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Production potential of paddy (Pooja) under bund plantation of *Eucalyptus tereticornis* in Agri-Silviculture module under agroforestry system in a farmer's field, Pattamundai, Kendrapada, Odisha

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Abstract
The present investigation entitled "Production Potential of Paddy (Pooja) under bund plantation of *Eucalyptus tereticornis* in Agri-Silviculture Module under Agroforestry system in a Farmer's Field, Pattamundai, Kendrapada, and Odisha" was conducted during Rabi season of 2020-21 in a Farmer's Field, Pattamundai, Kendrapada Odisha. The main objectives are to study the yield of paddy (Pooja) under Agri-silviculture under *Eucalyptus tereticornis* and as sole crop, Comparative study of B-C ratio of paddy as a sole crop and under *Eucalyptus tereticornis* bund plantation, growth increment in DBH and height of *Eucalyptus tereticornis* during the experimental period. Observations were recorded for growth and yield parameters such as Height measurement of paddy plants in 30-day interval till the harvest of crop 150 DAP, No. of Tillers /Plant at harvest, Panicle length of Paddy at harvest, Number of grains per panicle at harvest, Seed weight of 100 grains at harvest, Paddy yield (q/ha), Straw yield (q/ha), Biological Yield, Harvest index (%), for both the sole crop and under bund plantation of *Eucalyptus tereticornis* in a 30 days interval. Height of trees present in the field bunds, Daimeter at Breast Height (D.B.H.) was measured specifically for the tree components. After analyzing and computing the data results showed that if we consider only growth parameters and economic yield of paddy, bund plantation of trees has an adverse effect on paddy (Yield reduced up to 5% as compared to sole crop). But when we calculated the B-C ratio, the B-C ratio of sole crop was 2.22 whereas the B-C ratio of crop with the bund plantation of *Eucalyptus tereticornis* was 2.55 because tree components provide a huge return primarily in terms of wood biomass when harvested after each rotation period.

Keywords: Agri-silviculture, bund plantation, Pooja, *Eucalyptus tereticornis*

1. Introduction
Agroforestry is a branch of forestry where woody perennial are deliberately grown with the annual crops simultaneously and sequentially on the same land management unit over a period of time. In coastal Odisha tree species like Palm (*Borassus flabellifer*), *Casuarina equisetifolia*, *Pongamia pinnata*, *Acacia mangium*, *Samanea saman*, *Terminalia spp*., *Dendrocalamus strictus* and *Cocus nucifera*, etc. are maintained by the farmers along with their agricultural crops as field bund plantations. Paddy *(Oryza sativa)* contributes to more than 40 percent of total food grain production in India. The total paddy production during 2019-20 was estimated at a record 117.47 million tones. The most rice-producing states in India are Chhattisgarh, West Bengal, Uttar Pradesh, Odisha, Tamil Nadu, Andhra Pradesh, Telangana, Punjab, and Bihar. Paddy covers about 69% of the cultivated area in India. It is one of the major crops, covering about 63% of the total area under food grains. In Odisha, Rice is now grown on an area of 4.4 million hectares. It accounts for 91% of the area under cereals and contributes about 94% of total cereal production in Odisha. The Pooja variety of paddy is another very popular variety of Coastal Odisha which is the late duration (150 days) and short height (90-95cm) variety. It was released and notified (1999) for cultivation in Primarily shallow & low land areas of Odisha, Assam, Madhya Pradesh, and West Bengal. Pooja variety has medium slender grains and it gives an average yield of 5.0 t/ha. It possesses field tolerance to all major diseases & pests. It can tolerate water stagnation (up to 25 cm) and is even suitable for late transplanting with aged seedlings. Eucalyptus is a very popular tree to be grown with crops. It has some very attractive properties such as Fast growth, straightness, self-pruning, and wide utilities of wood in Furniture as well as Plywood and Paper & Pulp industries. Eucalyptus wood is being used for furniture, doors, windows, fuel, pulpwood, and even as a source of rayon and essential oil.

Eucalyptus can be grown as a boundary plantation tree as well as for block plantation. But preference should be given to boundary plantation. Eucalyptus is one of the most popular species to be planted along the edges of a plantation area or bunds of agricultural fields. Eucalyptus appears to be very well incorporated and well accepted in agroforestry especially in Indian Climatic Conditions (Tejwani, 1994). Eucalyptus species have some very distinct Silvicultural properties that make them very popular among farmers for a choice of the tree component in agroforestry species. Some of the characteristics are straightness of bole, narrow crown, self-pruning ability, high growth rates, adaptability to a wide range of soils and climates, very good coppicing ability, tendency not to spread like a weed, and wide utility of wood. Eucalyptus clones are very popular among the farmers for raising as block plantations. Eucalyptus has more than 600 varieties, among 175 which are closely related to two varieties, *Eucalyptus camaldulensis* Dehnh and *E. tereticornis* Smith. These are very popular among Indian farmers. These species are drought-tolerant varieties while also capable of withstanding water logging conditions, very hot summer temperatures, and suitable for a wide range of sites (Lal *et al*.,1997) [9].

2. Materials and Methods

The experiment was carried out in a Farmer's Field, Pattamundai, Kendrapada, Odisha. The study area reclined between 20° 58' N Latitude and 86° 56' E Longitude with an altitude of 13 M above Mean sea level. The average environmental temperature is 26.8 degrees, which ranges between 13.9 °C and 37.8 °C. The relative average humidity is approximately 78.5% and ranges from 39.7% to 96.9%. The Air pressure ranges between 1005 h/Pa which is 988 Pa and is approximately 1018 Pa on average. The average annual rainfall is 1428.61 mm. The soil consists primarily of alluvium and is arable land. Mixing grey soil (Inceptisol), which covers 1,43,39023 hectares of the total area of the district, dominates the soil type (2, 64,400 ha). The experiment was carried out in the Kharif season, from October to December in 2020. Pooja variety was cultivated in a 4 ha rectangular patch inside the farmer field. *Eucalyptus tereticornis* trees were already planted on field bunds at a spacing of 3m x 3m in the year 2009. Now these trees are in harvesting stage. The paddy crop was transplanted in the month of August 2020 in the field. The field was thoroughly ploughed three times and water filled in the field then puddling has been done properly with tractor drawn puddler. The paddy crop transplanted by hand manual method at a spacing of 25x20 cm. In the field Nitrogen, Phosphorous & Potassium containing fertilizers are applied @ 200kg, 100kg and 100kg / ha respectively. Occasional weeding is done in the field as and when required manually by the field laborers. The crop was harvested in the month of December 2020 using a combined mechanical harvester. Observations were taken for duration of 90 days from October to December at a 30 days interval. The observations recorded for paddy are height measurement in 30-day interval till the harvest of crop, no. of Tillers /Plant, Panicle length of Paddy, Number of grains per panicle, Seed weight of 100 grains, Grain yield (q/ha), Straw yield (q/ha), Biological yield (q/ha) & Harvest index (%). 10 Observations were taken at 10 random quadrates (1m x 1m) each both for the sole crop and the crop under bund plantation. Then mean values were calculated and the mean values from the quadrates have been used for the Statistical analysis. The observations recorded for trees were height of trees present in the field bunds and diameter at breast height (D.B.H.). Height measurement was done using Ravi altimeter and girth at breast height was measured using a tape with an accuracy of 1mm. While calculating tree volume, volumetric equation for the species *Eucalyptus tereticornis* for Odisha State was used (State of Forest Report, 2019). The Statistical Analysis was carried out with T-Test for two tails applied in the data collected for this experiment to know significant or insignificant value of the investigation.

3. Results and Discussion

3.1 Plant Height

Results revealed that the plant height of paddy crop was significantly highest at 90 days after planting in Q6 (94.5 cm) followed by Q3, Q4, Q5 (93.3 cm), and Q10 (92.5 cm) under control *i.e* light condition and lowest in Q7 (89.3 cm) followed by Q6 (89.6 cm) Q3 and Q4 (90.2 cm) under bund plantation of *Eucalyptus tereticornis*. The observation of 120 days after planting showed that the plant height growth of paddy crop was highest in Q10 (113.9 cm) followed by Q3 (113.4 cm) under control and lowest in Q3 (108.9 cm) followed by Q6 (109.1 cm) under bund plantation of Eucalyptus. At harvesting time *i.e* 150 days after planting the plant height of paddy was highest in Q9 (127.8 cm) under control and the lowest was in Q2 andQ8 (123.5cm) under the bund plantation of *Eucalyptus tereticornis* tree.

Table 1: Plant height (cm) of paddy (Pooja) at various growth stages under control farming and *Eucalyptus tereticornis* based agroforestry system

Quadrates	Plant Height on 90 days in cm		Plant Height on 120 days in cm		Plant Height on 150 days in cm	
	Control	Under the bund plantation of eucalyptus	Control	Under the bund plantation of eucalyptus	Control	Under the bund plantation of eucalyptus
Q1	92	91.8	112.2	109.4	124.8	124.8
Q2	91.7	90.5	110.7	109.7	127.6	123.5
Q3	93.3	90.2	113.4	108.9	126.4	124.7
Q4	93.3	90.2	111.2	110.7	124.9	124.8
Q5	93.3	92	112	109.2	126.9	123.6
Q6	94.5	89.6	110.8	109.1	127.2	125.6
Q7	92.1	89.3	111.6	110.6	127.1	124
Q8	92.2	91.5	112	111.9	125.7	123.5
Q9	92.2	91.8	112.3	110.3	127.8	125.9
Q10	92.5	90.4	113.9	110.8	125.2	124
t Stat	4.19		4.53		4.58	
T critical two-tail	2.26		2.26		2.26	
Significant /non-significant	Significant		Significant		Significant	

The data on plant height also showed that under the bund plantation of *Eucalyptus tereticornis* growth of paddy was slightly less than control open field i.e light condition and as a result, the lowest plant height was observed under the bund plantation of Eucalyptus and the highest plant height was observed under control condition. Similar observations were also recorded by Bahar (2006) [1], Nazir, *et al*., (1993) [11], Verma *et al*. (2014) [19]. The shade effect of trees and competition for growth factors between trees and crop plants may be the reason for the reduction in plant height of paddy under Eucalyptus trees planted on bunds. The variation in plant height at different sites may be due to the difference in soil nutrient availability and the difference in crown spread.

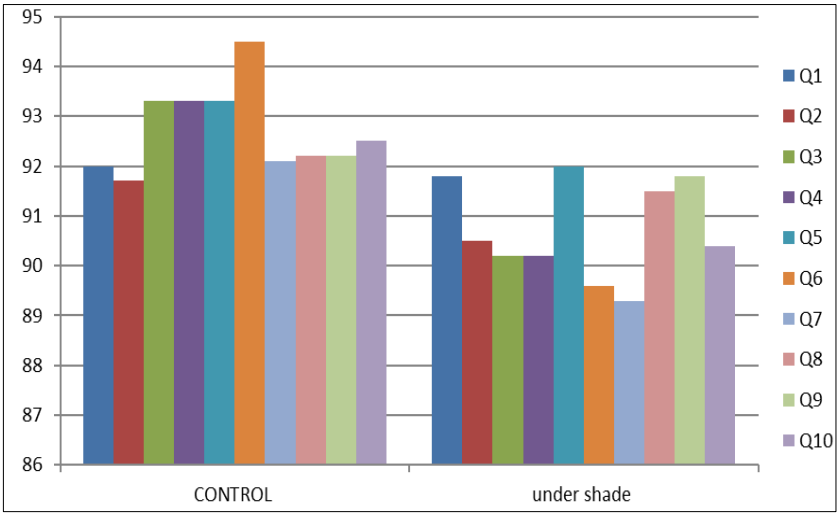

Fig 1: Height growth of paddy (Pooja variety) in control and under shade condition at 90 DAP

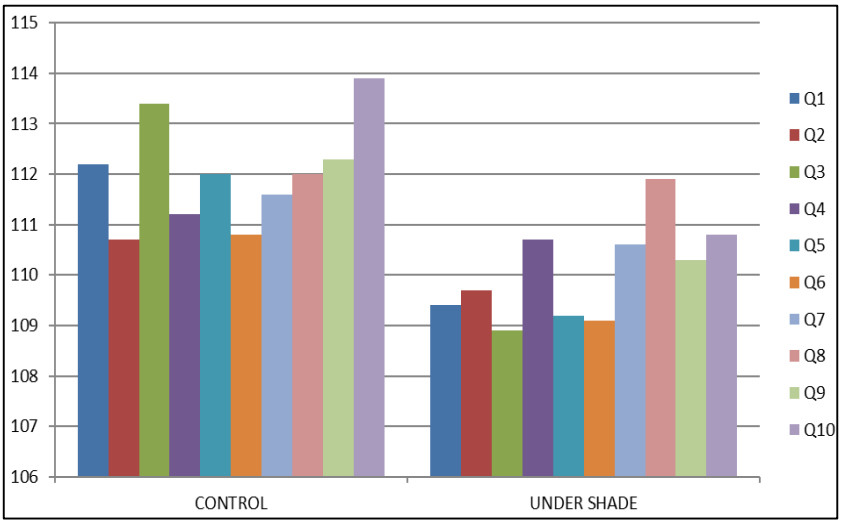

Fig 2: Plant Height of paddy (Pooja variety) in control and under shade condition at 120 DAP

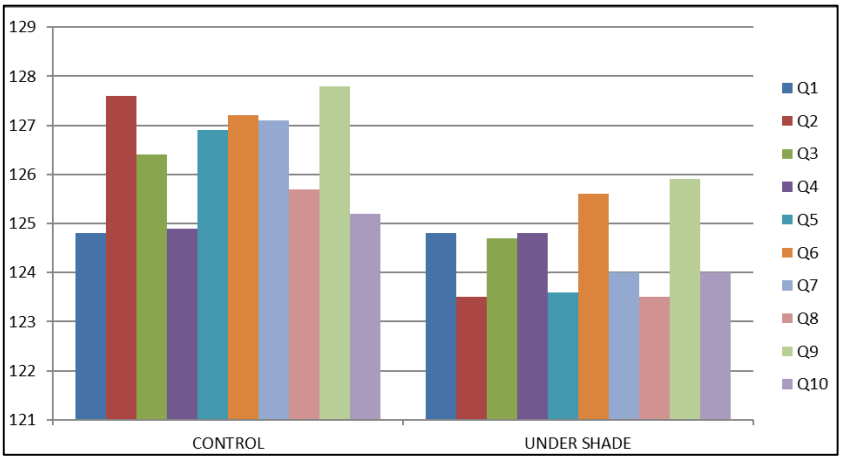

Fig 3: Plant Height of paddy (Pooja variety) in control and under bund plantation field condition at 150 DAP

Table 2: No of Tillers Plant^{-1}, Panicle length of paddy, No of Grains Panicle^{-1}, Weight of 100 grains (g) in the Paddy Field in Pattamundai, Kendrapada, Odisha

Quadrates	No of Tillers Plant^{-1} at harvest		Panicle length of paddy at harvest		No of Grains per Panicle at harvest		Weight of 100 grains (g) at harvest	
	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation
Q1	9.7	10.3	25	24.1	296.4	298.8	2.292	2.098
Q2	10.6	9.7	25.5	24.4	302.4	290	2.134	2.08
Q3	10	9.4	25.5	23.1	304.4	301.6	2.145	2.138
Q4	10	9.6	24.6	23.6	289.6	292	2.208	2.011
Q5	10.1	9.5	25	24.9	313.6	300.8	2.125	2.074
Q6	10.5	10.2	25.6	23.3	305.2	300.8	2.211	2.124
Q7	9.8	9.5	25.1	24.4	314.4	280.8	2.153	2.012
Q8	9.5	9.3	25	23.1	296.8	292	2.281	2.16
Q9	10	9.5	25.2	24.4	301.2	287.2	2.117	2.099
Q10	10	10	24.5	24.6	313.6	290.4	2.159	2.013
t Stat	2.48		4.13		2.85		4.67	
T critical two – tail	2.26		2.26		2.26		2.26	
Significant/non-Significant	Significant		Significant		Significant		Significant	

Table 3: Paddy Grain yield, Straw yield, Biological yield, Harvest index of cultivated Field in Pattamundai, Kendrapada, Odisha

Quadrates	Grain yield		Straw yield		Biological yield		Harvest index	
	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation	sole crop	Under bund plantation
Q1	4.524	4.26	5.685	5.467	10.20	9.72	44.31	43.8
Q2	4.842	4.01	5.821	4.936	10.66	8.94	45.41	44.82
Q3	4.596	4.066	4.772	5.019	9.368	9.08	49.06	44.76
Q4	4.927	3.973	5.772	4.421	10.69	8.39	46.05	47.33
Q5	4.758	3.899	5.577	4.702	10.33	8.60	46.04	45.33
Q6	4.616	4.127	4.751	5.281	9.367	9.40	49.28	43.87
Q7	4.78	4.052	5.845	4.825	10.62	8.87	44.99	45.65
Q8	4.851	4.169	5.691	5.139	10.54	9.30	46.01	44.79
Q9	4.604	4.137	5.391	5.496	9.995	9.63	46.06	42.95
Q10	4.957	3.973	5.919	5.167	10.87	9.14	45.58	43.47
t Stat	9.09		2.45		4.50		2.38	
T critical two – tail	2.26		2.26		2.26		2.26	
Significant/non-Significant	Significant		Significant		Significant		Significant	

No of tillers per plant

The no of tillers per plant was significantly highest in Q2 (10.6/plant) followed by Q6 (10.5/plant) and Q5 (10.1/plant) under control *i.e* light condition and lowest in Q8 (9.3/plant) followed by Q3 (9.4/plant) and Q5, Q7, Q9 (9.5/plant) under bund plantation of *Eucalyptus tereticornis*. The data on no of tillers per plant also showed that under the bund plantation of *Eucalyptus tereticornis* no of tillers of paddy was less than under control *i.e* light condition which is in line with the findings of Sharma (1992) [15] and Verma *et al*. (2014) [19]. The maximum no of tillers per plant of paddy reported under control condition it may be due to more interception of solar radiation by paddy crop (Kiran and Agnihotri, 2001) [8]. The maximum reduction in no of tillers per plant in shade condition can be due to low light intensity and the low temperature caused by plantation of Eucalyptus trees on bund. Significantly highest panicle length was observed also recorded in Q6 (25.6 cm) followed by Q2, Q3 (25.5 cm), and Q9 (25.2 cm) in open condition and lowest in Q3, Q8(23.1cm) followed by Q6(23.3cm) and Q4 (23.6 cm) under shade condition.

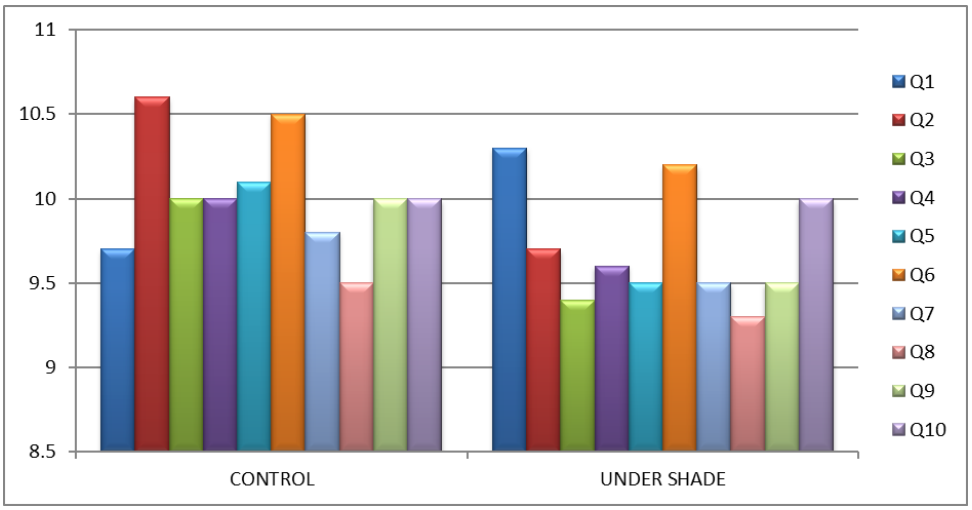

Fig 4: No of tillers per panicle in control and under shade condition

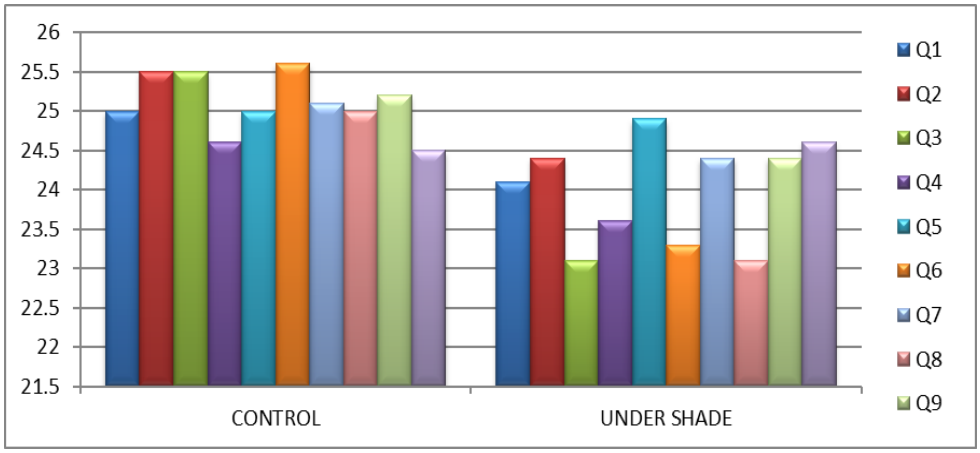

Fig 5: Panicle length of paddy (cm) in control and under shade condition

No of grains per panicle and Seed weight of 100 seeds

The result revealed that a statistically maximum number of grains per panicle was recorded in Q7 (314.4/panicle) followed by Q5, Q10 (313.6/panicle), and Q6 (305.2/panicle) in open conditions. The minimum number of grains per panicle was found when the crop was grown under bund plantation of eucalyptus in Q7 (280.8/panicle) followed by Q9 (287.2/panicle) and Q2 (290/panicle). The number of grains per panicle was significantly influenced by sunlight and bund plantation of eucalyptus. The maximum 100 grain weight was found in Q1 (2.292 gm) followed by Q8 (2.281gm) and Q6 (2.211 gm) when the crop was grown at open (control) condition and the minimum was found in Q4 (2.011 gm) followed by Q7 (2.012 gm) and Q10 (2.013gm) when the crop was grown under bund plantation of *Eucalyptus tereticornis*. The 100-grain weight was significantly influenced by sunlight and bund plantation of tree components.

Nazir *et al*., (1993) [11] stated that increasing the duration of shading may decrease the number of 1000-grain weight, grain protein concentration, and grain yield. Similarly, Jiang *et al*., (1994) [6] stated that total grain yield was affected by the tree crown area.

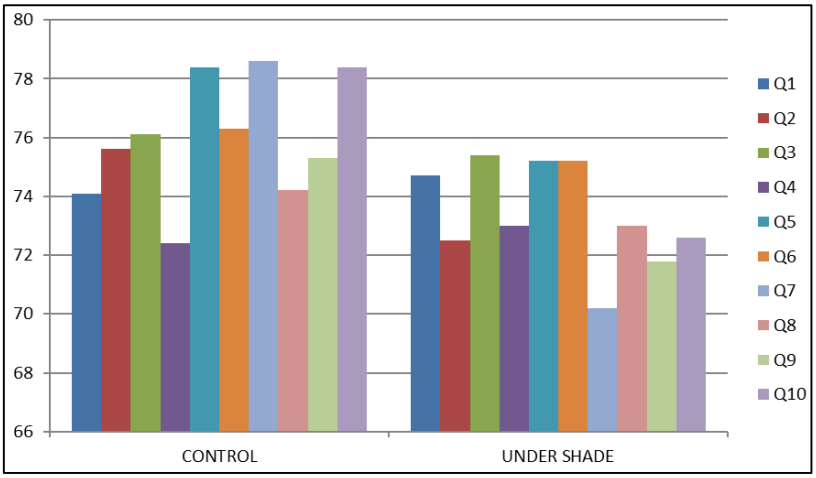

Fig 6: No of grains per panicle in control and under shade condition

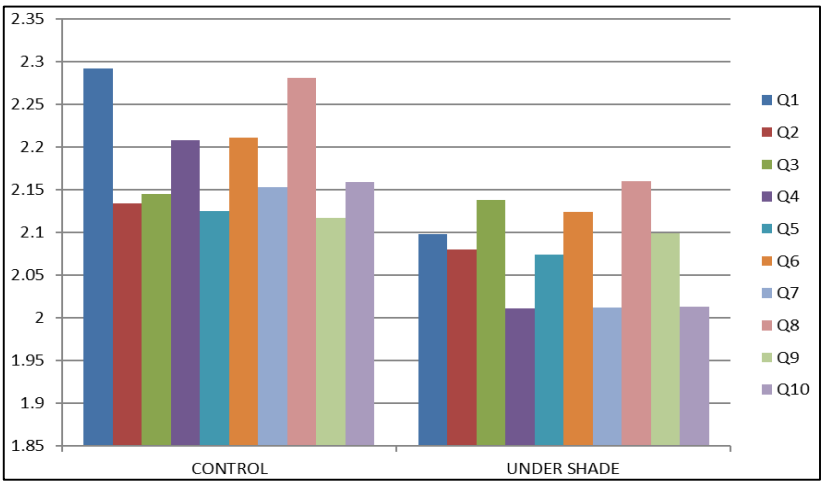

Fig 7: Weight of 100 grains (gm) in control and under shade condition

The variation in yield attributes of paddy (Pooja variety) was may be due to the difference in light availability. The solar radiation is greater in case of the open agricultural field than those of other factors of the study. Overall, there was a slight reduction in the yield attributes of agricultural crops due to the competition for light, water, and nutrients among trees and paddy crops at both sites. Similar findings have also been reported by Tomar and Srivastava (1986) [17], Newaj *et al.* (2003), and Chauhan *et al.* (2012). A number of workers have also reported a reduction of yield components due to shading effects; for example, reduced number of effective tillers (Kemp and Whingwiri, 1980) [7], reduced number of grains (Rawson and Ruwali, 1972; Fischer 1975) [14, 5], reduced weight of grain (Fischer, 1975; Kemp and Whingwiri, 1980) [5, 7].

Grain yield

The maximum number of grain yield was found at Q10 (4.957 t/ha) followed by Q4 (4.927 t ha-1) and Q8 (4.851 t ha-1) in the sole crop and the minimum was found in Q5 (3.899 t ha-1) followed by Q4, Q10 (3.973 t/ha) under bund plantation of eucalyptus. The grain yield was significantly influenced by light and bund plantation of tree. Due to the bound planting of *Eucalyptus tereticornis*, the grain yield of rice was slightly adversely affected means less. Similar findings have also been reported by Dhillon *et al.* (1984), Sharma (1992) [15], and Verma *et al.* (2014) [19]. Sharma *et al.*,(1992) [15] stated that the reduction in the yield of rice grown in association with trees reflects competition for growth resources such as radiant energy, nutrients, and moisture. As paddy is light demanding crop but under filtered light near trees existing on bund the shade effect was recorded in overall growth of the crop but the loss of production can be compensated with wood biomass is much higher as sole cropped field.

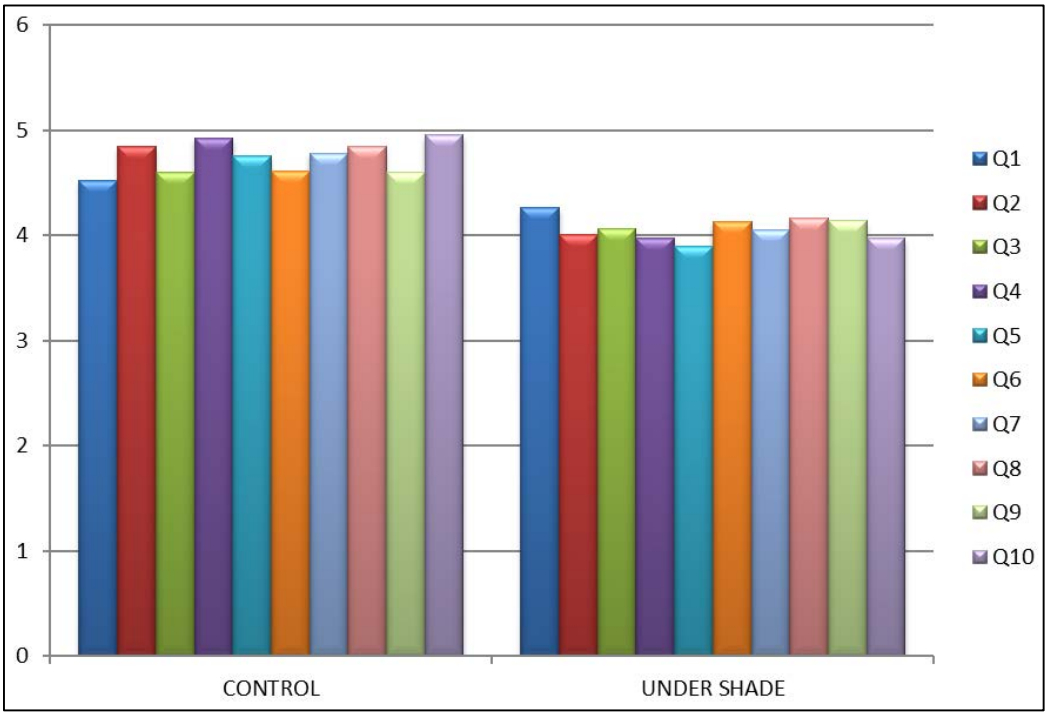

Fig 8: Grain yield per ha (tonne) in control and under shade condition

Straw yield

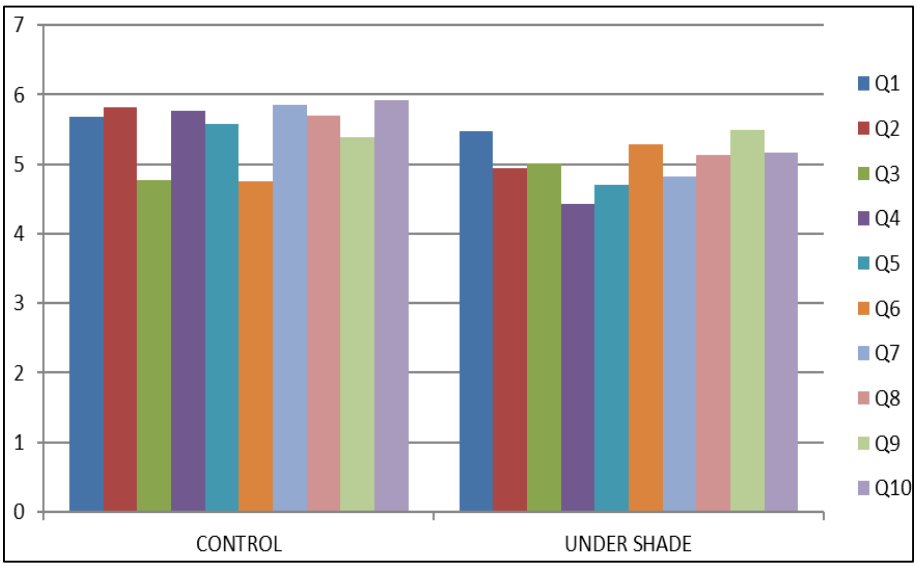

Fig 9: Straw yield per ha (tonne) in control and under shade condition

Biological yield and straw yield

The maximum straw yield was found in Q10 (5.919 t/ha) followed by Q7 (5.845 t/ha) and Q2 (5.821 t/ha) when the crop was grown at open (control) condition and the minimum was found in Q4 (4.421 t ha-1) followed by Q5 (4.702t ha-1) and Q7 (4.825 t ha-1) when the crop was grown under bund plantation of eucalyptus. The straw yield was significantly influenced by light and bund plantation of tree. A significantly higher biological yield was observed in the open (control) condition in Q10 (10.876 t ha-1) followed by Q4 (10.699 t/ha) and Q2 (10.663 t/ha). The minimum biological yield was found in Q4 (8.394t/ha) followed byQ5 (8.601 t/ha) and Q7 (8.877 t/ha) when the crop was grown under bund plantation of the eucalyptus tree. The biological yield was significantly influenced by the light and bund plantation of tree.

The instantaneous change in light intensity has a profound impact on the crop's photosynthetic response (Knapp and Smith, 1990), and the adverse effect on the yield and yield characteristics of rice might mainly be due to the decreased availability of photosynthetically active radiation (PAR) since it has been found that the rate of biomass production in many cereal crops is proportional to the PAR (Nandal *et al*., 1999) [10]. Ultimately, the decreased temperature due to the shading effect results in the rice crop's decreased water temperature, leaf temperature, leaf water ability, and leaf water quality and ultimately decreases the crop's yield and yield characteristics (Tripathi *et al*.,2005) [18].

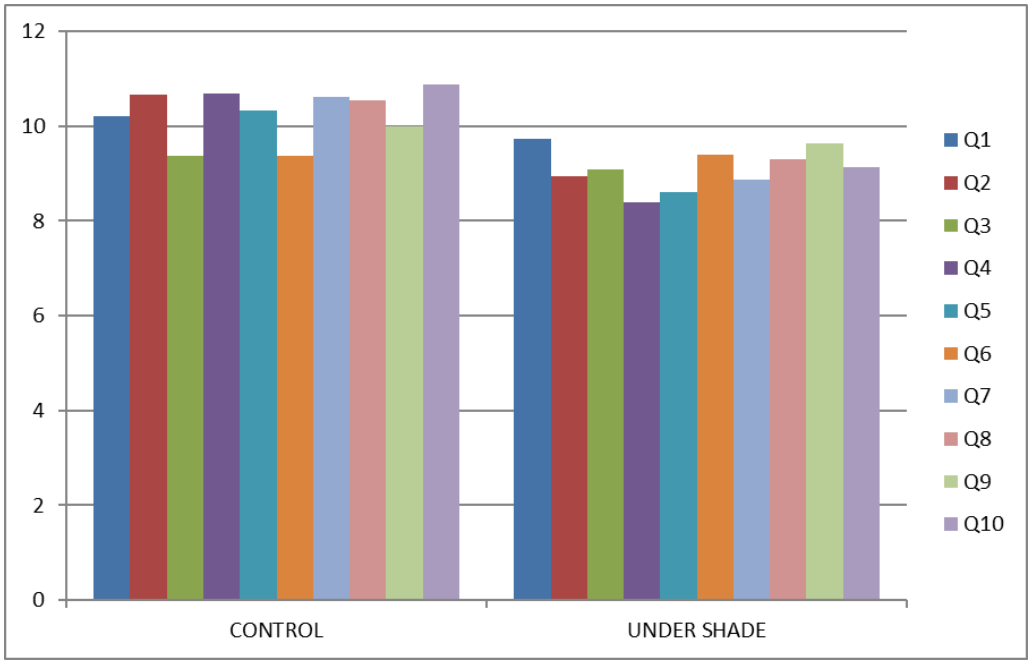

Fig 10: Biological yield per ha (Tone) in control and under shade condition

Harvest index

Maximum harvest index was found in Q6 (49.28 %) followed by Q3 (49.06%) and Q9 (46.06%) when the crop was grown in open (control) condition and minimum were found in Q9 (42.95%) followed by Q10 (43.47%) and Q1 (43.8%) under bund plantation of eucalyptus. The harvest index (%) was significantly influenced by light and bund plantation of tree.

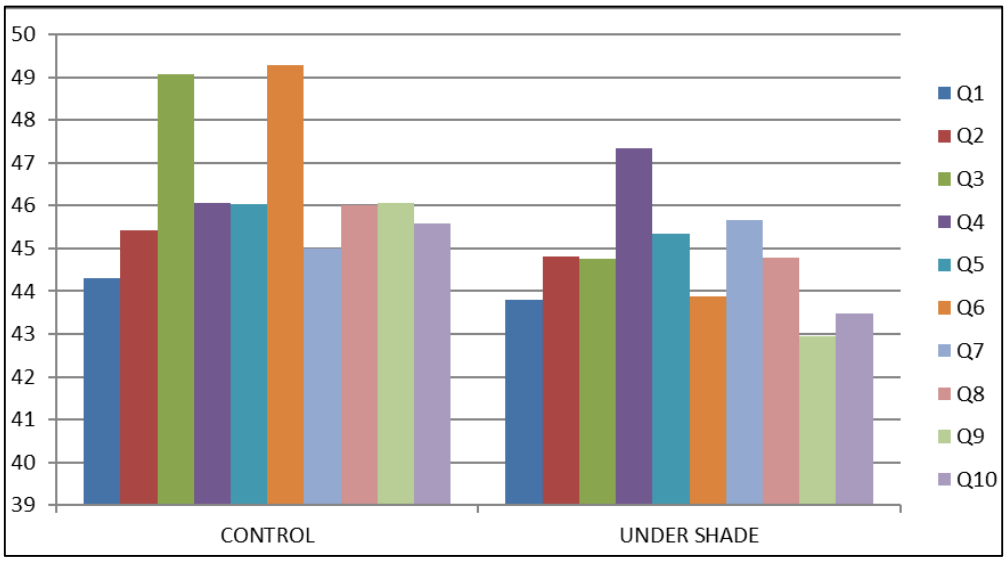

Fig 11: Harvest index (%) in control and under shade condition

Overall the reduction in the yield of intercrops due to the presence of trees may be attributed to differential patterns of canopy spread resulting in variation in light interception (shade effects) and competition of the tree roots for nutrients and moisture. These results are in confirmation with the findings of Sharma *et al.* (1996). The reduction of biological yield was due to the reduction in yield contributing factors (plant height, no of tillers and100-grain weight), which may have been affected by the micro-environmental changes *i.e.* solar radiation and air temperature under the canopy. The variation in harvest index between different sites may be due to the fact that different sites differ with respect to their grain and biological yield potential. These results are similar to those reported by Dhillon *et al.*(1984) [4], Vityakon *et al. (*1995), Bhardwaj *et al.(*2005), Chauhan *et al*.(2012).

B-C Ratio of cultivated paddy crop under bund plantation and as sole crop field: The B: C ratio is significantly higher in the eucalyptus and paddy-based agri-silviculture system (2.55) than in control farming (2.22). In comparison to control farming Eucalyptus-based agri-silviculture system provides more benefit. The reason behind more benefit in the agri-silviculture system than control farming is the production of wood from tree component. These results are similar to those reported by Rani *et al.*, (2016) [13].

Table 4: Cost of cultivation of Paddy (Rs. ha^{-1}), Gross return (Rs. ha^{-1}), net return (Rs. ha^{-1}) & B-C ratio of both the Experimental sites

	***Eucalyptus tereticornis* and paddy(Pooja variety) based agri-Silviculture system**	
	Sole crop	**Under eucalyptus based agri-silviculture system**
Cost of cultivation (Rs. ha^{-1})	45,650	52,390
Gross return (Rs. ha^{-1})	1,01,500	1,33,760
Net return (Rs. ha^{-1})	55,850	81,370
B-C ratio	2.22	2.55

Growth of *Eucalyptus tereticornis*

There is a significant increase in tree height in the period of planting of paddy to the harvesting of paddy crop. The initial mean height of *Eucalyptus tereticornis* before planting of paddy was 8.60m and after harvesting of crop the tree height increases to 8.64 m.

There is a significant difference in D.B.H of eucalyptus at before planting of paddy and after harvesting of paddy. D.B.H of eucalyptus has increased after harvesting of paddy from the D.B.H of eucalyptus before planting of paddy. The initial mean D.B.H of eucalyptus was 24.23cm and after harvesting of paddy the D.B.H of eucalyptus increases to 24.96 cm.

Table 5: D.B.H (cm) and Height of *Eucalyptus tereticornis* before and after harvesting of Paddy

Name of species	**Mean D.B.H (cm)**		**Mean Height (m)**	
	Before planting of paddy crop	**After harvesting of paddy crop**	**Before planting of paddy crop**	**After harvesting of paddy crop**
Eucalyptus tereticornis	24.23	24.96	8.60	8.64

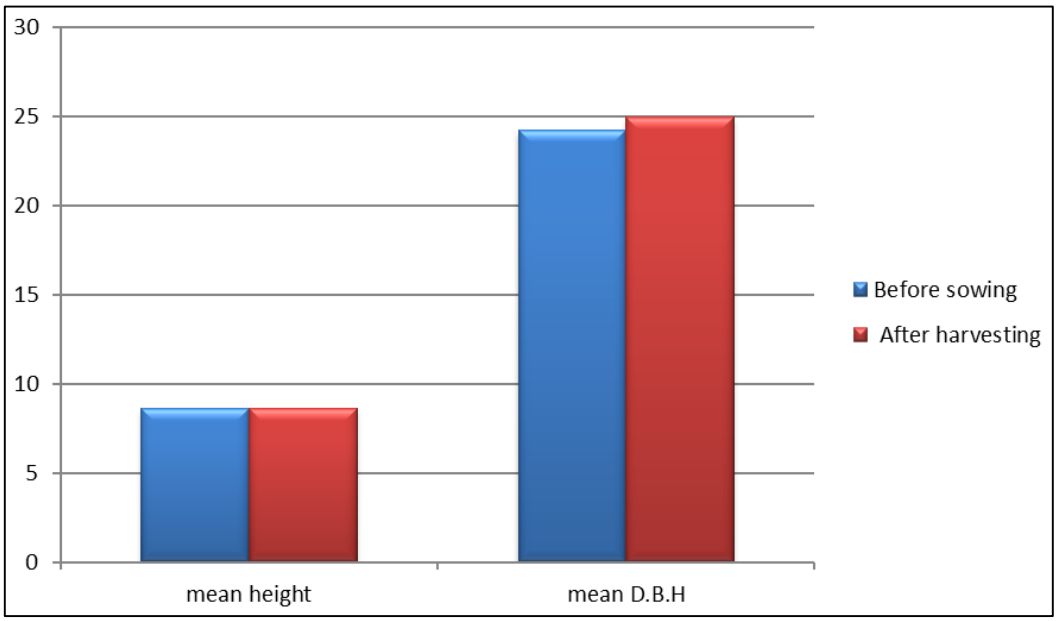

Fig 12: D.B.H (cm) and Height (m) of *Eucalyptus tereticornis* before and after harvesting of the crop

From the above observation of this investigation, it is revealed that the tree height and DBH both increase when intercropped with paddy and tree growth and survival are unaffected by paddy crop and no disease or pests are found in either the forest or Agricultural crops. The mean D.B.H and mean height of Eucalyptus significantly increased from initial cropping time to the harvesting time of the crop**.** These results are similar to those reported by Couto and Gomes (1995) [3], Mohsin *et al.*, (1996).

4. Conclusion

The above observation showed that under agroforestry system the different yield attributes of paddy crop such as plant height, no of tillers per plant, panicle length, no of grain per panicle, the weight of 100 grains, grain yield per ha was very slightly reduced as compared to control crop field where paddy was cultivated as a sole crop. In agroforestry system, the maximum gross return or B-C ratio was obtained from the Eucalyptus-Paddy (Pooja variety) based Agri-silviculture system, and on the other hand gross return or B-C ratio from control farming was found lower than Eucalyptus-paddy (Pooja) based Agri-silviculture system. Agroforestry system compare to the traditional farming system where paddy is grown as a sole crop. Although the grain yield of paddy was reduced slightly under agroforestry system due to shade effect of tree component compare to control farming but in the end, the loss of grain yield would be overcome through the wood biomass yield from the tree component and overall agroforestry system was found more remunerative economic benefit to the farmer than traditional farming of paddy *i.e* as a sole crop. Thus it can be concluded that the farmers should go with an agroforestry system instead of traditional farming in the region of Kendrapada district of Odisha for more economic benefit from a single piece of land by appropriate utilization of moisture and nutrient of the land through agroforestry system. The tree planted on field bund having positive impact on microclimate of field and in maturity it provides lot of income through wood biomass this system is very sustainable agriculture system.

Plate 1: Observations taking in the experimental Paddy Field in Pattamundai, Kendrapara, Odisha

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