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Growth, yield and economics of vetiver (*Vetiveria zizanioides* L. Nash) under intercropping system

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ABSTRACT

Vetiver (*Vetiveria zizanioides* L.) is a high value essential oil crop, used as fixative in perfumery and cosmetic industries. Besides, the crop is also used to check soil erosion, water conservation, and reclamation of salt affected soils. Being vetiver a wider spaced crop with a long initial lag phase, thus the only option to sustain its productivity is intercropping. In a field experiment conducted during July, 2010–February, 2012 and July, 2012–February, 2014 at Lucknow, 13 cropping systems: sole crop of each of vetiver, sweet basil–radish–*Tagetes minuta*, black gram–clarysage, kalmegh–garlic, okra–radish–geranium, pigeon pea–menthol mint, maize–radish–onion and intercropping of above cropping sequences with vetiver were evaluated in randomized block design with three replications. Intercropping of sweet basil–radish–*T. minuta* with vetiver during rainy and winter seasons though reduced vetiver oil yield by 16.7% but was highly productive in terms of land equivalent ratio (1.54), land use efficiency (130%) and relative net return (1.35) and a net return of US$ 4801.7 ha^{-1} followed by intercropping of maize–radish–onion with vetiver. The system also gave about 35% more profit over the sole cropping of vetiver.

1. Introduction

Vetiver (*Vetiveria zizanioides* L. Nash) is a perennial grass of family Poaceae, native to India and widely cultivated in the tropical and sub-tropical regions of the world. It is grown as an industrial crop for the production of its high value essential oil, used as a fixative in perfumery and cosmetic industries. The oil also has antifungal, antibacterial, anticancer, anti-inflammatory and antioxidant activities, thus having application in the pharmaceutical industry (Luu Thai Danh, 2010). Besides, the crop is also used for thatching, mulch, feed, control runoff mitigation and reclamation of salt affected soils (Narong, 2001; Singh et al., 1987; Truong et al., 2008). The demand of vetiver oil is increasing globally day by day due its unique odor and fixative properties and the oil can neither be substituted with reconstituted oil nor made synthetically (Truong et al., 2008). India produces about 20–25 tons vetiver oil as against the global production of 250 tons annually (Lavania, 2003; Truong et al., 2008). The internal demand particularly of Northern type oil always falls short of supply. The Indian consumption at present is about 100 tons and more than 80% is met through import. The world's major producing countries are Haiti, Java, Reunion and India (Adams et al., 1998).

In the north Indian conditions the crop is generally harvested after 18 months and planted during July at wider row spacing of 60–75 cm and plant to plant spacing of 45–60 cm (Singh et al., 1987, 2002; Maheshwari et al., 1997; Priyadarshani et al., 2013). Since growth of vetiver plants is very slow during first 70–90 days and remain dormant in the winter season (October–February), its inter row spaces virtually remain vacant allowing infestation of weeds which grow at faster rate and compete for soil moisture and nutrients (Pareek et al., 1991). To overcome this problem and making the vetiver system sustainable and profitable, intercropping of short duration crop is only possible alternative. Very meager information is available on the above aspect so far. In view of the above, intercropping of different food, vegetable, medicinal and aromatic crops with vetiver in different cropping season were studied to sustain the productivity of vetiver oil with available land resources.

2. Materials and methods

2.1. Experimental site and soil

Two field experiments, first during July, 2010–February, 2012 and second during July, 2012–February, 2014 were carried out at

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Table 1
Variety, sowing/planting, harvesting time, spacing and fertilizer applied in different crops under sole and intercropping system.

Crops	Variety	Sowing/planting time	Spacing (cm)	Harvesting time	Days to maturity	$N:P_2O_5:K_2O$ (kg ha^{-1})
Vetiver	CIM-Vriddhi	I week July	60 × 30	I week, February	575	150:60:60
Sweet basil	CIM-Saumya	I week, July	45 × 30	III week, September	75	80:40:40
Black gram	Type-9	I week, July	30 × 15	I week, November	90	20:40:40
Kalmegh	CIM-Megha	I week, August	30 × 15	III week, October	105	80:40:40
Okra	Arka	I week, July	45 × 15	I week, October	100	100:50:50
Pigeon pea	UPAS-120	II week, July	60 × 30	III week, November	135	20:40:40
Maize	Hybrid Ganga-2	I week, July	45 × 15	IV week, September	80	80:40:40
Clarysage	CIM-Chandni	II week, November	45 × 30	I week, April	135	80:50:50
Tagetes minuta	Van Phool	IV week, November	45 × 30	II week, April	135	100:50:50
Garlic	Local	IV week, October	15 × 10	III week, April	180	80:40:40
Radish	White Angel	IV week, September	15 × 10	II week, December	60	60:30:30
Geranium	CIM-Pawan	II week, January	50 × 50	II week, June	145	150:60:60
Menthol mint	Kosi	I week, March	45 × 15	I week, June	92	150:60:50
Onion	Nasik red	II week, December	15 × 15	III week, April	130	80:40:40

the research farm of the Central Institute of Medicinal and Aromatic Plants, Lucknow, India, located at 26°5′ N latitude, 80°5′ E longitude with an elevation of about 120 m above mean sea level. The experimental site classified as semi-arid sub-tropical climate with severe hot summers and fairly cool winters. In this region monsoon normally sets from last week of June and continues till end of September with an average annual rainfall of 1000 mm. About 80% of the monsoon rains are received during July–September. Winter also experiences some rains due to cyclonic disturbances in Arabic sea. Mean maximum and minimum temperature fluctuated from 24.5 to 44.5 °C and 6.9 to 27.5 °C, respectively. The temperature was lowest during mid December to end of January and an increasing trend in mean temperature was noticed from first week of February and reached to highest in mid May and it declines only after the onset of rains. The soil of the experimental site was sandy-loam (Entisol) in texture with pH 7.9 and low in organic carbon (OC, 0.25%) and available nitrogen (N, 132 kg ha^{-1}), medium in available phosphorus (P, 11.8 kg ha^{-1}) and potassium (K, 140 kg ha^{-1}).

2.2. Treatment and experimental design

Thirteen treatments consisting of sole crop of each of vetiver, sweet basil–radish–*Tagetes minuta*, black gram–clary sage, kalmegh–garlic, okra–radish–geranium, pigeon pea–menthol mint, maize–radish–onion and intercropping of above cropping sequences with vetiver were evaluated in a randomized block design with three replications and individual gross and net plot size of 4 m × 4 m and 3 m × 3 m, respectively.

2.3. Raising of crops

Farm yard manure (10 t ha^{-1}) was applied two weeks before planting. The sowing/planting dates, spacing, varieties used, fertilizers applied and harvesting dates of the crops evaluated under different cropping systems are given in Table 1. Full amount of P_2O_5 and K_2O through single superphosphate and murate of potash were applied as basal dose at the time of planting. In pigeon pea and black gram full dose of nitrogen was also applied as basal. Rooted slips of vetiver were planted in first week of July, 2010 and 2012 at 60 cm × 30 cm spacing. In inter cropping treatments one row of sweet basil, okra, maize, clarysage, *T. minuta*, geranium and menthol mint, two rows of black gram and kalmegh and four rows of garlic, onion and radish were grown in between two rows of vetiver. In vetiver nitrogen was applied in three equal splits at 2, 8 and 12 months after transplanting. In sequential and inter crops nitrogen was applied in two/three equal splits. Experiment was conducted in irrigated condition and weeding and hoeing were done as and when required.

2.4. Plant sampling and biometric observations

For recording observations on number of tillers $plant^{-1}$, root length, root canopy and root yield $plant^{-1}$, three vetiver plants were randomly selected from each plot and uprooted at the time of harvesting (second week of February). For the estimation of essential oil content 200 g fresh clean roots from each plot were hydro-distilled using Clevenger type apparatus. The oil yield was calculated by multiplying the root yield with oil content and 1.0 (approximate specific gravity of oil). Yield of different intercrops was recorded.

2.5. Chemical profile of essential oil

Gas chromatography (GC) analysis of essential oil samples were carried out on Nucon gas chromatography model 5765 equipped with a flame ionization detector (FID), BP-20 (30 m × 0.25 mm × 0.25 μm film thickness). The temperature was programmed from 70 to 230 °C at 4 °C/min with an initial and final hold time of 2 min. The split ratio was 1:3. The injector and detector temperature were 200 and 230 °C on BP-20; 220 and 300 °C on Pe-5 column, respectively. Gas chromatography–mass spectrometry (GC–MS) was carried out on a Perkin Elmer Auto System XL GC and turbo Mass Spectrometry fitted with a fused silica capillary column, PE-5 (50 m × 0.32 mm, film thickness 0.25 μm). The column temperature was programmed at 100–280 °C at 3 °C/min using helium as a carrier gas at a constant pressure of 10 psi. MS conditions were EI mode 70 eV, ion source temperature 250 °C.

2.6. Intercropping indices

To assess the advantage from intercropping land equivalent ratio (LER), area time equivalent ratio (ATER), land use efficiency (LUE) and relative net return (RNR) were calculated using the formula developed by Mead and Willey (1980).

$$\mathrm{LER} = \frac{\mathrm{Yab}}{\mathrm{Yaa}} + \frac{\mathrm{Yba}}{\mathrm{Ybb}}$$

$$\mathrm{ATER} = \left(\mathrm{Yab} \times \frac{\mathrm{ta}}{\mathrm{Yaa}}\right) + \left(\frac{\mathrm{Yba} \times (\mathrm{tb}/\mathrm{Ybb})}{\mathrm{t}}\right)$$

$$\mathrm{LUE} = \left(\mathrm{LER} + \frac{\mathrm{ATER}}{2}\right) \times 100$$

$$\mathrm{RNR} = \frac{[(\mathrm{Pa} \times \mathrm{Yab} + \mathrm{Pb} \times \mathrm{Yba}) \pm \mathrm{Dab}]}{\mathrm{Pa} \times \mathrm{Yaa}}$$

where Yaa and Ybb are the yield of crop a and b in sole cropping. Yab and Yba are yield of crop a and b in intercropping. ta and tb

Table 2
Yield attributes and root yield of vetiver in sole and intercropping system.

Intercropping systems	Number of tillers plant^{-1}	Root length (cm)	Root canopy (cm)	Root yield (g plant^{-1})	Oil content (%)
Vetiver sole	84	24	30	68.7	1.00
Vetiver + sweet basil–radish–*T. minuta*	60.3	32	24	58.5	1.01
Vetiver + black gram–clarysage	60	29.6	22	53.5	0.95
Vetiver + kalmegh–garlic	58	31	23	54.2	0.97
Vetiver + okra–radish–geranium	56	32	22	51.4	1.00
Vetiver + pigeon pea–menthol mint	54	26	22	54.4	0.96
Vetiver + maize–radish–onion	44	22	21.3	52.7	0.95
SEm±	1.9	1.2	1.2	2.3	0.02
CD (5%)	5.9	3.9	3.5	7.1	NS

are the duration of crop a and b in intercropping and t is the total duration of intercropping system. Pa and Pb are the prices of crop a and b. Dab is the differential cost of cultivation of crop combination ab, compared with mono crop a (vetiver).

2.7. Computation of economics

For the estimation of economics of different intercropping systems the current market prices of inputs and out puts were taken.

2.8. Statistical analysis

The data recorded were statistically analyzed using the techniques described by Panse and Sukhatme (1985). Critical difference (CD) values at 5% level of probability were calculated for comparing the treatment means.

3. Results and discussion

3.1. Yield attributes

A perusal of data (Table 2) showed that number of tillers plant^{-1}, root canopy and root yield plant^{-1} in vetiver were significantly reduced but root length increased due to various intercropping. Significantly higher number of tillers plant^{-1} and root canopy in sole vetiver as compared to all the intercropping resulted in higher root yield plant^{-1}. This was due to competition for space and other growth resources with intercrops. There was no marked difference in essential oil content of vetiver root due to treatments. Similar results were recorded by Pareek et al. (1991).

3.2. Vetiver yield

Data on fresh root and oil yield of vetiver presented in Table 3 showed that root and oil yield were significantly reduced due to intercropping. The reduction in root yield was 13.9–25.1% and in oil yield was 16.7–26.8% as compared to sole crop. The highest reduction (26.8%) in oil yield of vetiver was noticed with intercropping of maize followed by okra and pigeon pea in rainy season. It was due to greater competition for growth resources like photosynthetically active radiation, nutrients and water. Intercropping of sweet basil–radish–*T. minuta* cropping sequence caused lowest reduction (16.7%) in oil yield of vetiver as these crops were either short statured or less exhaustive. Previous studies have reported cases of relative yield being influenced by difference between component crops in growth, maturity dates and plant height (Yadav and Yadav, 2001; Singh et al., 1998, 2012).

3.3. Intercrop yield

Yield of different intercrops grown in three seasons is given in Table 3. A perusal of data revealed that yield of different inter crops grown during rainy season was reduced by 21–55%, the lowest (21%) being in pigeon pea followed by 26% in sweet basil and highest (55%) in black gram. While the reduction in yield of autumn/winter and summer intercrops was 37–83% and 84–93%, respectively. Maximum reduction (83%) occurred in garlic and the lowest (37%) in radish yield were noted during autumn/winter. The reduction in yield of summer crops geranium and menthol mint were 93% and 84%, respectively. During rainy season the growth of vetiver was very slow and more inter row space was available for intercrops. Growth of vetiver plant started during the month of September and October thus developed canopy caused partial shading on intercrops and by the end of winter season (March–April) vetiver plants developed sufficient canopy which adversely affected the growth

Table 3
Yield (kg ha^{-1}) of different crops in sole and intercropping system.

Cropping systems	Fresh root	Vetiver oil	Seasons		
			Rainy	Autumn/winter	Summer
Vetiver sole	3660	36.6	–	–	–
Sweet basil–radish–*T. minuta*		–	156	35183, 89.8	–
Black gram–clarysage		–	1670	14.1	–
Kalmegh–garlic		–	5010	11140	–
Okra–radish–geranium		–	4250	30369,	23.9
Pigeon pea–menthol mint		–	2130	–	171
Maize–radish–onion		–	7407	31407, 15550	–
Vetiver + sweet basil–radish–*T. minuta*	3000	30.0	114	22111, 18.7	–
Vetiver + black gram–clarysage	3150	30.5	740	4.4	–
Vetiver + Kalmegh–garlic	2970	28.9	3140	1850	–
Vetiver + okra–radish–geranium	2740	27.4	2390	22202	1.5
Vetiver + pigeon pea–menthol mint	2910	27.9	1680	–	26.5
Vetiver + maize–radish–onion	2820	26.8	4481	21222, 6500	–
SEm±	131	1.1			
CD (5%)	402	3.5			

Table 4
Land equivalent ratio (LER), area time equivalent ratio (ATER), relative net return (RNR) and land use efficiency (LUE) in different cropping systems.

Cropping systems	LER	ATER	RNR	LUE (%)
Vetiver + sweet basil–radish–*T. minuta*	1.54	1.05	1.35	130
Vetiver + black gram–clarysage	1.14	1.00	0.97	107
Vetiver + kalmegh–garlic	1.19	0.93	1.08	106
Vetiver + okra–radish–geranium	1.20	0.97	0.84	109
Vetiver + pigeon pea–menthol mint	1.26	0.97	0.85	112
Vetiver + maize–radish–onion	1. 29	0.94	1.09	112

and productivity of intercrops during winter and summer season as compared to rainy season. Lower reduction in yield of pigeon pea, sweet basil and radish was due to less competition for growth resources with basil and radish as these were short stature and short duration crops and pigeon pea was more competitive than vetiver.

3.4. Quantification of resource use efficiency

3.4.1. Land equivalent ratio (LER)

LER's were calculated for intercropping treatments to determine any advantage to be realized from the intercropping. All inter cropping systems gave LER greater than 1.0 (Table 4). The largest LER (1.54) was obtained from the vetiver + sweet basil–radish–*T. minuta* inter cropping system followed by vetiver + maize–radish–onion (LER = 1.29). The greater value of LER with sweet basil–radish–*T. minuta* was due to higher relative yield of component crops.

3.4.2. Area time equivalent ratio (ATER)

ATER's were calculated for intercropping treatments to determine yield advantage in relation to time and presented in Table 4. ATER value was also highest (1.05) in vetiver + sweet basil–radish–*T. minuta* intercropping system and lowest (0.93) in vetiver + kalmegh–garlic system.

3.4.3. Land use efficiency (LUE)

Land use efficiency calculated for intercropping treatments (Table 4) had similar trend as LER and ATER. Maximum (130%) was recorded in vetiver + sweet basil–radish–*T. minuta* intercropping system being lowest (106%) in vetiver + kalmegh–garlic system. This indicates that intercropping of sweet basil–radish–*T. minuta* with vetiver during rainy, autumn and winter seasons was found to be highly efficient.

3.4.4. Relative net return (RNR)

The highest RNR (1.35) was obtained from vetiver + sweet basil–radish–*T. minuta* intercropping system followed by vetiver + maize–radish–onion (1.09) and vetiver + kalmegh–garlic (1.08) while lowest RNR (0.84) was recorded with vetiver + okra–radish–geranium intercropping system (Table 4).

3.5. Economics

Intercropping of sweet basil–radish–*T. minuta* with vetiver during rainy, autumn and winter seasons gave maximum net return of US$ 4801.7 ha^{-1} which was 35% higher than US$ 3546.7 ha^{-1} obtained from sole crop of vetiver (Fig. 1).

3.6. Essential oil profile of vetiver oil

Vetiver oil samples were analyzed on GC/GCMS showed 126 constituents out of which only four major constituents, khusimol (16.8–18.2%), khusinol (4.5–4.9%), khusinone (8.5–9.2%) and khusimone (3.2–3.5%) were identified. There was no significant variation in constituents of vetiver oil due to intercropping systems (data not presented). The results are in conformity to those reported by Pareek et al. (1991).

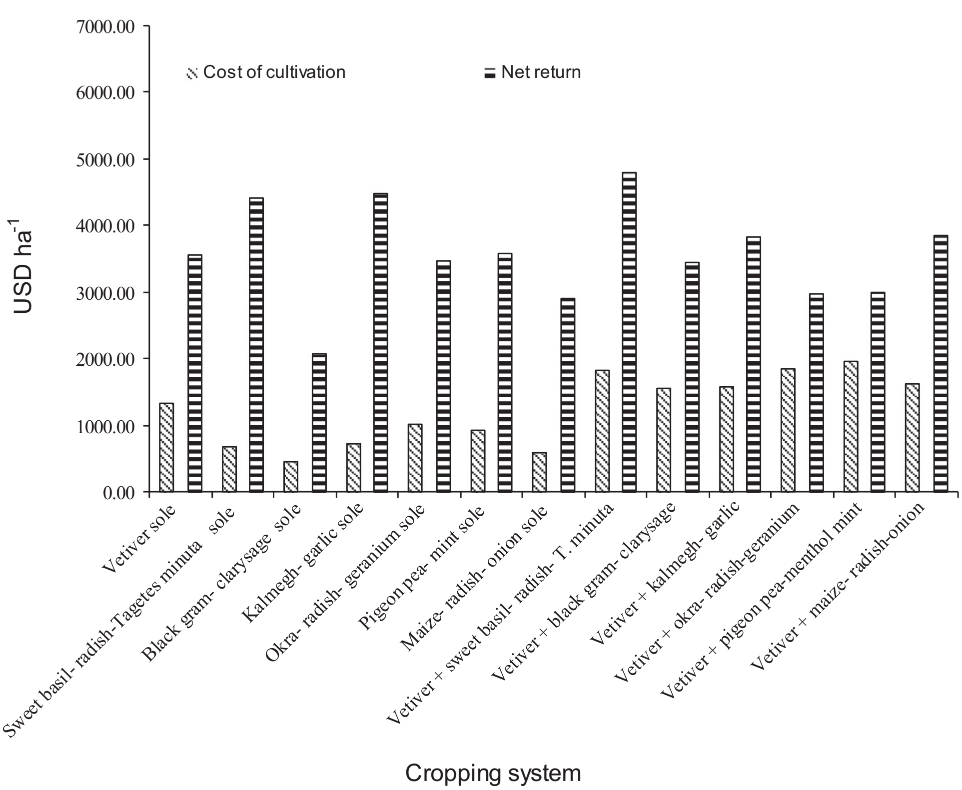

Fig. 1. Economics of different cropping systems.

4. Conclusion

On the basis of results obtained in this study, intercropping of sweet basil–radish–*T. minuta* with vetiver during rainy, autumn and winter season, respectively is suggested for higher productivity and return.

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