



## DRY MATTER PARTITIONING AND SEED WEIGHT OF CASTOR (*Ricinus communis* L.) AS INFLUENCED BY VARIETY, NUTRIENT SOURCES AND AGRO-ECOLOGY IN BAUCHI STATE, NIGERIA

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### ABSTRACT

The research was carried out at Abubakar Tafawa Balewa University teaching and research farm, Bauchi located in the Northern Guinea Savannah and Bulkachuwa village of Katagum LGA located in Sudan Savannah both in Bauchi state, during the wet seasons of 2016, 2017 and 2018 to study the dry matter partitioning and seed weight of castor (*Ricinus communis* L.) as influenced by variety, nutrient sources and agro-ecology. The treatments consisted of five nutrient sources (poultry manure, cow dung, chicken feather, municipal waste, mineral fertilizer) and a control and two varieties of castor (Ex-India 1 and 2), these were factorially combined to give 12 treatment and laid out in a randomized complete block design (RCBD) with three replications. The results of the experiment revealed a significant ( $P \leq 0.05$ ) difference among the treatments used throughout the study period. The result further indicated that, application of poultry manure, chicken feather and mineral NPK fertilizer produced statistically ( $P \leq 0.05$ ) similar results in most of the parameters observed but significantly ( $P \leq 0.05$ ) better than cowdung and municipal waste. The control consistently had the lower values for the parameters measured. The results also showed that, variety Ex-India 2 proved to be superior over Ex-India 1 on all the characters observed. Study on location on the other hand, Bauchi was found to be better than Bulkachuwa location throughout the study period. In terms of study season however, crop grown in 2018 performed statistically ( $P \leq 0.05$ ) better than those of 2016 and 2017 wet seasons on most of the characters studied. Based on the findings of this study, application of poultry manure or chicken feather at the rate of 2t/ha or mineral NPK fertilizer (at the rate of 100:50:50 kg/ha) to Ex-India 2 can be recommended for farmers in the study area.

**Keywords:** Dry matter, Seed weight, Organic manure and NPK fertilizer

### INTRODUCTION

The castor plant is a tall, glabrous annual, sometimes shrubby or arboreous (Colbeth, 1951). The leaves are alternate, broad, palmately seven-to many-lobes and serrated. Flowers are large in terminal sub-panicle racemes, monoecious, apetalous, upper male crowded, lower female disc shaped. The shoots and panicles are glaucous. Leaves are green or reddish of about 30 – 60 cm in diameter, membranous, lobed from oblong to linear, acute or acuminate, gland serrated (Vaheeduddin, 1951). Bedekar and Gulabuni (1977) described the seeds of most varieties of castor as being encased in a spiny brittle outer shell that is compressed dorsally and grown in clusters on spikes of the plant. The seeds are oval in shape and generally similar to but larger or smaller than a common bean, depending on the variety. The helium which is yellowish white is at the end of the seed. The seeds are mottled dark cream, black, light or dark brown, endosperm copious and white and embryo small while cotyledon is thin and papery (Rao *et al.*, 1981). Navarro *et al.* (2002) observed that castor bean is made up of approximately 75% kernel and 25% husk, and about two thirds of the weight of the kernel is oil.

The oil content of various domestic varieties of castor beans from trial plantings are as high as 54% on a moisture free basis. The small seeds can weigh between 0.1 to 1.0g, while



the larger seeds can weigh from 3.0 to 3.5g. Ghosh (2003) analyzed a Brazilian castor bean variety as having a typical oil value of 49%, 18% protein, 13% carbohydrate, 12.5% fibre and 2.5% ash. The bean also contains the enzyme lipase, which may be readily extractable, insoluble in water and has been shown to catalyze the synthesis of triglycerides as well as the hydrolysis of the oil in the presence of water (Modell, 2002). In most of the regions of castor production, seed yield can be rapidly increased with the use of improved agronomic practices. The main technologies include selection of the appropriate cultivar combined with the use of good quality seed, appropriate planting date, irrigation, soil fertilization, management of weed, pest and diseases, optimized plant population, mechanical harvesting and postharvest management. Optimizing planting population is an inexpensive practice that can significantly increase castor seed yield. However, the optimum plant population varies as influenced by the genotype, environmental conditions and agricultural practices. Because environmental conditions are not constant, there is not an individual plant density that can be broadly recommended for castor. Instead, researchers tend to focus on determining a range of plant populations, targeting the best yield across years and environmental conditions. As an example of environment influence, plant populations recommended for the cultivar BRS Nordestina (tall type) in different locations were 5000 plant ha<sup>-1</sup> (Severino *et al.*, 2006), 4200 plant ha<sup>-1</sup> and 12,500 plant ha<sup>-1</sup> (Carvalho *et al.*, 2010a).

## MATERIALS AND METHOD

### The Study Area

The experiment was conducted during the rainy seasons of 2016, 2017 and 2018 at the teaching and research farm of the Faculty of Agriculture and Agricultural Technology, Abubakar Tafawa Balewa University Bauchi, (10° 22'N and 9° 47'E) in the Northern Guinea Savanna ecological zone and also at Bulkachuwa Village (11°38'N and 10°31'E) of Katagum LGA in the Sudan Savanna ecological zone of Nigeria to study the dry matter partitioning and seed weight of castor as influenced by variety, nutrient sources and agro-ecology. The treatments consisted of five nutrient sources (poultry manure, cow dung, chicken feather, municipal waste, NPK fertilizer and a control), two varieties of castor (Ex-India 1 and 2) and conducted in two different agro-ecologies (Bauchi and Bulkachuwa). The five nutrient sources and two varieties were factorially combined to give 12 treatment combinations and laid out in a randomized complete block design (RCBD) with three replications. The field was ploughed once and harrowed twice to a fine tilth during the first year while manual tillage using hand hoe was carried out in the subsequent years so as to maintain the residual effects of the treatments in each plot. Each of the organic fertilizer source was applied at the rate of 2 tons/ha in each year of the study. Inorganic fertilizer however, was applied in the form of NPK 15:15:15 and urea at the rate of 100 kg N, 50 kg P<sub>2</sub>O<sub>5</sub> and 50 kg K<sub>2</sub>O/ha. Data were collected on total dry matter, crop growth rate, net assimilation rate, number of capsules/raceme, raceme yield and 100 seed weight. All data collected were subjected to combined analysis of variance (ANOVA) using the statistical analysis system procedure (SAS, 2003) while all the significantly different treatment means were separated using Duncan's Multiple Range Test (DMRT).

**RESULTS AND DISCUSSION**

**Effect of Nutrient Source, Variety, Location and Year on Total Dry Matter of Two Castor Cultivars**

**Total Dry Matter (g)**

Table 1 presented the result on effect of nutrient sources, variety, location and year on total dry matter of castor. The significant ( $P \leq 0.05$ ) difference observed throughout the study period on total dry matter in which application of various nutrient sources produced higher dry matter indicated the importance of fertilizer application on dry matter accumulation of castor. Dry matter accumulation, which is a good growth index to express photosynthetic efficiency of the plant was highest under the application of poultry manure, chicken feather and mineral fertilizer. This could be as a result of proliferation of more leaves and larger leaf area recorded in these treatments for efficient solar interception, increased photosynthesis and favourable dry matter partitioning.

**Table 1: Effect of nutrient source, variety, location and year on total dry matter of two castor cultivars**

Treatments	Total Dry Matter		
	4 WAS	8 WAS	12 WAS
<b>Nutrient source</b>			
Control	7.56 <sup>c</sup>	16.17 <sup>c</sup>	50.72 <sup>c</sup>
Poultry manure	21.35 <sup>a</sup>	55.84 <sup>a</sup>	172.42 <sup>a</sup>
Municipal waste	13.79 <sup>b</sup>	33.04 <sup>b</sup>	110.21 <sup>b</sup>
Chicken feather	20.53 <sup>a</sup>	51.95 <sup>a</sup>	164.62 <sup>a</sup>
Cowdung	12.34 <sup>b</sup>	29.62 <sup>b</sup>	103.86 <sup>b</sup>
Mineral fertilizer	19.71 <sup>a</sup>	54.50 <sup>a</sup>	171.52 <sup>a</sup>
LS	**	**	**
SE±	0.685	1.656	4.791
<b>Variety</b>			
Ex-India 1	14.47 <sup>b</sup>	37.16 <sup>b</sup>	124.25 <sup>b</sup>
Ex-India 2	17.28 <sup>a</sup>	43.21 <sup>a</sup>	133.54 <sup>a</sup>
LS	**	**	*
SE±	0.401	0.956	2.767
<b>Location</b>			
Bauchi	16.05	40.88	134.51 <sup>a</sup>
Bulkachuwa	15.71	39.49	123.27 <sup>b</sup>
LS	NS	NS	**
SE±	0.401	0.956	2.767
<b>Year</b>			
2016	18.63 <sup>b</sup>	30.12 <sup>c</sup>	145.18 <sup>b</sup>
2017	22.74 <sup>a</sup>	42.15 <sup>b</sup>	160.52 <sup>a</sup>
2018	15.26 <sup>c</sup>	48.29 <sup>a</sup>	80.97 <sup>c</sup>
LS	**	**	**
SE±	0.481	1.167	3.390
<b>Interaction</b>			
NxV	NS	*	**
VxL	NS	NS	NS
NxL	NS	NS	NS
NxY	**	**	**
LxY	NS	NS	NS
VxY	NS	NS	NS
NxVxLxY	NS	NS	NS

LS = Level of significance, SE± = Standard error, NS = Not significant, \* and \*\* = significant at 0.05 and 0.01 respectively. Means followed by different letters are statistically different following DMRT



The present result corroborate the findings of Rehman (2016) who reported that, dry matter accumulation is a function of number of leaves and its corresponding leaf area. This could also be as a result of availability of nitrogen in the soil for better crop uptake as poultry manure and chicken feathers exhibit a low carbon to nitrogen ratio. This is in line with the result of Domingo (2001) who reported that, total dry matter accumulation during growth and ripening phase is greatly influenced by availability of nitrogen in the soil. The higher dry matter observed under cowdung and municipal waste over control could be due to improvement in soil physical characteristics with water infiltration and aggregate stability. This is in agreement with the report of Mullens (2002) who observed an improvement in soil physical characteristics as a result of organic manure application.

Variety as a function of genetic variability exhibited a differential response and their ability to partition dry matter. Ex-India 2 being the large seeded variety produced significantly higher total dry matter than variety Ex-India 1. This could be linked to better performance in terms of plant height leading to higher number of leaves and wider leaf area by Ex-India 2 which eventually leads to increase in photosynthetic ability and better accumulation of photosynthates. The result of this agrees with that of Rehman (2016) who reported that, dry matter accumulation is a function of number of leaves and its corresponding leaf area.

### **Effect of Nutrient Source, Variety, Location and Year on Crop Growth Rate of Two Castor Cultivars**

#### ***Crop growth rate (CGR)***

The result as presented in Table 2 indicated that, a significant ( $P \leq 0.05$ ) difference in crop growth rate exist among the nutrient sources applied throughout the study period. Crop growth rate, a measure of the amount of dry matter produced by the plant per the land area covered by the plant in a specified period of time was affected by the different plant nutrient applied. The high performance of poultry manure, chicken feather and mineral fertilizer on crop growth rate throughout the study period revealed the importance of fertilizer application to castor. The significant growth rate observed under poultry manure and chicken feather could be as a result of their contribution to soil nutrient availability. This corroborate the findings of Akande *et al.* (2005) who reported that, application of poultry product have a significant impact on soil nutrient availability. The present findings also agrees with the much earlier report of Kumar *et al.* (2007) who opined that, the combination of nitrogen from different organic manures was comparable on equivalent basis in which poultry manure proved to be a better source. The significant increase in growth rate observed under cowdung and municipal waste over control indicated their importance as organic fertilizers in castor production. The increase in growth rate could be due to reduction in soil compactness and increase in soil aeration as a result of their application. Kuncoro *et al.* (2014) also lend support to the present findings that, organic additives reduce soil compactness by improving soil aeration and water penetration.

**Table 2: Effect of nutrient source, variety, location and year on crop growth rate of two castor cultivars**

Treatments	Crop Growth Rate	
	8 WAS	12 WAS
<b>Nutrient source</b>		
Control	0.64 <sup>c</sup>	2.48 <sup>c</sup>
Poultry manure	2.67 <sup>a</sup>	7.60 <sup>a</sup>
Municipal waste	1.61 <sup>c</sup>	4.97 <sup>b</sup>
Chicken feather	2.41 <sup>b</sup>	7.43 <sup>a</sup>
Cowdung	1.29 <sup>d</sup>	4.41 <sup>b</sup>
Mineral fertilizer	2.62 <sup>ab</sup>	7.55 <sup>a</sup>
LS	**	**
SE±	0.078	0.301
<b>Variety</b>		
Ex-India 1	1.78 <sup>b</sup>	5.70
Ex-India 2	1.96 <sup>a</sup>	5.80
LS	**	NS
SE±	0.035	0.181
<b>Location</b>		
Bauchi	1.89	5.89
Bulkachuwa	1.86	5.64
LS	NS	NS
SE±	0.034	0.180
<b>Year</b>		
2016	1.22 <sup>c</sup>	2.91 <sup>c</sup>
2017	1.54 <sup>b</sup>	6.69 <sup>b</sup>
2018	2.87 <sup>a</sup>	7.62 <sup>a</sup>
LS	**	**
SE±	0.045	0.221
<b>Interaction</b>		
NxV	**	**
VxL	NS	NS
NxL	NS	NS
NxY	**	**
LxY	NS	NS
VxY	NS	NS
NxVxLxY	NS	NS

LS = Level of significance, SE± = Standard error, NS = Not significant, \* and \*\* = significant at 0.05 and 0.01 respectively. Means followed by different letters are statistically different following DMRT

**Effect of Nutrient Source, Variety, Location and Year on Net Assimilation Rate of Two Castor Cultivars**

**Net Assimilation Rate (NAR)**

Table 3 shows the effect of nutrient sources, variety, location and year on net assimilation rate (NAR) of castor. The result revealed a significant ( $P \leq 0.05$ ) difference among the different nutrient sources used throughout the study period. Net assimilation rate, a measure of the rate of increase in dry matter per unit area of leaf per unit time and also a useful measure of photosynthetic efficiency of plants indicated a significant response to the different nutrient sources applied. The significantly ( $P \leq 0.01$ ) higher net assimilation rate observed throughout the study period when poultry manure, chicken feather and mineral



fertilizer were applied, indicated the superiority of the poultry products to other organic sources used and their potential to favorably compete or substitute inorganic fertilizer in castor production. The higher net assimilation rate observed could also be as a result of increased in the organic manure uptake, not only added nutrient to the soil, but also in its availability and uptake by plant. This conforms with what Amanullah *et al.* (2007) reported that, addition of organic matter not only acts as source of nutrient, but could also influence its availability in the soil. Lasekan *et al.* (2013) also reported that, preparation of bio-fertilizer using chicken feather could be a viable alternative in crop production to the use of inorganic fertilizers in crop performance. Even though municipal waste and cowdung produced lower net assimilation rate, the two nutrients sources had better results than the control. This indicated as a whole, their significant plant nutrient supply to the soil. This is in agreement with the report of Mbarki *et al.* (2008) who stated that, long term application of organic fertilizer develop good soil structure, improves water holding capacity and increases aggregate stability through the formation of cationic bridges.

**Table 3: Effect of nutrient source, variety, location and year on net assimilation rate of two castor cultivars**

Treatments	Net Assimilation Rate	
	8 WAS	12 WAS
<b>Nutrient source</b>		
Control	5.73 <sup>d</sup>	5.55 <sup>c</sup>
Poultry manure	2.16 <sup>b</sup>	1.85 <sup>a</sup>
Municipal waste	3.80 <sup>c</sup>	3.45 <sup>b</sup>
Chicken feather	1.97 <sup>ab</sup>	1.83 <sup>a</sup>
Cowdung	3.65 <sup>c</sup>	3.54 <sup>b</sup>
Mineral fertilizer	1.73 <sup>a</sup>	1.84 <sup>a</sup>
LS	**	**
SE±	0.091	0.131
<b>Variety</b>		
Ex-India 1	3.30 <sup>b</sup>	2.98
Ex-India 2	3.05 <sup>a</sup>	3.04
LS	**	NS
SE±	0.045	0.081
<b>Location</b>		
Bauchi	3.10	2.98
Bulkachuwa	3.24	3.04
LS	NS	NS
SE±	0.045	0.081
<b>Year</b>		
2016	3.49 <sup>b</sup>	3.25 <sup>b</sup>
2017	3.33 <sup>b</sup>	3.90 <sup>b</sup>
2018	2.70 <sup>a</sup>	2.88 <sup>a</sup>
LS	**	**
SE±	0.067	0.101
<b>Interaction</b>		
NxV	*	**
VxL	NS	NS
NxL	NS	NS
NxY	**	**
LxY	NS	NS
VxY	NS	NS
NxVxY	NS	NS

LS = Level of significance, SE± = Standard error, NS = Not significant, \* and \*\* = significant at 0.05 and 0.01 respectively. Means followed by different letters are statistically different following DMRT

**Effect of Nutrient Source, Variety, Location and Year on Number of Capsules per Raceme, Length of Raceme and 100 Seed Weight of Two Castor Cultivars*****Number of Capsules per Raceme***

Effect of nutrient source, variety, location and year on number of capsules per raceme is presented in Table 4. The significantly ( $P \leq 0.01$ ) higher number of capsules per raceme observed as a result of the application of mineral fertilizer over the other nutrient sources could be as a result quick release of plant nutrients to the soil by mineral fertilizer than organic fertilizers. This is in line with the report of Severino *et al.* (2006) that, mineral fertilizers were more effective than organic manures for supplying nutrient due to slow mineralization of organic materials in a semiarid environment. The higher number of capsules observed under poultry manure and chicken feather over cowmanure and municipal waste proved the contribution of poultry products to soil fertility. The increase in number of capsules with the addition of poultry manure could be due to increase in plant nutrient in the soil. The result of this study lend its support to the findings Ibeawuchi *et al.* (2006) who reported that, in degraded soils, poultry manure application increases the residual N, K, Ca, Mg and organic matter. The increase in number of capsules with the addition of chicken feather could also be as a result of continues release of nutrient to the plant over extended period of time. This corroborates the report of Tsavkelova *et al.* (2012) who affirmed that, once feather meal begins to release its nutrients, it will release at a steady rate for approximately three months where more than 75% of all the nitrogen will be utilized by the plant.

***Raceme Length***

The significantly ( $P \leq 0.05$ ) higher raceme length observed under poultry manure, chicken feathers and mineral fertilizer revealed the contribution of poultry product and synthetic fertilizer in the production of castor. This is in line with the report of Leles *et al.* (2010) who indicated a significant response of castor to fertilizer application. The increase in raceme length as observed with the application of poultry manure and chicken feather could be as a result of increase in phosphorous and nitrogen availability in the soil as a result of poultry products application. Silva *et al.* (2012) also agrees with the present findings that, chicken feather is a good source of nitrogen in compost heap, supplying the heap with nitrogen for a long period of time. An increase in raceme length was also observed under cowdung and municipal waste over the control. This could be as a result of increase in organic matter and nutrient content of the soil. The result of this findings is in support of the report of Meena *et al.* (2016) who observed that, combine application of municipal waste and mineral fertilizer increases soil organic carbon.

***100 Seed Weight***

The heavier grains as observed throughout the study period with various nutrient sources indicated the importance of fertilization to the yield of castor. Castor plant shows a differential response to various organic sources used. This could be as a result of their various contribution to fertility status of the soil. This corroborate the report of Kuncoro *et al.* (2014) who reaffirmed that, organic additives reduce the compactness of soil by improving soil aeration and water penetration. The heavier seeds observed under poultry manure and chicken feathers could be attributed to their low carbon to nitrogen ratio and their ability to increase the exchangeable basis in the soil and making the nutrient available

for better uptake by the plant. This is in conformity with the findings of Agbede *et al.* (2008) that, poultry products have an impact on soil pH and liming due to varying amounts of calcium carbonate and improve soil physical properties by reducing bulk density, temperature and increasing total porosity and moisture content. The increase in seed weight as observed under cowdung and municipal waste over the control, could be due to their positive impact on the soil quality. This is in agreement with the report of Nest *et al.* (2016) who proved that, application of municipal waste increased the aggregate stability of the soil.

**Table 4: Effect of nutrient source, variety, location and year on number of capsules per raceme, length of raceme and 100 seed weight of two castor cultivars**

Treatments	Characters		
	No. of Caps./Raceme	Raceme Length (cm)	100 Seed Weight (g)
<b>Nutrient source</b>			
Control	17.66 <sup>d</sup>	4.38 <sup>c</sup>	31.01 <sup>d</sup>
Poultry manure	32.66 <sup>b</sup>	7.54 <sup>a</sup>	48.64 <sup>a</sup>
Municipal waste	25.22 <sup>c</sup>	5.77 <sup>b</sup>	44.69 <sup>b</sup>
Chicken feather	32.55 <sup>b</sup>	7.37 <sup>a</sup>	47.06 <sup>ab</sup>
Cowdung	27.90 <sup>c</sup>	5.81 <sup>b</sup>	41.92 <sup>c</sup>
Mineral fertilizer	37.02 <sup>a</sup>	7.43 <sup>a</sup>	48.31 <sup>a</sup>
LS	**	**	**
SE±	0.991	0.078	0.941
<b>Variety</b>			
Ex-India 1	23.27 <sup>b</sup>	6.14 <sup>b</sup>	22.62 <sup>b</sup>
Ex-India 2	34.40 <sup>a</sup>	6.89 <sup>a</sup>	64.59 <sup>a</sup>
LS	**	**	**
SE±	0.571	0.050	0.542
<b>Location</b>			
Bauchi	29.35	6.24	43.65
Bulkachuwa	28.32	6.19	43.56
LS	NS	NS	NS
SE±	0.571	0.050	0.542
<b>Year</b>			
2016	24.93 <sup>c</sup>	5.62 <sup>c</sup>	29.98 <sup>c</sup>
2017	26.81 <sup>b</sup>	6.42 <sup>b</sup>	47.47 <sup>b</sup>
2018	34.76 <sup>a</sup>	6.61 <sup>a</sup>	53.57 <sup>a</sup>
LS	**	**	**
SE±	0.702	0.056	0.662
<b>Interaction</b>			
NxV	**	NS	**
VxL	NS	NS	NS
NxL	NS	NS	NS
NxY	NS	NS	NS
LxY	NS	NS	NS
VxY	NS	NS	NS
NxVxLxY	NS	NS	NS

LS = Level of significance, SE± = Standard error, NS = Not significant, \* and \*\* = significant at 0.05 and 0.01 respectively. Means followed by different letters are statistically different following DMRT





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**Table 5: Interaction of Variety and Nutrient Source on Number of Capsules per Raceme and 100 Seed Weight of Castor**

Treatments	Number of Capsules/Raceme		100 Seed Weight	
	Ex India 1	Ex India 2	Ex India 1	Ex India 2
<b>Nutrient sources</b>				
Control	21.97 <sup>f</sup>	25.76 <sup>f</sup>	21.44 <sup>c</sup>	48.63 <sup>c</sup>
Poultry manure	35.79 <sup>bcd</sup>	36.95 <sup>abc</sup>	30.90 <sup>d</sup>	75.89 <sup>a</sup>
Municipal waste	30.78 <sup>e</sup>	32.91 <sup>cde</sup>	27.07 <sup>de</sup>	65.68 <sup>b</sup>
Chicken feather	38.71 <sup>ab</sup>	41.42 <sup>a</sup>	28.77 <sup>d</sup>	75.50 <sup>a</sup>
Cowdung	31.84 <sup>de</sup>	39.86 <sup>ab</sup>	24.98 <sup>de</sup>	66.30 <sup>b</sup>
Mineral fertilizer	39.85 <sup>ab</sup>	41.32 <sup>a</sup>	30.22 <sup>d</sup>	74.24 <sup>a</sup>
LS		*		**
SE±		1.502		2.312

LS = Level of significance, SE± = Standard error, NS = Not significant, \* and \*\* = significant at 0.05 and 0.01 respectively. Means followed by different letters are statistically different following DMRT

## CONCLUSION AND RECOMMENDATIONS

Application of poultry manure, chicken feather and mineral fertilizer had an influence on the growth and yield of castor and outperform cowdung and municipal. The higher cost coupled with hazardous nature to the environment associated with mineral fertilizer is of great global concern. Therefore, in search of a more environmentally friendly organic source, this could serve as good news to castor growers in the study area. Based on the results of this study, application of poultry manure or chicken feather at the rate of 2 tons/ha or mineral fertilizer at the rate of 100 kg N, 50 kg P & K/ha should be adopted by farmers in the study area for profitable castor production. Ex-India 2 variety should be grown for good yield and oil content of castor. Continues application of organic manure in order to enhance soil fertility should be adhered to by farmers in the study area.

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