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HERBAGE AND ESSENTIAL OIL YIELD OF *OCIMUM* SPP. INTERCROPPED UNDER *PONGAMIA PINNATA* BASED SILVI-MEDICINAL SYSTEMS IN GUJARAT, INDIA

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ABSTRACT

Present investigation was carried out in ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. Four *Ocimum* species namely *O. sanctum*, *O. tenuiflorum*, *O. basilicum* and *O. gratissimum* were intercropped under 2.5 years old Karanja (*Pongamia pinnata*) based agroforestry systems named as silvi-medicinal system (Pongamia+*Ocimum* spp.) and sole cropping system following Factorial Randomized Block Design with three replications. Significantly higher fresh above and below ground and total herbage and oil yield of *Ocimum* spp. was recorded under silvi-medicinal systems compared to sole cropping. Out of four *Ocimum* species, maximum values of fresh above ground (10.54 t/ha) and total herbage yield (12.05 t/ha) were attained by *O. tenuiflorum*. Whereas, maximum below ground fresh herbage yield (20.08 t/ha) was recorded for *O. basilicum*. Among intercrops, significantly maximum oil yield (61.32 kg/ha) was obtained for *O. tenuiflorum*. The findings suggested that higher fresh herbage and oil yield can be achieved under silvi-medicinal systems (Karanja + *Ocimum* spp.) compared to sole cropping.

INTRODUCTION

The Planning Commission, India had set a target of establishing bio-fuel plantations on 400,000 ha for the year 2006-07 with blending of diesel with 20 per cent bio-diesel by the year 2012. In order to meet the projected diesel demand bio-diesel yielding species needed to be cultivated over an area of 2 million hectare to produce around 2.62 MT of bio-diesel. One of such potential tree borne oil seed species (TBOS) is *Pongamia pinnata*. Which apart from TBOS, is also a nitrogen fixer, suitable for problematic soils and drought conditions (Duke, 1983), used as fodder, construct cabinets, cart wheels, posts, agricultural implements, tool handles (Singh, 1982), with moderate dust collection potential and air pollution tolerance index (Thakar and Mishra, 2010), suitable tree in agroforestry (Beniwal and Chauhan, 2011) and a good botanical against phytopathogenic fungi (Kumari *et al.*, 2013 and Dhingani *et al.*, 2013). Though the plantations of different TBOS have been encouraged, however, studies revealed that the yields (0.6 to 1.1 t/ha) are not so economical (Rao *et al.*, 2012). Hence, it is advocated to grow short rotation crops to make TBOS plantations economically sustainable through intercropping in the initial years. The most important question is selection of suitable species, which have market demand, based on time and space tested. Studies revealed that, shade loving medicinal and aromatic plants are suitable intercrops with woody perennials (Vyas *et al.*, 1996; Shankarnarayan 1998; Vyas and Nein 1999; Singh *et al.*, 2008 a and b; Ravitchandirane and Haripriya, 2011) and the practice is termed as 'silvo-medicinal' systems (Zou and Sanford, 1990). Since, majority of the medicinal plants are found in forest and also shade tolerant; therefore agroforestry offers a convenient strategy for promoting their cultivation and conservation. The present investigation, therefore, anticipated to integrate *Ocimum* species with *Pongamia pinnata* (Karanja). Many species of *Ocimum* have medicinal value, oil of certain species of *Ocimum* has the antifungal, bactericidal and insecticidal properties too (Javanmardi *et al.*, 2002). Sweet basil (*Ocimum basilicum*) and holy basil (*Ocimum sanctum*) are the most widely grown basil species 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 with estimated annual trade of 500-1000, 1000-2000, 2000-5000 and 2000-5000 MT, respectively (www.nmpb.nic.in). Therefore, owing to the importance of both tree component (karanja) and intercrops (*Ocimum* spp.) the present investigation was carried to screen out the compatible species to evolve viable silvi-medicinal models.

MATERIALS AND METHODS

Site conditions

Present investigations were carried out in 2011, at ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India, situated at 20.95ºN latitude, 75.90ºE longitude at an altitude of 10 m above the mean sea level. The climate of the area is typically tropical with average maximum and minimum temperatures are 40ºC and 18ºC, respectively and the average annual rainfall is 1220mm.

Experimental techniques and data observations

Four *Ocimum* species viz.,*O. sanctum* (S_1), *O. tenuiflorum* (S_2), *O. basilicum* (S_3) and *O. gratissimum* (S_4) were intercropped under two and half year old Karanja(*Pongamia pinnata*). The agroforestry systems so formed were named as silvi-medicinal systems (Pongamia+*Ocimum* spp. =L_1) and sole cropping system or open land use (*Ocimum* spp. in open=L_0). The available N and P_2O_5 (kg ha^{-1}) were estimated following Subbiah and Asija (1956) and Olsen *et al.* (1954) whereas, K_2O (kg ha^{-1}), organic carbon (%) and pH were estimated following Jackson (1973), under both the land use systems. The light intensity under silvi-medicinal and open land use was measured with digital Lux meter, taken in each treatment at 10.00, 13.00 and 16.00 hours, during the investigation period, at five days interval. One month old seedlings of each species were planted at 30X30 cm spacing.

Farm Yard manure @ 20 tonnes/ha was applied to all the plots uniformly at the time of land preparation. Nitrogen (in the form of urea) @ 20 kg/ha was applied uniformly to all the plots as a basal dose. Fresh herbage yield (stem, branches, leaves and inflorescence) was recorded after harvesting the intercrops. Oil recovery was estimated by hydro distillation method using Clevenger Apparatus (Clevenger, 1928). To estimate the oil recovery (%) 100 gram of fresh herbage sample, comprising of leaves, inflorescence and very small twigs, was taken. The chopped sample was put in 500 ml capacity flask half filled with water. Distillation was done for about one and half hour. The oil being lighter than water was collected in the burette and reading was recorded. The oil yield per hectare was estimated by extrapolating the oil amount of oil recovered in the distillation. The total oil yield obtained was converted to kilogram per hectare multiplying litter per hectare by specific gravity of oil of individual species given below.

Species	**Specific gravity**
O. sanctum	0.92551
O. tenuiflorum	0.92551
O. basilicum	0.95500
O. gratissimum	0.91050

The data generated were subjected to the statistical analysis using factorial randomized block design (FRBD).

RESULTS AND DISCUSSION

Growth attributes of Pongamia trees and soil and light conditions

Average values of height (recorded with measuring tape) and collar diameter (recorded with digital calliper) of Pongamia trees were 2.88 m, 55.90 cm, respectively. The average crown spread was 2.19 m and 2.71 m in east-west and north-south directions, respectively.

The available N, P_2O_5, K_2O (kg ha^{-1}), organic carbon (%) and pH under (estimated following standard methods) Silvi-medicinal system (Pongamia + *Ocimum* spp.) was 233.76, 34.02, 321.71 and 0.82, respectively and the respective values in open field (sole *Ocimum* spp.) were 206.00, 30.67, 301.89 and 0.68.The soil reaction was above neutral (7.4).

The light intensity (measured with digital Lux meter) taken in each treatment at 10.00, 13.00 and 16.00 hours, during the investigation period, at five days interval. The mean monthly light intensity values [recorded from July to November (5 months, cropping period of *Ocimum* spp.)] were 354.64, 352.68, 362.29, 352.21, 364.27 under silvi-medicinal agroforestry systems and 564.64, 572.88, 529.97, 545.54, 578.15 under sole cropping systems (Fig. 1).

The soil physic-chemical analysis evinced that, nutrient and organic matter status better under Pongamia based silvi-medicinal systems. Improved soil physicochemical properties in Pongamia based agroforestry systems have been reported by Banerjee *et al.* (2013). The light intensity was less under silvi-medicinal systems as compared to open land use during the course of study.

Herbage yield of *Ocimum* spp. (tones/ha)

Maximum above ground fresh herbage yield (7.64 tonnes/ha) of *Ocimum* spp. was recorded under silvi-medicinal systems (Table 1) followed by sole grown crops (6.95 tonnes/ha). Amongst *Ocimum* species, maximum above ground fresh

Table 1: Fresh herbage yield (tonnes/ha) *Ocimum* species grown under *Pongamia pinnata* based silvi-medicinal and sole cropping systems

Land use systems	Above ground (t/ha) *Ocimum* spp.				Mean	Below ground (t/ha) *Ocimum* spp.				Mean	Total (*Panchang*)(t/ha) *Ocimum* spp.				Mean
	(S_1)	(S_2)	(S_3)	(S_4)		(S_1)	(S_2)	(S_3)	(S_4)		(S_1)	(S_2)	(S_3)	(S_4)	
(L_0)	5.88	9.86	5.94	6.12	6.95	1.73	1.41	1.88	1.30	1.58	7.61	11.27	7.81	7.42	8.53
(L_1)	6.29	11.21	7.20	5.85	7.64	1.81	1.61	2.28	1.26	1.74	8.10	12.82	9.48	7.10	9.38
Mean	6.09	10.54	6.57	5.98		1.77	1.51	2.08	1.28		7.86	12.05	8.65	7.26	
Sources	SE±		CD 5%	CV%		SE±		CD 5%		CV%		SE±	CD 5%		CV%
L	0.21		0.64	9.98		0.05		0.14		9.75		0.25	0.77		9.81
S	0.30		0.90			0.07		0.20				0.36	1.09		
L x S	0.42		NS			0.09		NS				0.51	NS		

(S_1)=*O. sanctum*, (S_2)=*O. tenuiflorum*, (S_3) =*O. basilicum*, (S_4) =*O. gratissimum*, (L_0) =Open condition, (L_1)=Silvi-medicinal

Table 2: Essential oil recovery (%) and yield (kg/ha) of *Ocimum* species grown under *Pongamia pinnata* based silvi-medicinal and sole cropping systems

Land use systems	Oil recovery (%) *Ocimum* spp.				Mean	Oil yield (kg/ha) *Ocimum* spp.				Mean
	(S_1)	(S_2)	(S_3)	(S_4)		(S_1)	(S_2)	(S_3)	(S_4)	
(L_0)	0.67	0.58	0.60	0.81	0.66	39.33	57.56	35.36	49.38	45.41
(L_1)	0.81	0.58	0.61	0.74	0.68	50.72	65.07	43.66	43.54	50.75
Mean	0.74	0.58	0.60	0.78		45.02	61.32	39.51	46.46	
Sources	SE±	CD 5%			CV%	SE ±		CD 5%		CV%
L	0.007	NS			3.41	1.43		4.33		10.29
S	0.009	0.03				2.02		6.12		
L x S	0.013	0.04				2.86		8.66		

(S_1) = *O. sanctum*, (S_2) = *O. tenuiflorum*, (S_3) = *O. basilicum*, (S_4) = *O. gratissimum*, (L_0) = Open condition, (L_1) = Silvi-medicinal

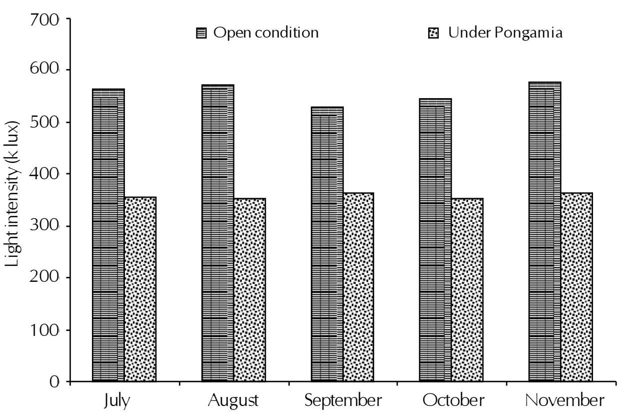

Figure 1: Average light intensity during intercropping period

herbage yield was recorded for *O. tenuiflorum* (10.54 tonnes/ha) followed by *O. basilicum* (6.57 tonnes/ha). The interaction effect due to two land use systems i.e. silvi-medicinal and sole crop was non-significant.

Below ground yield, of all intercrops under silvi-medicinal systems and sole crop as well as amongst *Ocimum* species, varied significantly. Higher below ground fresh yield (1.74 tonnes/ha) of *Ocimum* species was recorded under silvi-medicinal system as compared to sole crop (1.58 tonnes/ha). Among *Ocimum*s pecies, maximum below ground fresh yield (2.08 tonnes/ha) was obtained from *O. basilicum*, followed by *O. sanctum* (1.77 tonnes/ha).The interaction effect showed non-significant differences. Significant difference was observed in total fresh herbage yield i.e. Panchang (stem + leaves + inflorescence + seed +root) obtained from silvi-medicinal system and sole crop, and also among the *Ocimum*s pecies (Table 1). Maximum *Panchang* yield to the tune of 9.38 tonnes/ha was recorded from *Ocimum*s pecies intercropped under Karanja (L_1) as compared to open condition (L_0) in which it was 8.53 tonnes/ha. Among intercrops, *O. tenuiflorum* produced maximum *Panchang* (12.04 tonnes/ha), followed by *O. basilicum* (8.65 tonnes/ha). Interaction effect due to land use systems and intercrops did not show any significant difference.

The significant effect of silvi-medicinal land use systems on herbage yield may be ascribed to positive agroforestry interface (above and below ground) *i.e.* partial shade provided by karanja trees and difference in nutrient status (as described above) of land use systems (silvi-medicinal and sole cropping). Partial shade of trees may have favourable effect on the performance of the companion crop and hence the yield (Singh 1994; Maheta *et al.*, 1996; Partridge 1996; Vyas *et al.*, 1996). Growth, and bark and quinine yields of *Cinchona ledgeriana* grown in the Darjeeling hills, India, increased when it was associated with shade of five species compared with that of a non shaded stand (Nandi and Chatterjee, 1991). Higher yields of medicinal and aromatic, cereals and vegetables, under different agroforestry systems have been reported in various studies. The findings of Jasural *et al.* (1993), Ravindaran and Kulandaivelu (1998) and Vyas (2001) are in conformity with present investigation. Gangadharan and Menon (2003) reported that in case of under storey species, the effect of shade was significant, with lesser amount of shade promoting higher yield. Similar inferences have been drawn by (Ballare 1999; Pooter and Oliver 2000; Jha and Gupta, 1991; Nair *et al.*, 1991).

Synergistic effect in young mango orchards, on growth and yield of aloe and periwinkle (Ravitchandirane and Haripriya, 2011) and on cereals and vegetables (Singh *et al.*, 2008 a and b) have been reported. This was due to the fact that at the initial stage of fruit trees there are no adverse effect on the yield of intercrops. Since present studies were also carried out in young Pongamia plantation, the above arguments holds good and ascribed to higher yield of *Ocimum* species under silvi-medicinal system.

Crops like Ginger, galangal or *kacholam*(*Kaempferia galanga*) a medicinal and aromatic oil-yielding herb,*Plumbago rosea*, *K. galanga* and *Asparagus racemosus*, *Adhatoda beddomei* and *Holostemma adakodien*, *Pogostemon patchouli* grown in coconut gardens and *Curculigo orchioides* have performed better under agroforestry systems as compared sole cropping (Kumar *et al.*, 2001; Kumar *et al.*, 2005; Kurian *et al.*, 2003). Similar, results of increased fresh weight per plant of cardamom under the influence of Alnus were reported by Sharma *et al.* (1994). Finding of Maheswarppa and Nanjappa (2001) on galangal (*Koempfera galangal*) intercrop with coconut and Karikalan *et al.* (2002) in gymnema (*Gymnema sylvertre*) intercropped with Kapak (*Ceiba pentandra*). In contrary to present results, Singh (2003) reported lower herbage yield of lemongrass due to the shade of Casuarina. Sharanabasappa *et al.* (2007) observed marginal reduction (-2.39 to -14.02 %) in herbage yield of medicinal and aromatic crops.Agroforestry systems, particularly involving nitrogen fixing trees as well as other tree species have been found to improve the soil fertility and hence better crop yields (Chaudhry *et al*., 2007; Mohsin *et al*., 1996; Osman *et al*., 2001; Singh *et al*., 1989; Singh *et al*., 1997). The difference in nutrient status of land use systems *i.e.* Karanja (nitrogen fixing tree) based silvi-medicinal system and open condition may be endorsed to higher yield of intercrops in present study. Improved soil physicochemical properties under pongamia based agroforestry systems and higher intercrop yields have been reported by Banerjee *et al*. (2013).

Oil recovery and yield (kg/ha)

Oil yield of *Ocimum*s pecies, intercropped under karanja and as sole crop, differed significantly (Table 2). Maximum oil yield (50.75 kg/ha) from *Ocimum*s pecies was obtained from silvi-medicinal system (L_1) as compared to sole cropping (45.41 kg/ha).Among intercrops, significantly maximum oil yield (61.32 kg/ha) was recorded from *O. tenuiflorum* (S_2) which was followed by *O. sanctum* S_1 (45.02 kg/ha). Interaction due to land use system (silvi-medicinal and sole cropping) was statistically significant.

Oil yield, being dependent on the fresh herbage yield, was affected due to land use systems, significantly varied amongst *Ocimum* species as well as due to tree crop combinations and land use systems. *Ocimum* species grown under silvi-medicinal system gave higher oil yield. Out of the four *Ocimum* species, *O. tenuiflorum* produced maximum oil. The essential oil yield variation among the species may beascribed to genetic makeup individual species. Interaction due to land use system (silvi-medicinal and sole cropping) was statistically significant. Maximum oil yield was obtained from interaction L_1S_2 *i.e. O. tenuiflorum* grown under karanja.

The oil recovery in *O. sanctum* have been reported in the range of 0.5-1.0 per cent (Pareek and Gupta, 1984). Jeba and Vaidyanathan (2011) reported the percentage of essential oil obtained from fresh leaves of *Ocimum sanctum* (1.45 %w/w) and *O. basilicum* (0.98 %w/w), which higher compared to present values. The higher oil recovery from *O. sanctum* under silvi-medicinal may have resulted due to better soil nutrient status and positive effect of tree shade. Thakur *et al*. (2009) also reported significant effect on essential oil recovery from *O. sanctum* grown under peach, grewia and morus based agroforestry system. The bio synthesis of secondary metabolites in plants is an adaptive mechanism to shaded conditions, and is controlled by environment. These secondary products and alkaloids result from the breakdown and resynthesis from the primary products and this process is favoured by shaded conditions. This argument is supported by Ram *et al*. (1999) who reported that in patchouli (*Pogostemon patchouli*), patchouli alcohol was considerably higher in the intercropped situation of patchouli with papaya than in sole crop. Maheswarappa *et al*. (1998) also reported higher essential oil and oleoresin contents in the rhizomes of the intercropped kacholam. Comparatively higher essential oil yield in *O. basilicum*and *O. gratissimum* have also been reported (Pushpagandan and Bradu, 1995). Higher oil yield from *O. sanctum* grown under agroforestry systems in W. Himalayas has also been reported by Thakur *et al*. (2009), but with higher nitrogen application.

The findings of the present investigations suggested that higher fresh herbage yield of *Ocimum* spp. can be achieved under silvi-medicinal systems (Karanja + *Ocimum* spp.) compared to sole cropping. Among four *Ocimum* spp., *O. tenuiflorum* produced higher herbage yield and oil yield. Thus, the present investigation evinced that cultivation of *Ocimum* spp.can make karanja (a potential tree borne oil seed crop) plantation ecologically sustainable.

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