Verbenaceae) is fast growing species, itsintrinsic disease, fire and drought tolerance, as well asthe quality of its wood which is suitable for differenttypes of uses such as paper pulping, plywood or particleboard industry and furniture. It also known as white teak, a tropical deciduous tree native from moist tropicalforests of Asia (Rosero *et al*. 2011). It growsbest on deep, well drained, base-rich soils with pH between 5.0 and 8.0 with wide range of conditions from sea level to1200 m elevation and annual rainfall from 750 to 5000 mm. In addition, Gamhar is considered a pioneer plant speciescapable of rapidly colonizing eroded or low nutritionalquality lands, even-grained, soft, light and strongdemanded for paneling, carriages, furniture, boxes and carpentry of all kindswhich makes it interesting for reforestationor landscape restoration programs. The plant is widely used inAyurveda, one of the ingredients of Dashamoola rishtada (Sharma *et al*. 2001; Khare 2004). Despite its ecological and increasing economic importance, very little is known about the biology of this species and itsremarkable field behavior such as drought tolerance, atthe genetic, molecular and biochemical levels.

Planting trees and crops in association can alsoproduce direct financial benefits (Nissen *et al*. 2001). In spite of the above advantages, there is substantialevidence that competition effects in intercroppingsystems may reduce or override overall productivitygains and financial returns compared with tree monocultures.Therefore, the choice of intercrop alsodepends on characteristics of particular tree speciese.g. root system, canopy, allelopathic effect of litter, agroclimatic and edaphic conditions (Batish *et al*. 2007).There is a greatneed to identify the suitable agricultural andhorticultural crops, which can grow well along withtree species with limited solar energy availableunderneath the trees. In the present investigation on Gamhar woody perennial crop with the intention of growing agricultural crops viz., Gram (*Cicer arietinum*), Pea (*Pisum sativum*), Indian mustard (*Brassica nigra*) and horticultural crops such as Mango (*Magnifera indica*), Aonla (*Emblica officinalis*), and Papaya (*Carica papaya*) were intercropped. These crops were selected based on their adaptation, growing habit, production and requirement.

Study area

This experiment was conducted at field of Zonal Research Station, Darisai of Birsa Agricultural University, east Singhbhum District in Jharkhand. The altitude of site is about 622m above mean sea level. Geographically the site is located at $21^0$58' to $23^0$36' N latitude and $85^0$40’ to $86^0$54' E longitude in Chhotanagpur plateau. Darisai is situated on Zone VI (South Eastern Plateau Zone). The topographically the site is almost plain basic igneous rocks and granite in small pockets are the main geological sequence on which parent material and soil have developed.

Fig. 1. Map of study area inEast Singhbhum district in Jharkhand

Climate

The climate is classified as sub-humid with mean daily temperature of about 22.8^0C. The mean temperature of the coldest month (January) was 7^0C and the hottest month (May) was 38^0C. The mean relative humidity is about 70.88% in the area. The monsoon breaks out in the middle of June and last till mid-October. The annual rainfall in the area varies from 900-1500 mm. The mean wind velocity and evaporation varies from 3.61km/hr to 4.39 km hr^{-1} and 130 mm to 140mm, respectively.

Characteristics of soil

The soil of the field site is sandy loam to gravelly loam in texture, shallow soil depth (25-50cm), 0.3 percent and 3-5 percent slopes and slightly too moderately eroded, well drained with low water holding capacity and poor consistency. The soil colour varied from 7.5 YR 5/4 to 2.5YR 6/4 (brown to light yellowish brown). Medium in nutrient content, neutral to slightly acidic in reaction (pH 6.6).

Experimental design

The experiment was conducted in the field have boundary plantation of one tree species namely *Gmelina arborea* (Gamhar) and fruit crops namely Mango (*Mangifera indica*), Anola (*Emblica officinalis*), Papaya (*Carica papaya*). The agroforestry experiment along with the intention of growing agricultural crops namely Gram (*Cicer arietinum*), Pea (*Pisumsativum),* Indian mustard *(Brassica nigra)* and Fruit crops namely Mango (*Magniferaindica*), Aonla (*Emblica officinalis*), Papaya (*Carica papaya*). During the experimental period, standard cultural practices like weeding, hoeing and watering were done at weekly interval *i.e*. after 7 days (weeding) or when it is required (watering) to maintain the proper growth of agricultural crops.

A field experiment involving six treatments and three replication but the stand was established in June, 1999 while agricultural crop was set up on December, 2011 and horticultural crops was planted in June, 2009. The size of plot was 16.0 X 16.0 m, spacing of tree species was 2.0 m from the line of farm boundaries, the spacing of agricultural crops was 0.30 X 0.30 m; spacing of horticultural crops was 5.0 X 5.0 m.

The different growth parameters such as height, stem girth, crown width, and yield of horticulture crops and germination, crop height, and yield of agricultural crops were recorded for each treatment. The fruit yield of agricultural crops by harvesting mature fruit and taking their weight after the final harvesting.

The data recorded on various parameters were subjected to statistical analysis for statistical validity of the results and interpretations. The main objective of t-test was to examine if there is any significant difference between the mean values of different parameter for each provenances/seed source. The significance of different sources of variation was tested by variance ratio of mean sum of square (F-test) at probability level of 5%. Standard of variance (ANOVA), standard error of mean (SE), coefficient of variation, critical difference, *etc*. were calculated for each parameter for the purpose of interpretation. For statistical calculation Excel Package of M.S. Office was used in a computer.

Observations

Agroforestry technologies vary from region to region. Adoption and practice of these technologies depends on the edaphic-climatic, socioeconomic status and needs of peasants. These attributes lead to variation in the structure and composition of recommended technologies and existing agrarianism (Panchal *et al*., 2017).

Height

It indicated that height of *Gmelina arborea* in the sole plantation was 10.18m which was lowest among agri-silvicultural system. Among the agri-silvicultural system, the Gamhar has recorded different height with different agriculture crops which ranged from 10.82 to 11.36m. The height of Gamhar is found highest in case of Gamhar+Gram which is 11.36m whereas the minimum highest was recoded in Gamhar + Pea (10.82m) (Table 1). Similar to the present study Malik *et al*. (2005) and Malik and Surendran (2000) have reported better growth of tree in Agri-silvicultural system of *E. globules* and potato and also Gill and Roy (1992) reported better height growth in agroforestry than in sole tree planting at National Research Centre on Agroforestry (NRCAF), Jhansi by taking 12 multipurpose tree species.

Diameter

It indicated that diameter of *G. arborea* is maximum (10.81cm) in agri-silviculture system where as minimum diameter (10.14cm) found in sole plantation. Among the agri-silvicultural system, the Gamhar has recorded different diameter with different agriculture crops which ranged from 10.75 to 10.81cm (Table 1). The ascending order of diameter was recorded in Gamhar>Gamhar+Gram>Gamhar+Indian mustard>Gamhar+Pea. Similar result has found by Gill and Roy (1992) reported better diameter and height growth in agroforestry than in sole tree planting at NRCAF, Jhansi. Similarly, better growth of tree species have been reported by different tree species in agroforestry system (Tree+Agricultural crop), *i.e*. *Dalbergia sissoo* intercropped with wheat and paddy (Sharma 1987).

Crown diameter

The observation ndicated that crown diameter of *G. arborea* is maximum (3.65cm) in agri-silviculture system where as minimum diameter (2.12cm) found in sole plantation. Among the agri-silvicultural system, the Gamhar has recorded different crown diameter with different agriculture crops which ranged from 3.34 to 3.65cm. The ascending order of crown diameter was observed in Gamhar>Gamhar+Gram>Gamhar+ Indian mustard >Gamhar+Pea (Table 1).

Our result was also matched with Kaushik *et al*. (2002) was found crown spread of *Dalbergia sissoo* (40.10m^2), *A. indica* (24 m^2) and *M. alba* (10.90 m^2) in Agri-silvi-horticultural system in Arid India.

Basal area

The data showed that basal area of *G. arborea* (0.0092 m^2 plant^{-1}) in the agri-silviculture system was highest. Among the agri-silvicultural system, the Gamharwas recorded different basal area with different agriculture crops which ranged from 0.0091to 0.0092 m^2 plant^{-1} (Table 1). The basal area of Gamharwas found highest in Gamhar+Indian mustard and Gamhar+Pea (0.0092 m^2 plant^{-1}) whereas the minimum basal area was recorded in Gamhar+Gram (0.0091 m^2 plant^{-1}).

Table 1: Growth attributes of woody perennial species of Gamharin agri-silvicultural system

Treatments	Height (m)		Diameter (cm)		Crown diameter (m)		Basal area (m^2 plant^{-1})		Volume (m^3 plant^{-1})		Increment (m)
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	
Gamhar only	10.18	10.45	10.14	10.37	2.12	2.22	0.0081	0.0085	0.082	0.088	0.27
Gamhar + Pea	10.82	11.16	10.81	11.13	3.65	3.72	0.0092	0.0097	0.099	0.109	0.34
Gamhar + Gram	11.36	11.79	10.75	11.39	3.34	3.43	0.0091	0.0102	0.103	0.120	0.43
Gamhar + Indian mustard	11.08	11.51	10.81	11.44	3.59	3.86	0.0092	0.0103	0.102	0.118	0.43
Mean	10.86	11.23	10.63	11.08	3.18	3.31	0.0089	0.0097	0.097	0.109	0.37
S.Em	0.319	0.312	0.174	0.184	0.172	0.143	0.001	0.001	0.003	0.003	0.016
CV %	13.479	12.751	7.520	7.588	17.568	14.045	15.091	15.142	14.620	13.429	19.672
C.D. at 5%	1.007	0.984	0.549	0.578	0.384	0.319	0.001	0.001	0.010	0.010	0.050

Table 2: Growth attributes of horticultural crops species in hort-silvicultural system

Treatments	2011			2012			2011			2012			2011			2012			Papaya Yield (q/ha)
	Height (m)						Girth (cm)						Crown width (m)						
	Mango	Aonla	Papaya	Mango	Aonla	Papaya	Mango	Aonla	Papaya	Mango	Aonla	Papaya	Mango	Aonla	Papaya	Mango	Aonla	Papaya	
Fruit Tree only	1.92	2.05	1.46	2.06	3.12	1.82	22.76	21.66	44.18	24.65	23.66	46.20	103.30	264.12	121.17	109.60	279.64	121.54	476.53
Gamhar + Fruit Tree	2.11	2.17	1.54	2.20	2.17	1.89	23.42	23.19	45.98	25.28	24.44	47.29	104.61	265.43	123.05	110.54	283.17	124.05	553.11
Mean	2.01	2.11	1.50	2.13	2.65	1.86	23.09	22.42	45.08	24.97	24.05	46.75	103.96	264.78	122.11	110.07	281.41	122.80	514.82
S.Em	0.005	0.005	0.011	0.005	0.011	0.011	0.128	0.524	0.515	0.358	0.259	0.395	0.480	0.437	0.419	0.069	1.253	0.385	21.434
CV %	0.566	0.574	1.785	0.589	1.030	1.489	1.354	5.721	2.800	3.510	2.640	2.069	1.131	0.404	0.841	0.154	1.091	0.768	10.198
C.D. at 5%	0.015	0.016	0.034	0.016	0.035	0.036	0.402	1.650	1.623	1.127	0.817	1.244	1.512	1.376	1.322	0.218	3.949	1.213	67.535

Volume

The observation was indicated that volume of *G. arborea* (0.103 m^3 $pant^{-1}$) in the agri-silviculture system is highest. Among the agri-silvicultural system, the Gamhar has recorded different volume with different agriculture crops which ranged from 0.099 to 0.103 m^3 $pant^{-1}$. The volume of Gamhar is found highest in case of Gamhar + Gram which was 0.103cu.m/plant, whereas the minimum volume was obtained in Gamhar + Pea (0.099 m^3 $pant^{-1}$). Further there is an increase of 16.5 % in tree volume in the combination of Gamhar + Gram over a period of one year.The ascending order of increment was Gamhar + Indian mustard = Gamhar + Gram > Gamhar + Pea > Gamhar (Table 1).

Growth attributes of horticultural and agricultural crops

The data was indicated that in horti-silvicultural system, the height of Mango (2.06 m), Aonla (3.12 m) and Papaya (1.82 m) were statistically significantly higher than Mango (1.92 m), Aonla (2.05 m) and Papaya (1.46 m) planting in sole cropping (Table 2). The data indicated that height in horti-silvicultural system was more than in sole planting. Similar observation had been observed by Gill (1992) regards higher growth of height and less of mango in horticultural crops based intercropped agroforestry system. The stem girth of Mango (24.65 cm), Aonla (23.66 cm) and Papaya (46.20 cm) were statistically significantly higher than Mango (22.76 cm), Aonla (21.66 cm) and Papaya (44.18 cm) planting in sole cropping (Table 2). Stem girth of horti-silvicultural system has more than in sole planting and similar observation has been recorded by Gill and Roy (1992). The crown width of Mango (109.60 cm), Aonla (279.64 cm) and Papaya (121.54 cm) were statistically significantly higher than Mango (103.30 cm), Aonla (264.12 cm) and Papaya (121.17 cm) planting in sole cropping. Crown width of horti-silvicultural system has more than in sole planting.

Yield of horti-silvicultural system, the yield of Papaya (553.11 q ha^{-1}) were statistically significantly higher than Papaya (476.53 q ha^{-1}) planting in sole cropping (Table 2). Yield in horti-silvicultural system was more than in sole planting. The production of Mango and Aonla fruit has not started till date (Table 2).

Germination

The germination (%) of all agricultural crops are maximum in agri-silviculture system where as minimum germination (%) found in sole plantation. Among the agri-silvicultural system, the Pea, Gram and Indian mustard were recorded different germination (%) which is 91, 90.67 and 87.67 per cent respectively (Table 3).

Crop Height

The data was indicted that in agri-silvicultural system, the height of Pea (84.67 cm), Gram (66.58 cm) and Indian mustard (124.01cm) were statistically significantly higher than Pea (75.66 cm), Gram (56.80 cm) and Indian mustard (113.38 cm) planting in sole cropping (Table 3). The data indicated that height in agri-silvicultural system was more than in sole planting.

Seed yield

Similarly, seed yield of Pea (7.32 q ha^{-1}), Gram (11.25 q ha^{-1}) and Indian mustard (4.44 q ha^{-1}) were statistically significantly higher than Pea (7.03 q ha^{-1}), Gram (9.29 q ha^{-1}) and Indian mustard (4.17 q ha^{-1}) planting in sole cropping. Statistically revealed that seed yield in agri-silviculture system was more than in sole planting. Similarly, Dhyani and Chauhan (1989) studied the performance of agricultural crops gave higher yield in partial shade as compared to open conditions. Singh and Pradhan (1989) observed that various intercrops with Mandrin (*Citrcus reticulata*) orchards can yield 60.9 kg ha^{-1} with Ginger, 149 kg ha^{-1} with maize and 59kg/ha along with finger millet in agri-silvicultural system. Similarly, Anon (1989) reported that out of various treatment evaluated, Coriander + Subabul produced significantly higher yield (10.3 q ha^{-1}) than (8.5 q ha^{-1}) with Coriander alone. Findings of Varadaranganatha and Madiwalar (2010) have reported six prominent agroforestry systems practiced in the three distinct agro-ecological situations. In all the three situations, bund planting was the most prominent agroforestry practiced by farmers, followed by horti-silviculture system and less prominent practice was block plantation. Mango was found as dominant fruit tree species.

Table 3. Germination, crop height and seed yield of agricultural crops at maturity in sole and in agri-silvicultural system

Treatments	Germination (%)			Crop Height (cm)			Seed yield (q ha^{-1})		
	Pea	Gram	Indian mustard	Pea	Gram	Indian mustard	Pea	Gram	Indian mustard
Agricultural Crops only	89.33	88.00	85.33	75.66	56.80	113.38	7.03	9.29	4.17
Gamhar + Agricultural Crops	91.00	90.67	87.67	84.67	66.58	124.01	7.32	11.25	4.44
Mean	90.17	89.33	86.50	80.17	61.69	118.70	7.17	10.27	4.31
S.Em	0.236	1.027	0.850	0.120	0.325	0.742	1.110	0.747	0.104
CV %	0.640	2.817	2.407	0.368	1.290	1.532	3.792	17.826	5.886
C.D. at 5%	0.743	3.237	2.678	0.379	1.024	2.339	0.350	2.355	0.326

Financial yield of fuel wood, horticultural and agricultural crops

Productivity in terms of money, i.e. financial yield was calculated for tree, fruit and crop on the basis of market rate (Gamhar Rs. 600 ft $^{-3}$, Papaya Rs. 17 kg^{-1}, Pea Rs. 40 kg^{-1}; Gram Rs. 55 kg^{-1} and Indian mustard Rs. 35 kg^{-1}) (Table 4). The result indicated that in all cases the agroforestry system gave more income as compared to sole plantation. In agroforestry system, highest financial yield of Gamhar (Rs. 72,972 of total boundary plants), Papaya (Rs. 9,40,287 ha^{-1}), Pea (Rs. 29,280 ha^{-1}), Gram (Rs. 61,875 ha^{-1}), and Indian mustard (Rs. 15,540 ha^{-1}) whereas in sole plantation, the financial yield of Gamhar (Rs. 21,406 of total boundary plants), Papaya (Rs. 8,10,101 ha^{-1}), Pea (Rs. 28,120 ha^{-1}), Gram (Rs. 51,095 ha^{-1}), and Indian mustard (Rs. 14,595 ha^{-1}). Kumar *et al*. (2004) noticed that agricultural fields are one of the potential areas, where large scale planting of trees can be taken up along with the agricultural crops. Agroforestry models adopted by the farmers in Haryana and Uttaranchal states of India are highly lucrative, therefore, attracting farmers in a big way. Net Present Value (NPV) for different models on six years rotation varies from Rs. 26,626 to 72,705 ha^{-1}yr^{-1}, whereas B/C ratio and IRR vary from 2.35 to 3.73 and 94 to 389 per cent, respectively.

Table 4: Economic of Gamhar, horticultural crop species and agricultural crops in horti-silvicultural and agri-silvicultural system

Income	Tree species (Rs. ha^{-1})	Fruit tree species (Rs. ha^{-1})			Agricultural crops (Rs. ha^{-1})		
	Gamhar	Mango	Aonla	Papaya	Pea	Gram	Indian mustard
Tree/Fruits/ Crops only	21,406	—	—	8,10,101	28,120	51,095	14,595
Gamhar+ fruits/crops	72,972	—	—	9,40,287	29,280	61,875	15,540
Gross income	94,378	—	—	17,50,388	57,400	1,12,970	30,135
Net income from agroforestry system	51,566	—	—	1,30,186	1,160	10,780	945

Conclusion

On the basis of the results obtained and discussions, the following conclusions

i. Growth performance of horticultural and agricultural crop was found maximum under Gamhar tree as compare to sole plantation.

ii. Growth performance of Gamhar was also found better in agroforestry system.

iii. The yield of agriculture crop of Pea, Gram and Indian mustard was found maximum in agri-silvicultural system as compare to sole plantation.

iv. The overall performance of Gamhar, horticultural and agricultural crops was better under agroforestry system as compare to grown in sole system.

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