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Effect of sowing windows and irrigation schedules on yield and economics of castor (*Ricinus communis* L.)

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Abstract
A field experiment on "Influence of sowing windows and irrigation schedules on growth, yield and quality of castor (*Ricinus communis* L.)" was carried out during the years 2015-16 and 2016-17 at Instructional Farm, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) India. The experiment was laid in split plot design with three replications. The experiment consists of twelve treatment combinations with three main plot treatment (sowing windows) *i.e.* S_1: Second fortnight of June, S_2: Second fortnight of July, S_3: Second fortnight of August and four sub-plot treatments (irrigation levels) *i.e.* I_1: Rainfed (No irrigation), I_2: Irrigation at 50 mm CPE, I_3: Irrigation at 75 mm CPE and I_4: Irrigation at 100 mm CPE. Sowing of castor at second fortnight of June recorded maximum yield attributes *viz.* number of total raceme plant^{-1} (9.92), length of main stem (50.33 cm) and side branch raceme (35.03 cm), number of capsules raceme^{-1} (37.40), weight of dry capsule (306.88 g plant^{-1}), 100 seed weight (26.11 g) and maximum seed (3222.53 kg ha^{-1}) and stalk yield (7407.41 kg ha^{-1}) of castor, on pooled mean basis. Similarly, irrigation at 75 mm CPE recorded yield attributes *viz.*, number of total raceme plant^{-1} (9.79), length of main stem (52.33 cm), side branch raceme (38.04 cm), number of capsules raceme^{-1} (49.07), weight of dry capsule (298 g plant^{-1}), 100 seed weight (26.21 g) and maximum seed (3105.97 kg ha^{-1}) and stalk (7386.83 kg ha^{-1}) yield of castor on pooled mean basis. Sowing of castor at second fortnight of June recorded maximum gross monetary returns (169 x 10^3 ₹ ha^{-1}), net monetary returns (94 x 10^3 ₹ ha^{-1}) and B: C ratio (2.24) on pooled mean basis. However, treatment irrigation at 75 mm CPE recorded maximum gross monetary returns (163 x 10^3 ₹ ha^{-1}), net monetary returns (88 x 10^3 ₹ ha^{-1}) and B: C ratio (2.17) on pooled mean basis.

Keywords: sowing date, irrigation, yield attributes, yield, economics and castor

Introduction
Castor (*Ricinus communis* L.) is an important commercially grown non-edible oilseed crop of arid and semi-arid regions of the world having wide range of industrial uses. Castor has diversified uses of its products ranging from farm yard manure (5.3-6.0% N) and fuel to its multiple uses like leaves for feeding silkworms, oil traditionally used as purgative and in the preparation of various cosmetic products, plastic industry, lubricants and manufacturing of bio fuel. Presently, India is producing value added products like hydrogenated castor oil, dehydrated castor oil, hydro xystearic acid and lubricants of jet engines etc. Castor is one of the most poisonous plants in the world due to ricin contained in the bean, stem and leaves. Ricin is not found in the expressed oil but remains in the press cake. Its cake is used as manure and plant stalks as fuel or hatching material and for preparing paper pulp.

Cultivation of castor as an irrigated crop during kharif season is a new dimension. This experiment was conducted to find out an optimum date of sowing and irrigation level required for higher yield of castor during kharif season. Sowing of crop at optimum time along with other agronomic factors is the key to maximize productivity of any crop. Oil yield per unit area is the ultimate target in growing oilseed plants and sowing date is one of the important factors which have a clear role on production of active substances particularly in oilseeds. Therefore, this study was aimed to integrate time of sowing and different levels of irrigation for maximizing the castor yield.

Materials and Methods
The present experiment entitled "Influence of sowing windows and irrigation schedules on growth and yield of castor" was carried out at Post Graduate Institute, Research Farm,

Mahatma Phule Krishi Vidyapeeth, Rahuri during 2015-2016 and 2016-2017. The soil of the experimental plot was sandy clay loam in texture. The soil physical properties *viz.*, field capacity, permanent wilting point and bulk density were 30.21 per cent, 15.06 per cent and 1.28 g cm^{-3}, respectively. The soil chemical properties *viz.*, pH, EC and organic carbon content were 8.02, 0.47 dSm^{-1} and 0.48 per cent, respectively with low in available nitrogen (171.25 kg ha^{-1}), moderate in available phosphorous (21.24 kg ha^{-1}) and high in available potassium (352.67 kg ha^{-1}), respectively. The experiment was laid out in split plot design with twelve treatment combinations having three main plot treatment (sowing windows) *i.e.* S_1: Second fortnight of June, S_2: Second fortnight of July, S_3: Second fortnight of August and four sub-plot treatments (irrigation levels) *i.e.* I_1: Rainfed (No irrigation), I_2: Irrigation at 50 mm CPE, I_3: Irrigation at 75 mm CPE and I_4: Irrigation at 100 mm CPE.

The gross plot size was 6.0 m X 5.4 m. The seed of castor variety DCH 519 having good germination were selected and used for sowing. Seeds were treated with Dithane M 45 @ 3 g kg^{-1} as a prophylactic measures against seed borne diseases. The seeds were dibbled at the depth of 5-6 cm maintaining an intra row spacing of 60 cm and inter row spacing of 90 cm. The sowing was done at three different sowing dates as per the treatment schedules *i.e.* 22nd June, July 22nd and 22nd August, respectively in both the years of experiment. Farmyard manure was applied @ 1.5 t ha^{-1} at the time of land preparation. Fertilizers were applied @ 80: 40: 40 N, P_2O_5, K_2O kg ha^{-1} to the plot in rows. Full dose of NPK was given to rainfed treatment at the time of sowing. For irrigation treatments half dose of N and full dose of P and K was applied at the time of sowing as basal dose. Remaining half dose of N was applied one month after sowing as top dressing. Among the irrigation regimes no irrigation was given to rainfed treatment. Irrigation was applied at 50, 75 and 100 mm CPE with 5 cm depth at each irrigation turn of three treatments, respectively. The USWB class a pan evaporimeter was used for measurement of daily pan evaporation. The various biometric observations were recorded on five randomly selected plants from each net plot. The selected plants were tied with tags for their easy identification during both years by using standard methods. The crop was harvested in three picking based on physiological maturity of the main spikes and the spikes that are formed on secondaries and tertiaries. The harvested spikes were heaped, sun dried and threshed manually by beating with stick. The threshed produce was winnowed and seeds were cleaned. The crop was harvested by cutting the base of plant. The plants from each plots were sundried thoroughly and weighed to get stalk yield. The total cost of cultivation of castor was estimated by considering the various inputs, cost of irrigation system and interest on working capital. Similarly, the field operation charges such as wages, irrigation, inputs, plant protection measures etc. The gross monetary returns were obtained by multiplying prevailing market price of castor seeds with yield of castor seeds, while, net monetary returns were worked out by subtracting cost of cultivation from the gross monetary returns. The B: C ratio was worked out by dividing the gross monetary returns with cost of cultivation of respective treatment.

Result and discussion

1. Effect on yield and yield attributes

a) Sowing windows

The number of total raceme $plant^{-1}$, length of main stem and side branch raceme, number of capsules $raceme^{-1}$ and weight of dry capsule was influenced significantly due to the different sowing windows. Treatment second fortnight of June recorded significantly maximum number of total raceme $plant^{-1}$, length of main stem and side branch raceme, number of capsules $raceme^{-1}$ and weight of dry capsule than second fortnight of August, but it was at par with treatment second fortnight of July. Similar trend was found in respect of seed and straw yield of castor on pooled mean basis. Significantly minimum number of total raceme $plant^{-1}$, length of main stem and side branch raceme, number of capsules $raceme^{-1}$ and weight of dry capsule was found in treatment second fortnight of August. The 100 seed weight was found non-significant.

The total number of raceme $plant^{-1}$ was more at second fortnight of June might be because favorable temperature condition during the crop growth period and higher solar use efficiency. Higher number of racemes at every picking in crop sown at second fortnight of June might have also resulted in higher total number of raceme $plant^{-1}$. The highest length of main stem and side branch raceme was might be because favorable temperature condition during the crop growth period and higher solar use efficiency which led to more nutrient uptake by the crop. Nitrogen being an essential constituent of plant tissue is involved in cell division and cell elongation. Higher number of capsules per raceme and maximum transfer of assimilate from source to sink in the plants sown during second fortnight of June caused bold capsules which resulted in higher weight of dry capsule $plant^{-1}$. These results are similar to those qouted by Govindan *et al.*, (2002) [1] and Samant (2015) [6].

b. Irrigation levels

The number of total raceme $plant^{-1}$, length of main stem and side branch raceme, number of capsules $raceme^{-1}$ and weight of dry capsule was influenced significantly due to the different irrigation levels. Irrigation at 75 mm CPE recorded significantly higher number of total raceme $plant^{-1}$, length of main stem and side branch raceme, number of capsules $raceme^{-1}$ and weight of dry capsule than any other treatments, but it was at par with treatment irrigation at 50 mm CPE. Similar trend was found in respect of seed and straw yield of castor on pooled mean basis. Significantly minimum number of total raceme $plant^{-1}$, length of main stem and side branch raceme, number of capsules $raceme^{-1}$ and weight of dry capsule was found in treatment rainfed (No irrigation). The 100 seed weight was found non-significant.

Optimum irrigation water resulted in vigorous growth of crop during its vegetative and reproductive phase and resulted in higher production of racemes $plant^{-1}$ at every picking might have also resulted in higher total number of raceme $plant^{-1}$. Minimum length of main stem and side branch raceme was found in treatment rainfed might be because of moisture stress during crop growth period resulted in shrinking of growth of crop and shorter length of main stem and side branches. The number of capsules $raceme^{-1}$ of castor was maximum with irrigation at 75 mm CPE. This might be because optimum irrigation led to more uptake of nutrients through water and resulted in higher vegetative and reproductive phase and reflected as higher number of capsules $raceme^{-1}$. This might be because higher uptake of nutrients through 75 mm CPE irrigation and resulted in higher number of capsules per raceme and maximum transfer of assimilate from source to sink in the plants. These increased the size of capsule and resulted as maximum weight of dry capsule $plant^{-1}$.These results are in conformity to the results reported by

Nagabhushan and Raghavaih (2005) [2], Pratap Kumar Reddy *et al*. (2006) [5] Neto *et al*. (2010) [3] and Severino *et al*. (2013) [8].

c. Interaction

The interaction effect of sowing windows and irrigation levels on number of total raceme plant^{-1}, length of main stem and side branch raceme, number of capsules raceme^{-1}, weight of dry capsule and 100 seed weight was found non-significant on pooled mean basis.

2. Effect on economics of castor

a) Sowing windows

The gross monetary returns (10^3 ₹ ha^{-1}), net monetary returns (‘10^3 ₹ ha^{-1}) and B: C ratio of castor crop as influenced by different sowing windows. Treatment second fortnight of June recorded significantly maximum gross monetary returns (169 x 10^3 ₹ ha^{-1}) and net monetary returns for castor crop (94 x 10^3 ₹ ha^{-1}) as compared to second fortnight of August and was at par with second fortnight of July on pooled mean basis. Treatment second fortnight of June recorded numerically maximum B: C ratio of castor crop (2.24) as compared to second fortnight of July (1.66) followed by second fortnight of August (1.42) on pooled mean basis.

Higher yield through sowing of castor at second fortnight of June might have resulted in maximum gross monetary returns. Higher gross monetary returns might have resulted in maximum net monetary returns for castor crop for second fortnight of June sown castor. Higher gross monetary returns and net monetary returns for castor crop might have resulted in maximum B: C ratio of castor crop. These results are in conformity with finding of Sukhadia and Dhoble (1990) [10].

Irrigation levels

The gross monetary returns (10^3 ₹ ha^{-1}), net monetary returns (‘10^3 ₹ ha^{-1}) and B: C ratio of castor crop as influenced by different irrigation levels. Irrigation at 75 mm CPE recorded significantly maximum gross monetary returns (163 x 10^3 ₹ ha^{-1}) and net monetary returns (88 x 10^3 ₹ ha^{-1}) for castor crop than irrigation at 100 mm CPE and treatment rainfed (No irrigation). However, it was at par with irrigation at 50 mm CPE on pooled mean basis. Irrigation at 75 mm CPE recorded numerically maximum B: C ratio for castor crop (2.17) than irrigation at 50 mm CPE (1.84) and irrigation at 100 mm CPE (1.60) followed by treatment rainfed (No irrigation) (1.49) on pooled mean basis. Higher castor yield at 75 mm CPE might have resulted in maximum gross monetary returns. Higher gross monetary returns through irrigation at 75 mm CPE might have resulted in maximum net monetary returns for castor crop. Higher gross monetary returns and net monetary returns for castor crop might have resulted in maximum B: C ratio of castor crop. These results are in conformity with finding of Patel *et al.* (2004) [9], Sesha Saila Sree and Bhaskar Reddy (2005) [7] and Ramanjaneyulu *et al*. (2013) [5].

Table 1: Effect of sowing windows and irrigation schedules on yield attributes and yield of castor (pooled mean)

Treatment	No. of total raceme plant^{-1}	Raceme length plant^{-1} (cm)		Number of capsules raceme^{-1}	Weight of dry capsules (g plant^{-1})	100 Seed weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
		Main stem	Side branch					
A. Sowing windows (S)								
S_1: Second fortnight of June	9.92	50.33	35.03	37.40	306.88	26.11	3222.53	7407.41
S_2: Second fortnight of July	9.23	48.42	32.48	34.77	258.54	26.00	2342.59	6352.62
S_3: Second fortnight of August	6.01	44.33	29.88	32.05	187.58	25.96	1922.07	5103.40
S Em (±)	0.45	0.47	0.66	0.66	12.90	0.31	169.14	246.91
CD at 5%	1.46	1.55	2.15	2.15	42.06	NS	551.58	805.23
B. Irrigation levels (I)								
I_1 : Rainfed (No irrigation)	6.89	44.61	27.98	30.41	210.56	25.63	1952.67	5473.25
I_2 : Irrigation at 50 mm CPE	9.09	48.50	34.15	35.52	250.83	26.14	2700.62	6568.93
I_3 : Irrigation at 75 mm CPE	9.79	52.33	38.04	39.07	298.00	26.21	3105.97	7386.83
I_4 : Irrigation at 100 mm CPE	7.78	45.33	29.68	33.97	244.61	26.11	2223.66	5722.22
S Em (±)	0.41	1.02	0.92	0.89	11.98	0.23	107.56	202.14
CD at 5%	1.18	2.92	2.62	2.55	34.30	NS	307.94	578.70
C. Interaction effect								
S x I	NS	NS	NS	NS	NS	NS	Sig.	Sig.
General mean	8.39	47.69	32.46	34.74	251.00	26.02	2495.73	6287.81

Table 2: Effect of sowing windows and irrigation schedules on economics of castor (pooled mean)

Treatment	Gross monetary returns (10^3 ₹ ha^{-1})	Net monetary returns (10^3 ₹ ha^{-1})	B: C ratio
A. Sowing windows (S)			
S_1: Second fortnight of June	169	94	2.24
S_2: Second fortnight of July	123	49	1.66
S_3: Second fortnight of August	101	30	1.42
S Em (±)	09	09	--
CD at 5%	29	29	--
B. Irrigation levels (I)			
I_1 : Rainfed (No irrigation)	102	34	1.49
I_2 : Irrigation at 50 mm CPE	141	65	1.84
I_3 : Irrigation at 75 mm CPE	163	88	2.17
I_4 : Irrigation at 100 mm CPE	116	43	1.60
S Em (±)	06	06	--
CD at 5%	16	16	--
C. Interaction effect			
S x I	NS	NS	--
General mean	131	57	1.77

Conclusion

Based on two years of experimentation, it could be concluded that sowing of castor at second fortnight of June with irrigation schedule at 75 mm CPE registered maximum Yield attributes, yield net monetary returns and B:C ratio of castor.

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