Research Article

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Effect of rate of irrigation and brown bat manure on the growth and yield of castor (*Ricinus communis* L.) in Mokwa

Abstract

This study determines the effect of rates of irrigation and brown bat manure on the growth and yield of castor. The experiment was conducted in Mokwa, Niger state. A completely randomized design (CRD) was set up potted with improvised drip irrigation system with five treatments replicated three times. The pots were spaced at 2m x 2m distance. The treatments were; T1 – 2 liters (Ls) of water per week (w), T2- 2 Ls daily for 2 days/w (4 liters per week), T3 – 2 L daily for 3 days /w (6 liters per week), T4 – 2 L daily for 4 days / w (8 liters per week) and T5 – one liter a week. The soil preparation was done by treating the soil with bat manure; 50 Kg bags were half filled with soil from the college orchard, each bag was mixed with 2 Kg of bat manure. The soil was moistened for three days and allow for partial decomposition. Soil physical and chemical analysis was done before treatment by taking sample from a pot at depth of 0 - 20 cm with soil augers. The plant parameters determined include; Seedling Emergence, Plant Height (cm), Number leaves, Number of branches, Days to 50% Flowering, total Pod Number and seed oil yield. From the trial conducted the following conclusions were drawn: although castor can tolerate moisture stress, it performs well with irrigation at 8 liters per week per plant. The appropriate rate of irrigation that gives a better growth and yield of Castor plant were determined to be 8 liters per every 4 days. No irrigation should be given during maturity stage because it delayed maturity and also influences new vegetative growth. Farmers can work with the recommended rate of 8 L/4 days for castor for optimum yield.

Keywords: castor, drip irrigation, water requirement, soil bulk density, oil extraction

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Introduction

Castor which is from the family (*Ricinus communis L.*) is an important plant that has gain popularity in the agricultural industry because of its immense value in agro industries. It is sued in pharmaceutical industries and for cosmetics (Weiss 2000).[1] The extent of cultivation is still low compared to the demand it represents only 0.15% of the crop oil processed in the world.[2] This is related to the unpopular nature of the plant which is connected to the fact that it is not an edible crop of arable crop particularly among peasant farmers in rural areas. Another contributing factor is the rigor involved in the processing of the product to end product like oil. The processing requires training and skills and technology involving the use of machines. The cost of all these is a bottle neck that has contributed to the unpopularity of the crop. However, the value, the significance of the crop to man cannot be overemphasized. Water and sufficient nutrient are key requirements for every plant to produce maximally. Irrigation is important to castor because it is a complicated plant that initiates racemes at different times depending on the environmental factors, this affect the seed formation, seed number and weight.[1–3] Though castor can produce in harsh weather condition and relatively depleted soil, it strive better when it has sufficient water and nutrient.[4–7,3] For instance, under an improved irrigation level, a seed yield of 3780 kg ha^{-1} was attained in India using the hybrid GCH-5.[8] The requirement of water for castor fluctuates from 466 mm to 1178 mm[9] subject to soil type and locality. This research tends to explore the efficacy of bat manure as an alternative to synthetic fertilizer on the development and yield of castor. It also investigates the effect of various irrigation rates on castor and to see the most appropriate rate.

Materials and method

Materials

The materials used in this study include: Sacks, plastic bottles, drippers, castor seeds, auger, meter rule, weighing balance, pan.

Study area

Figure 1 shows the location of the trial on an elevation of 88 meters above sea level with coordinates of 9°16’60” N and 5°3’0” E in DMS.

Figure 1 Map Niger with study Area of Mokwa.

Source: Philip 2011.

Climate and Agro - ecology

The study area is located in the southern Guinea Savanna of Nigeria. The yearly rainfall is between 1000 mm to 1,200 mm and takes between 150 to 210 days. The temperatures are between 40ºC around March and 23ºC January. The dry season starts in October and the wet season in April.

Methods

Mean daily evaporation

The mean evaporation was determined using the pan evaporation method[10] and equation 1 was adopted as:

ETo = K pan × E pan (1)

with:

ETo: reference crop evapotranspiration

K pan: pan coefficient

E pan: pan evaporation

Application rates

The drip application rate was determined using equation 2, Figure 2

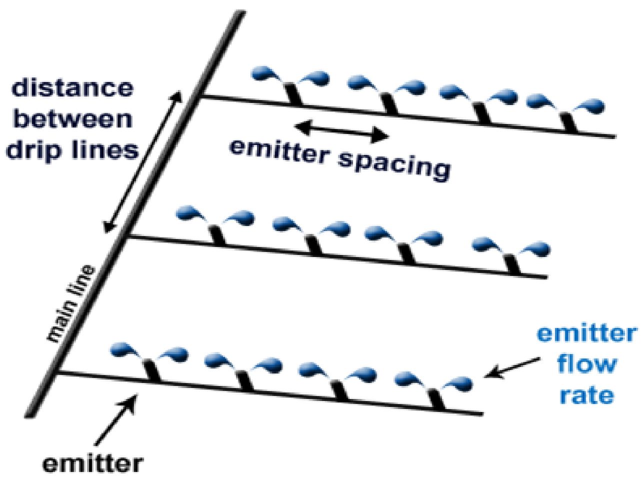

Figure 2 Schematic of Drip Irrigation System.[11]

$$\text{system application rate mm/hr}=\frac{(\text{maximum daily water requiremt mm/day})}{(\text{Hours required per day})} \quad (2)$$

Soil preparation

The soil was treated with bat manure which contain substantial amount of macro and micro elements (7.9 N, 2.4 P, 1.1 K, and 3.5 - 9% Ca, 1.5 - 8% Mg, 0.4 - 0.8 % Mn, 0.2- 0.5 % Cu, 0.5 - 1.3 % Fe, and 0.2 - 0.4 % Zn) as; 50 Kg bags were half filled with soil from the college orchard, each bag was mixed with about 2 Kg of bat manure. The soil was moistened for three days and allow for partial decomposition.

Soil chemical and physical analysis

samples were taken from each pot at depth of 0 - 20 cm using soil augers this is to evaluate basic soil characteristics before and after treatments. The particle size distribution was determined adopting the hydrometer method.[12] The bulk density of the soil was determined using intact core samplers to collect a known volume of soil (the volume of the core sampler) and by determining the weight of the soil after drying.[13,14] The bulk density was calculated as the oven dry mass of the soil divided by the core volume.

Bulk density (g/cm^3) = Dry soil weight (g) / Soil volume (cm^3). (3)

Soil nutrient analysis was done before treatments. Macronutrients: N, K, Ca, Mg, P, and S, and Micronutrients: Cl, Fe, B, Mn, Zn, Cu, Mo, and Ni using standard laboratory procedure.

Irrigation schedule

Irrigation was applied as below Table 1.

Table 1 Experimental Treatments

Treatment	Application rate	Quantity (Litres)
T1	Once a week	2
T2	Twice a week	4
T3	Thrice a week	6
T4	Four time a week	8
T5	Once a week	1

Pot layout and agronomic practices

The pots were laid in square form with a distance of 2 m apart. Twelve days after sowing, the rate of seedling emergence was taken as the ratio of the number of seedlings that emerged to the total number of seeds planted and multiplied by 100. The height of plants from two (2) randomly selected plants from each pot was measured using meter rule from the base of the plant to the growing tip at 2 WAS up to 12 WAS and at harvest. Number of leaves were counted at 2, 4, 6, 8 and 10 weeks after planting. Total number of branches of randomly selected plants in each treatment were counted. Leave area of randomly selected plants from each treatment were taken. The days to first flowering were determined as the number of days from sowing to the first day flowering is observed. Days to Fifty Percent Flowering This was determined as the number of days from sowing to the time when fifty percent of the plant flowers.

Total number of pods from randomly selected plants from each treatment were be taken. Shelling was done manually. All the shelled seed from randomly selected plants per pot were counted and weighed after harvest. The castor oil extraction procedure was done by Taking fresh seeds from the field which were shelled and cleaned. The seeds were roasted at 140 °C for at least 40 minutes, this is to remove the poisonous resins. The seeds were roasted until the seeds turn brown, they were then allowed to cool down and blended using a blender into a smooth paste. Small water was added and boil with continuous turn for about 40 minutes, after boiling, the liquid was poured into pan and some water was added to make it runny. The liquid was then boiled on medium heat and stirred intermittently for at least 40 minutes. The chaff was then strained out using a sieve or a strainer. The settled oil on top of water was scooped using spoon or allowed to freeze in a freezer to have two layers of oil and water, which was separated. The rest liquid was recycled for total oil extraction, i.e., boiled again until the water evaporated completely. Screen was used to remove the dirt. The extracted oil was measured using graduated container in mills.

Experimental design

A completely randomized design (CRD) was set up. The experiment was a potted with improvised drip irrigation system with five treatments replicated three times. The pots were spaced at 2m x 2m distance Figure 3.

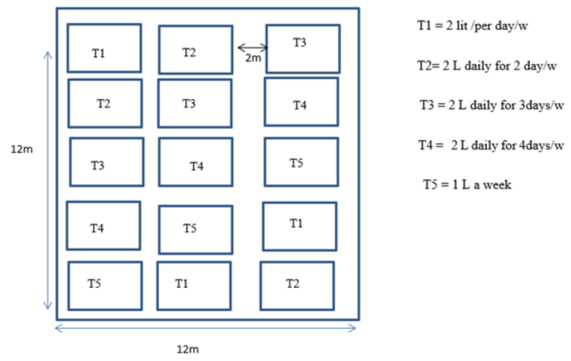

Figure 3 Experimental Layout.

Data analysis

The data collected were subjected to analysis of variance (ANOVA) using Minitab 17 and descriptive statistics (bar charts and line graphs) were used to do further analysis.

Result and discussion

Table 2 In modern agriculture, soil testing is the most important practise to manage fertiliser application and crop production. Without soil testing, it is very difficult to ensure the right application of fertilisers for the crop and get the optimum yield. Table 3.1 shows soil physical and chemical analysis of soil samples from the study area. It was done to ascertain the fertility of the soil before and after treatment. Which makes drip irrigation more suitable. It could be observed that the value of the elements increases as the concentration of the treatment increases. Only in few cases do we have variations from normal trend. From the table the physical soil analysis shows that the soil is sandy loam suitable for castor cultivation. This assertion was reported by Niconor[15] in his work Land Suitability for Castor Cultivation. This affected the water retention capacity of the soil and informed the use of drip irrigation in this research Table 3.

Table 2 Laboratory Analysis of the Soil Samples

TR	pH	Elec. cond	O.C	O.M	Aval	Total N	Exchangeable cations				E.A	CFC	Soil particle size			
SS		Ppm	g/kg	g/kg	P mg/ kg	g/kg	Na Cmol/ kg	K Cmol/ kg	Ca Cmol/ kg	Mg Cmol/ kg	Cmol/ kg	Cmol/ kg	SAND %	CLAY %	SILT %	Bulk Density (g/cm^3)
T1	5.84	8	15.36	26.48	26.12	0.37	4.23	0.37	0.16	0.16	0.63	5.99	92.08	6.16	1.76	1.73
T2	5.42	18	18.15	31.3	31.71	0.36	2.78	0.28	0.41	0.41	0.37	5.15	92.08	6.16	1.76	1.7
T3	5.78	6	18.95	32.67	38.98	0.84	2.75	0.28	1.88	1.88	0.45	7.24	92.08	6.16	1.76	1.68
T4	5.82	6	19.3	33.43	39.24	0.86	2.76	0.29	1.98	1.89	0.52	7.43	92.09	6.16	1.78	1.62
T5	4.48	6	12.33	19.43	14.13	0.21	2.43	0.12	0.21	0.02	0.3	3.23	90.64	7.15	2.21	1.75

Table 3 Physicochemical and Microbiological Characteristics of Bat Guano (n=5; mean ± SD; Range in Parentheses)

Characteristics	Faecal pellets
Fresh weight	2.9±0.4
(kg/m^2)*	(2.5-3.5)
Dry weight	2.5±0.4
(kg/m^2)*	(2-3)
pH	7.5±0.1
	(7.4-7.6)
Conductivity	2.8±0.4
(m mhos/cm)	(2.5-3.1)
Organic matter	79.3±5.3
(%)	(70.2-86)
Total carbon (%)	46±3.1
	(40.7-49.9)
Total nitrogen (%)	7.9±0.7
	(7.7-8.5)
C/N ratio	5.9±0.6
	(5-6.8)
Phosphate (%)	2.4±0.3
	(2-3)
Potassium (%)	1.14±0.1
	(1-1.2)
Calcium (%)	1.1±0.1
	(1-1.3)
Magnesium (%)	2.8±0.1
	(2.7-2.9)
Bacteria	0.43±0.3 × 10 7
(cfu/g dry wt)	(0.07-0.8)
Actinomycetes	1.78±0.5 × 10 3
(cfu/g dry wt)	(1.2-2.4)
Fungi	0.3±0.2 × 10 5
(cfu /g dry wt)	(0.1-0.7)

*Accumulation in three months' duration (source: Sridhar *et al.*, (2006)

Rate of evaporation as taken during the trials

Figure 4 shows the rate of evaporation during period of the trial of two months. The highest evaporation rates were in the month of January 13th and 17th and 1st of February during which temperature were high in dry season of peak periods within the months. The lowest evaporation recorded was 16th of February this could be as a result of changes in weather particularly as it relates to winter. The rate evaporation and transpiration determine the irrigation rates and the amount of water utilized by plant for metabolism.

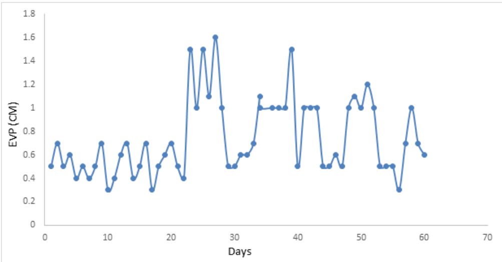

Figure 4 Daily Rate of Evaporation (20/12/22 – 17/2/23).

Seedling emergence

Emergence represents the point in time when a seedling is weaned from dependence upon nonrenewable seed reserves originally produced by its parent, and when photosynthetic autotrophism begins. Figure 5 depicts the castor seedling emergence as affected by the treatments applied (T1 = 2L once /w, T2= 2L daily for 2 day/w, T3 = 2L daily for 3days/w, T4 = 2L daily for 4 days/w, T5 = 1L once a week. T4 and T3 have the highest emergence followed by T1and T5. T2 has the lowest emergence of 6 seedlings out of ten planted. The sufficient moisture applied to the samples affected positively the seedling emergence with a minimum of 90 to 80% emergence. It also shows that the soil environment was also favorable for germination and emergence of the seedlings. Table 4 shows the ANOVA table for the seedling emergence. It shows that there is significant difference between T2 and T1, T3, T4 and T5 but there is no significant difference between T1 and T3, T4 and T5. T4 with 8 liters per week and T3 with 6 liters a week have the highest emergence of 90%. This could be related to the adequate moisture available to the seeds during germination.

Table 4 Seedling Emergence as Affected by the Treatments

Treatment	Seedling emergence
T1	8a
T2	6.3b
T3	9.3a
T4	9.3a
T5	8a

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$)

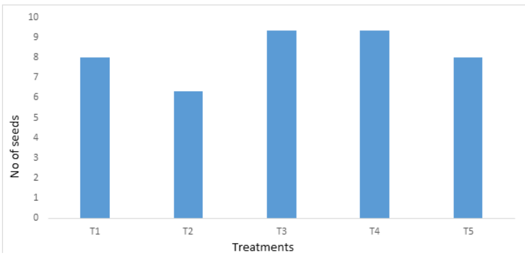

Figure 5 Seedling Emergence as Affected by the Treatments.

Plant height as affected by treatments within the trial period of twelve weeks

Plant height is a central part of plant ecological strategy. It is strongly correlated with life span, seed mass and time to maturity, and is a major determinant of a species' ability to compete for sunlight. Table 5 displays the plant height at two weeks as affected by rates of irrigation applied. It shows T4 with the highest length of 6cm followed by T3 and T4 with 4.7 cm and T1 with 4.3 cm and T5 with minimum irrigation application has 3.3cm. It shows that the rate of application as applied in the treatment contributed positively to the development of the plant. The table shows that at week two there is significant difference between T4 and T5 and other treatments. In week four there is significant difference between T4, T5 and other treatments. The trend is similar in the other weeks. It shows that T4 with the highest rate of application has the tallest plant (19 cm) after four weeks followed by T3 with 16 cm and then T2 with 11 cm and T1 with 10.3 cm. T5 was the shortest with 8.7 cm in height. At the sixth week, treatment four has the highest length of 29.3 cm followed by T2 with 20 cm, T3 with 18 cm and T1 with 15 cm. T5 with minimum application has the lowest height.

Table 5 Plant Height as affected by Treatments within the Trial Period of Twelve Weeks

TRT	2w	4w	6w	8w	10w	12w
T1	4.3a	10.3a	15a	21a	38.7a	57a
T2	4.7a	11a	20b	21.3a	39a	57.3a
T3	4.7a	16b	18.3c	22a	28.3b	41.3b
T4	6.3b	19c	29.3d	34.7b	40.7c	60c
T5	3.3c	8.7d	7.7e	17.7c	23.7d	31d

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$).

At twelve weeks, T4, has the height of 60 cm as compared to T2 with 57.3cm and T1 57.cm. T3 has 41.3 cm length. This could be attributed to other factors which hinders the growth despite the adequate water supply. T5 has the lowest height (31 cm) this could be as a result of insufficient water supply. This also shows that as the time progresses the rate of application of water affected the plant positively. As the rate increases the growth increases.

These results are similar to that of Femi and Ajani (2012) where they concluded in their experiment on pepper that yield quality parameters of pepper responded positively to varying irrigation water application. This is also in line with the earlier finding of Ngouajia *et al*., (2008) that irrigation treatments were capable of influencing pepper fruit number, yield, and fruit size.

Number of leaves at two weeks

Water is essential to plants as it help dissolve the mineral contained in the soil and help in uptake of food for plants. The adequate supply of water assists the plant to grow and have more leaves for photosynthesis. Table 6 shows the analysis of variance for the rates of irrigation applied to the castors as it relates to leave formation. At six weeks there is significant difference between T4 with maximum application, T5 with minimum and other treatments. At eight weeks there was significant difference between T3, T4, T5 and other treatments and also other weeks of ten and 12 have similar trend. It means that rate of application influences leave formation. This is similar to Danni et al.,[16] where they asserted that rates of irrigation influences leave formation. At week two and four the number of leaves formed are same for all the treatment. This could be because the plants are at their initial developmental stage. The number of leaves for all the treatments at weeks two and four are were 2 and 4 for the fourth week. At sixth week the number of leaves increased substantially from 4 to the highest T4 with 11 leaves followed by T1 with 7 leaves then T2 with 7 and T3 with 6 leaves. T5 has the lowest number of leaves. It shows that T4 with having maximum application of 8 liters for 4 days have more positive effect on number of leaves formed.

Days to first flowering

Days to flowering' (DF) refers to number of days from sowing to a stage when 50% of plants have begun to flower. Figure 6 and 4.4 shows the days to first flowering and days to 50% flowering T3 and T5 had earlier flowering of 24 and 26 days respectively. T1, T2, T4 had longer days to first flowering at 37, 36 and 26 days respectively. The earlier formation of flowers by T3 and T5 could be out of water stress which is common among plants when there is no sufficient nutrient and water they go into early maturity. This behavior is similar in the case of 50% flowering Figure 7, Table 7. Table 8 shows the analysis of variance of days to 50% flowering as affected by rate of drip irrigation. There was significant difference between T3 and T5 and other treatments. This was also shown in the bar charts.

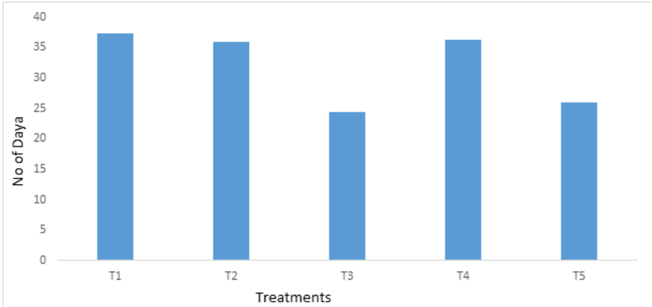

Figure 6 Days to First Flowering as Affected by Treatments.

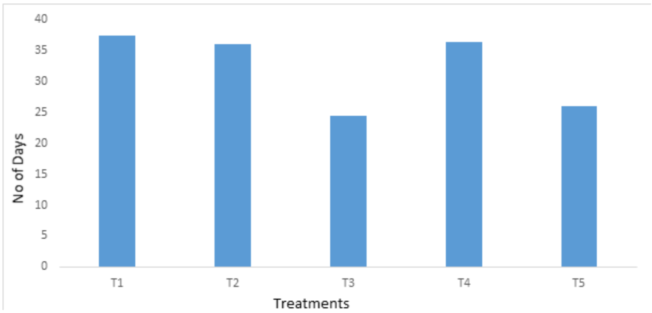

Figure 7 Days to 50% Flowering as Affected by Treatments.

Table 6 Number of Leaves as Affected by Treatments within the Trial Period of Twelve Weeks

TRT	2w	4w	6w	8w	10w	12w
T1	2a	4a	7.3a	15.3a	27.3a	29.3a
T2	2a	4a	6.7a	14.7a	26.7a	28.6a
T3	2a	4a	6a	12.7b	20.7b	22b
T4	2a	4a	11.3b	27.3c	38c	42c
T5	2a	4a	4c	9.3d	17.3d	18.7d

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$)

Table 7 Days to First Flowering (DTFF) as Affected by Treatments

TRT	DTFF
T1	37.3a
T2	36a
T3	24.3b
T4	36.3a
T5	26c

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$)

Table 8 Days to 50% Flowering (DTFF) as Affected by Treatments

TRT	Day to 50% Flowering
T1	37.3a
T2	36a
T3	24.3b
T4	36.3a
T5	26c

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$)

Number of branches at two weeks

Table 9 shows ANOVA for number of branches, it shows that at 6 weeks there is significant difference between T4, T5 and other treatments. But there is no significant difference between T2 and T3. At 8 weeks it shows that there is no significant difference between T1, T2, and T3 but there is significant difference between T4, T5 and other treatments. The trend is similar to week 10 and 12. The table shows number of braches formed within 6, 8, 10, and 12 weeks it shows that T4 with maximum application of 8liters per 4 days has the highest number of branches followed by T1 and T2 and T3 respectively. T5 has the lowest number of branches, this shows that adequate water supply enhances branches formation. This result is similar to that of Ramanjaneyulu[4] where they concluded that Early sowing of castor during post rainy season around 1st October and scheduling of irrigation at 50–75 mm CPE are recommended for realizing higher castor seed yield on alfisols.

Table 9 Number of Branches as Affected by Treatments Within the Trial Period

TRT	6w	8w	10w	12w
T1	2.3a	4a	7.3a	11.3a
T2	4.3b	5.7a	7.7a	11a
T3	3.7b	4.3a	6a	9b
T4	6.3c	8b	10b	16c
T5	0.7d	2c	4.3c	6.3d

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$)

Number of racemes per plant

The association or early planting of castor bean with irrigation practice can improve yield components such as the number of racemes per plant and capsules per racemes. Figure 8 and Table 10 shows the racemes formed as affected by the treatments and analysis of variance of the data obtained. T4 has the highest raceme followed by T3. T1 and T2 have 2 and 1 respectively. There was also significant difference between T5 and T4 and between other treatments. T5 has the lowest raceme formed.

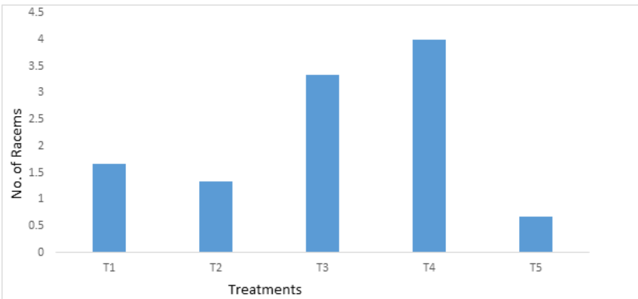

Figure 8 Number of Racemes per Plant as Affected by Treatments.

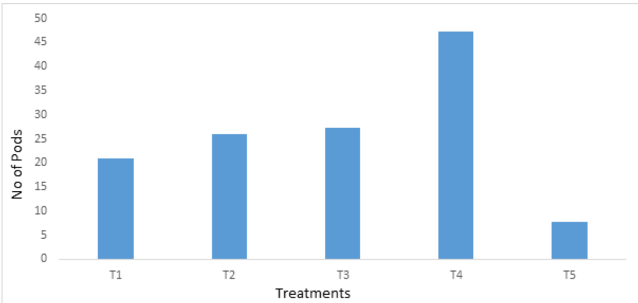

Figure 10 Number of Pods per Plant as Affected by Treatments.

Number of pods per plant

Fruits are ellipsoid to sub globose, usually three-lobed smooth or spiny capsule, 1.5–2.5 cm long, brown, dehiscing in three cocci each opening by a vulva and one-seeded. Figure 10, Table 11 shows the number of pods formed after 12 weeks with T4 with maximum irrigation having the highest number of pods of 47 followed by T3 with 27, T2 with 26 and T1 with 21. T5 5 with no application and the control has the lowest number of pods of 7. Table 4.8 shows the analysis of variance of the number of pods. All the treatments were significantly different from one another except T2 and T3 that were not significantly different from one another. It shows the rate of irrigation influences pod formation in castor.

Table 10 Number of Racemes per Plant Affected by Treatment

TRT	No of racemes
T1	1.7a
T2	1.3a
T3	3.3b
T4	4.0b
T5	0.7c

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$).

Table 11 Number of Pods per Plant as Affected by Treatment

TRT	Pods per plant
T1	21a
T2	26b
T3	27.3b
T4	47.3c
T5	7.7d

Means within the column followed by the same letter are not significantly different using fisher's least significant difference test ($p<0.05$)

Oil extraction

From Table 12 it shows that T4 has more oil, followed by T2 and then T3 and T1. T5 has the lowest. This is influence by the number of seed harvested as more seeds give more oil. The irrigation treatments influenced the seed yield and oil formation. This result is similar to that of Michalis et al.,[17] where they conducted and experiment on Irrigation of Castor Bean (*Ricinus communis L.*) and Sunflower (*Helianthus annus L.*) Plant Species with Municipal Wastewater Effluent: Impacts on Soil Properties and Seed Yield. They concluded that irrigation of castor influences oil formation in castor.[18–22]

Table 12 Extracted oil as Affected by Treatment

Treatment	Extracted oil (ml)
T1	6
T2	6.4
T3	6
T4	10.2
T5	2.1

Conclusion

From the trial conducted it was found that, although castor can tolerate moisture stress, it performs well to irrigation and that if castor is subjected to moisture stress during seedling to flowering stage, it shows poor performance. It was also found that the appropriate rate of irrigation that gives a better growth and yield of Castor Plant were determined to be 8 liters per every 4 days. The rate of irrigation of 4L/day yield more oil than other trial rates. It is recommended that no irrigation should be given during maturity stage because it delayed maturity and also influences new vegetative growth and that that farmers can work with the recommended rate of 4L/4day for castor for better yield.

Acknowledgments

None.

Conflicts of interest

The author declares there is no conflict of interest.

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