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Ganesha BH
Ph.D., Scholar, Department of Silviculture and Agroforestry, College of Forestry, Sirsi, Karnataka, India

Sahu ML
Senior Scientist, Department of Forestry, JNKVV, Jabalpur, Madhya Pradesh, India

Mahesh Naik BL
Ph.D., Scholar, Department of Silviculture and Agroforestry, College of Forestry, Sirsi, Karnataka, India

Venkatesh L
Scientist, Department of Agroforestry, ICAR-Krishi Vigyan Kendra, Sirsi, Karnataka, India

Corresponding Author:
Ganesha BH
Ph.D., Scholar, Department of Silviculture and Agroforestry, College of Forestry, Sirsi, Karnataka, India

Assessment water productivity under different pruning intensities in Dalbergia sissoo: Wheat based Agri-Silviculture system

Ganesha BH, Sahu ML, Mahesh Naik BL and Venkatesh L

Abstract
Water is essential for all living beings but in the present context water availability is decrease in rapid way. Along with this per capita land availability is also decreasing due to varies developmental activities. Now it is the time to switch on to the research that increases more biomass per unit drop of water. Our study was carried out during 2015-16 in combination of *Dalbergia sissoo* and wheat agroforestry system in rabi season. It is expressed in terms in terms of equivalent grain production kg per m^3 or kg per cm depth of water used. Wheat equivalent water productivity (WEWP) of 17 year *Dalbergia sissoo*-wheat agrisilviculture system under four pruning treatment was evaluated in central India. Four treatments *viz.* no pruning 0% (P_0), light pruning 25% (P_{25}), moderate pruning 50% (P_{50}) and high pruning 75% (P_{75}) were taken. Our study reveals that Wheat grain yield was significantly superior in P_{75} (3066 kg ha^{-1}) to the other treatments. Grain yield of P_{50} (2654 kg ha^{-1}) was significantly superior to P_{25} (2136 kg ha^{-1}) and P_0 (1826 kg ha^{-1}). The water productivity (kg ha^{-1} cm^{-1}) of agroforestry system in rabi season in response to different pruning intensities (P_0, P_{25}, P_{50} and P_{75}) shows that among the different pruning intensities, the water productivity of P_{25} is highest (255 kg ha^{-1} cm^{-1}) followed by P_{50} (249 kg ha^{-1} cm^{-1}), P_{75} (189 kg ha^{-1} cm^{-1}) and P_0 (196 kg ha^{-1} cm^{-1}).

Keywords: Water productivity, agroforestry, pruning

Introduction

Water is essential for survival of all living beings including from small tiny organisms to big trees and animals. Due to the rapid growth in world population, the pressure on water resources is increasing (Rijsberman, 2006) [18]. In systems where water is becoming the limiting factor, agricultural production should be expressed per unit of water consumed instead of production expressed per unit land. It is inevitable that the production per unit water consumed, the water productivity must be increased to meet this challenge. The need to increase water productivity is a growing global concern as the World Commission on Water has estimated that demand for water will increase tremendously for the next 30 years and approximately half of the world's population will experience conditions of severe water stress by 2025 (Ong *et al*. 2006) [14]. Higher water productivity reduces the need for additional water and land resources in irrigated and rainfed systems. Total eradication of hunger in India requires around 1,860 km^3 $year^{-1}$ of water by 2030 and more than 2,000 km^3 $year^{-1}$ by 2050, increases by 160 & 180 percent compared to the current consumption of water, which already contributes to depleting of several large rivers before they reach the ocean (SEI, 2005). Along with this per capita availability of land has declined from 0.48 ha in 1950 to 0.12 ha in 2004 (Sahu 2006) [20]. Together, the increasing food demand and decreasing water allocation suggest that the agriculture sector has to produce more food with less water (Cai *et al*. 2010) [2].

However, in many tropical areas the main factors determining the success or failure of agroforestry systems is usually either water availability or physical constraint (Singh *et al.*, 1989) [23]. Agroforestry may improve productivity by increasing the proportion of annual rainfall capture and it is the most effective in utilizing available soil moisture. One of the principal biophysical premises of agroforestry in dry land systems is to conserve and maximize the use of limited water supplies (Broadhead *et al.*, 2003) [1]. Potential to maintain higher levels of biodiversity and greater biomass than mono crop or pasture system (Seeta *et al*. 2016) [22]. Water conservation and more productive use of water is one of the key benefits of agroforestry (Ong and Swallow 2003) [13].

Tree pruning is a common management practice in agroforestry for mulching and reducing competition between the annual and perennial crop (Peter and Lehmann, 2000) [5]. Pruning of tree is a powerful approach to regulate light, nutrients and other resources competition (Frank and Eduardo, 2003) [7]. Generally canopy management will often have direct bearing on root characteristics as well as growth, vigor and biomass of tree itself (Thakur and Singhl 2000) [24]. Generally unmanaged tree canopy not only reduces the productivity of agricultural crops, but in most cases deteriorates the quality of the produce as well (Duguma *et al*. 1988) [6].

By considering the above facts, the experimental study was carried with objectives of “Assessment of water productivity under different pruning intensities in *Dalbergia sissoo* - Wheat Agrisilviculture system” and “evaluation of water productivity under different farming practices in *Dalbergia sissoo* - Wheat Agrisilviculture system”.

Materials and Methods

Experimental study was carried out during rabi season of 2015-16, in seventeen year old *Dalbergia sissoo* Roxb., plantation in India. These trees were planted in July 1998 with 5 m x 5 m planting geometry. Wheat was grown in *rabi* season as a intercrop. The water productivity of different pruning intensities was determined. In addition water productivity was also determined for four pruning treatments and three combinations of nitrogen dose and seed rate.

Study Area

Study area lies at 23º12’50” North latitude and 79º57’56” East longitude. The area belongs to Kymore Plateau and Satpura Hills Agro-climatic Zone as per the classification of National Agricultural Research Project of India. Study area enjoys a typical subtropical climate with hot dry summer and cool dry winter. Temperature varies between minimum temperatures of 2 ^{0}C in December-January to maximum temperature of 46 ^{0}C in May–June. Based on 20 years mean meteorological data, the average annual rainfall of the area is 1350 mm, which mostly received between mid-June to end of September with few occasional winter showers during December and January. Generally relative humidity remains very low (20 to 23%) during summer, moderate (60 to 75%) during winter and high (80 to 95%) during rainy season.

Table 1: Experimental Details

Treatment	Details
Number of replications	5
P_0	No pruning
P25	Pruning up to 25% of total tree height
P50	Pruning up to 50% of total tree height
P75	Pruning up to 75% of total tree height
Design	Strip plot

Observations

Various observations on meteorological parameters (daily rainfall and daily pan- evaporation), soil physical parameters (soil texture and water holding capacity of soil), tree growth parameter (diameter at breast height) and crop yield parameters (grain yield and straw yield) were recorded.

Data compilation

By using FAO method (1974) the effective rainfall was derived. For the estimation fuel wood and timber different allometric models (Sahu *et.al*, 2015) [21] were used.

Outputs

Output of different practices was grain and straw in case of agriculture, wood in case of silviculture and grain, straw and wood in case of agroforestry. Wood was further classified as large-sized timber (diameter ≥ 10 cm), small-sized timber (diameter < 10 cm and ≥ 7cm) and fuel wood (diameter < 7 cm). All outputs were converted into wheat equivalent yield considering the current market prices of the produces. The market prices were Rs 16 kg^{-1}, Rs 5 kg^{-1}, Rs 5 kg^{-1}, Rs 17200 m^{-3} (Rs 500 ft^{-3}) and Rs 27600 m^{-3} (Rs 800 ft^{-3}) respectively for wheat grain, straw, fuel wood, small-sized timber and large-sized timber.

Seasonal Increment of Tree Output

Diameters at breast height were recorded just prior to rabi season (November 2015). On the basis of diameter at breast height the quantity of large sized timber, small sized timber and fuel wood was derived for November 2015, considering the local volume equations (allometric models). Similarly again at the end of rabi season (May 2016) the diameters at breast height were recorded for each tree. The quantity of large sized timber, small sized timber and fuel wood was derived for May 2016 for each tree. The respective growth difference of each tree for May 2016 and November 2015 was taken as seasonal increment and considered for water productivity determination.

Water Used

It includes the effective rainfall, irrigation and percolation. The effective rainfall has been derived by Potential Evapotranspiration / Precipitation Ratio Method (Dastane 1978) [3], considering daily rainfall, mean monthly pan-evaporation and soil moisture holding capacity. Irrigation was applied by pipe irrigation method. The depth of irrigation water was measured by collecting it into drum in the field. The depth of percolation was calculated on the basis of actual pounding period of rainfall on the field.

Water Productivity

The wheat equivalent yield (WEY) was divided by the depth of total water used to determine the water productivity of each treatment. The water productivity was computed using the following formula:

$$\text{Water productivity (kg ha}^{-1}\text{ cm}^{-1}) = \frac{\text{Wheat equivalent yield (kg ha-1)}}{\text{Water use (cm)}}$$

Results and Discussion

Effect of pruning and package of practices on total WEY of crop component

It was observed that the grain yield varies significantly within different pruning intensity. Grain yield was significantly superior in P_{75} (3066 kg ha^{-1}) to the other treatments. Grain yield of P_{50} (2654 kg ha^{-1}) was significantly superior to P_{25} and P_0. P_{25} (2136 kg ha^{-1}) was significantly superior P_0 (1826 kg ha^{-1}). Grain yield were in order of $P_0 < P_{25} < P_{50} < P_{75}$. (Table 2)

The trend of straw yield was exactly similar to grain yield. Straw yield in each treatment was significantly superior to each other. It was also in the order of $P_0 < P_{25} < P_{50} < P_{75}$.

LST (Large sized timber): Quantity of large sized timber produced during Rabi season were significantly superior in P_{25} (2.67 m^3 ha^{-1}) and P_{50} (2.60 m^3 ha^{-1}) as compare to P_0 (1.42 m^3 ha^{-1}). The quantity of LST in P_0. (1.42 m^3 ha^{-1}) and P_{75} (1.96 m^3 ha^{-1}) (Table 2). SST(Small sized timber): The quantity of small size timber were at par in all the pruning intensity with numeric value as 0.18 m^3 ha^{-1} (P_0), 0.25m^3 ha^{-1} (P_{25}), 0.20 m^3 ha^{-1} (P_{50}) and 0.31m^3 ha^{-1} (P_{75}) (Table 2). Fuel Wood: Similar to SST, the fuel wood quantity were at par in all the pruning intensities with numeric value as 387 kg ha^{-1} (P_0), 361 kg ha^{-1} (P_{25}), 398 kg ha^{-1} (P_{50}) and 369 kg ha^{-1} (P_{75}) (Table 2).

It makes the conclusion that the different pruning intensity affects the yield of grain due to the less penetration of sunlight on understory crop. The yield under 0% pruning intensity affected more than other pruning intensities. These results were conformity with the findings of (Islam *et al*., 2006) [10] in *Dalbergia sissoo*- rice agroforestry system. Handa *et al*. (2007) [9] Black gram under *Hardwickia binata, Anogeissus pendula and A latifolia* where they reported that under 75% pruning intensity the yield of understory crop is higher in compare to yield of crop under 0% pruning intensity. Similar result was also reported by Okun et.al. (2001) [12] for the combination of Maize under *Albizia procera*. This may be due to fact that tree canopy could affected the penetration of light and due to shading effect on the under storey annual crops, growth is effected (Dauzata and Eroy, 1997, Upadhyaya and Nema, 2003) [4, 25]. Handa and Rai (2001-02) [8] tried 10, 25, 50, and 75% canopy pruning of different tree species and reported better performance of intercrop with 75% canopy pruning of tree. Droppelmann *et al.* (2000) [5] was also reported that pruning in *Acacia Saligna* Increased the yield of intercrop as compared to unpruned trees.

Table 2: Effect of pruning intensities on wheat yield, LST, SST and FW yield

Pruning intensity	Wheat yield (kg ha^{-1})			LST (m^3 ha^{-1})	SST (m^3 ha^{-1})	FW (kg ha^{-1})
	Grain	Straw	Total			
P_0- No pruning	1826	2647	2653	1.42	0.18	387
P_{25}-25% pruning	2136	3097	3103	2.67	0.25	361
P_{50}-50% pruning	2654	3848	3856	2.60	0.20	398
P_{75}-75% pruning	3066	4445	4455	1.96	0.31	369
S.Em+	146	212	213	0.31	0.04	51
CD (P=0.05)	451	654	655	0.96	NS	NS

Influence of different pruning intensity on total wheat equivalent yield

Wheat grain and straw yield are the produce of crop. The straw yield was converted into wheat equivalent yield (WEY) and added with the yield of wheat grain. It is the WEY of crop. Significantly superior WEY is recorded in P_{75} (4455 kg ha^{-1}), followed by P_{50} (3856 kg ha^{-1}), P_{25} (3103 kg ha^{-1}) and P_0 (2653 kg ha^{-1}).WEY was significantly differing with each other. It was in order of $P_0<P_{25}<P_{50}<P_{75}$. (Table 3).

Current seasonal increment of LST, SST and Fuel Wood was converted into wheat equivalent yield. This total wheat equivalent yield were at par in P_{75} (2427 kg ha^{-1}), P_{50} (3054 kg ha^{-1}) and P_{25} (3147 kg ha^{-1}) but significantly superior to P_0 (1761 kg ha^{-1}). Whereas P_0 was at par with P_{75} (Table 3).

Table 3: Effect of different pruning intensities on WEY of grain, straw, LST' SST and FW

Pruning intensity	Grain	Straw	Total	LST (kg ha^{-1})	SST (kg ha^{-1})	FW (kg ha^{-1})	Tree (kg ha^{-1})
P_0- No pruning	1826	827	2653	1521	119	121	1761
P_{25}-25% pruning	2136	968	3103	2873	161	113	3147
P_{50}-50% pruning	2654	1202	3856	2795	134	124	3054
P_{75}-75% pruning	3066	1389	4455	2106	205	115	2427
S.Em+	146	66	213	333	28	16	371
CD (P=0.05)	451	204	655	1026	87	NS	1142

Table 4: Effect of different pruning intensities on WEY of crop and tree components

Pruning intensity	Wheat equivalent yield (kg ha^{-1})		
	Crop	Tree	Agroforestry system
P_0- No pruning	2653	1761	4414
P_{25}-25% pruning	3103	3147	6251
P_{50}-50% pruning	3856	3054	6910
P_{75}-75% pruning	4455	2427	6881
S.Em+	213	371	472
CD (P=0.05)	655	1142	1455

Wheat equivalent yield of tree component (LST+SST+ FW) and the crop component (grain + straw) were added together to set the grand WEY of agroforestry. Grand WEY of P_{75} (6881 kg ha^{-1}), P_{25} (6251 kg ha^{-1}) and P_{50} (6910 kg ha^{-1}) were at par but significantly superior to P_0 (4414 kg ha^{-1}). It were numerically in order at $P_{50}>P_{75}>P_{25}>P_0$. During pruning, twigs and branches of lower portion of stem are removed which changes the stem to more cylindrical shape and thus, resulting in more biomass accumulation. Similar results were reported by Muhairwe (1994) [11], Pinkard *et al*. (2004) [15] and Ranjan and Sahu (2016) [17]. Muhairwe (1994) [11] reported that pruning changes the stem to more cylindrical shape rather to conical shape. Pinkard *et al.* (2004) [15] reported that stem volume was significantly reduced more in 0% pruning than in other lighter intensities of pruning Ranjan and Sahu (2016) [17] reported higher timber volume in 25% pruning over 0 and 75% pruning.

Table 5: Effect of different pruning intensities on water productivity of Agri-Silviculture system

Pruning intensity	Total WEY	Green water used (cm)	Blue water used (cm)	Total water used (cm)	Water productivity (kg ha^{-1} cm^{-1})
P_0- No pruning	4414	4.5	18	22.5	196
P_{25}-25% pruning	6251	4.5	20	24.5	255
P_{50}-50% pruning	6910	4.5	23	27.7	249
P_{75}-75% pruning	6881	4.5	32	36.5	189
S.Em+	472	NS	NS	NS	17
CD (P=0.05)	1455	NS	NS	NS	53

The total water used during Rabi was at par in all four pruning intensities with numeric value as 22.5 cm (P_0), 24.5 cm (P_{25}), 27.7 cm (P_{50}) and 36.5 cm (P_{75}) (Table 5). The present findings were little vary with finding of Wei *et al*. (2009), where they reported the less moisture content in heavy pruning intensity whereas more moisture content in less pruned trees.

Statistical analysis revealed that pruning intensities have significant effect on Rabi water productivity under agroforestry system. Water productivity of P_{25} (255 kg ha^{-1} cm^{-1}) and P_{50} (249 kg ha^{-1} cm^{-1}) were at par but significantly superior to P_{75} (189 kg ha^{-1} cm^{-1}). P_{25} was significantly superior P_0 (196 kg ha^{-1} cm^{-1})(Table 5). Results of water productivity were in similar trend as recorded in grand WEY of agroforestry. Numeric value of water productivity are in order P_{25}>P_{50} >P_{75}> P_0 (Table 5).

The 25% pruning intensity yielded the highest water productivity among all the selected pruning intensity which was followed by 50% pruning intensity. It leads to conclusion that light pruning is beneficial for efficient use of water and also higher water productivity as compare to no pruning and heavy pruning of trees. These results were in agreement of minutely with the findings of Rajan and Sahu (2016) [17]. They also reported the highest productivity under 25% pruning intensity in *Dalbergia sissoo*- paddy agroforestry system.

Conclusion

Agroforestry practices in combination with *Dalbergia sissoo* + wheat are best practice to obtain maximum yield per drop of water with light pruning. Our experiment results states that practicing of light pruning that is 25% pruning yields highest water productivity followed by P_{50}, P_{75} and P_0.

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