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SJ Vaghela
Chimanbhai Patel College of Agriculture, S.D. Agricultural University, Sardarkrushinagaer, Gujarat, India

JC Patel
Chimanbhai Patel College of Agriculture, S.D. Agricultural University, Sardarkrushinagaer, Gujarat, India

DG Patel
Chimanbhai Patel College of Agriculture, S.D. Agricultural University, Sardarkrushinagaer, Gujarat, India

BL Yadav
Chimanbhai Patel College of Agriculture, S.D. Agricultural University, Sardarkrushinagaer, Gujarat, India

JS Dabhi
Chimanbhai Patel College of Agriculture, S.D. Agricultural University, Sardarkrushinagaer, Gujarat, India

Correspondence
SJ Vaghela
Chimanbhai Patel College of Agriculture, S.D. Agricultural University, Sardarkrushinagaer, Gujarat, India

Effect of different castor (*Ricinus communis* L.) based cropping systems on yield, nutrient content and uptake by different crops in North Gujarat agro-climatic condition

SJ Vaghela, JC Patel, DG Patel, BL Yadav and JS Dabhi

Abstract
A field experiment was conducted during the years 2011-12 and 2012-13 to study the effect of different cropping systems on yield, nutrient content and uptake by different crops in North Gujarat Agro-climatic condition on loamy sand soils of Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The experiment was laid out in randomised block design with four replications comprising ten treatments *viz.*, T_1 : Castor sole, T_2 : Greengram + castor (2:1), T_3 : Cowpea + castor (2:1), T_4 : Groundnut + castor (2:1), T_5 : Sesamum + castor (2:1), T_6 : Greengram-*rabi* castor, T_7 : Castor-summer pearl millet, T_8 : Castor-summer greengram, T_9 : Castor-summer sesamum and T_{10} : Castor-summer mothbean. Among cropping systems, castor sole and groundnut + castor inter cropping system produced significantly higher seed and stalk yield of castor than that of other treatments. Maximum content of nitrogen by castor crops as well as inter/sequence crops was recorded in castor + groundnut intercropping system while, phosphorus content by castor seeds was recorded with castor-summer pearl millet. Significantly maximum potassium content by castor seed was recorded under treatment T_9 (Castor-summer sesamum) while, significantly higher potassium content by castor stalk was recorded with treatment T_3 [cowpea + castor (2:1)]. Significantly maximum potassium content by seeds, stalk of castor and seed and straw/haulm of inter crop/sequence crop was recorded when groundnut was sown as inter crop. Significantly the highest sulphur content of seeds and haulm of groundnut was obtained when, it grown as groundnut + castor (2:1) inter cropping system. Castor-summer pearl millet system recorded maximum uptake of N, P_2O_5 and K_2O while groundnut + castor recorded maximum uptake of sulphur.

Keywords: crop production, cropping systems, nutrient content, nutrient uptake

Introduction
Castor (*Ricinus communis* L.) is one of the most important oilseed crops of India as its oil has a diversified uses and great value in foreign trade. It is a non-edible oil seed crop (45 to 50 % oil) having high industrial importance due to presence of unique fatty acid and ricinoleic acid. It belongs to family *Euphorbiaceae*, and originated from Ethiopia. Castor is extensively cultivated in India, China, Brazil, Ethiopia and Thailand. India has achieved monopolistic grip on international castor trade, earning of annual ₹ 5000 crores. India's average productivity is higher than the world average. The contribution of India in the world is 56 per cent in area and 84 per cent in production of castor. Thus, India is a leading country in the world not only in area and production, but also in productivity of castor. The castor oil is differs from other vegetable oil due to its non-freezing nature up to temperature of -18°C. It is therefore, considered to be the best lubricating agent particularly for both high speed engines and aeroplanes. Castor oil has many medicinal uses, *viz.*, curing in constipation (when taken internally), relief from pain, inflammation and stomach problems. It has also cosmetic uses and has been said to restore a youthful glow and maintain smooth and supple skin. It is also been used in the manufacturing of dyes, detergents, plaster of paris, soaps, polishes, greases, rubber, hydraulic brake fluids, polymers, wetting agents, surfactants, surface coatings *etc.* To reduce the duration and increase cropping intensity along with saving of irrigation water, cultivation of castor during *rabi* season is a suitable option. Intercropping is a common practice followed by farmers of semi-arid and arid tropics where primary concern is to secure their investment in order to sustain their living under the vagaries of nature. Thus, intercropping is intrinsically more secure and dependable in providing some returns than sole cropping (Chetty and Rao, 1979) [2].

Shortage of pulse and oil seeds in our country have focused the attention on their inclusion in intercropping systems which have a capacity to get more return per unit area as well as to improve the physical, biological and chemical properties of soil. As the wide space is available between two rows of main crop in which profitable short duration crop can be grown during early growth stage of the crop as intercrop which gives an additional income also (Chetterjee and Mandal, 1992) [1]. Sequence crop is also used to control pests and diseases that can become established in the soil over time. Sequence cropping could also help in maintaining soil fertility provided suitable crops such as legumes may be included in the cropping system. An important aspect of sequence cropping is the utilisation of nutrients more efficiently as the crops growing on the same piece of land would have different nutritional requirements.

Materials and Methods

A field experiment was conducted to study the effect of different cropping systems on yield, nutrient content and uptake by different crops in North Gujarat Agro-climatic condition on loamy sand soils during *kharif* seasons of 2011-12 and 2012-13. The experiment was laid out at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District: Banaskantha (North Gujarat). Sardarkrushinagar. It is situated in the North Gujarat Agro-climatic Zone of the Gujarat State. This zone is characterised by arid and semi-arid climate with extreme cold winter and hot and dry windy summer. The soil of the experimental plot was low in organic carbon (0.18 %) and available nitrogen (148 kg/ha), medium in phosphorus (47 kg/ha) and available potash (284 kg/ha). The experiment was laid out in randomised block design with four replications comprising ten treatments *viz.*, T_1 : Castor sole, T_2 : Greengram + castor (2:1), T_3 : Cowpea + castor (2:1), T_4 : Groundnut + castor (2:1), T_5 : Sesamum + castor (2:1), T_6 : Greengram-*rabi* castor, T_7 : Castor-summer pearl millet, T_8 : Castor-summer green gram, T_9 : Castor-summer sesamum and T_{10} : Castor-summer moth bean. Castor: GCH 7, mungbean: GM 4, cowpea: GC 5, groundnut: GG2, sesamum: GT 2, pearl millet: GHB 558, moth bean: GMo 2 were taken for experiment. The RDF of castor, mungbean, cowpea, groundnut, sesamum, pearl millet and mothbean were 180-37.5-00-20, 20-40-00-00, 20-40-00-00, 25-50-00-00, 50-25-00-20, 80-40-00-00 and 20-40-00-00 N-P-K-S kg/ha respectively. The total rainfall received during July-October, November-March and April-June was 916.1, 0 and 0 mm during 2011-12 and 590.6, 2.0 and 199.5 mm during 2012-13 respectively.. The average monthly air temperature, relative humidity and sunshine hours were almost similar during both years.

Castor was sown in the first fortnight of August during both the years and harvested in the last week of January to first week of March (2012) while during 2013 castor was harvested in the first week of February to first week of March. *Rabi* casor was sown in the first fortnight of October and harvested in the third week of February to second week of March during both the years. Greengram, groundnut, cowpea and sesamum were sown on second fortnight of July during 2011 and 2012 as an intercrops. Greengram and cowpea were harvested in the last week of the September while sesamum was harvested in the first fortnight of October and groundnut was harvested in first fortnight of November. Sowing of summer greengram, pearl millet, sesamum and mothbean on last week of march during both the years as summer sequence crops. Greengram and mothbean were harvested in the first week of june while peal millet and sesamum were harvested on third and fourth week of June, respectively. The number of irrigations applied in the *kharif* castor was 7 and in intercrop greengram, groundnut, cowpea and sesamum were 3 and in *rabi* castor was 5 while in summer sequence crop 7 irrigations were applied in pearl millet and sesamum while 5 irrigations were applied in greengram and mothbean. For nutrient content seed and stalk/haulm/straw samples of different crops are analysed and recorded while for uptake nutrient content is multiplied by yield of crops and devided by 100. The statistical analysis of data of various characters was done using analysis of variance techniques as suggested by Panse and Sukhatme (1985) [8].

Results and Discussion

Seed and stalk yield (kg/ha)

Among all the cropping systems when castor crop sown during *kharif* season as a sole crop produced higher seed yield as compared to it sown as inter crop (Table 1). This might be due to relatively less inter row competition in sole castor and better use of resources like water, nutrients, space and sunlight ultimately resulted into higher number of spikes per plant and number of capsules per spike which showed positive correlation with seed yield. These finding are in close conformity with the findings of Hegde and Reddy (1987) [3], Mudalagiriyappa *et al.* (2011), Neginhal *et al.* (2011) [7], Kumar *et al.* (2011) [4] and Kumavat *et al.* (2016) [5]. On the other hand, among intercropping systems, groundnut + castor (2:1) recorded significantly higher castor seed yield than that of other intercropping systems. Among all the cropping systems when castor crop sown during *kharif* season as a sole crop produced higher stalk yield as compared to crop sown as inter crop. This might be due to relatively less inter row competition in sole castor and better use of water, nutrients, space and sun radiation which turned into higher plant height and more number of branches as a result of better vegetative growth resulted into higher stalk yield in these systems. These finding are in close conformity with the findings of Mudalagiriyappa *et al.* (2011).

Nitrogen content and uptake in seeds and stalk of castor

The data presented in Table 2 indicated that significantly the highest nitrogen content in castor seed was recorded under treatment T_4 [groundnut + castor (2:1)]. Groundnut is nitrogen fixing crop which supply nitrogen to neighboring castor crop resulted into higher absorption owing to higher nitrogen content recorded with castor crop. Though, nitrogen content in castor stalk was found non-significant due to different cropping systems. Significantly maximum uptake of nitrogen (65.55 kg/ha) by castor seed was recorded under treatment T_4 [groundnut + castor (2:1)]. Significantly higher nitrogen uptake by castor stalk was recorded with treatment T_{10} (Castor-summer mothbean).

Nitrogen content and uptake in seeds and straw/haulm of inter/sequence crops

The data presented in Table 2 indicated that significantly maximum values of nitrogen content in seed of inter/sequence crop was recorded by groundnut in groundnut + castor (2:1) cropping system in pooled results. Similarly, significantly higher content of nitrogen in haulm of groundnut was recorded as compared to other inter/sequence crops. Significantly the highest uptake of nitrogen by seeds was recorded with groundnut crop when, it grown as groundnut + castor intercropping system in pooled results. Significantly the highest nitrogen uptake by straw of pearl millet was recorded when crop was grown as sequence crop during summer after castor in pooled results.

Phosphorus content and uptake in seeds and stalk of castor

The data presented in Table 3 revealed that significantly the highest phosphorus content in castor seed was recorded under treatment T_7 (castor-summer pearl millet). Significantly the highest phosphorus content in castor stalk was recorded with treatment T_4 [groundnut + castor (2:1)] and T_{10} (castor-summer mothbean). In pooled results significantly higher uptake of phosphorus by seeds of castor was registered with treatment T_9 (castor-summer sesamum) than other systems.

Phosphorus content and uptake in seeds and straw/haulm of inter/sequence crops

The data presented in Table 3 revealed that significantly the maximum values of phosphorus content was recorded in groundnut seed when groundnut sown as intercrop in groundnut + castor (2:1)] system in pooled results. Significantly the highest uptake of phosphorus by seeds of summer pearl millet crop was recorded when it grown as castor-summer pearl millet as a sequence crop in pooled results. Similar trend was obtained with respect to phosphorus uptake in straw.

Potassium content and uptake in seeds and stalk of castor

The data presented in Table 4 revealed that significantly maximum potassium content (1.35 %) by castor seed was recorded under treatment T_9 (castor-summer sesamum) and T_8 (castor-summer greengram) and potassium content by castor stalk was recorded under treatment T_3 [cowpea + castor (2:1)]. The results indicated that the highest potassium uptake by seeds of castor was recorded with treatment T_8 (castor-summer greengram) while significantly maximum values of potassium uptake by castor stalk was recorded with treatment T_{10} (castor-summer mothbean).

Potassium content and uptake in seeds and straw/haulm of inter/sequence crops

The data presented in Table 4 revealed that significantly maximum potassium content by seeds of groundnut as inter crop was recorded when grown as groundnut + castor (2:1). Significantly the highest potassium content was recorded in haulm of groundnut when groundnut grown as groundnut + castor (2:1) intercropping system. Significantly higher uptake of potassium was recorded by seeds and straw of summer pearl millet when, it is grown as sequence crop under treatment T_7 (castor-summer pearl millet) than that of other inter/sequence crops.

Sulphur content and uptake in seeds and stalk of castor

The data presented in Table 5 revealed that sulphur content in castor seed and stalk was found non-significant due to different cropping systems. The results indicated that significantly higher uptake of sulphur by seed of castor was recorded with treatment castor-summer pearl millet sequence while maximum values of sulphur uptake by castor stalk was recorded with castor-summer mothbean sequence.

Sulphur content and uptake in seeds and straw/haulm of inter/sequence crops

The data presented in Table 5 revealed that significantly the highest sulphur content in seeds and haulm was recorded in groundnut when crop was grown as groundnut + castor (2:1). Significantly higher sulphur uptake by seeds of groundnut was recorded with groundnut + castor (2:1) intercropping system while significantly the highest sulphur uptake by straw of pearl millet crop was recorded when it grown as castor-summer pearl millet sequence.

Table 1: Castor yield and component crop yield (average 2 years) as influenced by different castor (*Ricinus communis* L.) based cropping systems

Treatment	**Castor yield (kg/ha)**		**Intercrop/ sequence crop yield (kg/ha)**	
	Seed	Stalk	Seed	**Straw/stover/haulm**
Castor sole	3718^{a}	4360^{a}	-	-
Greengram + castor (2:1)	2796^{bc}	3677^{ab}	726	1280
Cowpea + castor (2:1)	2390^{c}	3016^{b}	688	1258
Groundnut + castor (2:1)	3495^{ab}	4134^{a}	999	2087
Sesamum + castor (2:1)	2240^{c}	2759^{b}	347	893
Greengram-*rabi* castor	2012^{c}	2921^{b}	758	1219
Castor-summer pearl millet	3729^{a}	4432^{a}	1269	3691
astor–summer greengram	3796^{a}	4541^{a}	652	1106
Castor–summer sesamum	3670^{ab}	4247^{a}	359	997
Castor–summer mothbean	3752^{a}	4370^{a}	336	799
S.Em.±	272.8	326.1	-	-
C.D.at 5 %	17.3	17.0	-	-

Note : Treatment means with the letter/letters in common are not significant by DNMRT at 5 % level of significance

Table 2: Nitrogen content and uptake in seed and stalk of castor, seed and straw/haulm of inter/sequence crop (average 2 years) as influenced by different castor (*Ricinus communis* L.) based cropping systems

Treatment	**Nitrogen content (%) in castor**		**Nitrogen uptake (kg/ha) in castor**		**Nitrogen content (%) in inter/sequence crop**		**Nitrogen uptake (kg/ha) in inter/sequence crop**	
	Seed	**Stalk**	**Seed**	**Stalk**	**Seed**	**Straw/haulm**	**Seed**	**Straw/haulm**
Castor sole	1.73	0.89	66.05	38.58	-	-	-	-
Greengram + castor (2:1)	1.76	0.96	49.56	35.12	2.36	1.26	17.13	16.05
Cowpea + castor (2:1)	1.73	0.89	41.51	26.79	2.27	1.36	15.69	17.15
Groundnut + castor (2:1)	1.92	0.95	63.64	39.95	2.61	1.67	26.09	34.78
Sesamum + castor (2:1)	1.69	0.84	40.70	23.21	2.03	1.46	6.92	13.04
Greengram-*rabi* castor	1.56	0.90	31.39	26.30	2.28	1.54	17.31	18.76

Castor-summer pearl millet	1.50	0.79	56.02	35.24	1.90	1.57	24.22	58.05
Castor–summer greengram	1.62	0.96	61.48	42.02	2.56	1.38	16.63	15.27
Castor–summer sesamum	1.76	0.84	64.51	36.39	1.99	1.27	7.12	12.63
Castor–summer mothbean	1.64	0.94	61.19	40.88	2.46	1.35	8.24	10.79
S.Em.±	0.12	0.08	5.55	2.95	0.10	0.05	1.40	1.98
C.D.at 5 %	0.18	NS	16.09	8.57	0.29	0.15	4.06	5.75
C.V. %	7.27	4.74	20.72	17.20	9.72	7.82	20.06	20.21

Table 3: Phosphorus content and uptake in seed and stalk of castor, seed and straw/haulm of inter/sequence crop (average 2 years) as influenced by different castor (*Ricinus communis* L.) based cropping systems

Treatment	Phosphorus content (%) in castor		Phosphorus uptake (kg/ha) in castor		Phosphorus content (%) in inter/sequence crop		Phosphorus uptake (kg/ha) in inter/sequence crop	
	Seed	Stalk	Seed	Stalk	Seed	Straw/haulm	Seed	Straw/haulm
Castor sole	0.25	0.18	9.22	7.86	-	-	-	-
Greengram + castor (2:1)	0.25	0.20	6.80	7.14	1.43	0.57	10.31	7.31
Cowpea + castor (2:1)	0.22	0.18	5.25	5.38	1.48	0.67	10.16	8.38
Groundnut + castor (2:1)	0.24	0.21	8.15	8.48	1.60	0.78	15.96	16.18
Sesamum + castor (2:1)	0.24	0.19	5.26	5.13	1.57	0.70	5.45	6.21
Greengram-*rabi* castor	0.21	0.17	4.13	4.84	1.42	0.60	10.77	7.31
Castor-summer pearl millet	0.27	0.19	9.70	8.50	1.55	0.69	19.86	25.30
Castor–summer greengram	0.24	0.20	9.17	8.83	1.65	0.58	10.74	6.42
Castor–summer sesamum	0.26	0.18	9.74	7.80	1.52	0.68	5.47	6.79
Castor–summer mothbean	0.25	0.20	9.20	8.74	1.30	0.58	4.37	4.62
S.Em.±	0.01	0.01	0.77	0.65	0.05	0.02	1.08	0.81
C.D.at 5 %	0.03	0.02	2.25	1.88	0.16	0.06	3.14	2.36
C.V. %	7.51	7.14	19.90	17.84	7.94	6.59	23.25	18.54

Table 4: Potassium content and uptake in seed and stalk of castor, seed and straw/haulm of inter/sequence crop (average 2 years) as influenced by different castor (*Ricinus communis* L.) based cropping systems

Treatment	Potassium content (%) in castor		Potassium uptake (kg/ha) in castor		Potassium content (%) in inter/sequence crop		Potassium uptake (kg/ha) in inter/sequence crop	
	Seed	Stalk	Seed	Stalk	Seed	Straw/haulm	Seed	Straw/haulm
Castor sole	1.24	2.31	46.06	100.50	-	-	-	-
Greengram + castor (2:1)	1.16	2.03	32.54	74.36	1.34	2.36	9.69	30.15
Cowpea + castor (2:1)	1.22	2.63	29.14	79.34	1.36	2.27	9.39	28.60
Groundnut + castor (2:1)	1.22	1.98	43.28	82.19	1.67	2.70	16.76	56.24
Sesamum + castor (2:1)	1.20	2.38	26.81	65.59	1.46	2.18	5.06	18.09
Greengram-*rabi* castor	1.26	2.20	25.30	65.55	1.54	2.28	11.69	27.73
Castor-summer pearl millet	1.28	2.45	47.71	109.30	1.57	2.20	19.81	81.10
Castor–summer greengram	1.35	2.16	50.99	95.84	1.38	2.56	8.98	28.31
Castor–summer sesamum	1.35	2.47	49.53	106.94	1.27	2.41	4.55	23.98
Castor–summer mothbean	1.24	2.60	46.43	113.51	1.35	2.46	4.54	19.62
S.Em.±	0.04	0.07	3.73	8.73	0.06	0.06	0.86	2.67
C.D.at 5 %	0.12	0.20	10.81	25.34	0.16	0.17	2.51	7.75
C.V. %	7.04	6.01	18.65	19.54	8.68	5.61	19.03	17.08

Table 5: Sulphur content and uptake in seed and stalk of castor, seed and straw/haulm of inter/sequence crop (average 2 years) as influenced by different castor (*Ricinus communis* L.) based cropping systems

Treatment	Sulphur content (%) in castor		Sulphur uptake (kg/ha) in castor		Sulphur content (%) in inter/sequence crop		Sulphur uptake (kg/ha) in inter/sequence crop	
	Seed	Stalk	Seed	Stalk	Seed	Straw/haulm	Seed	Straw/haulm
Castor sole	0.17	0.14	6.11	6.09	-	-	-	-
Greengram + castor (2:1)	0.15	0.15	4.34	5.29	0.19	0.12	1.38	1.47
Cowpea + castor (2:1)	0.16	0.17	3.95	4.97	0.19	0.09	1.27	1.18
Groundnut + castor (2:1)	0.14	0.16	5.01	6.56	0.27	0.15	2.74	3.03
Sesamum + castor (2:1)	0.15	0.14	3.34	3.85	0.26	0.13	0.91	1.12
Greengram-*rabi* castor	0.16	0.15	3.19	4.45	0.16	0.11	1.17	1.28
Castor-summer pearl millet	0.17	0.16	6.19	6.91	0.17	0.11	2.08	3.88
Castor–summer greengram	0.16	0.15	6.07	6.45	0.14	0.12	0.91	1.34
Castor–summer sesamum	0.15	0.14	5.61	6.21	0.24	0.13	0.86	1.26
Castor–summer mothbean	0.16	0.17	5.94	7.21	0.16	0.11	0.54	0.88
S.Em.±	0.01	0.01	0.49	0.62	0.00	0.01	0.11	0.15
C.D.at 5 %	NS	NS	1.43	1.81	0.01	0.02	0.33	0.44
C.V. %	14.38	12.88	19.71	21.77	4.45	11.86	18.93	19.42

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