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Effect of spacing on growth performance and soil dynamics in *Hardwickia binata* Roxb. under arid ecosystem

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Abstract
Hardwickia binata comes under the endemic biodiversity category and it is multipurpose tree species useful for agroforestry and dry land areas with medicinal, fodder, fuel, fibre, timber and manure utility/ potential. It is essential to know more about its growth performance in arid condition. In present studies the attempts have been made to investigate the growth performance of 30 year's old planted *H. binata* tree at different spacing and amelioration of soil. Tree growth data viz., height, diameter at breast height (dbh), clear bole length and crown diameter were measured during the study under rainfed condition of fixed sample trees in rows on a yearly basis in all the treatments and soil sample were collected. The result revealed that *H. binata* tree growth performance was found better at 5x5 m^2 spacing in respect of dbh, clear bole length and volume in rainfed condition. Soil pH was lower at closer spacing and higher at wider spacing and EC and OC was higher at closer spacing and low at wider spacing. This study results may be useful for plantation of *H. binata* trees on farmer's fields, road side and agroforetry in arid condition.

Keywords: *Hardwickia binata*, tree growth, arid ecosystem, soil, and volume

Introduction
Hardwickia binata Roxb. is commonly known as 'Anjan' and tree belong to the family leguminosae, subfamily caesalpinoidae is a valuable multi-purpose tree in India. The *H. binata* is native to South East Asia and is considered endemic to India, Pakistan and Nepal. Populations have also been found in Bangladesh, Cambodia, Laos, Thailand, Vietnam, Myanmar, Malaysia, Philippines, Brunei, Indonesia and Papua New Guinea in the West (Kundu, 2011) [5]. In India, it is found in Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and also in Uttar Pradesh and Bihar. In Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka there are certain gregarious patches of *H. binata* designated as *Hardwickia* forest which is found on shallow hard gravelly soil over trap rock (Singh *et al*., 2007) [9]. The tree yields extremely hard, very heavy and durable timber apart from high quality fuel-wood (Roy, 1996) [8] and rich fodder in terms of crude protein (Singh, 1982) [10]. The species is also Nitrogen fixer, soil improver, inter-croper, timber production and bark yields a strong fibre largely employed for making ropes (Orwa *et al*., 2009) [7]. It is also source of fiber, fuel, high quality fodder for the cattle and uses as main component in the different agroforestry systems of arid and semi arid regions. It is propagated mainly by direct sowing of seeds and raising seedlings in the nursery. This tree is a striking deciduous tree and characteristic species of degraded dry deciduous forests. The tree remains leafless during the end of winter season for a very short period. The leaf renewal starts subsequently in April. The specialty of this tree is that the tree is completely with leaves during the hot summer and can be distinctly seen among its associates. The pale yellowish green flowers appear from July to September. The pods develop by November and ripen in April or May. Anjan normally found at an altitudinal gradient of 0-300 m with mean annual temperature of 22-340 C and mean annual rainfall of 250-1500 mm. For its better growth, the tree prefers deep porous soil with fissured underlying rock. It tolerates acidic to neutral soils. This tree can thrive well in dry areas and even can withstand in prolonged drought condition. Due to it wider uses and climatic adaptability the present studies attempts were made to investigate the growth performance of tree species in arid climate in rainfed condition and to standardized the best spacing for plantation on farmers fields, road side and farm boundary in hot arid zone.

Material and Methods

The experiments was conducted on systematically planted 30 years old *H. binata* trees in different row spacing 5x3, 5x4, 5x5, 5x6, 5x7 and 5x8 m spacing in rainfed condition at Agricultural Research Station, Fatehpur-shekhawati, Sikar (latitude 27˚56'10.37" N, longitude 074˚59'04.51" E) in Rajasthan, India. The climate of experimental site is tropical and characterized by hot dry summer, cold dry winter (minimum temperature of -5 ºC) and warm rainy seasons. Summers is very hot with high air temperature (up to 48 ºC in mid May), extends from mid March to mid June or up to receive of pre-monsoon rainfall. The strong winds (20-60 km h^{-1}) prevailing in summer and most of rainfall received from July to September. The soil of the experiments site is loamy sand with low organic carbon content. Tree growth data viz., height, diameter at breast height (dbh), clear bole length and crown diameter measured during the study under rainfed condition of ten fixed sample trees in rows on a yearly basis in all the treatments. The soil samples were also collected from all the treatments and evaluated for pH, EC and organic carbon (OC). The pH of soil was determined in 1:2 (soil: water) suspension using combined electrode (glass and calomel electrodes) by digital pH meter. The electrical conductivity (EC) was determined in the supernatant liquid of the same extracts with the help of Conductivity Bridge and expressed in dS m^{-1} at 25 °C (Jackson, 1973) [4]. Soil organic carbon (SOC) was determined by rapid titration method (Walkley and Black 1934) [14]. The data were analyzed using in standard statistical methods.

Result and Discussion

The tree height was significantly highest (9.2 m) at narrow spacing (3x5 m^2) followed by spacing of 5x5 m^2 (8.8 m) and 4x5 m^2 (8.5 m). However, the diameter at breast height (dbh) was significantly highest at 5x5 m^2 spacing (23.0 cm) followed by wider spacing 6x5 m^2 (21.4 m), 7x5 m^2 (21.1 m) and 8x5 m^2 (20.2 m) Table 1. This shows that tree would attain it optimum growth at the spacing 5x5 m^2 spacing. The ability of the tree to grow taller in denser stands and in high dbh in less denser stands was evident; the similar trend observed by Hummel (2000) [3]. This could be due to the natural adaptive mechanism to density stress by the trees (Hiura *et al*., 1998) [2]. The clear bole length (cbl) was recorded significantly highest at 3x5 m^2 spacing and decreased trend in cbl observed in respect with increased spacing except 4x5 m^2 spacing. It found that higher the tree density will lead to clearer bole than the lower density due to competition among trees results increasing the self-pruning ability. In canopy diameter increasing trend observed along wider spacing i.e., 3x5 m^2 (3.1 m) to 8x5 m^2 (5.2 m) Table 1. It indicated that there is more crown expansion in trees having wider spacing and lesser crown expansion in trees having closer spacing. (Britt and Reynolds, 2011) [1] also reported that the lower crown spread in closer spacing might be due to reduced availability of light as a result of increased competition from neighboring trees. Canopy diameter was better in wider spacing as compared to closer spacing. It indicated that spacing is very important factor for crown development in *Hardwickia binata* plantation. According to (Samsuzzamam *et al*. 2002) proper tree crop spacing and pruning management helps to reduce negative tree crop interaction and thereby greatly influence the component productivity. It indicated that there is more crown expansion in trees having wider spacing and lesser crown expansion in trees having closer spacing.

The maximum tree volume 0.37 m^3/tree was recorded at 5x5 m^2 spacing and lowest (0.18 m^3/tree) at 3x5 m^2 spacing. This is due to closer spacing having low dbh and wider spacing (5x5 m^2) has on an average higher dbh and higher height. However, when it will converted into m^3/ha the volume was highest at 5x5 m^2 spacing (148.0 m^3/ha) and lowest in 8x5 m^2 spacing (63.0 m^3/ha) Fig 1. The same trend results are fond by (Singh *et al*., 1983) [12]. This may be ascribed to better utilization of moisture, fertilizers and nutrients beyond the reach of arable crops with additional benefit of wider spacing and of cultural operations. Reducing spacing between trees will therefore exacerbate the negative effects. Sands and Nambiar (1984) [13] and Nambiar and Sands (1993) [6] reported serious growth losses resulting from intense competition for water and nutrients arising from competition effects. The experiment results prove that *H. binata* tree in arid condition achieved its maximum growth at 5x5 m^2 spacing and for plantation in arid region the spacing of 5x5 m^2 is best for achieving the maximum volume under rainfed condition in arid climate.

The pH was low at closer spacing and high at wider spacing, and EC registered high in close spacing and low in higher spacing; however the effect was no much. The soil organic carbon percent were increases with decrease in spacing and was high at 3x5 m^2 lower spacing (0.29%) and low (0.24%) at 8x5 m^2 higher spacing Table 2. This is due to high leaf litter fall in closer spacing (high density of trees plantation) compared to wide spacing (low density of trees plantation) and decomposition of other organic matter fall from trees.

Table 1: Mean growth parameters, tree density and volume at different spacing.

Spacing (m)	Height (m)	DBH (cm)	CBL (m)	Canopy Diameter (m)	Tree Density/ha	Volume m^3/tree	Volume m^3/ha
3x5	9.2	15.9	6.3	3.1	666	0.18	120.0
4x5	8.5	18.4	5.7	3.3	500	0.23	115.0
5x5	8.8	23.0	5.8	4.3	400	0.37	148.0
6x5	8.0	21.4	5.6	4.6	333	0.29	97.0
7x5	7.7	21.1	5.6	4.7	285	0.27	77.0
8x5	7.8	20.2	5.4	5.2	250	0.25	63.0
SE(m)	0.186	0.637	0.13	0.38			
CD (5%)	0.55	1.89	3.38	0.12			

Table 2: Effect of tree density on soil attributes.

Spacing (m)	pH	EC (ds m^{-1})	Soil Organic Carbon (%)
3x5	7.95	0.03	0.29
4x5	7.98	0.03	0.28
5x5	7.99	0.02	0.26
6x5	8.01	0.02	0.25
7x5	8.03	0.02	0.24
8x5	8.05	0.02	0.24

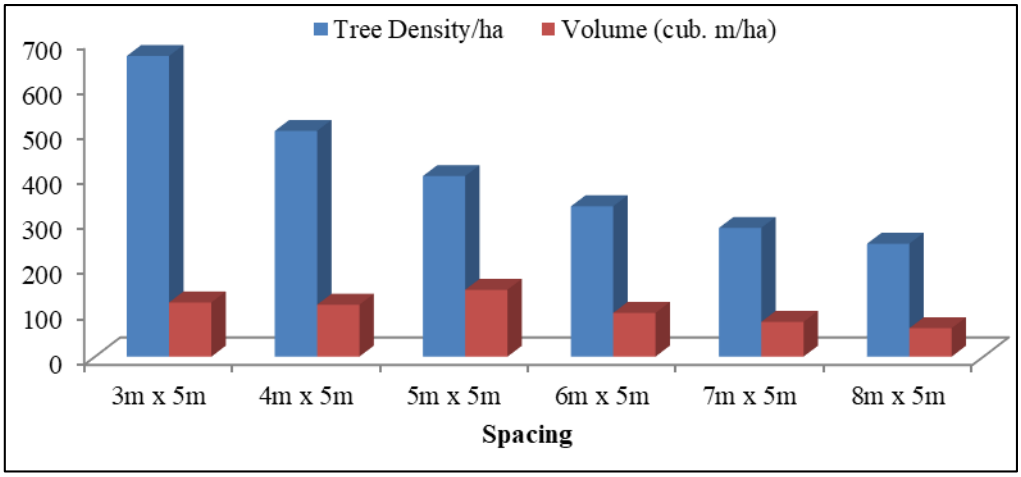

Fig 1: Tree density and volume at different spacing

Conclusion

The present investigation on growth performance of *H. binata* revealed that tree species achieved over all good growth at 5x5 m^2 spacing in arid condition of Rajasthan in respect of dbh and volume and high tree density plantation contribute more soil organic carbon in compared to low density plantation. Further this species needs special attention for commercial plantation in the various land use systems in the different regions to obtain maximum commercial benefits and this study provides key useful information on growth performance of the tree species and soil amelioration in arid regions on India.

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