African Journal of Biotechnology Vol. 11(84), pp. 15002-15011, 18 October, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB12.1764

Full Length Research Paper

New and improved method of bamboo cultivation in semi arid areas of Indian Thar desert

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Accepted 29 August, 2012

Bamboo (*Dendrocalamus strictus* Roxb.) is widely utilized in construction, pulp and paper, furniture, food and medicine, fuel and handicrafts for a long time. Due to its wider application, a field experiment was carried out to check its cultivation requirements besides its success rate in semi arid area of Indian Thar desert. In the present work, Guggul (*Commiphora wightii* Arnott.) which is a resident plant of Thar desert has been proved as a potential intercrop in bamboo cultivation. Improved growth was observed in bamboo with plant height (8.92 to 20.74 feet), number of culms (19 to 38), culm diameter (2.2 to 4.3 cm) during intercropping of guggul. Among different methods of irrigation, highest growth was recorded in drip irrigated plants where 50% recommended N:P:K and organic manure were given in combination followed by N:P:K sole. This study indicates that Guggul may play a role in microclimate development in the bamboo cultivation. This is the first report on successful bamboo cultivation in semi arid area of desert using an intercrop.

Key words: *Dendrocalamus*, soil enzymes, fertilization, guggul, nitrogen.

INTRODUCTION

Bamboo belongs to the grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae. This versatile and evergreen plant is found everywhere in the world. Approximately 1500 species under 87 genera are distributed worldwide (Ohmberger, 1999; Zhaohua, 2004). Bamboos are very valuable plant with diverse applications in construction, furniture, handicrafts, fodder, paper, wood fuel, bio-remediation, medicines, human food (Shi and Yang, 1992) and also has enormous potential for alleviating environmental problems such as soil erosion, holding soil, protecting riverbanks, preventing landslides, water conservation (Litter fall accumulation, moisture retention, rainfall interception), land rehabilitation, carbon sequestration (Ben-Zhi et al., 2005). Due to bamboo's economic benefits, the research emphasis has long been put to its biological characteristics and the techniques for its propagation, organized cultivation, management and utilization. This requires the use of a different package of practice which normally holds better soil, water and light conditions, and more intensive management. Standardized cultivation practices at various locations such as arid and semi-arid areas are being encouraged by government and non-government organizations, especially in tribal areas in order to harmonize the international food safety, security and nutrition.

In India, 13.58 Lakh km^2 land comes under arid and semi-arid type which is not used for cultivation. This area is 41.4% of total land (Narain et al., 2000). Therefore, methods for the improvement of bamboo cultivation are required in these non-cultivable areas. Till date, there is no report on bamboo cultivation in arid and semi-arid regions. In India, Rajasthan covers a wide area of arid and semi-arid region, and these areas are characterized by nutrient deficient sandy soil, low organic matter, high wind velocity coupled with high evaporation rate, high temperature and solar radiation, low and irregular distribution of rainfall and generally experience water deficit during plant growth period. Vegetation of this area is often hindered by the lack of resident micro flora, which acts as source and sinks for essential plant nutrients, and

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is fundamental to the transformation of various nutrients (Panwar and Tarafdar, 2006). Therefore, there is a great need to use semi-arid area for bamboo cultivation because bamboo cultivation increases NPK mineralization rate, microbial biomass, carbon and net primary production (Singh and Singh, 1999).

In recent years, researchers are emphasizing on intercropping experiments (Ghosh et al., 2006) to cultivate agricultural crops in bamboo plantations which will mutually helpful for both the crops (Seshadri, 1985; Shanmughavel and Francis, 1998). Shanmughavel and Francis (2001) tested intercropping of some agricultural crops (pigeonpea, soybean, turmeric and ginger) in bamboo plantations, and maximum land equivalent ratio was found with bamboo/pigeonpea and bamboo/soybean models. So, it is desirable to identify suitable agricultural and horticultural crops which can grow well with bamboo in plantation conditions (Shanmughavel and Francis, 2001). In the present research work, an attempt was made to cultivate bamboo using guggul as intercrop because guggul *(C. wightii)* is a resident crop of western Rajasthan. Its root has capacity to sustain good moisture in their rhizosphere and developing a microclimate which will be beneficial to nearby plants. This plant grows well in arid and semi-arid climates, and is tolerant to poor soil with high commercial value due to the production of a resinous sap known as gum guggul. The extract of this gum is widely used as incense, to make lacquers, varnishes, and ointments, as a fixative in perfumes, and in medicine for the treatment of nervous diseases, hemiplegia, leprosy, marasmus, muscle spasms, neuralgia, ophthalmia, pyelitis, pyorrhea, scrofula, skin disorders, spongy gums, ulcerative pharyngitis, hypertension, ischaemia, hypertension, and urinary disorders (Scott, 2005). Therefore, it was in need to develop sustainable agricultural model for its cultivation in semi-arid area of Indian Thar desert which will give support to marginal farmers besides judiciary use of barren land of developing country. To the best of our knowledge, this is the first report on efficient bamboo cultivation in the semi-arid regions.

MATERIALS AND METHODS

Study area

The study area was located at Amity University, Jaipur, India and lies at 27° 20' latitude and 75° 95' longitude; altitude was 431 m above sea level. This area has red soil, with pH between 7.4 and 7.8. Soil nitrogen, phosphorus and potassium were 3800, 360 and 3600 kg/ha, respectively. The mean temperature and rainfall are 31 ± 2°C and 250 mm, respectively.

Seedling preparations

Bamboo

D. strictus (Roxb.) rhizome was replanted in 2 kg capacity polybags containing general nursery soil mixture consisting of soil, pond silt and farm yard manure (3:1:1 v/v) and watered daily in first fortnight, and later on, twice in a week. Seedlings were kept in nursery where humidity and temperature were controlled to 80% and 35°C, respectively. Nursery was equipped with micro irrigation facility and humidity and temperature measuring units.

Guggul

Two year old *C. wightii* (Arnott.) twigs were kept in 200 ppm indole butyric acid solution for 12 h and then planted in polythene bags of one each (Bankar and Prasad, 1992). Polybags contains the same soil mixture.

Field preparation, irrigation and fertilization

Four months old seedlings were transferred from nursery to central research farm in the month of May 2008. Two feet depth and 1 foot diameter pits were prepared and filled with the soil mixture. Plant to plant, five meter standard distance was maintained. In each plot, bamboos were planted on boundaries and guggul were in centre, and reverse in T-13 to T-16. Randomized block design (RBD) was adopted to lay out field experiment with three replicates each. All plants were watered and fertilized timely, using different treatments (Table 1). As per lay out, some plots were irrigated by drip irrigation system, 32 and 192 l/month/plant water has been given to guggul and bamboo, respectively, and in flood irrigation, 60 and 300 l/month/plant was given to guggul and bamboo. Average of 230 mm rain fall was received in 2008 to 2011, so it was calculated as it is for rain fed treatment, but life saving irrigation was given in summers. As per fertilization plan, nitrogen (urea), phosphorus (sugar phosphate) and potassium (muriate of potash) were given every three months in the ratio 39:36:18 g/plant in bamboo and 10:6:3 g/plant in guggul. In some plots, organic manure (farm yard manure) was given every three months, 900 and 150 g in bamboo and guggul, respectively.

Rhizosphere soil and plant analysis

Initially, basic soil analysis was performed to characterize the experimental site. Dehydrogenase activity, a measure of soil microbial activity was determined by procedure of Tabatabai (1982). One gram of soil sample was mixed with 0.2 ml of 3% (w/v) 2,3,5-triphenyl tetrazolium chloride (TTC) solution and 0.5 ml of 1% glucose solution, incubated at 30 ± 1°C for 24 h. Then, 10 ml methanol was added to each tube and the contents were mixed thoroughly and kept in refrigerator for 3 h. Intensity of the colour was measured at 485 nm using spectrophotometer. Standard curve was drawn by taking 1 to 10 ppm triphenyl formazon (TPF) in methanol. The amount of triphenyl formazon produced was computed. One unit of dehydrogenase activity was defined as the production of 1 picomol of TPF in 1 min, under the described conditions.

Phosphatases, the enzymes that cause hydrolytic cleavage of phosphate esters have been reported to occur in various soils (Neal, 1973). Phosphorus present in organic compounds is converted to plant available form by the dephosphorylating action of these enzymes. For acid phosphatase activity, 1 g of soil sample was mixed with 4 ml of 0.25% p-nitrophenyl phosphate in 0.2 M acetate buffer of pH 5.4, in a 100 ml Erlenmeyor flask (Tabatabai and Bremner, 1969) and incubated at 35 ± 1°C for 1 h. After incubation, 1 ml of 0.5 M $CaCl_2$ and 4 ml of 0.5 NaOH were added and mixed thoroughly for arresting the reaction. The soil suspension was filtered through Whatman no 42 filter paper. The intensity of the yellow colour was measured immediately in

Table 1. Field layout of various parameters.

Treatment	Description
T-1	Control rain fed
T-2	Organic manure rain fed
T-3	Recommended nitrogen/phosphorus/potassium dose rain fed
T-4	Recommended nitrogen/phosphorus/potassium dose (50%) and recommended organic manure rain fed
T-5	Control flood irrigation
T-6	Organic flood irrigation
T-7	Recommended nitrogen/phosphorus/potassium dose flood irrigation
T-8	Recommended nitrogen/phosphorus/potassium dose (50%) and recommended organic fertilizer flood irrigation
T-9	Control drip irrigation
T-10	Organic drip irrigation
T-11	Recommended nitrogen/phosphorus/potassium dose drip irrigation
T-12	Recommended nitrogen/phosphorus/potassium dose (50%) and recommended organic fertilizer drip irrigation
T-13	Control drip irrigation, guggul boundary
T-14	Organic drip irrigation, guggul boundary
T-15	Recommended nitrogen/phosphorus/potassium dose flood irrigation, guggul boundary
T-16	Recommended nitrogen/phosphorus/potassium dose (50%) and recommended organic fertilizer flood irrigation, guggul boundary

spectrophotometer at 420 nm. The p-nitrophenol contents of the filtrate were computed from the standard curve made from different concentrations of p-nitrophenol. Alkaline phosphatase, procedure followed for the estimation of alkaline phosphatase is similar to that of acid phosphatase, except that borax-NaOH buffer (pH 9.4) was used instead of acetate buffer. The enzyme activity was expressed in nano katals and 1 nano katal of phosphatase activity was determined as the amount of enzyme required to hydrolyze 1 nanomol of p-nitrophenyl phosphate per second per gram dry soil at 35 ± 1°C, at pH 5.4.

Hydrolysis of fluorescein diacetate (FDA) activity known as esterase activity was determined (Schnurer and Rosswall, 1982) and the fluorescein released was quantified with spectrophotometer. Sample (0.1 g) was placed in plastic tubes and 10 ml sterile potassium buffer (pH 7.6, 60 mM) added. The reaction started after adding fluorescein diacetate (1 mg ml^{-1} in acetone), tubes were sealed and kept in an incubator at 37°C for 4 h and 10 ml acetone added to arrest the reaction. After centrifugation (3200 rpm), supernatant optical density was determined in 490 nm. One unit of esterase activity was defined as the production of 1 picomol of fluorescein in 1 min under the described conditions. Phytase activity was assayed by measuring the amount of inorganic phosphate (Pi) released by hydrolysis using sodium phytate (Ames, 1966). The reaction was initiated by addition of 100 ml phytase preparation to an assay mixture (1.0 ml) containing 0.2 M sodium acetate buffer (pH 4.5) and 1 mM sodium phytate and incubated at 37°C for 1 h. The reaction was terminated by the addition of 0.5 ml 10% trichloro acetic acid. Proteins precipitated by TCA were removed by centrifugation at 10000 rpm for 10 min and the supernatant was analyzed for liberated Pi. One unit of phytase activity was defined as the amount of enzyme which liberated 1 μ kat inorganic phosphate per min.

Total chlorophyll (Arnon, 1949) was measured by spectrophotometer at 645 and 663 nm wavelengths against a blank of 80% alcohol. Ethanol extract of fresh leaves has been prepared (Mahadeven et al., 1965) for estimation of total phenols (Bray and Thorpe, 1955), reducing sugars (Nelson, 1944) and amino nitrogen (Moore and Stein, 1948). Dry powder of shoot was used for analyzing total nitrogen (by microkjeldhal method), phosphorus (by vanado-molybdo phosphoric yellow colour method), potassium (by flame photometer), calcium and magnesium (by titrimetry employing disodium salt of EDTA) after di/tri acid digestion (Jackson, 1967). Estimates of copper, zinc, manganese and iron were made by using atomic absorption spectrophotometer (Varian AA1475). Microbial biomass carbon was analyzed in six months according to the Vance et al. (1987), and average data was compiled. Plant height, number and diameter of culms of bamboo were recorded monthly and average data of 2008 to 2011 recorded Guggul collar diameter was observed, and plant canopy was calculated after observing mean diameter of horizontal crown from all directions, and then radius square multiplied by 3.14. Microsoft Excel 2007 was used in statistical processing of the data (Standard error mean).

RESULTS AND DISCUSSION

Central research farm soil contains less organic matter and very low water holding capacity, so it gives negative impact on soil microbial enzyme activity. Total phosphorus is abundant but due to less microbial and rhizosphere action, mineralization was very slow (Table 2). Besides high temperature and evergreen dry weather, this soil has typical semi arid characteristics. Rhizosphere dehydrogenase, acid and alkaline phosphatase, phytase, FDA'se (Fluorescein diacetate hydrolysis), leaf chlorophyll and reducing sugar were estimated half yearly in bamboo, and mean data of three years after transplantation are presented in Table 3. Effect of fertilization and irrigation was observed on enzyme activities in rhizosphere zone. Overall scattered type of enzyme activity was observed among various treatments, activity was increased from 32 to 56%. It might be due to the application of organic manure and balanced chemical fertilizers which are responsible for enhancement in

Table 2. Initial soil biochemistry of field.

S/N	Parameter	Field
1	pH	8.0
2	Esterase (EU × 10^{-3})	140
3	Acid phosphatase (p Kat g^{-1})	30
4	Alkaline phosphatase (p Kat g^{-1})	55
5	Dehydrogenase (p Kat g^{-1})	4.8
6	Total-P (mg kg^{-1})	242
7	Mineral P (mg kg^{-1})	90
8	Olsen-P (mg kg^{-1})	8.6
9	Microbial biomass carbon (mg kg^{-1})	40
10	Soil texture	Loamy sand
11	Rain fall (mm)	389-460

Table 3. Effect of various treatments on rhizosphere enzymes and plant metabolites in bamboo.

Treatment	Dehydrogenase	Acid phosphotase	Alkaline phosphotase	Phytase	FDA'se	Total chlorophyll	Reducing sugar
	(p Kat g^{-1})					(mg g^{-1} fresh weight)	
T-1	10.84	44.04	103.6	0.056	1594	3.74	2.76
T-2	11.47	43.76	113.7	0.057	1522	3.88	2.87
T-3	11.61	51.67	114.8	0.038	1766	3.69	2.63
T-4	9.72	38.25	94.8	0.055	2665	3.92	2.94
T-5	4.44	52.88	101.5	0.06	2323	4.67	3.21
T-6	5.87	39.67	101.4	0.048	4038	4.89	3.33
T-7	10.27	32.46	82.5	0.057	2881	4.82	3.24
T-8	8.92	40.46	85.2	0.052	2376	4.96	3.39
T-9	9.14	42.35	72.7	0.058	2735	5.62	3.31
T-10	6.26	40.65	81.8	0.062	6482	5.72	3.35
T-11	7.16	42.56	102.2	0.061	6354	5.69	3.32
T-12	13.47	46.36	99.4	0.075	4668	5.84	3.45
T-13	6.58	53.35	95.6	0.068	5355	5.43	3.24
T-14	11.08	47.67	108.8	0.073	5144	5.58	3.26
T-15	12.06	47.77	102.1	0.088	5545	4.78	3.21
T-16	5.63	40.88	106.8	0.071	3146	4.91	3.38
LSD (5%)	0.04	0.32	1.64	0.002	83	0.03	0.01

rhizosphere micro flora which increases enzyme activity, followed by mineralization. These results were similar to Silvia et al. (2008) where they suggested that microorganisms are responsible for chemical transformations in the soil, and rhizosphere enzymes are key indicators of mineralization and overall soil fertility.

Significant accumulation of total chlorophyll and reducing sugar in plant leaves were recorded in T-12 followed by T-11 after drip irrigation plant metabolites were observed highest in flood irrigated plots, followed by rain fed irrigation. Timely irrigation and fertilization allows plant to absorb nutrients and use them in metabolism for synthesis of molecules, which are necessary for growth. Effect of nitrogen fertilizers on yield and leaf chlorophyll content was also seen in safflower (Christos and Dordas CS, 2008). This accumulation will help the plant in future for better growth and defence in all weather condition. Three years old bamboo leaves were analysed for macro (N-P-K) and micronutrients - Cu, Zn, Mn and Fe (Table 4). Higher influx of N-P-K was observed in T-12, followed by T-16, T-8 and T-11. It is an impact of compatible dose of organic and chemical fertilizers. Therefore, 100% recommended chemical fertilizers could not make significant impact on above mineral absorption. In the micronutrient uptake, the 50:50 combination and organic manure sole with drip irrigation performed

Table 4. Effect of various treatments on nutrient uptake of bamboo.

Treatment	Nutrient uptake						
	Macro-nutrient (%)			Micro-nutrient (PPM)			
	Nitrogen	Phosphorus	Potassium	Copper	Zinc	Manganese	Iron
T-1	1.01	0.58	1.32	21	117	200	206
T-2	1.34	0.61	1.29	22	119	201	208
T-3	1.76	0.64	1.42	24	124	207	212
T-4	1.87	0.68	1.46	25	133	212	218
T-5	1.07	0.65	1.53	24	125	198	211
T-6	1.98	0.72	1.67	25	126	204	215
T-7	2.13	0.78	1.72	27	132	214	219
T-8	2.28	0.81	1.79	29	139	223	225
T-9	1.23	0.71	1.57	25	121	213	219
T-10	2.09	0.73	1.81	27	127	224	223
T-11	2.26	0.79	1.86	29	138	232	227
T-12	2.43	0.84	1.98	32	142	246	230
T-13	1.25	0.69	1.58	26	122	212	220
T-14	2.11	0.71	1.83	33	128	225	225
T-15	2.15	0.76	1.71	27	132	214	219
T-16	2.31	0.81	1.79	28	137	225	235
LSD (5%)	0.02	0.03	0.04	0.05	0.09	0.19	0.15

significantly (T-12, 14 and 16 found maximum followed by T-7). Overall 9 to 48% in N-P-K and 5 to 21% in micronutrients enhancement was recorded in various treatments. Nitrogen uptake was very much influenced by fertilization and irrigation, and enhancement went up to 48% over the respective control. Similar results were reported by Ming-Gang et al. (2008) in rice, they also observed highest yield with organic manures when it was mixed with 50% recommended dose of chemical fertilizers, followed by chemical fertilizer sole.

Dehydrogenase, FDA'ase, total chlorophyll, reducing sugars, nitrogen, phosphorus and potassium were estimated in 28 month old Guggul plant after transplantation to field (Table 5). The response of 50:50% combinations of fertilizers and drip irrigation were observed significantly in T-12. Flood and rain fed irrigation were also found satisfactory in T-8 and T-4, respectively. Particularly in guggul, only 4 to 10% difference was observed among all irrigation and fertilization treatments but enhancement was significant over the respective control. Guggul is hard in nature, retain enough moisture in rhizosphere, and shed entire leaves in summers, so overall, its transpiration rate is very slow through its areal part. Its rhizosphere and leaf metabolism is also different from other tropical crops (Yadav and Yadav, 2008). Therefore, guggul was taken as intercrop in this experiment because it develops micro-climate which gives platform for cultivation of bamboo.

Bamboo plant height (Figure 1), number of culms (Figure 2) and culm diameter (Figure 3) were recorded. In first year, all the treatments were not clearly differentiated. Response of fertilization and irrigation were distinguished from second year onwards. In bamboo, T-12 showed maximum enhancement in growth where 50:50 combinations of recommended chemical fertilizers and organic manure were given, followed by T-11. Effect of organic manure in T-2 is also clearly visible on plant height, number and diameter of culms of bamboo in first two years but in third year, it was less than all drip irrigated plots. Since T-2 is rain fed plot, so it may be due to good rain fall in these years. These results confirmed the earlier findings of Gosh et al. (2004) who reported that organic manure and recommended dose of N, P and K enhance yield when it applied in combination on soybean compared to sole, 25% chemical fertilizer can be saved. Average 55% enhancement was observed in bamboo over than rain fed control and among irrigation treatments, it was 15 and 30% in rain fed and flood irrigation, respectively. Overall drip irrigation response was found satisfactory, followed by flood and rain fed irrigation over the control. In T-13, 14, 15 and 16, where bamboo was planted inside and guggul on the boundaries, no significant result was observed in all the fertilization and irrigation treatments but response was better than control.

In recent observations, highest plant height was observed in T-12 followed by T-11, 10 and 9 and drip irrigation significantly enhanced number and diameter of culm, followed by flood and rain fed irrigation. T-9, T-2 and 16 were also found satisfactory over the control as compared to other treatments. It might be due to the availability of nutrients and water in plant rhizosphere. It

Table 5. Effect of various treatments on rhizosphere enzymes, metabolites and nutrient uptake in guggul.

Treatment	Soil enzymes (p Kat g^{-1})		Plant metabolites (mg g^{-1} fresh weight)		Nutrient uptake (%)		
	Dehydrogenase	Fluorscein diacetate	Total chlorophyll	Reducing sugar	Nitrogen	Phosphorus	Potassium
T -1	8.8	3450	5.13	2.89	2.31	0.72	1.58
T -2	10.5	4156	6.04	3.24	2.47	0.79	1.76
T -3	9.8	3213	5.46	3.19	2.41	0.81	1.68
T -4	10.2	4056	6.09	3.24	2.48	0.83	1.71
T -5	9.6	3765	5.76	3.32	2.35	0.73	1.68
T -6	10.2	3876	5.87	3.39	2.41	0.75	1.71
T -7	10.5	3987	5.96	3.46	2.49	0.79	1.73
T -8	11.0	4150	6.14	3.54	2.54	0.82	1.78
T -9	9.0	4034	5.98	3.32	2.52	0.78	1.79
T -10	10.7	4114	6.08	3.47	2.56	0.79	1.82
T -11	10.9	4289	6.16	3.53	2.61	0.82	1.87
T -12	11.5	4345	6.27	3.62	2.69	0.86	1.85
T -13	9.2	4015	5.96	3.31	2.52	0.77	1.78
T -14	10.6	4111	5.98	3.44	2.55	0.76	1.82
T -15	10.7	3845	4.89	3.44	2.46	0.77	1.72
T -16	11.8	4112	5.78	3.55	2.48	0.79	1.76
LSD (5%)	0.05	15.9	0.07	0.03	0.01	0.01	0.01

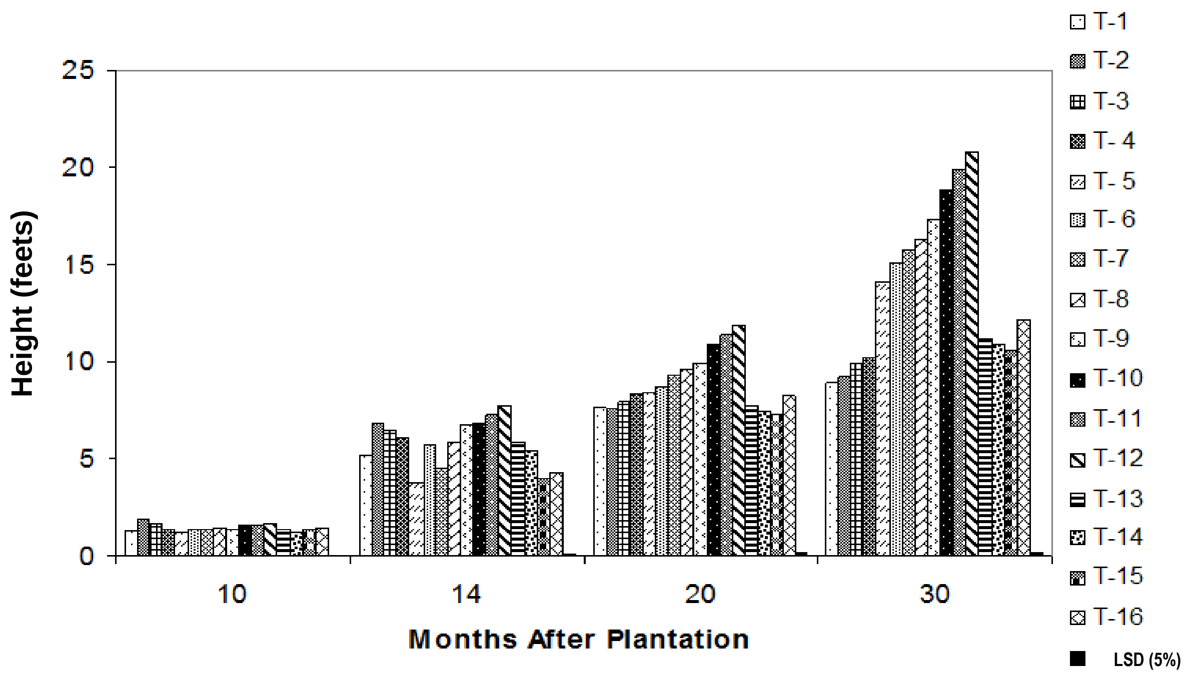

Figure 1. Effect of fertilization and irrigation on plant height of bamboo.

has also been concluded by Yang et al. (2011) that drip irrigation provides water to plants in a balanced mode, which allow plants for proper nutrient uptake.

Guggul collar diameter (Figure 4) and plant canopy Figure 5) were measured, until one and half year response, there was no significance among all the treatments except rain fed treatment, but over the control, it was good. After one year, significant growth was

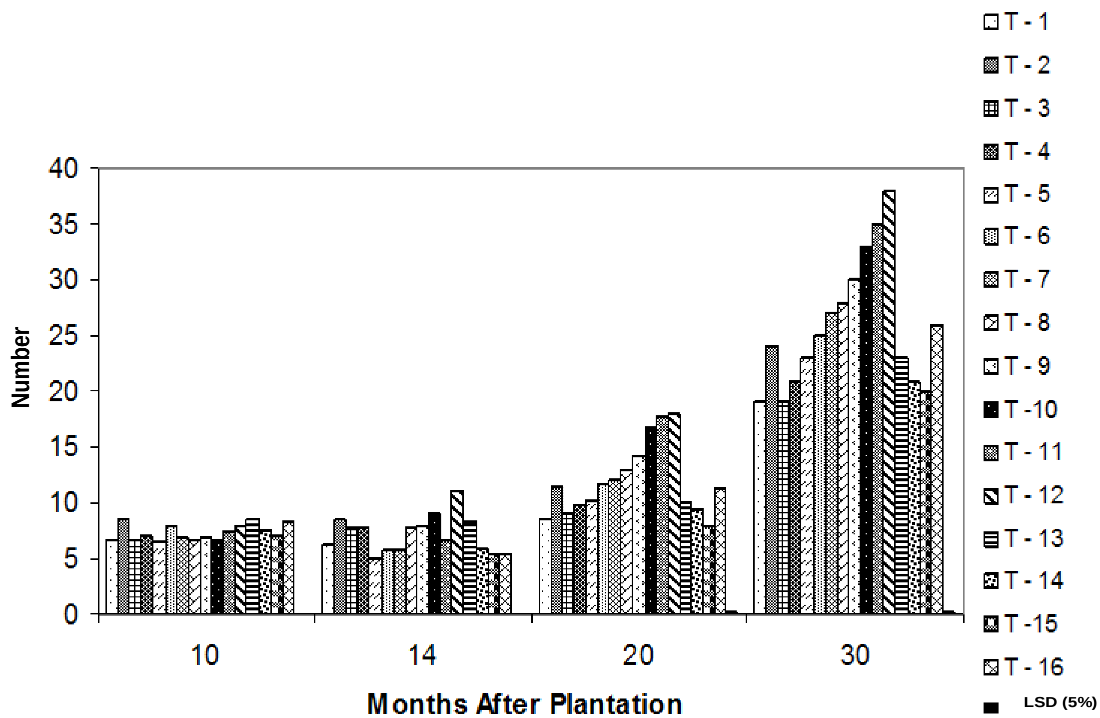

Figure 2. Effect of fertilization and irrigation on number of culms of bamboo.

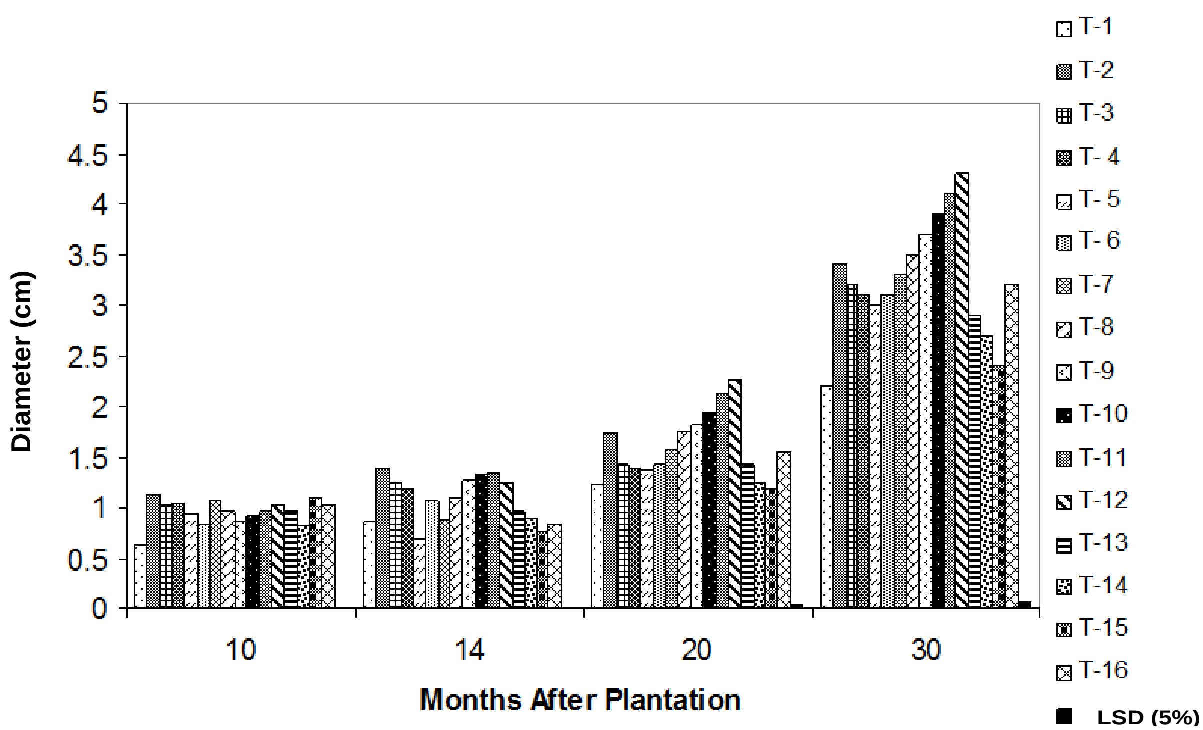

Figure 3. Effect of fertilization and irrigation on culm diameter of bamboo.

observed in T-12 followed by T-11 and T-10 in drip irrigation. At par, response were observed in T-2, T-3 and T-4 also. Drip irrigation enhanced the growth, and 6% difference was found in between rain fed and drip irrigation. The same trend was observed in the third year also.

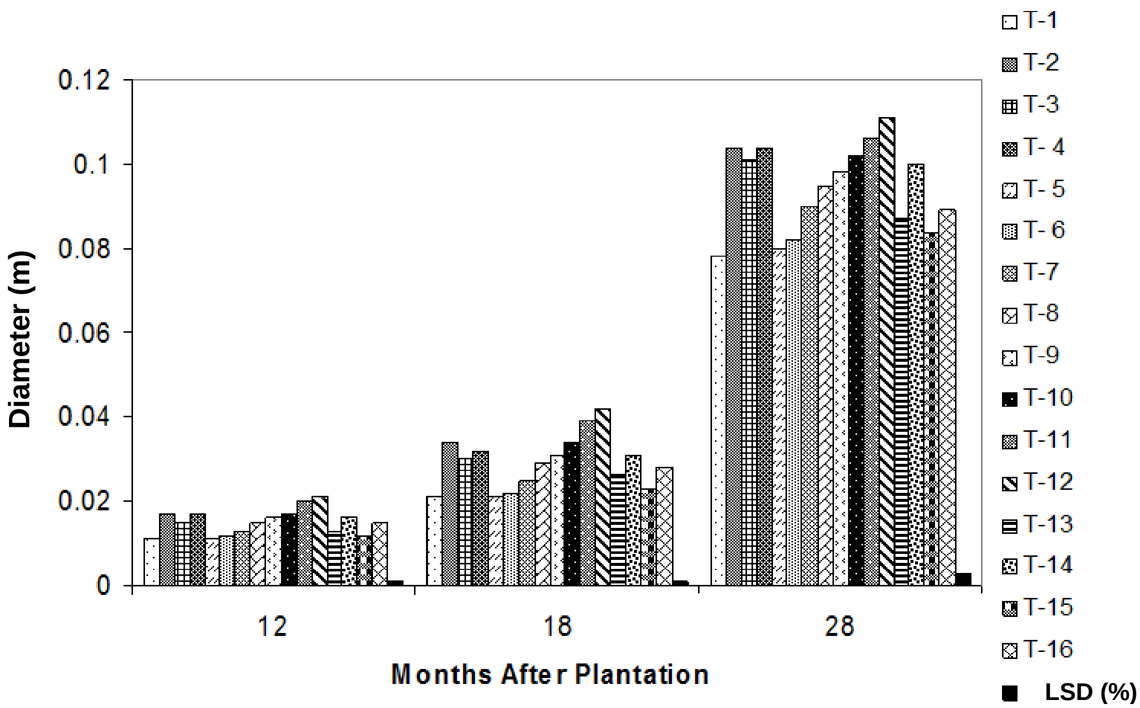

Figure 4. Role of fertilization and irrigation on collar diameter of guggul.

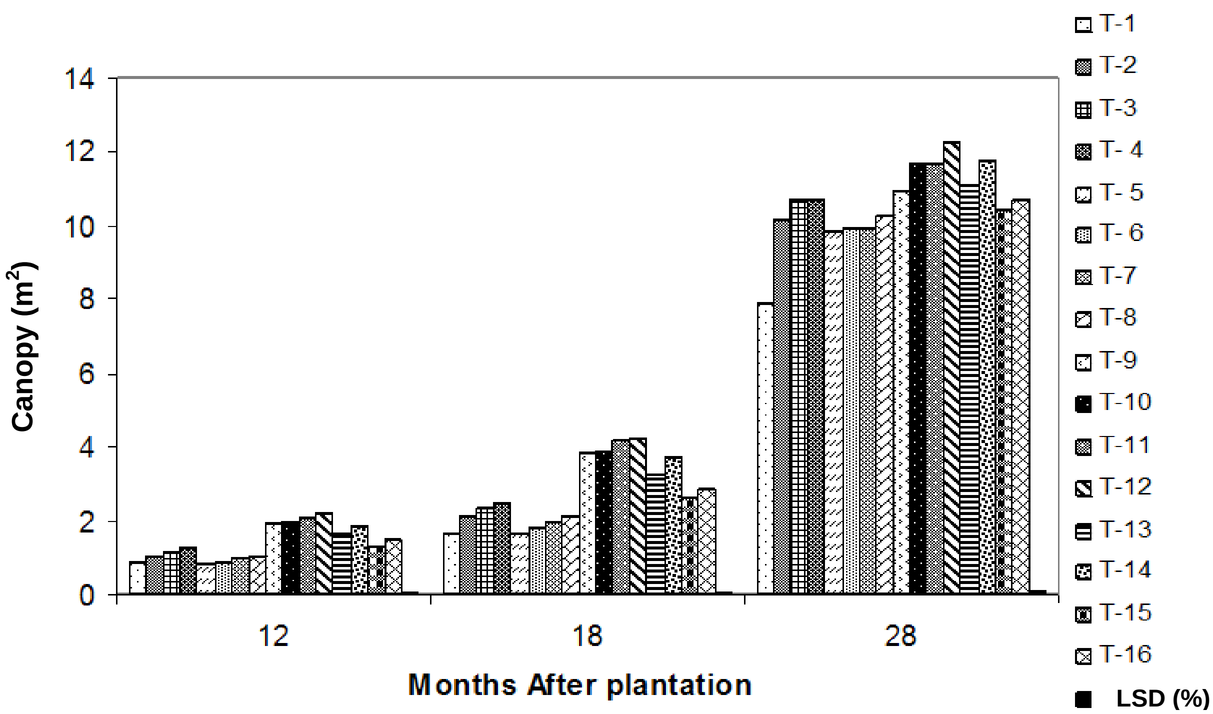

Figure 5. Role of fertilization and irrigation on plant canopy of guggul.

Microbial biomass carbon (Figure 6) fluctuated as per fertilization and irrigation. In first year, highest biomass carbon was observed in T-10 followed by T-6 and T-12, similar pattern was observed in second year onwards but after T-10, maximum was in T-12 followed by T-6. Microbial biomass carbon and nitrogen increased by

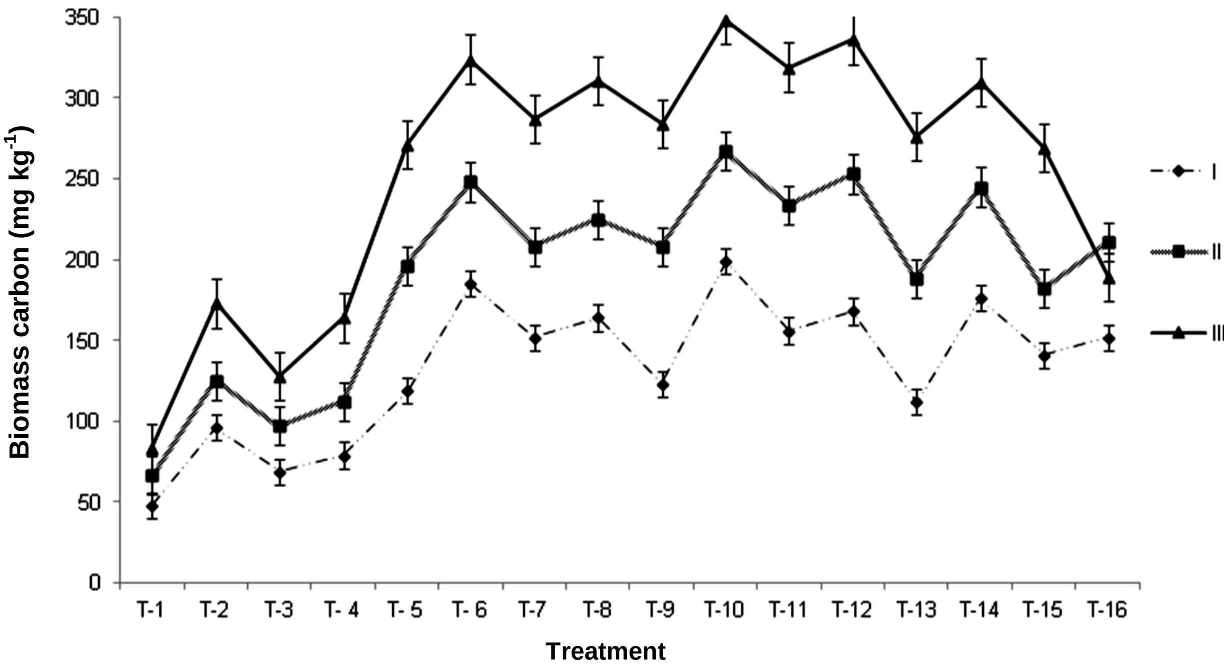

Figure 6. Effect of fertilization and irrigation in bamboo field.

application of organic manure in initial two years, and this practice can change the entire microbial ecology, besides enhanced microbe mediated mineralization. So, in the third year, biomass C and N was reduced but crop yield was increased. It is due to the development of sustainable microbial community in rhizosphere zone which affect biomass C and N in organic farming system (Tu et al., 2006). Successful cultivation of bamboo was recorded in this experiment which is first time in semi arid regions of Indian Thar desert because of balanced fertilization and drip irrigation. In spite of all, micro-climate which is developed by intercrop guggul cannot be ruled out for bamboo cultivation.

Conclusion

In this study, effect of various irrigation and fertilization methods were observed on bamboo cultivation in semi arid area of Indian Thar desert, and guggul (*Commiphora wightii* Arnott.) was identified as intercrop which is resident of this area. Therefore, it can be concluded that bamboo can be cultivated in semi arid areas also but it is desirable to identify an intercrop that is resident of the particular ecosystem. This practice may help in the establishment of bamboo forests for socio-economic benefits.

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