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Influence of sowing windows and irrigation schedules on growth and yield 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 growth attributes *viz.*, plant height (249.53 cm), number of branches plant^{-1} (6.39), number of functional leaves plant^{-1} (29.02), number of nodes to main stem (19.14), number of raceme plant^{-1} (5.88), days to 50 per cent maturity (109.33) and dry matter (165.15 g plant^{-1}) of castor crop, While irrigation at 75 mm CPE recorded maximum growth attributes *viz.*, plant height (247.12 cm), number of branches plant^{-1} (6.14), number of functional leaves plant^{-1} (39.16), number of node to main stem (19.28) number of raceme plant^{-1} (5.73), days to 50 per cent maturity (110.89) and dry matter (173.31 g plant^{-1}) on pooled mean basis. 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.

Keywords: sowing date, irrigation, growth characters, yield attributes, yield, castor

Introduction
Among nine cultivated oilseed crops, castor (*Ricinus communis* L.) is the most important non-edible industrial oilseed crop and is grown across the world in tropical, sub-tropical and warm temperate regions. Its seed oil has multifarious applications in production of wide industrial products ranging from medicines to lower molecular weight aviation fuels, fuel additives, biopolymers and biodiesel. 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 yield of castor.

Materials and Methods
The present experiment entitled "Influence of sowing windows and irrigation schedules on

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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, Instructional 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 field was divided into 36 plots with gross plot size of 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 and then covered with soil, 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. 22^{nd} June, July 22^{nd} and 22^{nd} 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. 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.

Result and Discussion

1. Effect on growth parameters

a. Sowing windows

The plant height, number of branches $plant^{-1}$, number of functional leaves $plant^{-1}$, number of nodes to main stem, number of raceme $plant^{-1}$, days to 50 per cent maturity of primary raceme and dry matter $plant^{-1}$ of castor was influenced significantly due to the different sowing windows (Table 1). Significantly more plant height, number of branches $plant^{-1}$, number of functional leaves $plant^{-1}$, number of nodes to main stem, number of raceme $plant^{-1}$, days to 50 per cent maturity of primary raceme and dry matter $plant^{-1}$ was recorded when crop was sown at second fortnight of June. However, it was at par with sowing at second fortnight of July. Significantly minimum plant height, number of branches $plant^{-1}$, number of functional leaves $plant^{-1}$, number of nodes to main stem, number of raceme $plant^{-1}$, days to 50 per cent maturity of primary raceme and dry matter $plant^{-1}$ was registered in second fortnight of August on pooled mean basis.

Highest plant height of castor at second fortnight of June might be due to the enhanced vegetative development of crop due to the favourable weather condition that facilitated better shoot growth, higher uptake of nutrients as it has capacity of more vigorous growth and branching, more number of functional leaves due to more number of branches and higher uptake of nutrients due to favourable weather condition, higher number of nodes up to primary raceme of castor might be due to higher plant height and higher uptake of nutrients by the plant under favourable weather condition. The higher uptake of nutrients in plant triggers the activation of enzymes, cell elongation and many biochemical process which leads to increase the number of nodes per plant. The maximum dry matter $plant^{-1}$ of castor was might be due to more favourable condition provided to crop during sowing which helps in proper growth and development of crop. Also higher uptake of nutrients lead to higher growth parameters and ultimately reflected as maximum dry matter of plant. These results are accordance with those of Govindan *et al.* (2002) [2], Chouhan and Yakadri (2004) [1], Patel *et al.* (2005) [6] and Ramanjaneyulu *et al.* (2013) [8].

b. Irrigation levels

The plant height, number of branches $plant^{-1}$, number of functional leaves $plant^{-1}$, number of nodes to main stem, number of raceme $plant^{-1}$, days to 50 % maturity of primary raceme and dry matter $plant^{-1}$ of castor was influenced significantly due to the different Irrigation levels. Irrigation at 75 mm CPE registered significantly higher plant height, number of branches $plant^{-1}$, number of functional leaves plant-

^{1}, number of nodes to main stem, number of raceme plant^{-1}, days to 50 per cent maturity of primary raceme and dry matter plant^{-1} of castor. It was at par with 50 mm CPE at all the stages of crop growth on pooled mean basis. Significantly minimum plant height was recorded under treatment rainfed (No irrigation) at all the crop growth stages.

Irrigation at 75 mm CPE registered higher periodical plant height might have increased availability of nutrients along with optimum irrigation up to grand growth phase of crop which increases the cell elongation and faster multiplication of meristematic region resulted in increasing plant height. Highest number of branches plant^{-1} of castor at irrigation at 75 mm CPE might be recorded due to higher plant height and vigour growth of crop due to optimum application of water. Higher periodical number of functional leaves plant^{-1} was might be because of more number of branches and more plant height of crop at irrigation of 75 mm CPE. Higher uptake of nutrients by the plant under favourable weather condition along with the irrigation water led to luxurious vegetative growth of plants. These resulted in maximum number of nodes to main stem of castor. Higher irrigation water resulted in vigorous growth of crop during its vegetative and reproductive phase and resulted in higher production of racemes plant^{-1}. Optimum amount of irrigation to crop lead to vigorous growth which resulted in higher uptake of nutrients and growth parameters and reflected as maximum dry matter of plant. These results are similar to those reported Kiran (2003) [3], Nagabhushan and Raghavaih (2005), Pratap Kumar Reddy *et al*. (2006) [7] and Ramanjaneyulu *et al*. (2013) [8].

c. Interaction

The interaction effect between sowing windows and irrigation levels were found non-significant in respect of plant height, number of branches plant^{-1}, number of functional leaves plant^{-1}, number of nodes to main stem, number of raceme plant^{-1}, days to 50 per cent maturity of primary raceme and dry matter plant^{-1} of castor on pooled mean basis.

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

Treatment	Plant Height (cm)	No. of branches Plant^{-1}	No. of functional leaves plant^{-1}	No. of nodes to main stem	No. of raceme plant^{-1}	Days to 50% maturity of primary raceme	Dry matter (g Plant^{-1})
A. Sowing windows (S)							
S_1: Second fortnight of June	249.53	6.39	37.24	19.14	5.88	109.33	165.15
S_2: Second fortnight of July	240.15	5.61	35.38	18.49	5.31	107.42	158.32
S_3: Second fortnight of August	196.98	4.39	32.30	17.29	3.76	104.58	144.10
S Em (±)	4.89	0.24	0.62	0.23	0.20	0.60	2.10
CD at 5%	15.96	0.78	2.03	0.75	0.65	1.97	6.85
B. Irrigation levels (I)							
I_1 : Rainfed (No irrigation)	211.50	4.61	29.99	17.41	4.13	102.50	128.73
I_2 : Irrigation at 50 mm CPE	236.73	5.82	36.76	18.77	5.34	109.28	167.18
I_3 : Irrigation at 75 mm CPE	247.12	6.14	39.16	19.28	5.73	110.89	173.31
I_4 : Irrigation at 100 mm CPE	220.18	5.29	33.99	17.78	4.74	105.78	154.20
S Em (±)	3.76	0.26	0.87	0.28	0.18	0.59	3.33
CD at 5%	10.76	0.74	2.48	0.80	0.53	1.69	9.53
C. Interaction effect							
S x I	NS	NS	NS	NS	NS	NS	NS
General mean	228.88	5.46	34.98	18.31	4.98	107.11	155.86

Table 2: 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

2. 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 on pooled mean basis. Similar trend was found in respect of seed and straw yield of castor.

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 favourable 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 favourable 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 Samant (2015) [9] and Terefe *et al.* (2015) [11].

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 in pooled mean. Similar trend was found in respect of seed and straw yield of castor. 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 same as reported by Nagabhushan and Raghavaih (2005), Pratap Kumar Reddy *et al*. (2006) [7], Neto *et al*. (2010) and Severino *et al.* (2013).

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.

Conclusion

On the basis of two years of experimentation, it could be concluded that, growth, yield attributes and yield of castor can be increased by sowing of castor at second fortnight of June along with irrigation at 75 mm CPE in Maharashtra.

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