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Intercropping of Roselle with Red Gram and Nipped Castor is Beneficial to Dry Land Farmer

T.N. Pushpa[1*], K. Umesha[2], M. Vasundhara[3], B.K. Ramachandrappa[4], B.S. Sreeramu[3] and D. Srikantaprasad[1]

[1]Department of PSMA, KRCCH, Arabhavi, Gokak Tq. Belagavi Dist. Karnataka 591218, India
[2]Department of PSMA, College of Horticulture (UHS) Bengaluru, Karnataka 560065, India
[3]Division of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru, Karnataka 560065, India
[4]AICRP on Dryland Agriculture, UAS, GKVK, Bengaluru, Karnataka 560065, India
**Corresponding author*

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A B S T R A C T

This study was conducted on intercropping of medicinal crops *viz*., ashwagandha, garden rue, roselle and holy basil with pigeon pea and nipped castor in *alfisols* of eastern dry zone of Karnataka in *kharif* 2011. The growth and yield of pigeon pea and castor were high in sole crop than all intercropping systems. The growth and yield of ashwagandha, roselle and holy basils were reduced under intercropping systems. The highest fresh calyces yield of roselle was recorded in sole crop (6.75 t ha^{-1}) followed by pigeon pea + roselle (4.06 t ha^{-1}) and lowest in castor + roselle (3.39 t ha^{-1}). The yield of holy basil in pigeon pea + holy basil intercropping (1.75 t ha^{-1}) was *at par* with castor + holy basil (0.81 tha^{-1}) intercropping system. The pigeon pea + roselle intercropping system recorded significantly highest LER, ATER and net returns (1.41, 1.35 and `76012.00 $ha^{-1}$, respectively) followed by castor + roselle (1.29, 1.29 and `62944.00 ha^{-1}, respectively).

Introduction

Ever increasing human and livestock population need additional food which has to come from the dry land farming only. But, the system is characterized by erratic rainfall and crop failure due to droughts during critical stages. With an estimated annual turn-over of the herbal industry in the country to a tune of ₹ 8800 crores (Ved and Goraya, 2008), besides the staple food crops, medicinal crops are also important for mankind. They constitute 30 per cent of the allopathic drugs and a major part of many traditional medical systems. Systematic cultivation of medicinal crops as pure crops is not encouraging as they may associate with unattractive benefit, long gestation period, large fluctuation in production potential and discouraging government policies (Prakasa Rao, 1996). Under these circumstances, the only option open is through time and space utilization in rainfed agriculture systems (Sankaran and Rangaswamy, 1990) by adopting

intercropping systems. As a step forward in this direction, a study on intercropping of medicinal crops in *alfisols* of dry land conditions in Eastern Dry zone of Karnataka was carried out to integrate the medicinal crops (garden rue, ashwagandha, roselle and holy basil) as intercrops with pigeon pea and castor.

Materials and Methods

The field experiment was carried out at the Post Graduate Center, University of Horticultural Sciences (Bagalkot), Gandhi Krishi Vignana Kendra, Bengaluru, during *kharif* 2011. The experimental site is situated in Eastern Dry Zone of Karnataka at 12^0 51' North and 77^0 35' East with an altitude of 930 m above MSL. The soil was red sandy loam with acidic pH (5.11), medium EC (0.086 dSm^{-1}), low organic carbon (0.45%) and available P_2O_5 (29.37 kg ha^{-1}), and medium in available N and K_2O (297.92 and 163kg ha^{-1}, respectively) and grouped under *Alfisols*. The highest monthly rainfall in 2011 was received in August (253.2 mm, 17 rainy days) and the lowest was in June (30.0 mm, 5 rainy days). During the cropping season (May - November), a total of 725.3 mm rainfall was received. There was a short dry spell observed during the germination stage and intermittent dry spells during early reproductive and maturity stage of pigeon pea and castor. Hence, two lifesaving irrigations were given to ensure uniform germination of seeds.

The experiment comprised of 4 medicinal plants *viz*., garden rue (*Ruta graveolens L.*), ashwagandha (*Withania somnifera* Dunal. cv. Poshita), roselle (*Hibiscus sabdariffa* L. var. sabdariffa) and purple type of holy basil (*Ocimum sanctum* L.) and two field crops *viz*., pigeon pea (*Cajanus cajan* (L.) Millsp. cv. BRG-1) and nipped castor (*Ricinus communis* cv. DCH-9) laid out in Randomized Complete Block Design (RCBD) with three replications with a gross plot size of 28.8 sq. m.

The treatments consisted of six sole crops, four intercropping combinations of medicinal crops with each of red gram and castor. Three rows of ashwagandha, two rows of garden rue and holy basil and one row of roselle were grown as intercrops in between two rows of pigeon pea and castor which was spaced 120cm apart. The seed rate for sole crop of garden rue, ashwagandha, roselle and holy basil was 2-2.5, 5.00, 2-3 and 0.2-0.3 kg ha^{-1}. While, it was 12 kg ha^{-1} for both red gram and castor. Whereas 40:40:40, 0:0:0, 90: 60:40, 120:105:105, 25:50:25 + Zinc-15 + Sulphur-20 and 38:38:25kgs of N, P_2O_5 and K_2O were applied to garden rue, ashwagandha, roselle, holy basil, pigeon pea and castor respectively.

The land was ploughed twice, clods were crushed and brought to fine tilth by passing harrow. Irrespective of crops, farm yard manure was applied to each plot at the rate of 10 tons ha^{-1} a month before final levelling and mixed thoroughly. Fifty per cent of nitrogen and entire dose of P and K were applied as basal dose at the time of sowing. The remaining fifty per cent of nitrogen was given as top dressing during earthing up at thirty day after sowing. Bold and healthy seeds of pigeon pea, castor, ashwagandha and roselle were soaked in water over night. Pigeon pea seeds were treated with *Rizobium* and *Trichoderma harzianum*, while, castor, ashwagandha and roselle seeds were treated with Captan @ 2g per kg. Pigeon pea, castor and roselle seeds were dibbled at 0.5 cm depth and the seeds of ashwagandha sown in shallow furrows and the rows were covered with soil in the second week of June. The garden rue and holy basil seedlings were raised in nursery for a month and transplanted to the experimental plots during second week of July. The gap filling was done after eight

days of sowing/transplanting and the plots were kept weed free throughout the experimentation.

Castor was nipped at the height of first spike initiation and initiated spike was removed and a vertical branch was allowed to grow from the node below the first spike. Finally four spikes were maintained per plant. The inflorescence was nipped off in holy basil for initial two months of planting to ensure maximum branching and more vegetative growth. Observations were recorded from five randomly tagged plants in each plot. The growth parameters like plant height (cm), plant spread (cm), number of branches per plant, number of leaves per plant, leaf area at harvest (sq. cm) and dry weight of different plant components (g plant^{-1}) and different yield parameters were recorded according to the crop. The major chemical constituents of medicinal plants such as anthocyanin in roselle calyces and eugenol in essential oil of holy basil were determined.

The essential oil of shade dried holy basil herb was obtained using Clevenger's apparatus and expressed in percentage on shade dry weight basis. Gas Chromatography analysis was carried out to estimate the eugenol in holy basil essential oil by employing Varian 450GC fitted with Auto injector, CPSil8 column (250 mm × 4.6 mm) and FID detector. Nitrogen was used as mobile phase and makeup gas. The injector port was heated and held at 250°C, the column temperature was initially held at 40°C for three minutes, then heated to 228°C at a rate of 4°C per minute and finally held at this temperature for two minutes. The flow rate was set to 1ml per minute with a run time of 52 minutes, while the spilt ratio was 1:36 and the ionization was detected at 280°C. Pure eugenol (98.3%) obtained from M/S Natural Remedies India, Pvt. Ltd. Co. Bengaluru was used as the reference compound.

Calyces were extracted with ethanol (95%) and 1.5 N HCl in the ratio of 85:15. The extract was transferred to 100 ml volumetric flask, made up the volume and stored in the refrigerator overnight at 4°C, and then filtered through Whatman no. 1 filter paper and the optical density (OD) was measured at 535 nm using spectrophotometer. The anthocyanin content was calculated and expressed as mg per 100 g fresh weight of calyces.

Land equivalent ratio (Willey, 1979) and area time equivalent ratio (Hiebsch, 1980) were calculated. The economic analysis was done by considering the market price prevailed during 2011-12.

Result and Discussion

Effect of intercropping systems on growth and yield parameters of pigeon pea

The higher values for growth and yield parameters like, plant height (165.1 cm), plant spread (95.0 cm), Number of branches per plant (14.0), maximum leaf area (4608 sq. cm plant^{-1}), dry weight of leaves (21.60 g), maximum number of pods (207) and seed yield (127.87 g plant^{-1} and 23.10 q ha^{-1}) were recorded by sole crop of pigeon pea (Table 1). While, the pigeon pea + ashwagandha intercropping system recorded least values for all these characters and the values were not comparable with a normal crop. Since there was no space to collect the soil and to raise along the pigeon pea row when ashwagandha was grown as intercrop, it was deprived of the advantages of earthing up. Similarly, higher yields from sole crop of pigeon pea than in intercropping systems are reported by Koppalkar (2007) when ashwagandha was incorporated with various row proportions.

Roselle offered greater competition to the pigeon pea due to its robust branches with broader leaves. Since the early uptake of

nutrients seems to be the key to success in competition for mobile nutrients such as nitrogen and potassium (Kawano *et al.,* 1974). The growth of pigeon pea was reduced when grown with roselle. Roselle might also have competed with pigeon pea for nutrients as recommended dose of fertilizer was applied only to pigeon pea and not for roselle. Both the crops are deep rooted dry land crops and there might have been a stiff competition for nutrients.

Due to very poor growth of garden rue, there was no competition in pigeon pea + garden rue intercropping system, and it recorded yield comparable with that of sole crop of pigeon pea.

Effect of intercropping systems on growth and yield parameters of castor

Similar to pigeon pea, castor also recorded lower values for growth parameters when grown along with ashwagandha. The lowest leaf area was recorded in castor + roselle (1580 sq. cm plant^{-1}) intercropping system (Table 2). Since castor with roselle recorded significantly less plant spread (82.7cm) as a result of competition between crops, it had lesser leaf area. Whereas, there was no or less intercrop competition in sole crop of castor, castor + holy basil and castor + garden rue intercropping systems and the leaf area of castor remain unchanged (these systems were *on par*). The trend was more or less same with respect to dry weight of leaves.

The length of spike remained unchanged due to intercropping with garden rue and holy basil, while, the spike length varied significantly due to intercropping with ashwagandha and roselle (Table 2). But, the number of capsules per spike differed significantly even with intercropping of garden rue (33) as compared to sole crop of castor (37). Since, the previously discussed growth parameters were found to be better in sole crop of castor, castor + holy basil and castor + garden rue intercropping systems, the yield parameters were also found better as compared to other treatments. The yield was found to be high in sole crop of castor which did not vary with other intercropping system, except ashwagandha, since the growth and yield attributes like plant height, plant spread, number of leaves, leaf area; dry weight of leaf, spike length and number of capsule were found to be high in these intercropping systems. While, the yield was reduced to a greater extent in castor + ashwagandha intercropping system, as it was found to reduce various growth and yield attributing parameters. From a similar study, Prasad and Verma (1986) reported that seed yield of castor was unaffected when green gram and black gram were intercropped with it, while, sesamum and sorghum reduced the yield. When castor was intercropped with maize, the yield reduction was 46.26 per cent (Gupta and Rathore, 1993) due to mutual competition.

Effect of intercropping systems on growth and yield parameters of garden rue

The garden rue crop failed to establish in the experimental plots as the bare rooted seedlings were transplanted to main field. This may be due to transplanting shock. Therefore, no data were recorded.

Effect of intercropping systems on growth, yield and quality parameters of ashwagandha

The effect of intercropping on plant height and number of branches was not significant at all the growth stages. While, the plant spread was influenced by intercropping system only at harvest. Due to shading effect of pigeon pea and castor and resulted in lanky growth, but higher in sole crop of ashwagandha (Table 3).

Table.1 Effect of intercropping systems on growth and yield parameters of pigeon pea

Treatments	Plant height at harvest (cm)	Plant spread at harvest (cm)	Number of branches per plant at harvest	Leaf area (sq. cm plant^{-1})	Dry weight of leaves (g plant^{-1})	Number of pods plant^{-1}	Seed yield (g plant^{-1})	Seed yield (q ha^{-1})
T_{5}- Sole Pigeon pea	165.1	95.0	14.0	4608	21.60	207	127.87	23.10
T_{7}- Pigeon pea + Garden rue	160.3	89.5	12.3	3987	17.08	188	111.20	19.75
T_{8}- Pigeon pea + Ashwagandha	151.9	83.4	11.8	3564	16.24	140	91.80	16.22
T_{9}- Pigeon pea + Roselle	160.7	81.7	11.5	3588	17.03	147	101.00	18.27
T_{10}- Pigeon pea + Holy basil	162.9	89.6	13.7	4578	18.67	204	122.40	19.06
S.Em±	2.4	2.2	0.8	167	0.53	13	6.91	1.17
C.D. at 5%	9.4*	7.2*	NS	546*	1.74*	37*	22.54*	3.84*

*:- Significant, NS: - Non significant

Table.2 Effect of intercropping systems on growth and yield parameters of castor

Treatments	Plant height (cm)At harvest	Plant spread (cm)At harvest	Number of leaves per plant At harvest	Leaf area (sq. cm plant^{-1})	Dry weight of leaves (g plant^{-1})	Number of spikes plant^{-1}	Length of spike (cm)	Number of capsules spike^{-1}	100 seed weight (g plant^{-1})	Seed yield (g plant^{-1})	Seed yield (q ha^{-1})
T_{6}- Sole Castor	155.3	96.3	10	2642	6.27	4	37.1	37	22.13	106.87	20.59
T_{11}- Castor + Garden rue	154.3	92.0	10	2013	4.85	3	37.9	33	21.80	96.87	18.94
T_{12}- Castor + Ashwagandha	127.2	90.0	10	1649	3.82	3	30.7	33	22.20	86.27	15.71
T_{13}- Castor +Roselle	151.5	82.7	9	1580	3.90	3	31.1	30	22.80	89.13	18.02
T_{14}- Castor + Holy basil	157.3	93.9	10	2600	6.25	4	34.0	36	22.60	99.40	19.04
S.Em±	3.5	2.6	0.5	219	0.50	0.17	1.67	1.13	0.27	3.13	0.88
C.D. at 5%	13.9*	8.3*	NS	713*	1.63*	NS	5.4*	4*	NS	10.22*	2.87*

*:- Significant, NS: - Non significant

Table.3 Effect of intercropping systems on growth, yield and quality parameters of ashwagandha

Treatments	Plant height at harvest (cm)	Plant spread at harvest (cm)	Number of branches plant^{-1} at harvest	Number of primary roots	Length of roots (cm)	Thickness of roots (mm)	Plant dry weight (g)	Dry weight of roots (g plant^{-1})	Root yield (kg ha^{-1})	Grade
T_{2}- Sole Ashwagandha	33.8	17.8	3.9	3.93	10.8	6.8	4.71	0.57	29.91	B
T_{8}- Pigeon pea + Ashwagandha	30.1	16.1	3.1	2.27	7.9	5.1	2.39	0.33	13.89	B
T_{12}- Castor + Ashwagandha	33.4	11.9	2.7	2.47	8.9	6.7	1.85	0.41	9.07	B
S.Em+	3.30	1.16	0.3	0.62	0.7	0.42	0.58	0.04	4.04	-
C.D. at 5%	NS	4.54*	NS	NS	NS	NS	2.26*	0.15*	15.85*	-

*:- Significant, NS: - Non significant

Table.4 Effect of intercropping systems on growth, yield and quality parameters of roselle

Treatments	Plant height at harvest (cm)	Plant spread at harvest(cm)	Number of branches at harvest	Leaf area at harvest (sq. cm plant^{-1})	Dry weight of leaf (g plant^{-1})	Number of flowers plant^{-1}	Fresh weight of calyces (g plant^{-1})	Dry weight of calyces (g plant^{-1})	Fresh calyces yield (t ha^{-1})	Dry calyces yield (t ha^{-1})	Seed yield (g plant^{-1})	Seed yield (q ha^{-1})	Anthocyanin content (mg 100 g^{-1})	Anthocyanin yield (kg ha^{-1})
T_{3}- Sole Roselle	135.7	72.0	14.8	5185	27.10	72	325.33	28.62	6.75	0.60	26.93	8.12	35.10	2.34
T_{9}- Pigeon pea + Roselle	144.9	68.5	13.8	3361	14.80	61	236.27	20.13	4.06	0.41	19.20	4.38	30.01	1.24
T_{13}- Castor + Roselle	147.6	58.5	9.8	2961	11.85	39	155.20	15.13	3.39	0.36	17.13	3.38	26.48	0.89
S.Em+	1.3	2.5	0.6	438	2.95	6	30.12	2.17	0.64	0.05	1.94	0.85	0.84	0.12
C.D. at 5%	5.0*	9.9*	2.2*	1721*	11.58*	24*	118.25*	8.50*	2.51*	0.19*	7.60*	3.34*	3.29*	0.80*

*:- Significant, NS: - Non significant

Table.5 Effect of intercropping systems on growth, yield and quality parameters of holy basil

Treatments	Plant height (cm)At harvest	Plant spread (cm)At harvest	Number of primary branches per plant At harvest	Leaf area at harvest (sq. cm plant^{-1})	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})	Shade dried herb yield (t ha^{-1})	Essential oil content (%)	Oil yield (kg ha^{-1})	Eugenol (%)	Eugenol yield (kg ha^{-1})
T_{4}- Sole Holy basil	57.7	54.3	11.0	1907	98.33	15.44	4.33	0.26	11.34	68.95	7.82
T_{10}- Pigeon pea + Holy basil	60.0	51.0	8.2	1545	57.61	7.72	1.75	0.22	3.79	65.81	2.49
T_{14}- Castor + Holy basil	63.7	25.0	6.6	688	26.64	3.98	0.81	0.22	1.75	66.63	1.17
S.Em+	1.1	4.4	0.7	173	10.29	1.34	0.36	0.01	0.86	NA	0.58
C.D. at 5%	4.4*	17.6*	2.8*	681*	40.42*	5.27*	1.42*	0.03*	3.38*	NA	2.26*

*:- Significant, NS: - Non significant

Table.6 Assessment of yield advantage and economic analysis of different intercropping systems

Treatments	LER	ATER	Pigeon pea equivalent yield (q ha^{-1})	Castor equivalent yield (q ha^{-1})	Gross return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
T_1-Garden rue	-	-	-	-	0.0	16171.0	-16171.0	-1.00
T_2-Ashwagandha	1.00	1.00	0.75	0.85	2991.0	11880.0	-8889.0	-0.75
T_3-Roselle	1.00	1.00	6.03	12.70	44300.0	21245.0	23055.0	1.09
T_4-Holy basil	1.00	1.00	5.41	6.18	21650.0	23596.0	-1946.0	-0.08
T_5-Pigeon pea	1.00	1.00	23.10	26.40	92400.0	19572.0	72828.0	3.72
T_6-Castor	1.00	1.00	18.02	20.59	72065.0	18880.0	53185.0	2.82
T_7-Pigeon pea + Garden rue	0.86	0.86	19.75	22.57	79000.0	22687.0	56313.0	2.48
T_8- Pigeon pea + Ashwagandha	1.18	1.10	16.57	18.94	66269.0	22192.0	44077.0	1.99
T_9-Pigeon pea + Roselle	1.41	1.35	25.08	28.66	100430.0	24418.0	76012.0	3.11
T_{10}- Pigeon pea + Holy basil	1.25	1.09	21.25	24.29	84990.0	23687.0	61303.0	2.59
T_{11}- Castor + Garden rue	0.92	0.92	16.57	18.94	66290.0	21995.0	44295.0	2.01
T_{12}-Castor + Ashwagandha	1.20	1.18	16.00	18.28	55892.0	21600.0	34292.0	1.59
T_{13}-Castor + Roselle	1.29	1.29	19.49	22.27	85920.0	22976.0	62944.0	2.74
T_{14}- Castor + Holy basil	1.11	1.05	17.67	20.20	70690.0	22995.0	47695.0	2.07
S.Em±	0.07	0.06	1.02	1.23				
C.D. at 5%	0.21*	0.19*	2.97*	3.60*				

*:- Significant,

Table.7 Market price of various crops prevailed respective during cropping seasons (2011-12)

Crop	Yield A	Yield B	Price (A)	Price (B)	Source
Garden rue	Dried herb		₹ 25000.00 t-^{1}		Himalaya Drugs, Bangalore
Ashwagandha	Dried root		₹ 100.00 kg^{-1}		
Roselle	Dried calyces	Seed	₹ 40000.00 t^{-1}	₹ 2500.00 q^{-1}	UAS, Bangalore
Holy basil	Shade dried herb		₹ 5000.00 t^{-1}		Himalaya Drugs, Bangalore
Pigeon pea	Seed yield		₹ 4000.00 q^{-1}		APMC, Karnataka
Castor	Seed yield		₹ 3500.00 q^{-1}		

Intercropping did not have any effect on number of primary roots, length of roots and thickness of roots. But, the dry weight of root per plant was reduced significantly by intercropping due to reduced availability of light which in turn reduced photosynthesis, and accumulation of photosynthates. As the sole ashwagandha recorded higher dry weight of roots per plant (0.57 g), it recorded highest dry weight of roots per hectare (29.91 kg). The severe reduction in root yield under intercropping may also be due to reduction in plant population by 22 per cent as compared to sole crop. In a similar study, dry root yield was reduced, similarly when ashwagandha was intercropped with pigeon pea in various row proportions (Koppalkar, 2007). The yield of ashwagandha was very low as compared to normal yield of 300-500 kg ha^{-1}; (Farooqi and Sreeramu, 2004) and the roots obtained from all treatments were of B grade (Table 3).

Effect of intercropping systems on growth, yield and quality of roselle

Maximum plant height was recorded in roselle intercropped with castor (147.60 cm), followed by pigeon pea, which was significantly higher than sole crop (135.73 cm) due to shade effect. Branching is an important growth parameter in roselle as the flowers are produced in leaf axiles. Number branches lead to more yield. Due to lack of intercomponent competition, more number of branches was recorded in sole crop (14.8 at harvest), while, it was significantly low in intercropping with castor (9.8 at harvest). Sole roselle recorded significantly highest leaf area, flowers per plant and dry weight of leaves at harvest (5185 sq. cm $plant^{-1}$, 72 and 27.10 g $plant^{-1}$, respectively), which was followed by pigeon pea intercropping (3361 sq. cm $plant^{-1}$, 61 and 14.80 g $plant^{-1}$, respectively) and least in castor (2961 sq. cm $plant^{-1}$, 39 and 11.85 g $plant^{-1}$, respectively) intercropping. Sole crop of roselle recorded maximum fresh and dry weights of calyces (325.33 and 28.62 g) and seed yield per plant (26.93g), followed by pigeon pea + roselle intercropping system (Table 4). The anthocyanin content and its yield were also high in sole crop of roselle (35.10 mg 100 g^{-1} and 2.34 kg ha^{-1}, respectively). In a similar study, Fadl and Gebauer (2004) reported, decrease in growth and yield of roselle when grown under *Acasia senegal*, a tree species. Basavaraju (2010) also reported reduced active ingredients in kalmegh due to its intercropping under coconut.

Effect of intercropping systems on growth, yield and quality of holy basil

The plant height increased under castor as a result of shade. The holy basil plants were lean and lanky in growth, recording maximum plant height (63.7 cm at harvest) (Table 5). But, at the same time, they recorded lowest number of branches (6.6 at harvest), and lower values for other growth parameters (688 sq. cm $plant^{-1}$ leaf area at harvest) and yield as well (0.81 t ha^{-1}). The sole crop of holy basil recorded the highest number of branches (11.00), which also recorded higher plant spread (54.3cm), maximum leaf area (1907 sq. cm $plant^{-1}$) and fresh and dry herb yield per plant (98.33 and 15.44 g, respectively). The results tally with the finding of Channabasappa *et al.,* (2007), who reported reduction in growth when basil was grown under areca nut. Basavaraju (2010) in a study on intercropping of basil in coconut garden recorded lower yield of holy basil due to reduced branching, number of leaves per plant and dry matter per plant.

It also yielded highest shade dried herb per hectare (4.33 ton). The yield of holy basil in pigeon pea + holy basil intercropping (1.75 ton ha^{-1}) was *at par* with castor + holy basil (0.81 ton ha^{-1}) intercropping system as the growth of holy basil under castor was reduced

to a greater extent owing to its shade (Table 5). The oil content was also highest in sole crop of holy basil (0.26 %) as the crop received maximum sun light. While, the oil content did not differ in holy basil grown with pigeon pea (0.22 %) and castor (0.22 %) and the same trend was recorded in case of oil and eugenol yield (11.73 and 7.82 kg ha^{-1}, respectively).

Assessment of yield advantage and economic analysis of different intercropping system

Land equivalent ratio is a measure of efficiency of a particular cropping system. It is evident from the data intercropping systems are more efficient than the sole crops. The pigeon pea + roselle intercropping system recorded significantly highest LER (1.41). Garden rue failed completely, recording LER < 1. After pigeon pea + roselle, the next best system was castor + roselle, with no much reduction in castor yield due to roselle showing a LER of 1.29 (Table 6). ATER followed almost the similar trend as that of LER. In a similar study, Maitra *et al.*, (2000) recorded higher land equivalent ratio from finger millet + pigeon pea as there was less competition between the component crops as compared to pigeon pea with ground nut. In the current study, the ATER of intercropping systems involving holy basil was lesser than that of roselle as the holy basil experienced shade to a greater extent especially under castor.

The pigeon pea + roselle system recorded highest gross and net returns due to combined yield of component crops and with higher market price of both crops which recorded 25.11 q of pigeon pea equivalent yield ha^{-1}. Even though, the cost of cultivation for this system was high (₹ 24418.0 ha^{-1}) due to the high labour input required to harvest the calyces of roselle, the system recorded highest net returns. Among the castor intercropping systems, the one with roselle recorded highest collective yield (24.55 q castor equivalent yield ha^{-1}) than that of sole castor (20.59 q ha^{-1}). In roselle we can take calyces and after maturity of capsule seeds are obtained that is both calyces and seeds are economic parts. The selling price of roselle calyces and seed was ₹ 40 and 25 respectively. Hence, the systems with roselle performed better even though the yield of main crop was reduced due to roselle as an intercrop. The other cropping systems were poor performers as either they recorded less yield as in case of pigeon pea + ashwagandha (pigeon pea equivalent yield of 16.57 q ha^{-1}) and castor + ashwagandha (pigeon pea equivalent yield of 13.97 q ha^{-1}), or the produce fetches less market price (Holy basil ₹ 5.00 kg^{-1} of dried herb). Since, the cost of cultivation was less for sole crops (₹ 19572.00 ha^{-1} for pigeon pea and ₹ 18880.0 ha^{-1} for castor), the highest benefit cost ratios were obtained in sole crops of pigeon pea (3.72) and castor (2.82) (Table 6).

The inter-space available in case of pigeon pea and castor can be successfully utilized for cultivation of medicinal crops under dry land conditions in *alfisols* of Eastern dry zone of Karnataka. Whenever pigeon pea and castor are sown in early to mid *Kharif* and good rains are expected, roselle can be grown as an intercrop by sowing a row in between two rows of pigeon pea and castor without reducing their population.

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