Indian J. of Agroforestry Vol. 18 No. 1 : 84-89 (2016)

A sustainable livelihood option for farmers' of semi-arid region: Bamboo + Chickpea based Agroforestry model

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ABSTRACT: Bamboo plays a significant role in the Indian economy and is providing livelihood support to millions of people. A study was conducted on bamboo + chickpea based agroforestry model at ICAR-Central Agroforestry Research Institute, Jhansi (Uttar Pradesh) during 2007 to 2012. Bamboo recorded 100% survival (3rd year onwards) and No. of culms clump^{-1} varied in the range of 29.07 to 32.15 at harvest stage. Chickpea grown as intercrop recorded seed yield of 1.27 - 1.77 t ha^{-1} against 1.70 to 1.85 t ha^{-1} in sole cropping. Seed yield was 25.95% (bamboo-10mx10m) and 21.08% (bamboo-12mx10m) lower in comparison to sole chickpea during 3rd year. Distance from the clump also had significant influence on the seed yield (27.6, 18.08 and 11.86% lower at 1, 2 and 3m, respectively away from bamboo clump) than the seed yield (1.77 t ha^{-1}) at 4m distance.

Key words: Bamboo growth, chickpea yields, *Dendrocalamus strictus* and livelihood options.

Received on: 26/05/2016 Accepted on: 13/06/2016

1. INTRODUCTION

Bamboo is playing a significant role in the Indian economy and is providing livelihood support to millions of people. Bamboo being one of the fastest growing plant, perennial nature and ability to produce culms every year, gives very high return in comparison of timber trees. Bamboos have an estimated 1500 uses including food, construction, fuel, charcoal, medicinal products and the manufacture of paper, flooring , screens and clothing (Filho and Badr, 2004; Pilliere, 2008; Chauhan and Kumar, 2005). Bamboo is not only of economic importance to rural communities in most Asian countries, but also of ecological importance in preventing soil erosion by its strongly developed rhizomes and roots (Bystriakova *et al*., 2003).

The international trade represents only a small proportion of total bamboo usage, domestic use is estimated to account for at least 80%. Currently there is a mismatch in demand and supply. The demand for bamboo was 26.9 million tonnes against the supply of 13.47 million tonnes (Mandal and Khanduri, 2004) with almost 50% deficit.

The semi-arid tropic regions are characterized by low and unpredictable seasonal rainfall, high mean annual temperatures and high evaporative demand, which severely limit water supplies for agricultural use. Further, poor soil fertility may also limit productivity (Bramel Cox *et al*., 2000). Bamboos have the potential to be incorporated into agroforestry systems in the semi-arid tropics in place of conventional tree species due to their adaptability and versatility. They are among the world's most important fastest growing woody species (Kleinhenz *et al*., 2003; Bosire, 2007; Sandhu *et al.,* 2010), partly because of large leaf canopies, which captures light very effectively.

Popularly known as 'lathi bans', *Dendrocalamus strictus* (Roxb.), belongs to the subfamily Bambusoideae of the family Poaceae is most commonly found bamboo species in India (Tewari *et al*., 2016). Traditionally, *D. strictus* has both medicinal and industrial uses. The pulp is extensively used in paper industries. The culms are used for making various agricultural and industrial implements (Reddy, 2006) and new shoots are edible as well.

ICAR-Central Agroforestry Research Institute (CAFRI) (erstwhile, NRCAF), Jhansi initiated a bamboo coordinated research project in 2007 on "Development of bamboo based agroforestry systems for six agro-climatic zones" with funds under R&D project of National Bamboo Mission, Ministry of Agriculture, New Delhi. The present study was conducted to develop bamboo based agroforestry systems suitable to semi-tropic environment conditions.

2. MATERIALS AND METHODS

This study was carried out at the research farm of ICAR-Central Agroforestry Research Institute, Jhansi (Uttar Pradesh), India during 2007 to 2012. The site of experimental field was situated at 25º 30' - 25' 32º N latitude and 78º 32' - 78º 34' E longitudes at an altitude of 272 m above msl. Soil of the experimental site was low in fertility and inter-mixed red and black soil group of Bundelkhand region of Uttar Pradesh covered under the order of Alfisol. Initial status of soil was 6.54 (pH), 0.180 dSm^{-1} (EC), 3.92 kg^{-1} (soil O.C.), 213 kg ha^{-1} (available N), 5.28 kg ha^{-1} (available P) and 185 kg ha^{-1} (available K). Mean annual rainfall of the region is 867mm. The area received less than the average rainfall during 2007 and 2009. While, during rest of the study period it was normal/above normal (Fig. 1). The experiment was laid out in randomized block design with three replications and five treatments *viz.*, T_1: 10m x10m bamboo + chickpea; T_2: 12m x 10m bamboo + chickpea; T_3: 10m x10 m pure bamboo; T_4: 12 mx10 m pure bamboo and T_5: pure crop (chickpea). In the experiment 12 clumps per plot (3 x 4: rows x clumps) having100 clumps ha^{-1}(10m x 10m) and 84 clumps ha^{-1} (12m x 10m) were maintained. Observations on chickpea were recorded at a distance of 1.0, 2.0, 3.0 and 4.0m (considering as sub plot treatments) from bamboo clump and were analyzed under split plot design. Chickpea crop was grown during *rabi* (winter) seasons as intercrop as per treatments with standard package of practices.

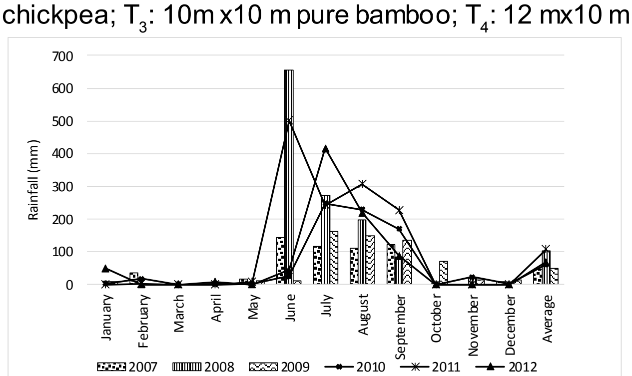

Fig. 1. Rainfall pattern during 2007 to 2012 at Central Research Farm of ICAR-CAFRI, Jhansi

From the study area, five clumps were randomly selected in each treatment and identified with paint marking. The number of culms in these selected clumps were counted. All the observations were made for the basal area girth, DBH, height and internodal length. Survival (%) was recorded over the years. The standard analysis of variance (ANOVA) test was performed using SPSS 17.0 statistical software to compare the treatment means for each year separately. Treatment means were compared at the 5% level of significance ($P<0.05$) using least significant difference. The variance over years was estimated homogeneously, hence results of analysis are presented here to draw logical inferences.

3. RESULTS AND DISCUSSION

Survival and growth parameters of bamboo

During first year, the survival varied from 62 to 77% with an average of 70%. During second year the survival ranged from 86 to 96% with an average of 90.75% and remained 100% during 3rd year onwards due to frequent irrigation (Fig. 2). The mortality during the initial years

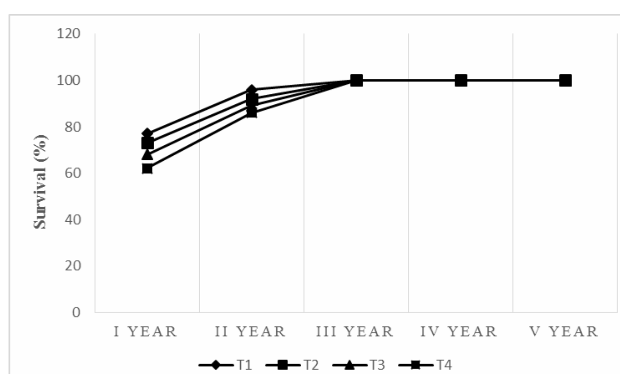

Fig. 2. Survival (%) of *D. strictus*
T_1: 10m x10m bamboo + chickpea; T_2: 12m x 10m bamboo + chickpea; T_3: 10m x10 m pure bamboo; T_4: 12 mx10 m pure bamboo

was due to delay in planting *i.e.*, at the end of September, when the planting season was over (Bundelkhand region remained under severe drought during 2004-2007).

Number of culm clump^{-1}

On an average, each clump had 3.01, 13.02, 19.88, 27.05 and 30.68 number of culms during 1st to 5th year, respectively. No. of culm clump^{-1} varied from 2.14 to 3.88 (1st year); 11.23 to 14.82 (2nd year); 18.08 to 21.70 (3rd year); 25.37 to 29.01 (4th year) and 29.07 to 32.15 (5th year *i.e.*, at harvest stage). Significantly more number of culm were obtained in T_1 (bamboo–10m x 10m + chickpea) over the years as compared to pure bamboo at both the spacing (Table 1). A total of 3215 (10m x 10m); 2670 (10m x 12m) culms ha^{-1} were observed in AFS, while 2946 and 2422 culms ha^{-1} were observed in sole bamboo at the same density.

Yield and yield contributing characters of chickpea

Data presented on yield and yield contributing characters (Tables 2 & 3 and Fig. 3) indicated that due to no competition offered by bamboo during initial growth period for first two years of establishment, chickpea intercrop in AFS by and large recorded at par for different yield parameters. During the subsequent years various yield contributing parameters were influenced in the bamboo based AFSs.

Plant population: Plant population of chickpea was not influenced either by bamboo spacing or distance

Table 1. Number of culm clump^{-1} of *D. strictus* under agroforestry system

Treatments	1st year	2nd year	3rd year	4th year	5th year	Culms ha^{-1}
T_1-10m x 10m bamboo+chickpea	3.88	14.39	21.34	29.01	32.15	3215
T_2-12m x 10m bamboo+chickpea	3.75	14.82	21.70	28.60	32.05	2670
T_3-10m x 10m pure bamboo	2.26	11.64	18.65	25.37	29.46	2946
T_4-12m x 10m pure bamboo	2.14	11.23	18.08	26.19	29.07	2422
SEm±	0.10	0.40	0.61	0.63	0.78	
CD (p= 0.05)	0.33	1.39	2.12	2.16	2.69	

Table 2. Yield contributing characters of chickpea under bamboo based agroforestry system

Treatments	Plant population (m^{-2})					Branches plant^{-1}					Seed weight plant^{-1} (g)				
	2007-08	2008-09	2009-10	2010-11	2011-12	2007-08	2008-09	2009-10	2010-11	2011-12	2007-08	2008-09	2009-10	2010-11	2011-12
Main (Bamboo spacing)															
M1: 10m x 10m	32.1^{a}	35.5^{a}	33.8^{b}	32.8^{b}	31.6^{b}	5.85^{a}	6.00^{a}	5.34^{b}	5.30^{b}	5.36^{b}	12.08^{a}	12.62^{a}	9.38^{b}	10.10^{b}	9.80^{b}
M2: 10m x 12m	34.2^{a}	33.7^{a}	34.6^{b}	32.3^{b}	32.8^{b}	6.25^{a}	5.93^{a}	5.50^{b}	5.57^{ab}	5.36^{b}	12.23^{a}	12.31^{a}	9.75^{b}	10.63^{b}	10.51^{b}
M3: Pure crop	33.6^{a}	34.0^{a}	36.9^{a}	33.8^{a}	35.2^{a}	6.35^{a}	6.06^{a}	5.91^{a}	5.60^{a}	6.1^{a}	12.79^{a}	12.80^{a}	12.5^{a}	13.50^{a}	13.10^{a}
Sub (Distance from bamboo clump)															
S1: 1.0m	32.3^{a}	33.5^{a}	31.9^{b}	30.7^{b}	30.0^{b}	6.20^{a}	5.94^{a}	5.00^{c}	5.15^{c}	4.80^{c}	12.11^{a}	12.05^{a}	8.25^{c}	8.97^{c}	8.85^{c}
S2: 2.0m	32.8^{a}	34.0^{a}	33.0^{b}	31.8^{b}	31.3^{b}	6.00^{a}	5.88^{a}	5.18^{c}	5.35^{bc}	5.30^{b}	12.31^{a}	12.33^{a}	8.63^{c}	9.38^{c}	9.24^{c}
S3: 3.0m	33.6^{a}	35.1^{a}	35.3^{a}	34.5^{a}	33.5^{a}	6.20^{a}	6.15^{a}	5.65^{bc}	5.44^{b}	5.57^{ab}	12.60^{a}	12.67^{a}	9.75^{bc}	10.49^{b}	11.22^{b}
S4: 4.0m	34.0^{a}	35.8^{a}	36.5^{a}	35.1^{a}	33.9^{a}	6.00^{a}	6.14^{a}	5.88^{a}	5.80^{a}	5.79^{a}	12.68^{a}	12.91^{a}	11.9^{b}	12.63^{b}	12.45^{a}

^{a,b,c} Within column, value represents with different letter indicate significant difference (p= 0.05)

Table 3. Yield (seed and stover) and harvest index of chickpea under bamboo based agroforestry system

Treatments	Seed yield (t ha^{-1})					Stover yield (t ha^{-1})					Harvest index (%)				
	2007-08	2008-09	2009-10	2010-11	2011-12	2007-08	2008-09	2009-10	2010-11	2011-12	2007-08	2008-09	2009-10	2010-11	2011-12
Main (Bamboo spacing)															
M1: 10m x 10m	1.80^{a}	1.75^{a}	1.37^{c}	1.33^{c}	1.27^{c}	2.42^{a}	2.42^{a}	2.15^{b}	2.10^{b}	2.15^{b}	42.7^{a}	42.0^{a}	38.92^{b}	38.78^{b}	37.13^{b}
M2: 10m x 12m	1.76^{a}	1.77^{a}	1.46^{c}	1.47^{c}	1.41^{c}	2.38^{a}	2.37^{a}	2.31^{b}	2.21^{b}	2.27^{a}	42.5^{a}	42.8^{a}	38.73^{b}	39.95^{b}	38.32^{b}
M3: Pure crop	1.81^{a}	1.76^{a}	1.85^{a}	1.81^{a}	1.70^{a}	2.34^{a}	2.39^{a}	2.48^{a}	2.37^{a}	2.34^{a}	43.6^{a}	42.4^{a}	42.73^{a}	43.30^{a}	42.08^{a}
Sub (Distance from bamboo clump)															
S1: 1.0m	1.77^{a}	1.71^{a}	1.28^{c}	1.28^{c}	1.21^{c}	2.41^{a}	2.32^{a}	2.18^{c}	2.01^{c}	2.06^{c}	42.3^{a}	42.4^{a}	36.99^{b}	38.91^{c}	37.00^{c}
S2: 2.0m	1.76^{a}	1.72^{a}	1.45^{c}	1.37^{c}	1.36^{c}	2.38^{a}	2.36^{a}	2.08^{c}	2.12^{b}	2.14^{b}	42.5^{a}	42.2^{a}	41.08^{ab}	39.26^{b}	38.86^{b}
S3: 3.0m	1.80^{a}	1.76^{a}	1.56^{b}	1.54^{b}	1.50^{b}	2.42^{a}	2.42^{a}	2.34^{b}	2.25^{ab}	2.22^{ab}	42.7^{a}	42.1^{a}	40.00^{b}	40.63^{b}	40.32^{ab}
S4: 4.0m	1.83^{a}	1.79^{a}	1.77^{a}	1.76^{a}	1.64^{a}	2.45^{a}	2.48^{a}	2.41^{a}	2.31^{a}	2.26^{a}	42.8^{a}	41.9^{a}	42.34^{a}	43.24^{a}	42.05^{a}

^{a,b,c} Within column, value represents with different letter indicate significant difference (p= 0.05)

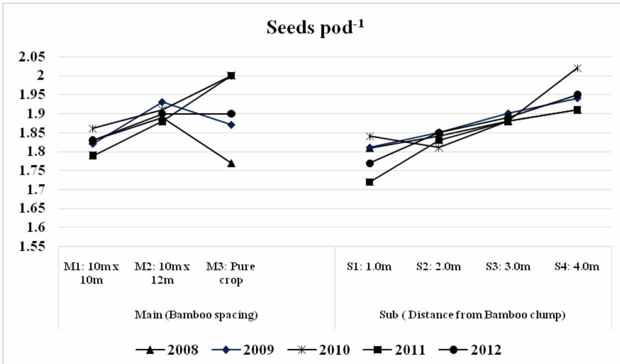

Fig. 3. Seeds pod^{-1} of chickpea under bamboo based AFS

from the bamboo clump during initial two years of bamboo establishment. During third year, chickpea intercrop at both the spacing (M_1 and M_2) had significantly lower plant population than pure crop, however (M_1 and M_2) were at par with each other. Distance from the clump influenced the plant population and a significantly lower plant population was observed at a distance of 1.0 and 2.0m from the bamboo clump as compared to plant population at a distance of 3.0m and 4.0m. In both the spacing of bamboo (M_1: 10m x 10m, and M_2: 10m x 12m), reduction in chickpea plant population of 13.6, 10.6, 4.3 and 1.1% were observed at a distance of 1.0, 2.0, 3.0 and 4.0m, respectively from the clump, as compared to pure crop. During 4th and 5th year of bamboo plantation, plant population of chickpea followed similar pattern as observed in 3rd year of bamboo plantation. 3rd year onward, bamboo growth was enough to influence the plant population of chickpea in AFSs and at various distance from bamboo clump (Table 2).

***Branches plant^{-1}*:** During first two years, bamboo spacing and distance from the clump did not influence the branches plant^{-1}. During third year, it was observed that sole crop had significantly higher branches plant^{-1} as compared to chickpea intercrop in bamboo based AFS. Number of branch plant^{-1} recorded at a distance of 1.0 and 2.0m from clump were substantially lower as compared to branches plant^{-1} at 3.0 and 4.0m distances (Table 2). Competition for various resources observed in intercrop under bamboo AFS and distance nearer from the clump had substantial influence on branches plant^{-1}. By and large similar pattern as observed in 3rd year was realized in 4th and 5th year of bamboo plantation.

***Seeds pod^{-1} and seed weight plant^{-1}*:** A perusal of the data depicted in Fig. 3 reveals that number of seed pod^{-1} varied from 1.77 to 2.0 over the years. During initial two years, the number of seeds pod^{-1} and seed weight plant^{-1} were not influenced by the distance from the clump and bamboo spacing. During 3rd year onward sole crop and intercrop in AFS recorded at par seeds pod^{-1}. However, at 3.0 and 4.0m distances from bamboo clump, significantly higher number of seeds pod^{-1} were observed as compared to 1.0 and 2.0m distance from the clump. Similar trend was observed for seed weight plant^{-1}. Lower number of seed pod^{-1} and seed weight plant^{-1} at a distance of 1.0 and 2.0m from clump could be attributed to the fact that there was more competition for various resources *viz.* light, water, nutrients *etc.* on account of bamboo growth (Chauhan *et al.,* 2012).

***Test weight and seed yield*:** Test weight of chickpea crop varied in the range of 175.9-178.3 g (sole crop); 172.0 -176.9 g (M_1) and 172-176.4 g (M_2) over the years, however the test weight was not influenced by spacing of bamboo as well as distance from the clump. Seed yield of chickpea presented in Table 3 showed variation of 1.70 to 1.85 (sole crop), 1.27–1.80 (M_1) and 1.41-1.77 t ha^{-1} (M_2). No significant variation in seed yield was observed during first two years as bamboo plants did not impose any competition to the intercropped chickpea. Seed yield recorded at a distance of 1.0, 2.0, 3.0 and 4.0m was also at par during initial two years. During 3rd year, seed yield in sole crop was significantly higher as compared to AFS, however seed yield in M_1 and M_2 were at par with each other. Data also indicated that seed yield was 25.95 (M_1) and 21.08% (M_2) lower as compared to sole chickpea during 3rd year. Distance from the clump had also significant influence on the seed yield. During 3rd year seed yield recorded at a distance of 4.0m from the bamboo clump was significantly higher as compared to 1.0, 2.0 and 3.0m distance. Seed yield was observed 27.6, 18.08 and 11.86% (1, 2 and 3m distance from bamboo clump, respectively) lower than the seed yield (1.77 t ha^{-1}) recorded at 4.0m during 3rd year of bamboo plantation. By and large similar trend was observed in seed yield during 4th and 5th year of plantation.

***Stover yield*:** Data presented in Table 3 indicated that stover yield was not influenced during initial two years.

Stover yield under sole crop, AFS and stover yield recorded at different distances (1.0, 2.0, 3.0 and 4.0m) followed almost similar trend as observed in seed yield during 3rd year of bamboo plantation. In 4th and 5th year, stover yield at 1.0m distance from clump observed significantly lowest than other distances.

Harvest Index: Data presented in Table 3 indicated that harvest index of chickpea varied in the range of 42.8-43.6 (sole crop), 37.13-42.70 (10m x 10m) and 38.32-42.8% (10m x 12m) over the years. During the initial two years, no significant differences were observed in harvest index. However, during 3rd year of bamboo plantation, harvest index at both the spacing was observed significantly lower than pure crop. Likewise, at 4.0m distance from clump, harvest index was significantly higher than other distances from the clump. Similar trend as observed in 3rd year was realized in 4th and 5th year of bamboo plantation. Because of less seed yield plant^{-1} lowest harvest index was observed at 1.0m distance from clump during 3rd, 4th and 5th year of bamboo plantation.

The reduction in plant population under AFS and nearer to the bamboo clump may be due to allelopathic effect of bamboo or shade besides increased competition for resources on account of fast growth of bamboo. Rahangdale *et al.,* (2014) reported lower plant population of soybean, paddy, green gram and sesame crops in Central India under bamboo based AFS. Sharma and Chauhan (2003), Chauhan *et al.,* (2010; 2012), Dey *et al*., (2007) and Pandey *et al*., (2010) have reported reduction in various growth parameters and yield attributing parameters under different AFS. The reduction in seed yield of chickpea may be attributed to reduced PAR (Photosynthetically Active Radiation) under bamboo canopy and competition for various other resources *viz*., water, nutrients, space etc. in comparison to sole crop of chickpea. Bamboo as well as other agroforestry species become more competitive with age and consequently decrease the crop yields (Behari, 2001; Shanmughavel and Francis, 2001; Dev *et a1*., 2015, Ahlawat *et al*., 2008 and Chauhan *et al.,* 2010b).

4. CONCLUSION

Bamboo based agroforestry system produced bamboo stock as well as sustained crop production over the years. During initial two years, no significant influence of bamboo was observed on crop, however due to increase in number of bamboo culms over the years, and increased competition for resources, the chickpea yield got reduced gradually, however, the crop loss may be compensated by the higher number of bamboo culms. Bamboo based AFS is not only advantageous economically, but environmentally as well, therefore could be one of the best alternative livelihood options for the farmers of semi-arid tropics.

ACKNOWLEDGEMENT

Authors are thankful to the National Bamboo Mission for providing the funds for the study and Director, ICAR-CAFRI for providing necessary facilities and guidance for executing the experiment.

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