Effect of teak (*Tectona grandis* L)-*Ocimum* spp-based silvi-medicinal systems on growth and physiological parameters of *Ocimum* spp

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ABSTRACT

To investigate the effect of teak + *Ocimum* spp silvi-medicinal systems on growth and physiology of *Ocimum* spp, *Ocimum tenuiflorum*, *O gratissimum* and *O basilicum* were cultivated under 18 year-old teak (*Tectona grandis*)-based silvi-medicinal and sole cropping systems. All the *Ocimum* species showed better growth under sole cropping as compared to silvi-medicinal system. Superior plant height (0.69 m), maximum number of branches (12.30), leaves per plant (139.18) and largest plant spread (0.22 m) were recorded in *O tenuiflorum*. The specific leaf weight was maximum (2.71 mg/cm^2) under sole cropping whereas chlorophyll content index (15.53) and leaf nitrogen (1.83%) were higher under silvi-medicinal system. Amongst *Ocimum* spp the maximum leaf area (15.69 cm^2/leaf), specific leaf weight (2.76 mg/cm^2), chlorophyll content index (19.84) and leaf nitrogen content (2.07%) were recorded in *O tenuiflorum.* Growth and physiological attributes of *O gratissimum* were better under teak-based silvi-medicinal system hence this species was proved as better intercrop to be grown with teak.

Keywords: Agroforestry; *Ocimum* spp; *Tectona grandis*; growth; chlorophyll; leaf nitrogen

INTRODUCTION

Mixed and intercropping are the sustainable systems which increase stability of the farming systems by increasing diversity and complexity (Zhang and Li 2003) and may increase yield compared to sole crops (Bedoussac and Justes 2010). In intercropping using a variety of plants in the field (woody and non-woody) results in increased production and in total optimal utilization of resources (Mazaheri 1993). Intercropping is considered a practical application of basic ecological principles such as diversity, competition and facilitation (Schoeny et al 2010). These ecological principles do exist in agroforestry systems and light is the major limiting factor for the growth of understory vegetation in agroforestry system (Basavraju et al 2001, Peri et al 2007, Reynolds et al 2007, Mishra et al 2010) along other microclimatic parameters manipulating the growth and assimilatory functioning of the under-canopy crops in the agroforestry systems. Sometimes the intercrops are chosen wisely considering their light requirement or conversely their ability to grow in intimate association with the trees under shade. One such group of plants is medicinal and aromatic plants (MAPs) which grow under shade in wild (Vyas et al 1996, Shankarnarayan 1998, Vyas and Nein 1999). This shade loving nature of MAPs has been tested by intercropping them under tree-based agroforestry systems (Karikalan et al 2002, Dutt and Thakur 2004, Singh et al 2008a, Singh et al 2008b, Ravitchandirane and Haripriya 2011, Thakur et al 2014). Thus there is ample scope to devise MAP-based intercropping or agroforestry systems integrating these valuable plants under tree canopy. A long list of industrially important MAPs exists and out of these one such genus is *Ocimum*. Many species of genus *Ocimum* are used in pharmaceutical industries as whole herb and essential oils are used in perfumery and cosmetics industries (Javanmardi et al 2002) and grown in the world either for the fresh market or for essential oil production (Zheljazkov et al 2008). *O americanum*, *O basilicum*, *O sanctum* and *O tenuiflorum* are among the 178 high trade species in India (Ved and Goraya

2007). On the other hand teak is recognized for its durable timber. According to world teak conference (Anon 2013) total Area under commercial teak plantation in India is 2561000 ha. According to FAO reports in the past 10 years (2005-2014) there has been a significant rise in the global trade of teak round-wood volume which was above 1 million m^3 on average per year which is about 3 per cent of the value of global timber trade (Anon 2015). Since the rotation of teak is very long there is need to develop agroforestry models by intercropping compatible intercrops for early returns. Although considerable work has been done on the production aspect of medicinal and aromatic plants in agroforestry systems (Thakur et al 2009, Verma et al 2010, Thakur et al 2011, Ravitchandirane and Haripriya 2011, Thakur and Verma 2012, Suvera et al 2015) yet information on tree-crop interaction with respect to shading effect on growth and physiological processes of the MAPs under commercial tree canopies need more exploration. Therefore the present study was intended to investigate the comparative effect of intercropping and sole cropping systems on growth and some physiological attributes of three *Ocimum* spp.

MATERIAL and METHODS

Site conditions

The investigation was carried out during 2013-2014 in experimental farm of ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat situated at 20.95º N latitude and 75.90º E longitude at an altitude of 10 m amsl. The climate of the area is typically tropical with average annual maximum and minimum temperatures of 40 and 18ºC respectively and average annual rainfall of 1220 mm. Available N and P_2O_5 were estimated as per Subbiah and Asija (1956) and Olsen et al (1954) respectively whereas K_2O (kg/ha), organic carbon (%) electrical conductivity and pH were estimated following Jackson (1973). The physico-chemical analysis of soil showed that the values of available N, P_2O_5, K_2O (kg/ha) and organic carbon (%) under silvi-medicinal system (teak + *Ocimum* spp) were 238.67, 35.46, 340.31 and 0.88 and the respective values in open field (sole *Ocimum* spp) were 197.46, 31.28, 311.23 and 0.59 respectively. The soil reaction was above neutral (7.7) with electrical conductivity of 0.36 DS/m. The light intensity under silvi-medicinal and open land use was measured with digital Lux meter taken at 10.00, 13.00 and 16.00 hours in each treatment during the investigation period at five days interval. The mean monthly light intensity values recorded from October 2013 to March 2014 (6 months, cropping period of *Ocimum* spp) under silvi-medicinal systems were less as compared to sole cropping systems and these increased from planting time to final harvest (Fig 1). The average height and diameter at breast height (DBH) of teak trees were 13.30 m and 21.90 cm respectively. The average crown spread was 3.80 (E-W direction) and 4.10 m (N-S direction).

Experimental techniques and data recording

Three *Ocimum* spp namely *O tenuiflorum* (O_1), *O gratissimum* (O_2) and *O basilicum* (O_3) were intercropped under 18 year old teak (*Tectona grandis*) plantation. The agroforestry systems so formed were named as silvi-medicinal systems (*T grandis* + *Ocimum* spp= LU_1) and sole cropping system or open land use (*Ocimum* spp in open= LU_2). The respective species was grown following standard agro-techniques (Hussain et al 1988). Plant height of intercrops was recorded at maturity from base to top in meters. Number of branches and leaves per plant were counted from randomly selected ten plants and the average values were calculated under each land use system. Plant spread of *Ocimum* spp was calculated by measurements in two directions viz east-west and north-south. Leaf area was measured with anatomical leaf area meter. Leaf specific weight was determined by the formula SLW (g/dm^2)= Leaf dry weight per plant (g)/Leaf area per plant (dm^2) (Radford 1967). Leaf chlorophyll content index was measured by using chlorophyll meter (Opti-sciences, CCM 200, USA) (Richardson et al 2002). Leaf nitrogen content of *Ocimum* spp was determined by using modified Kjeldahl's method (Kjeldahl 1883). The data generated were subjected to the statistical analysis using factorial randomized block design (FRBD) as outlined by Gomez and Gomez (1984).

RESULTS and DISCUSSION

Growth parameters of *Ocimum* spp

Results of the study revealed that growth attributes of *Ocimum* spp were significantly affected due to land use systems viz teak-based silvi-medicinal and sole cropping (Table 1a). These attributes also varied among *Ocimum* spp as well. Significantly maximum plant height (0.68 m), number of branches per plant (11.91), number of leaves per plant (117.24) and plant spread (0.19 m) were recorded under sole cropping as compared to silvi-medicinal system. Amongst *Ocimum* spp superior plant height (0.69 m), maximum number of branches (12.30), leaves per plant (139.18) and largest plant spread (0.22 m) were

Table 1a. Growth and physiological parameters of *Ocimum* species grown under *Tectona grandis*-based silvi-medicinal and sole cropping systems

Land use system	Plant height (m)				# branches/plant				# leaves/plant				Plant spread (E-W & N-S) (m)			
	O_1	O_2	O_3	Mean	O_1	O_2	O_3	Mean	O_1	O_2	O_3	Mean	O_1	O_2	O_3	Mean
LU_1	0.72	0.64	0.68	0.68	13.85	10.55	11.33	11.91	149.53	73.28	128.93	117.24	0.23	0.13	0.20	0.19
LU_2	0.65	0.54	0.60	0.60	10.75	6.75	7.38	8.29	128.83	58.02	113.14	99.99	0.20	0.10	0.17	0.16
Mean	0.69	0.59	0.64		12.30	8.65	9.35		139.18	65.65	121.03		0.22	0.12	0.18	

LU_1= Sole crop, LU_2= Teak + *Ocimum* species, O_1= *Ocimum tenuiflorum*, O_2= *O gratissimum*, O_3= *O basilicum*

	Plant height		# branches/plant		# leaves/plant		Plant spread	
	SEm±	$CD_{0.05}$	SEm±	$CD_{0.05}$	SEm±	$CD_{0.05}$	SEm±	$CD_{0.05}$
LU	0.016	0.048	0.26	0.78	2.65	7.99	0.005	0.015
O	0.019	0.06	0.32	0.96	3.25	9.78	0.006	0.019
LU x O	0.028	NS	0.45	NS	4.59	NS	0.009	NS

Table 1b. Growth and physiological parameters of *Ocimum* species grown under *Tectona grandis*-based silvi-medicinal and sole cropping systems

Land use system	Leaf area (cm^2)				Specific leaf weight (mg/cm^2)				Chlorophyll content index (CCI)				Leaf nitrogen content (%)			
	O_1	O_2	O_3	Mean	O_1	O_2	O_3	Mean	O_1	O_2	O_3	Mean	O_1	O_2	O_3	Mean
LU_1	4.03	16.10	3.86	7.99	2.49	3.02	2.61	2.71	9.96	17.85	7.76	11.86	1.60	1.94	1.50	1.68
LU_2	3.77	15.28	3.69	7.58	1.76	2.49	1.93	2.06	13.98	21.83	10.79	15.53	1.70	2.19	1.62	1.83
Mean	3.90	15.69	3.77		2.13	2.76	2.27		11.97	19.84	9.27		1.66	2.07	1.56	

LU_1= Sole crop, LU_2= Teak + *Ocimum* species, O_1= *Ocimum tenuiflorum*, O_2= *O gratissimum*, O_3= *O basilicum*

	Leaf area		Specific leaf weight		C hlorophyll content index		Leaf nitrogen content	
	SEm±	$CD_{0.05}$	SEm±	$CD_{0.05}$	SEm±	$CD_{0.05}$	SEm±	$CD_{0.05}$
LU	0.151	NS	0.049	0.15	0.29	0.89	0.022	0.07
O	0.19	0.56	0.06	0.181	0.36	1.09	0.027	0.08
LU x O	0.261	NS	0.085	NS	0.51	NS	0.04	NS

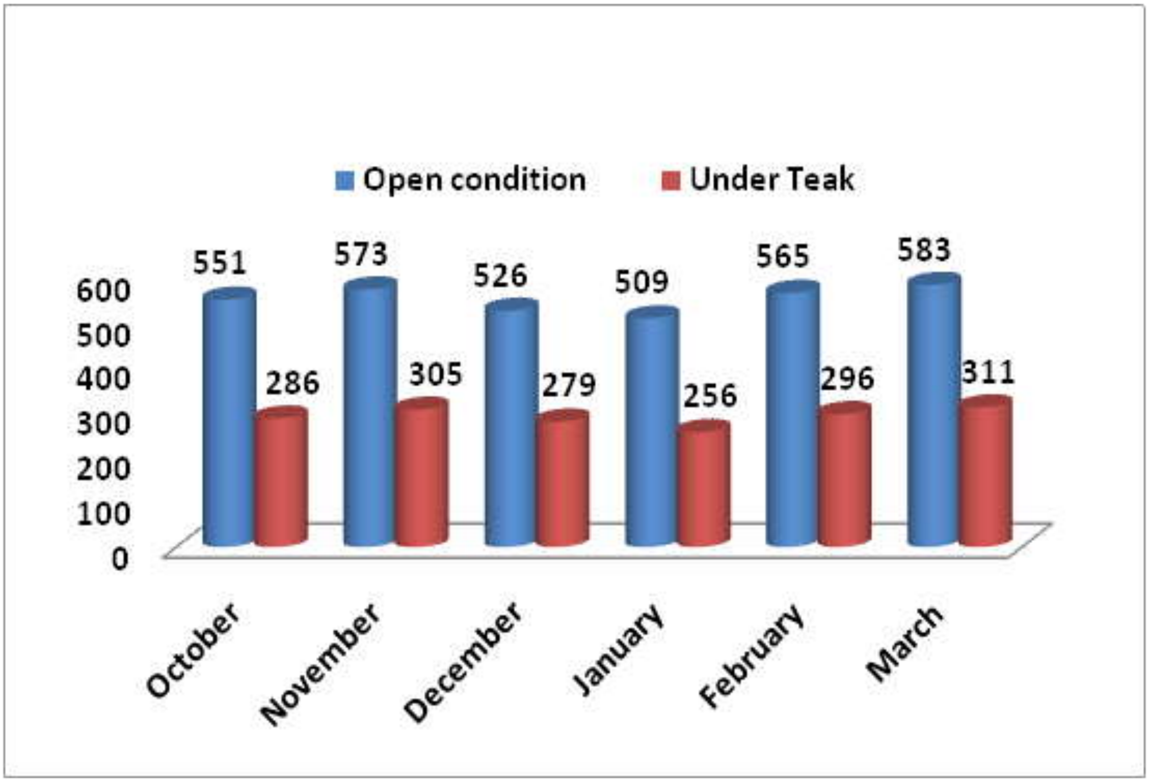

Fig 1. Average light intensity during intercropping period

recorded in *O tenuiflorum*. The interaction effect due to two land use systems was non-significant.

The reduced plant growth under teak-based silvi-medicinal system may be attributed to reduction in cell turgidity as a result of stress imposed due to competition for water which lead to decrease in cell elongation and might also be due to reduced light intensity (Fig 1). Since sole crop had a competition-free environment thus resulted in better growth (Patil et al 2011). Similar results were also recorded by Sharma et al (2011a, 2011b), Mutanal et al (2009) and Nagarajaiah et al (2012).

Intercrops under agroforestry due to competitive effect of teak attained less plant height, number of leaves and also leaf area (Patil et al 2011). Reduced plant height and number of branches of medicinal and aromatic crops (*Aloe*, Kalmegh, *Stevia*, *Citronella*, lemongrass, palmarosa and patchouli) under teak (Nagarajaiah et al 2012), kapok (Karikalan et al 2002) and wheat under teak (Sharma et al 2011b) have been reported due to reduced light intensity and competition for moisture between tree species and intercrops. Lesser amount of light allowed by teak might have negative effect on growth of *Ocimum* spp.

Physiological parameters

Specific leaf weight (mg/cm^2), chlorophyll content index and leaf nitrogen content (%) of all the *Ocimum* spp varied significantly under silvi-medicinal and sole cropping as well as among the species (Table 1b). Land use systems failed to exhibit any significant effect on leaf area however it varied significantly among species.

The specific leaf weight (SLW) was maximum (2.71 mg/cm^2) under sole cropping whereas chlorophyll content index (15.53) and leaf nitrogen (1.83%) were higher under silvi-medicinal system. Among *Ocimum* spp the maximum leaf area (15.69 cm^2/leaf), specific leaf weight (2.76 mg/cm^2), chlorophyll content index (19.84) and leaf nitrogen content (2.07%) were recorded in *O tenuiflorum.* The interaction due to land use systems failed to show any significant effect on physiological parameters. Higher SLW in open conditions may be due to higher deposition of wax/cuticle and/or development of more palisade layer. Shading due to tree component lead to low specific leaf weight resulting in reduced tissues available in unit leaf area (Allard et al 1991). Similar results have been reported by Singh (1997) and Rao and Mitra (1988). The low photosynthetic rate in shade-grown plants can be attributed to lower RUBP carboxylase activity (Usuda et al 1985) and lower stomatal conductance (Vandana and Bhatt 1999). Chlorophyll content index (CCI) in *Ocimum* leaves was recorded significantly higher under agroforestry system as compared to sole cropping. This might be due to less light intensity leading to the total protein, amino acids and total carbohydrates while it had promoting effect on the synthesis of total chlorophyll which might have helped in increasing light absorption.

Higher chlorophyll content of *Cenchrus ciliaris* grown under *Acacia tortilis* has been reported by Mishra et al (2010). The higher chlorophyll content due to shading effect has also been reported in several crops grown under agroforestry systems (Koocheki et al 2001, Ghosh et al 2006, Rezaei-Chianeh et al 2010, Hamzei 2012), Tsubo et al (2005) and Shaker-Koohi et al (2014). The results are in agreement with present study.

Leaf nitrogen content of *Ocimum* spp was recorded significantly higher in shade condition as compared to open condition indicated by higher accumulation of protein, carbohydrates and nutrients. Photosynthetic proteins represent a large proportion to total leaf N (Evans 1989, Field and Mooney 1986). Chlorophyll content is approximately proportional to leaf nitrogen content too (Evans 1983). Recent studies have indicated a close relationship between chlorophyll content and leaf nitrogen content which is important because most of the leaf nitrogen is constrained in chlorophyll molecules (Vrbnicanin et al 2012). The crude protein is directly related to the available nitrogen content in the leaves and stem and it is assumed that under high shading environment the inorganic nitrogen is in the form of nitrate which might be due to slow process of nitrogen assimilation (Mishra et al 2010).

CONCLUSION

The investigation pointed out that the growth and physiological attributes of *Ocimum* spp were significantly affected due to land use systems. There was significant reduction in growth attributes under silvi-medicinal land use however the chlorophyll content index and leaf nitrogen were increased. Among *Ocimum* spp growth and physiological attributes of *O gratissimum* were better under teak-based silvi-medicinal systems hence this species proved better intercrop with teak.

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