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Effect of Intercropping in Nipped Castor (*Ricinus communis* L.) Under Rainfed Conditions

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ABSTRACT: A field experiment was conducted at Dryland Agricultural Project, U.A.S., Bengaluru during the rainy seasons from 2009-10 to 2014-15 to study the performance of different intercrops in nipped castor (*Ricinus communis* L.) under *Alfisols* in rainfed conditions. Intercropping castor with finger millet in 1:2 row proportion recorded significantly higher castor equivalent yield (1753 kg/ha) compared to rest of intercropping systems and sole castor (1214 kg/ha). Intercropping efficiency indices *viz.,* land equivalent ratio (LER) (1.27) and area time equivalent ratio (ATER) (0.95) were maximum with castor + finger millet (1:2) followed by castor + field bean (1:1) intercropping system. The highest net returns per ha accrued (₹ 34615/ha) and B: C ratio (2.84) was recorded with castor + finger millet (1:2) intercropping, while the lowest was with castor + grain amaranth. The sustainable yield index (0.36) and rain water use efficiency (5.45 kg/ha-mm) were highest with castor + finger millet intercropping in 1:2 row proportions.

Key words: Castor, economics, LER, intercropping, yield

Introduction

The productivity of dryland crops is very low because of low and erratic rainfall and poor adoption of improved technologies. To bridge this gap, the crop diversification is required for increasing the productivity and profitability per unit area per unit time. Intercropping systems play an important role in subsistence and food production in developing countries (Tsubo and Walker, 2002). Intercropping is also an efficient strategy that can be followed with desirable outcomes in the present climate change scenario (Venkateswarlu and Shankar, 2009).

Castor (*Ricinus communis* L.) is an important industrial oilseed crop, finds a prominent place in dryland agriculture cropping systems in India, because of its drought resistance through deep root system, wax coating on the shoot and quick growth. In Karnataka, castor is grown in about 0.12 lakh ha with production 0.11 lakh tons and productivity 942 kg/ha (2013-14). Under prevailing agro-climatic conditions of South interior Karnataka, monocropping of castor is not remunerative. In such situations to enhance productivity as well as a monetary advantage to the farmers, castor based intercropping along with nipping is found to be more efficient in utilization of resources under dryland conditions and to enhance returns per unit area. Castor is perennial in nature with indeterminate growth habit. Hence, it putforths lot of vegetative growth with numerous spikes *viz*., primary, secondary, tertiary, quaternary etc., which leads to uneven source-sink relationship. Therefore, periodical staggered nipping helps to maintain few branches is-à-vi's spikes with controlled canopy growth and it also helps to control botrytis disease. The intercropping of castor with suitable crops has been found to be beneficial in fetching higher monetary returns (Bhondave *et al.,* 1994). The main consideration for mixed or intercropping is to cover the risk of failure and better use of natural resources, *viz*., sunlight, land and water. In this context, the present investigation was carried out to find out the suitable intercrops for nipped castor on *Alfisols* under rainfed conditions.

Materials and Methods

The experiment was conducted for six years from 2009-10 to 2014-15 at Dryland Agricultural Project, University of Agricultural Sciences, Bengaluru, Karnataka which is located 12° 35' North latitude and 77° 35' East longitude and at an altitude of 930 meters above mean sea level. The soil of experimental plot was typical lateritic and these soils are classified as fine, kaolinitic, isohyperthermic and typic kandiustalf as per USDA classification. The annual normal rainfall of the station is 913.8 mm. The rainfall during the cropping period (July to January) was 475.7, 647.8, 582.1, 451.9, 599.2 and 793.4 mm during 2009-10, 2010-11, 2012-13, 2013-14 and 2014-15, respectively. The actual rainfall was less than normal rainfall (663.7 mm) during all the years except 2014-15. In this experiment, castor as base crop and six intercrops *viz*., finger millet, chilli, cowpea, cluster bean, field bean and grain amaranth were tested. Treatments were made from combinations involving intercropping and sole crops of all the crops. The treatment details with row proportion and varieties adopted are detailed below.

T_1: Castor + finger millet (1:2)
T_2: Castor + chilli (green) (1:1)
T_3: Castor + cowpea (1:1)
T_4: Castor + cluster bean (vegetable) (1:2)
T_5: Castor + field bean (vegetable) (1:1)
T_6: Castor + grain Amaranth (1:1)
T_7: Castor sole (DCS-9)
T_8: Finger millet sole (G.P.U-28)
T_9 : Chilli sole (Samruudhi)
T_{10}: Cowpea sole (IT-38956-1)
T_{11}: Cluster bean sole (Local)
T_{12}: Field bean sole (HA-4)
T_{13}: Grain amaranth sole (Suvarna)

The experiment was laid out in a randomized complete block design with three replications.

All the intercropped components, base crop and sole crops were planted simultaneously. Crops were sown on onset of monsoon. The nursery requirement for chilli was established as planned. In intercropping system, sole castor crop and various intercrops were fertilized with recommended dose fertilizer (38:38:25 N P_2O_5 K_2O kg/ha) of castor. No additional dose of fertilizer was applied to intercrops. For sole crop treatments, recommended dose of fertilizers by U.A.S., Bengaluru was adopted *viz*., finger millet 50:40:25, chilli 100:50:50, cowpea 25:50:25, cluster bean 25:50:25, field bean 25:50:25 and grain amaranth 40:20:20 N P_2O_5 K_2O kg/ha. The spacing followed for castor, finger millet, chilli, cowpea, cluster bean, field bean and grain Amaranth were 90 cm X 45 cm, 30 cm x 10 cm, 45 cm X 45 cm, 45 cm X 15 cm, 30 cm X 15 cm, 45 cm X 30 cm and 45 cm X 15 cm, respectively. The intercropping was an additive series where the components were combined with their full sole castor crop density. Nipping was followed as per technique developed by AICRPDA, Bengaluru wherein one receme is retained at a time removing other recemes and is being done at weekly interval retain upto 4-5th order recemes. In nipped castor, three pickings were done during all the years. Chilli, field bean and cluster bean crops were harvested for vegetable purpose. Castor, finger millet, cowpea and grain Amranth was harvested as and when they attained maturity. Seed yield and green vegetable yields obtained were recorded and net returns accrued were calculated on the basis of prevailing market prices. Castor equivalent yield (CEY) was calculated by using following expression: CEY = Castor yield + ((Intercrop yield x intercrop price)/castor price). The intercropping efficiency was analyzed using the land equivalent ratio (LER) and the area time equivalent ratio (ATER) as detailed below:

$$\text{Land equivalent ratio} = \frac{(Yab)}{Yaa} + \frac{(Yba)}{Ybb}$$

Where, Yaa and Ybb were sole yield of crops 'a' and 'b' respectively, Yab and Yba were mixture yield of crops 'a' and 'b' respectively (Willey, 1979). Area Time Equivalent Ratio was determined as described by Hiebsch and Mc Collum (1987).

$$\text{Area time equivalent ratio} = \frac{(Rya \text{ X } ta) + (Ryb \text{ X } tb)}{T}$$

Where, Rya and Ryb are the relative yield of the crop 'a' and 'b' respectively, 'ta' is the duration (days) for crop 'a' and 'b' respectively, T is the total duration (days) of the intercropping system. The SYI of different castor based intercropping systems was calculated following the equation suggested by Sharma *et al*., 2004.

$$\text{Sustainability yield index (SYI)} = \frac{(A\text{-}SD)}{Y_{max}}$$

A = Average yield over the years for a particular treatment;

SD = Standard deviation for the treatment; Y_{max} = Maximum yield obtained in any of the treatments over the years. Rain water use efficiency (kg/ha-mm) was calculated by dividing the yield (kg/ha) by the total volume of rainfall (mm) received during the crop growth period (Ramchandrappa *et al*., 2014). The economics of various treatments were calculated individually for all the years considering the existing price of inputs and produce. The per ha net return accrued was worked out by subtracting cost of cultivation (₹/ha) from the gross return (₹/ha). The data obtained during the course of the investigation were subjected to statistical analysis for determining the significance of difference between the treatments and to draw valid conclusions by adopting 'Analysis of Variance' technique as outlined by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was p=0.05. Critical difference values were calculated, wherever 'F' test was found significant.

Results and Discussion

Castor seed yield was differed significantly due to intercropping during all the years of experimentation. Sole castor recorded significantly higher seed yield as compared to castor in intercropping system. The castor seed yield was significantly decreased in intercropping systems during all the years. The reduction in castor seed yield with intercropping could be attributed to the vigorous growth of intercrops, which competed for the limited supply of soil moisture in shallow soils. The performance of castor was severely affected by intercropping of cowpea and grain amaranth compared to other intercrops. This may be due to the initial slow growth of castor and quick growth of intercrops *viz*., cowpea and grain amaranth. In the year 2014-15, sole castor yield was not varied significantly with intercropping of cluster bean, chilli, field bean and grain amaranth. It may be due to satisfactory and good distribution, rainfall during the cropping period resulted in less competition between the crops for moisture. Rao *et al*. (1989) and Padmavathi and Raghavaiah (2004) revealed that castor seed yield was not affected due to intercropping when seasonal rainfall (mm) was satisfactory. Intercropping with castor decreased intercrop yields compared to the respective sole yields during all the years (Table 1).

Castor equivalent yield significantly affected due to intercropping and maximum was recorded with castor + finger millet (1:2) compared to other intercropping systems. Yield of sole castor was statistically at par with castor equivalent yield of castor + field bean and significantly higher compared to other intercrops indicating that under drought situation, sole cropping of castor is better than its intercropping with cowpea, chilli, cluster bean and grain amaranth. Pooled data of six years indicated, CEY of castor + finger millet was significantly higher (1753 kg/ha) compared to all other treatments (Table 2). This was followed by sole castor (1214 kg/ha) and castor + field bean (1151 kg/ha) and lower CEY registered by castor + grain amaranth (761 kg/ha). The higher castor equivalent yield with finger millet intercropping was due to higher additional grain yield of finger millet. These results are in agreement with the findings of Thanunathan *et al*. (2006). The lower castor equivalent yield with other intercrops might be due to the severe competition for resources between castor and intercrops.

Intercropping efficiency

On the basis of mean data among different intercrops, maximum land equivalent ratio (1.27) was recorded with castor + finger millet (1:2) intercropping system, indicating more efficient

Table 1 : Yield of castor and intercrops (kg/ha) over years, 2009-2014

Treatment	Yield (kg/ha)													
	Castor	Inter crop	Castor	Inter crop	Castor	Inter crop	Castor	Inter crop	Castor	Inter crop	Castor	Inter crop	Castor	Inter crop
	2009		2010		2011		2012		2013		2014		Pooled	
T_1:Castor + finger millet (1:2)	724	3279	752	1434	313	3241	259	1881	360	2363	915	1952	554	2358
T_2:Castor + chilli (1:1)	1161	788	450	811	481	865	394	359	564	506	1090	535	691	649
T_3:Castor + cow pea (1:1)	703	669	470	35	362	630	241	641	306	741	971	530	523	563
T_4:Castor + cluster bean (1:2)	1430	476	457	663	531	439	435	190	570	535	1129	782	715	548
T_5:Castor + field bean(1:1)	1025	983	665	542	453	921	376	364	517	635	1071	355	685	633
T_6:Castor + grain amaranth (1:1)	750	740	137	125	383	643	276	123	388	870	1031	195	524	389
T_7:Castor	1848		1691		855		717		994		1179		1214	
T_8:Finger millet		3789		2022		3589		2387		2569		2996		2892
T_9:Chilli		2099		6843		1812		830		1329		1270		2356
T_{10}:Cow pea		810		271		860		988		1041		952		853
T_{11}:Cluster bean		1111		2384		910		620		1282		1728		1299
T_{12}:Field bean		1271		2270		1133		800		1305		1182		1327
T_{13}:Grain amaranth		1296		143		898		394		1235		626		781
S.Em.±	59.73		45.4		14.47		14.43		17.17		51.42		16.60	
C.D. (P=0.05)	184.06		137.8		44.59		44.46		52.92		158.43		51.14	

Table 2 : Castor bean equivalent yield (CEY) in nipped castor based intercropping systems

Treatment	CEY (kg/ha)						
	2009	2010	2011	2012	2013	2014	Pooled
T_1:Castor + finger millet (1:2)	2911	1709	1332	886	1541	2135	1753
T_2:Castor + chilli (1:1)	1686	991	729	454	691	1357	985
T_3:Castor + cow pea (1:1)	1818	553	902	775	1232	1634	1106
T_4:Castor + cluster bean (1:2)	1747	899	709	561	1105	1520	1090
T_5:Castor + field bean(1:1)	1680	1027	1243	528	914	1515	1151
T_6:Castor + grain amaranth (1:1)	1243	236	622	359	780	1324	761
T_7:Castor	1848	1691	855	717	994	1179	1214
S.Em.±	190.4	62	47.4	40.12	45.65	88.55	25.36
C.D. (P=0.05)	538.5	188.1	143.9	126.43	143.84	258.46	71.56

use of land than sole castor followed by castor + field bean (1.08), castor + chilli (0.97) and castor + grain amranth (0.98). In years 2010, 2012, 2013 and 2014, castor + finger millet was advantageous than other intercropping systems (Table 3). Intercropping efficiency analysis using the ATER approach has also shown differences among different associations (Table 3). The higher mean values of ATER was recorded by the castor + finger millet (0.95) intercropping system. It was due to higher intercrop yield and a lower reduction in base crop yield. While, the lowest ATER value was recorded by the castor + grain amranth (0.71). These results are in conformity with Mudalagiriyappa *et al*. (2011) and Walelign Worku (2014).

Sustainable yield index (SYI)

The data given in Table 3 revealed that castor + finger millet (1:2) intercropping system recorded the highest sustainable yield index (0.36) as compared to sole castor (0.26) and other intercropping systems. Similar findings were reported by Koli *et al*. (2004). Finger millet was found to be a compatible intercrop with castor for efficient use of resources and sustainability under dryland situations.

Rain water use efficiency (RWUE)

Among the different intercrops with castor, the castor + finger millet intercropping system recorded substantially higher RWUE (5.45 kg/ha-mm), the lowest RWUE (1.49 kg/ha-mm) was being recorded in case of castor + amaranth (Table 4). The highest RWUE compared to lower RWUE (5.95 kg/ha-mm) of castor was done to the fact that the plants were able to utilize all the available water from different layers of the soil in case of the former. Similar results were observed by Rao *et al.* (2010) in sorghum. Among sole crops, the higher RWUE was recorded by finger millet (6.26 kg/ha-mm) followed by chilli (6.09 kg/ha-mm) and the lowest RWUE was recorded by sole crop of grain amranth (1.63 kg/ha-mm).

Economics

Costs and returns analysis was worked out and the results are given in Tables 5 and 6. During all the six years of experimentation, intercropping of castor + finger millet (1:2) recorded higher mean net returns accrued per ha (₹ 34615/ha) and B: C ratio (2.84) than sole castor and other intercropping systems owing to higher yield of both castor and finger millet in the intercropping system (Table 6). Mudalagiriyappa *et al*. (2011) also recorded better returns with castor based intercropping systems. Among the various intercropping systems, the lowest net returns (₹ 7045/ha) and B: C ratio (1.30) was recorded by castor + grain amaranth intercropping system. It was due to lower yield of castor and grain amaranth. Among sole crops, finger millet recorded higher mean net returns accrued (₹ 28738/ha) and B: C ratio (2.69) and lowest with grain amaranth (Table 6).

Thus, farmers would get greater advantage from practice of growing finger millet as an intercrop in nipped castor with 1:2 row proportion.

Table 3 : Land equivalent ratio (LER), area time equivalent ratio (ATER) and sustainable yield index (SYI) in nipped castor based intercropping system

Treatment	LER							ATER							SYI
	2009	2010	2011	2012	2013	2014	Mean	2009	2010	2011	2012	2013	2014	Mean	
T_1:Castor + finger millet (1:2)	1.26	1.2	1.27	1.15	1.28	1.43	1.27	0.98	1.02	0.60	0.90	0.99	1.23	0.95	0.36
T_2:Castor + chilli (1:1)	1.00	0.4	1.1	0.99	0.99	1.35	0.97	0.90	0.38	0.76	0.72	0.86	1.19	0.80	0.18
T_3:Castor + cow pea (1:1)	1.21	0.6	1.17	0.99	1.10	1.38	1.08	0.80	0.31	0.56	0.76	0.69	1.12	0.71	0.19
T_4:Castor + cluster bean (1:2)	1.20	0.5	1.15	0.91	1.02	1.41	1.03	1.09	0.45	0.52	0.64	0.82	1.20	0.79	0.23
T_5:Castor + field bean(1:1)	1.33	0.6	1.34	0.99	1.01	1.22	1.08	1.00	0.51	0.71	0.72	0.81	1.08	0.81	0.25
T_6:Castor + grain amaranth (1:1)	0.98	1.0	1.04	0.71	0.95	1.22	0.98	0.69	0.93	0.73	0.52	0.77	1.03	0.78	0.16
S.Em.±	0.05	0.06	0.03	0.04	0. 06	0.05	-	NA	0.01	0.06	0.03	0.04	0.04	-	-
C.D. (p=0.05)	0.15	0.19	0.09	0.12	0.20	0.15	-	NA	0.03	NS	0.09	0.13	0.12	-	-

Note: NA- Not analyzed

Table 4 : Rain water use efficiency by castor and its intercrop components over years, 2009-2014

Treatment	RWUE (kg/ha-mm)						
	2009	2010	2011	2012	2013	2014	Mean
T_1:Castor + finger millet (1:2)	7.22	6.5	6.34	7.22	2.67	2.73	5.45
T_2:Castor + chilli (1:1)	1.74	3.0	1.89	1.38	1.92	1.73	1.94
T_3:Castor + cow pea (1:1)	1.65	0.2	2.31	2.46	1.35	2.17	1.69
T_4:Castor + cluster bean (1:2)	1.05	3.0	2.11	0.73	2.14	2.18	1.87
T_5:Castor + field bean(1:1)	2.38	3.3	3.14	1.4	1.59	2.01	2.30
T_6:Castor + grain amaranth (1:1)	1.82	0.6	2.4	0.47	1.20	2.44	1.49
T_7:Castor	3.99	6.2	1.52	2.75	1.72	1.49	2.95
T_8:Finger millet	8.34	9.2	5.78	5.66	4.76	3.83	6.26
T_9:Chilli	4.62	25.0	0.94	1.97	2.38	1.62	6.09
T_{10}:Cow pea	2.0	1.5	1.63	4.97	2.55	1.26	2.32
T_{11}:Cluster bean	2.45	10.8	1.46	2.46	2.15	2.47	3.63
T_{12}:Field bean	3.08	13.9	2.33	1.02	2.42	1.57	4.05
T_{13}:Grain amaranth	3.20	0.6	1.54	1.01	2.31	1.15	1.63

Table 5 : Total cost of cultivation and gross returns as influenced by nipped castor based intercropping systems over years, 2009-2014

Tr.	Total cost of cultivation (₹/ha)							Gross returns (₹/ha)						
	2009	2010	2011	2012	2013	2014	Mean	2009	2010	2011	2012	2013	2014	Mean
T_1	14600	13494	16084	19138	20077	25008	18067	43658	25632	46613	53145	61658	85385	52682
T_2	15600	15916	16588	19888	20827	30757	19929	25292	14868	25508	27219	27631	54297	29136
T_3	14700	12074	16280	20388	21327	25028	18300	27264	8294	31582	46502	49265	65362	38045
T_4	14800	14841	17160	24888	25827	26258	20629	26211	13492	27377	33686	44209	60788	34294
T_5	14801	14570	16291	21288	22227	27158	19389	25207	15403	43497	31687	36567	60600	35494
T_6	14425	14374	16170	19264	20097	25758	18348	20094	3540	23069	21517	31182	52957	25393
T_7	14000	13324	16934	18888	19827	24757	17955	27723	25365	29925	43020	39741	47172	35491
T_8	12500	12444	13300	18065	18988	23879	16529	37885	20223	39479	47737	51382	74897	45267
T_9	14450	14441	15500	22840	24491	31966	20615	20987	68430	18120	8304	13286	25397	25754
T_{10}	10700	10600	10925	19378	21022	22676	15884	20254	9485	25800	49383	52028	47619	34095
T_{11}	9500	13367	16184	25490	27118	25952	19602	11111	23845	18200	24809	51264	34568	27300
T_{12}	10200	13096	12300	20837	21923	26852	17535	12706	22704	34000	19988	32628	59083	30185
T_{13}	11850	10600	12198	17255	17779	29755	16573	15548	1716	13650	15755	22222	37531	17737

Selling price of produce (₹/kg)

Produce	2009	2010	2011	2012	2013	2014
Castor seed	15.00	15.00	35.00	60.00	40.00	40.00
Finger millet	10.00	10.00	11.00	20.00	20.00	25.00
Green chilli	10.00	10.00	10.00	10.00	10.00	20.00
Cowpea	25.00	35.00	30.00	50.00	50.00	50.00
Cluster bean	10.00	10.00	20.00	40.00	40.00	20.00
Field bean	10.00	10.00	30.00	25.00	25.00	50.00
Grain amaranth	12.00	12.00	15.00	40.00	18.00	60.00

Table 6 : Per ha net returns accrued (₹) and B:C ratio as influenced by nipped castor based intercropping systems over years, 2009-2014

Tr.	Net returns (₹/ha)							B: C ratio						
	2009	2010	2011	2012	2013	2014	Mean	2009	2010	2011	2012	2013	2014	Mean
T_1	29058	12138	30529	34007	41581	60377	34615	2.98	1.90	2.90	2.78	3.07	3.4	2.84
T_2	9692	-1048	8920	7331	6804	23540	9207	1.62	0.93	1.54	1.37	1.33	1.8	1.43
T_3	12564	-3780	15302	26114	27938	40334	19745	1.85	0.69	1.94	2.28	2.31	2.6	1.95
T_4	11411	-1349	10217	8798	18382	34530	13665	1.77	0.91	1.60	1.35	1.71	2.3	1.61
T_5	10406	833	27206	10399	14340	33442	16104	1.70	1.06	2.67	1.49	1.65	2.2	1.80
T_6	5669	-10834	6899	2253	11085	27199	7045	1.39	0.25	1.43	1.12	1.55	2.1	1.30
T_7	13723	12041	12991	24132	19914	22415	17536	1.98	1.90	1.77	2.28	2.00	1.9	1.97
T_8	25385	7779	26179	29672	32394	51018	28738	3.03	1.63	2.97	2.64	2.71	3.1	2.69
T_9	6537	53989	2620	-14536	-11205	-6569	5139	1.45	4.74	1.17	0.36	0.54	0.8	1.51
T_{10}	9554	-1115	14875	30005	31006	24943	18211	1.89	0.89	2.36	2.55	2.47	2.1	2.04
T_{11}	1611	10478	2016	-681	24146	8616	7698	1.17	0.78	1.12	0.97	1.89	1.3	1.38
T_{12}	2506	9608	21700	-849	10705	32231	12650	1.25	1.73	2.76	0.96	1.49	2.2	1.73
T_{13}	3698	-8884	1452	-1500	4443	7776	1164	1.31	0.16	1.12	0.91	1.25	1.3	1.00

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