E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(7): 109-112
Received: 02-04-2024
Accepted: 06-05-2024

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Effect of *Terminalia arjuna* trees on the performance of paddy crop under bund-based agroforestry system

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i7Sb.1026

Abstract
The study was carried out in a Randomized Block Design (RBD) with one control. The tree diameter at breast height (DBH) and crown width ranges from 16.55 - 27.69 cm and 5.28 - 8.65 m, respectively. Data on the growth and yield of paddy were recorded at 1 m, 3 m, 5 m, 7 m, and 9 m and control >9 m from tree trunk. The results showed that the bund agroforestry of *Terminalia arjuna* has adverse effect on the growth and yield of paddy, which differed from the different DBH and crown width of the tree row and distance from the tree bund. Due to higher crown width and closeness to the tree, the growth of paddy, *i.e.* the number of hills/m^2 and the shoot length (cm) of paddy, were drastically reduced. The highest average number of hills/m^2 (30.00±0.58) and mean shoot length (100.10±1.48 cm) were recorded at a distance of 9 m from tree line and the minimum average number of hills/m^2 (20.67±0.33) and mean shoot length (92.65±0.53 cm) were at the distance of 1 m from tree line. However, the mean grain yield of paddy recorded maximum (45.65±5.16 q/ha) at a distance of 9 m from tree line, and minimum (11.35±0.53 q/ha) mean grain yield of paddy recorded at 1 m distance from tree. Mean straw yield of paddy maximum (42.82±1.58 q/ha), at a distance of 9 m from tree, and minimum (22.05±0.78 q/ha) at a distance of 1 m from tree line was recorded. Paddy yield reduction was measured highest (83.58±0.53%) at 1 m distance from the tree line and lowest (33.93±5.27%) at 9 m distance from the tree line, similarly straw yield reduction highest (57.52±1.05%) at 1m distance from the tree line and lowest (17.51±2.15%) at 9 m distance from the tree line.

Keywords: Agroforestry system, *Terminalia arjuna*, crown width, sun light

Introduction
Agroforestry is an alternative agricultural policy based on the growing of trees with crops. It is a land use option that reduces vulnerability to climate and environmental change and increases the scope of livelihood. It improves the economic conditions of farmers, besides conserving the natural resources of soil, water, and biological diversity. Trees on farm lands help in increasing agricultural resilience to meet the challenges of global climate change (Mbow *et al.*, 2014; Lasco *et al.*, 2014) [8, 6].

Several agroforestry technologies and systems have been developed in diverse agro-ecological zones of the country. These systems have ensured higher returns to the farmers and, additionally, ensured livelihood security and protection against crop failure due to climatic deviations, mainly in the inarid and semi-arid conditions of the country (Sarvade and Singh, 2014) [15].

Tree litter improves soil fertility not only through the addition of nutrients to the soil by mineralization, but also by adding soil organic matter to the soil (Dollinger and Jose, 2018) [3]. The systematic integration of trees with crops improves microclimatic conditions, which has a positive effect on the consequences of productivity. The trees regulate the complex of environmental changes, affecting not only the available light but also the air temperature, soil moisture content, soil temperature, wind movement, relative humidity, rainfall infiltration, evapo-transpiration, soil structure, micro-fauna, reduced pest and disease complexes, etc. (Sileshi *et al.*, 2007) [19]. Agro-forestry systems, along with maintaining ecological balance, uplift the socioeconomic status of the farmers and substantially contribute to the production of wood for industries and other commercial purposes. It offers a cost-effective and ecologically viable option for large-scale diversification in agriculture on one hand and environmental

betterment on the other (Nayak *et al.*, 2014) [10].

One of the most important commercial food crops by far is rice (*Oryza sativa* L.). Its annual yield worldwide is approximately 535 million tons. The domestication and cultivation of rice is one of the most important events in history that has had the greatest impact on the most people. Rice is a nutritious cereal crop and the main source of energy. It provides adequate amounts of protein, zinc, and niacin, *i.e.* vitamin B_3. However, rice is deficient in Ca (calcium), Fe (iron), and vitamins like vit. B1 (thiamine) and vit. B_2 (riboflavin). Rice protein has the property of high digestibility (approx. 88%) among other cereal proteins. It provides sufficient fibre for easy digestion and minerals. It accounts for 50-80% of the everyday calorie intake from rice.

The ayurvedic plant *Terminalia arjuna* (Roxb.) has significant medicinal value. It is also known as Arjuna, Arjun, Indradru, Partha, and Veeravriksha (Sharma *et al*., 2005) [16]. It is a member of the Combretaceae family, which includes nearly 200 species worldwide. Nearly 24 species of Terminalia have been identified in India, with *Terminalia arjuna* and *Terminalia spp.* being among the most notable.

The tree is large, about 60-80 feet in height, evergreen with a spreading crown and having drooping branches. New leaves appear in the hot season (February to April). This tree is exotic in India. In India, it is found in Uttar Pradesh, South Bihar, Madhya Pradesh, Delhi and the Deccan region near ponds, rivers and banks of streams (Ali *et al.*, 2003) [1]. *Terminalia arjuna* leaves are simple, with crenulations, and are borne sub-opposite. They are coriaceous, oblong or elliptic, and have a short acute or obtuse apex. Their upper faces are pale or dark green, with a pale brown lower face. White sessile bisexual flowers appear in short auxiliary spikes or in a terminal panicle arrangement on the tree. The Arjuna is seen across the Indian Subcontinent, and is usually found growing on river banks or near dry river beds in Uttar Pradesh, Bihar, Maharashtra, Madhya Pradesh, West Bengal, Odisha, and south and central India, along with Sri Lanka and Bangladesh. It has also been planted in Malaysia, Indonesia, and Kenya. (Rastogi, 2008) [14].

Since ancient times, *Terminalia arjuna* has been valued as a source of medicine (Ayurveda, Siddha, and Unani), tannins, tassar silk, timber, and fuel (Paarakh, 2010) [11]. Farmers get high cash returns on a short-term tree harvest period by using the agroforestry (Rice + Arjun) scheme, and labour input on farms is spread more evenly across the year.

Studies on bund based agroforestry systems of *Acacia nilotica*, *Butea monosperma, and Eucalyptus* species have been done in Chhattisgarh by many workers, but similar studies related to *Terminalia species* are not available.

Materials and Methods

The present study was laid out in Randomized Block design in the experimental field of village Katalbod of Dhamtari district (C.G.), during *kharif* season (July-November) in the year 2020-21. The mean monthly temperature varies between 21 °C (December) and 35 °C (May), and the annual temperature averages 27 °C. The mean annual rainfall is 1247.0 mm, 95% of which occurs during the rainy season. About 8 months of the year are dry. Soils of this order are tropical black with tremendous swell-shrink behaviour, deep (> 50rm) with high base saturation and dominated by smectite kinds of clay minerals. These soils swell on wetting and shrink on drying, which induces the development of wide, deep cracks and a mostly angular, blocky structure. The cracking, followed by filling of cracks and swelling, results in the development of a 'galgai micro-relief.

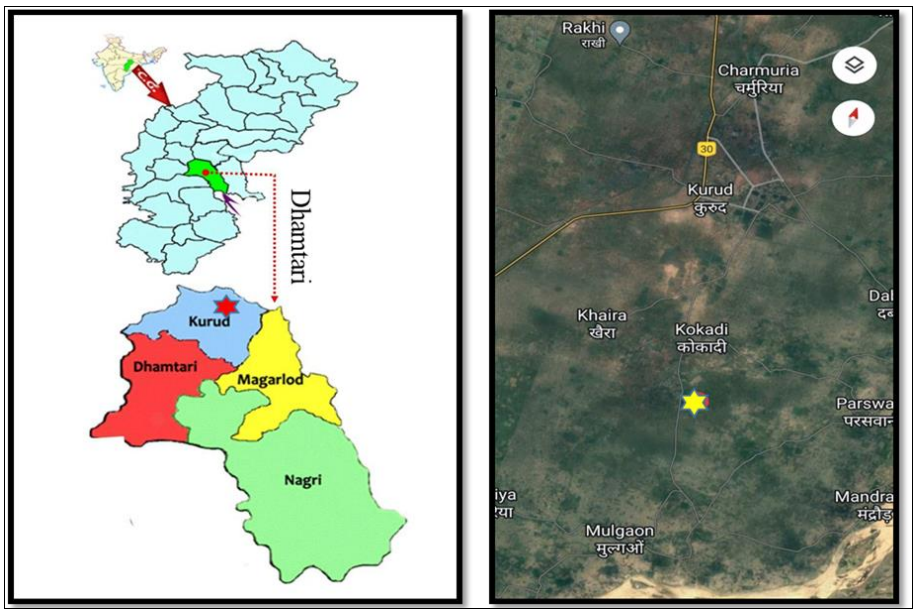

Fig 1: Map of study area

Data collection: The paddy crop variety Samba Mashuri (BPT-5204) is transplanted under *Terminalia arjuna* bund plantation. In bund plantation selection of three tree (Tree 1, Tree 2, and Tree 3) of *Terminalia arjuna* and measure the tree parameter such as girth at breast height (GBH) and crown width. The effect of *Terminalia arjuna* on paddy was estimated by studding crop parameter like number of hills/m^2, shoot length (cm), grain yield (q/ha), and straw yield (q/ha). For the measurement of paddy crop sample plots of $1m^2$ ware laid in a line running perpendicular to the tree line with 5 treatment and replicated four times, the line ware T_1(1m), T_2(3m), T_3(5m), T_4(7m), T_5(9m) and control plot(>9m considered as an open area).

In each quadrat, the number of hills was counted along with the number of tillers. The mean tiller value was multiplied with the number of hills to find out the total number of tillers in the quadrate. At harvesting, 5 tillers were removed and kept in

labelled polythene bags and brought to the laboratory from each quadrate estimate the biomass and yield. Tiller density and shoot biomass were measured when the crop was at its peak growth. The sample for grain yield was taken when the crop was harvestable. The result of various observation recorded during the experiment were statistically analysed in order to find out the significance of different treatment.

Results and Discussion

Tree dimension of *Terminalia arjuna:* The *Terminalia arjuna* trees were grows naturally on field bund in Cjhhattisgarh plain region.Tree girth, diameter at breast height (DBH) and crown width are given in Table 1. The distance from tree to tree ranged between 1.5 to 3 m. Tree DBH, and crown width ranged respectively, between 16.55 to 27.69 cm, and 5.28 m to 8.65 m.

Table 1: Tree dimension of *Terminalia arjuna*

Tree	Girth (cm)	DBH(cm)	Crown width(m)
T_1	52 cm.	16.55 cm.	5.28
T_2	64 cm.	20.37 cm.	7.57
T_3	87 cm.	27.69 cm.	8.65

T_1, T_2 and T_3 respectively represented the tree one, tree two and tree three

Number of hills m^{-2}: The number of hills increased as the distance from the trees increased in the case of all the three trees. The number of hills was highest under the control plot and lowest at the close distance of 1 m from the tree. The average number of hills ranged from 20.67±0.33 at 1 m distance to 30.00±0.58 at 9 m distance from the base line of the tree and control plot (>9 meter distance from tree bund) observed the maximum (33) number of hills.

Shoot length (cm): The shoot length of paddy was positively affected due to the bund trees of *Terminalia arjuna*. The data presented in Tables 2 indicates that the paddy crop growing on different aspects differs significantly with respect to shoot length. Among the different planting aspects, the mean shoot length ranged from (100.10±1.48 cm) was found at 9 m distance from the tree line to the mean shoot length (92.65±0.53 cm) was observed at 1 m distance from tree bund. The maximum shoot length was observe in control plot (>9 meter distance from tree bund).

Grain yield q/ha: The data given in Table 2 revealed a major difference in the average grain yield of paddy due to distance from the tree. At a distance of 9 m from tree line (45.65±5.16 q/ha) and the control plot (69.09 q/ha), the highest grain yield was observed, which was significantly higher than the grain yield recorded at other distances. The lowest average grain yield (11.35±0.53 q/ha) was recorded at 1m distance from tree line.

Straw yield q/ha: The data indicates Table 2 that, relative to all other distances, the mean straw yield of paddy reported at a distance of 9 m from the tree line (42.81±1.58 q/ha) and lowest (22.047±0.78 q/ha) at a distance of 1m. The straw yield was significantly higher than that observed on the control plot (51.91 q/ha). Data clearly indicated that the decline in straw yield successively decreased with the increasing distance from the tree line and crown width.

Yield reduction: The impact of crown width and distance from the tree line on paddy yield reduction percent is shown in Table 2 indicated that the decline in grain yield due to distance was highest (83.58±0.53%) at 1 m distance from the tree line and lowest (33.93±5.27%) at 9 m distance from the tree line.
The percent reduction in straw yield due to distance is shown in Table 2 The minimum (17.51±2.15%) straw yield reduction due to distance was observed at a 9 m distance from the tree line and the maximum (57.52±1.05%) at 1 m distance from the tree line.

Table 2: Effect of *Terminalia arjuna* trees on the performance of paddy crop under bund based agroforestry system

S. N.	Distance from tree	Average number of hills/m^2	Mean shoot length (in cm)	Mean grain yield (q/ha)	Mean straw yield (q/ha)	% reduction in grain yield	% reduction in straw yield
1.	T_1 = 1 m	20.67±0.33	92.65±0.53	11.35±0.53	22.05±0.78	83.58±0.53	57.52±1.05
2.	T_2 = 3 m	21.67±0.33	94.06±0.58	13.82±0.60	25.03±1.07	79.99±0.61	51.77±1.45
3.	T_3= 5 m	25.33±0.33	95.54±0.45	21.49±0.95	33.06±1.36	68.90±0.97	36.32±1.85
4.	T_4= 7 m	26.67±0.33	97.23±0.68	33.49±2.87	34.99±0.68	51.52±2.93	32.58±0.93
5.	T_5= 9 m	30.00±0.58	100.10±1.48	45.65±5.16	42.82±1.58	33.93±5.27	17.51±2.15
6.	Control	33.00±00	103.66±00	69.09±00	51.91±00	00	00
7.	Mean	26.22	97.21	32.48	34.98	64.50	41.26
8.	SEm±	0.23	0.56	1.98	0.79	2.86	1.52
9.	C.D. at 5%	1.50	1.80	6.32	2.53	9.15	4.86

T_1, T_2, T_3, T_4 and T_5, respectively represent 1 meter, 3 meter, 5 meter, 7 meter and 9 meter sampling distance from tree whereas control plot was taken at >9m as an open area.
The climate of study area is sub humid and soil water is not limiting to plant growth and productivity. Variation of dry matter production could rise from differences in the amount of cumulative intercepted radiation (Hamzei and Soltani 2012) [5]. Productivity of any crop depends on the total net accumulation of assimilated carbon, in general, and on photosynthetic rate per unit leaf area, in particular (Mohotii and Lawlor 2002) [9]. The effect of temperature on rice growth is well established (Shimono and Ishii, 2012; Dutta *et al.*, 2012) [17, 4]. The growth of crop is a complex process and is the resultant effect of canopy radiation capture, photosynthesis and the conversion of photosynthesis to the biomass (Shimono *et al.*, 2002) [18]. During the vegetative and reproductive periods, the limited leaf area and canopy radiation interception were the major reasons for reduced dry matter increase in rice (Shimono *et al.*, 2002) [18].
Shade is often associated with cooler temperatures during day, warmer temperatures at night, and higher air humidity and soil moisture. It may also be associated with increased herbivory (Baraza *et al.*, 2004) [2] and greater competition for below-ground resources because dense above-ground vegetation also exploits below-ground space heavily (Valladares and Pearcy 2002) [21]. Reducing light intensity, damping temperature variation and ameliorating soil conditions under the canopy are some mechanisms by which established plants facilitate other plants (Valiente-Banuet and Ezcurra 1991; Pugnaire *et al.*, 2004) [20, 13], but in most cases facilitation effects are less significant as water and nutrient availabilities become lower (Maestre *et al.*,

2006) [7]. The density and grain yield of different crops were directly related to distance from tree. The intensity of light generally increases with increasing distance from the tree trunk (Pandey *et al*., 1999) [12].

Conclusion

The results showed that the bund agroforestry of *Terminalia arjuna* (Arjuna) had an adverse effect on the growth and yield of paddy. The effect on growth resources of *Terminalia arjuna* (Arjuna) boundary plantation differs with the different DBH and crown width of the tree row and distance from the tree line. Thus, the adverse impact of the tree line on maximum growth and paddy yield near the tree line. The yield and yield characteristics of paddy increase as the distance from the line of the tree increases. The farmers allow it to grow in their agricultural fields as they consider it as important constituent of land use system as a source of fuel wood, timber, agricultural implements, rearing of tasar silk and medicinal uses. This study indicates that the potential of traditional agroforestry system needs to be developed to solve the land management (including tree management) problems of Chhattisgarh plains.

Acknowledgements

We acknowledge the help and cooperation received from the authority of IGKV, Raipur and Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya Raipur (C.G.) during the study period.

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