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Effect of Plant and Row Spacing on the Yield and Oil Contents of Castor (*Ricinus communis* L.) in the Central Rift Valley, Ethiopia

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Abstract

*Castor (***Ricinus communis L***.) is an industrial non edible oilseed adapted to drier areas. An experiment was conducted in the Central Rift Valley of Ethiopia to determine optimum plant population of castor variety Hiruy. Four plant (50, 60, 70 and 80 cm) and four row spacing (60,80,100 and 120 cm) were arranged in factorial combination and RCBD design in three replications. The experiment was carried out for two years at Melkassa and Arsi Negelle in the Central Rift Valley of Ethiopia. The result showed that plant population has no effect on the oil content of Castor. Plant spacing of 60 cm and row spacing of 80 cm resulted in longer main raceme, heavier seed weight and higher seed yield. Therefore, a plant population of about 20 833 plants per hectare or plant and row spacing of 60 x 80 cm can be used for castor production in the Central Rift Valley of Ethiopia for an upper branching variety such as Hiruy. Length of main raceme, capsules per plant and seed weight are the main yield components in castor.*

Key words: Castor, Plant spacing, row spacing, seed yield

Introduction

Castor (*Ricinus communis* L.) is a member of the Euphorbiaceae family that is found throughtout the tropics and sub tropics (Weiss 2000). Castor originated in East Africa probably Ethiopia where it shows tremendous genetic variability. In Ethiopia, the size of castor plant varies from small tree perennials mostly in the highlands to small annuals. Castor shows different growth and branching habits such as erect and top branching as well as bushy and lower branching types. Mostly erect and top branching types with large raceme are preferred for cultivation due to their ease in field management.

Castor bears oil in its seed that is entirely used for industrial purposes such as in pharmaceutical, paint, ink, cosmetics, polymer etc industries (Severino et al.2012). Castor oil is unique among vegetable oils due to its high content of hydroxylated ricinoleic acid. Unlike other plant oils castor oil contains about 90% ricinoleic acid. There is little variation in the ricinoleic acid of castor genotypes grown in different environments. Castor oil is one of the renewable raw materials in the chemical and polymer industries due to its several applications. The meal remaining after the oil extraction is used neither for food or feed due to its high content of noxious compounds.

Seed yield of castor can be maximized by using appropriate variety combined with optimum plant population, fertilizer, quality seed, weeding practices, optimum plant population and sowing date. Optimum plant population can significantly increase seed yield however it can be affected by the growth habit of the variety to be planted. In India, plant populations from 10,000 to 22,000 plants per hectare for the tall variety Gurani (Bizinoto et al. 2010) did not affect seed yield. The effect of plant population on the yield and yield components of castor in irrigated and non irrigated castor was studied for three years in Texas (Kittock and Williams 1970). The optimum plant population of dwarf irrigated castor was 55, 000 plants/ha. Row spacing from 0.5 to 1.0 m did not affect seed yield if plant population was held constant or narrow intra row spacing (Kittock and Williams 1970). Low plant populations in non irrigated castor decreased plant height, length of primary raceme, number of raceme per sequential set and yield of all sets of racemes. Plant population had no effect on oil content. The Effect of five inter and intra row spacing (0.90 x 0.44, 0.90 x 0.20, 0.75 x 0.24, 0.60 x 0.30, and 0.45 x 0.40) on the yield and oil contents of two varieties of caster were evaluated in Sao Paulo Brazil (Peres 2011). The higher plant population (55,000 plants /ha) by the narrower plant spacing (0.45 x 0.60) combination produced a higher seed yield. Weiss (1980) suggested that if there are no local recommendations, intra row spacing of 25-30 cm for dwarf and 30-40 cm for taller hybrids or about 25 000 to 30 000 plants/ha for crops grown in the 750 to 900 mm rain fall is optimum. He further recommended that for every 120 mm decrease in rainfall the intra row spacing should be increased by 30 cm. Therefore, plant population varies according to the plant growth habit as well as rainfall of the area. For irrigated castor production the row width can be determined by the system of watering and when water is not limiting a plant population of 30 000 to 40 000 plants/ha is recommended. Again this is subject to the particular variety with specific growth habit.

The effect of five plant populations on three open pollinated and one hybrid safflower was studied for two years at three locations in North Dakota, USA (Gonzalez et al. 1994). The result showed that plant populations did not affect seed yield in all four varieties. As plant population increased acheme yield per plant decreased and maximum acheme yield per plant was achieved at the lowest plant population. The primary yield components in safflower were no of captula/plant, number of achemes per plant and acheme weight. Oil content was not affected b y plant populations.

The Ethiopian castor breeding program is designed to develop varieties having short internode, large primary raceme, high seed yield and oil content with resistance to wilt. The most resent variety Hiruy is a tall top branching with single large primary raceme. However the optimum plant population and its effect on the seed yield and oil content was not studied. Therefore this experiment was designed to develop optimum row and plant spacing for the castor variety Hiruy.

Materials and Methods

The experiment was conducted at Melkassa and Arsi Negelle in the Rift Valley of Ethiopia for two years during 2011 and 2012 main season. Melkassa is geographically located at 8°24' N latitude, 39°21' E longitude, and at altitude of 1,550 meters. The majority of the soil of the center has relatively high pH, which ranges from 7 to 8.2. Since the center is located in semi-arid region where weathering is at low rate, most of the soil has high CEC values. In general, the rating showed that the CEC of the soils range from medium to high (20-37.8 meq/100). The values of organic carbon (OC) was 0.778-1.496% and total nitrogen (TN) 0.067-0.154%. The total rain fall for Melkassa for the last 20 years vary from less than 500 mm to over a 1000 with poor distribution (Table 1). The rain comes largely in July and August and the length of growing period is less than 95 days indicating that field crops should be supplemented with irrigation for adequate seed yield. The relative humidity is quite low with high mean maximum and mean minimum temperature. Climate and soils data for Arsi negelle was not available.

The variety Hiruy was used as a testing genotype. Four row spacing (60, 80,100 and 120 cm) and four intra row spacing (50, 60, 70, and 80 cm) were arranged in factorial combinations making 16 treatments. The test was designed in Randomized Complete Block Design with three replications. The test was planted at the second week of June in 2010 and 2011 season and harvested in December. During planting, two seeds per hill were planted and reduced to one plant after three leaf stage. The test was cultivated once and weeded twice every year. Days to first and second flowering was counted as the number of days from planting to flowering of the main and secondary raceme. Days to first and second maturity was counted as the number of days from planting to maturity of the main and secondary raceme. Plant height in cm was measured from the ground to the tip of the main raceme. Length of the main raceme in cm was measured as the length of the main raceme carrying capsules. Harvesting was done when the capsules turned brown and in two cycles first the main raceme followed by the secondary raceme. Hulling was done manually by forcing the seed out using nails. Seed weight per plot was recorded as the weight of the seed per plot. Seed weight was recorded as the weight of 100 seeds in gram. Oil content was recorded as NMR reading of the moisture free seed (Madsen 1976).

Both vegetative and yield data over years and locations were subjected to Analysis of Variance (ANOVA) using GLM procedure in SAS statistical software (SAS 2002). Square root transformation ($(x+0.5)^{1/2}$, where x is number of first branch) was made to fulfill the assumption of analysis of variance. However, the untransformed values were used for simplicity in the result section adopting the results from the statistical analysis. The treatment means that were significant at 0.05 probability level were separated using Least significant differences (LSD) test (Gomez and Gomez1984).

Table 1. Total rainfall, mean minimum and maximum temperatures in ºC and relative humidity at Melkassa during 1992 to 2011.

	Years (1992-2011)																			
Climate factors	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11
Total rainfall in mm	780.7	873.7	737.5	733.4	836.9	804	1046.9	793.1	853.5	820.6	548.7	899	822.5	882.4	928.6	1064.7	1052.7	679.4	1093.1	810.1
Mean Minimum temperature ºC	14.34	13.95	13.7	14.0	13.9	13.8	12.5	9.4	12.5	13.7	14.8	14.1	14.3	13.9	14.6	14.0	13.64	14.1	14.6	9.1
Mean Maximum temperature ºC	29.6	28.1	28.5	29.0	27.5	28.8	28.9	28.7	28.6	28.5	29.5	28.6	28.6	29.3	29.2	28.7	28.7	29.7	28.5	29.0
Relative Humidity %	56	56	54	53	49	51	55	57	55	52	53	53	49	52	51	52	55	54	49	48

Results and Discussion

Length of the Main Raceme

The mean length of the main raceme from two locations and two years was 36.cm (Table 2). The length of the main raceme constitutes over 75% of the seed born on the plant (Kittock and Williams 1970). The main raceme is also affected by the number of female flowers born on the main raceme which is also affected by the environment (Severino et al. 2012). In the present study, the length of the main raceme was highest at 60 cm intra and 100 cm inter row spacing.

Table 2. Effect of inter and Intra row spacing on the length of main raceme in cm of castor Var. Hiruy.

Intra row spacing cm	Inter row spacing in cm				Mean
	60	80	100	120	
50	34.1[defg]	40.6[a]	36.4[bcde]	39.9[ab]	37.8
60	39.9[abc]	38.1[abcd]	40.2[ab]	37.5[abcde]	38.9
70	30.1[g]	32.0[fg]	36.0[bcdef]	35.4[def]	33.4
80	34.1[defg]	33.5[fg]	36.5[bcde]	35.6[cdef]	34.9
Mean	34.6	36.0	37.3	37.1	36.2

100 Seed Weight

The mean 100 seed weight of the castor variety Hiruy was 52.5 (525 g per 1000 seeds). In castor larger seeds contain relatively higher oil content than smaller seeds (Weiss 1980). In castor, oil is deposited in the endosperm and larger seeds tend to have larger endosperm. In this study, largest seed weight was obtained at 60 cm inter and intra row spacing. It appeared that, the seed weight decreases as the inter and intra row spacing increases (Table 3). The reason could be that in narrow spacing the length of the main raceme is shorter and posses lower number of capsules that may have less competition and hence larger seeds. In the wider spacing the length of main raceme is longer and tends to have more number of capsules that may have competition and hence smaller seeds. The optimum intra row spacing seems to be 60 cm with inter row spacing of 80 cm which is equivalent of 20,833 plants per hectare.

Table 3. Effect of row and plant spacing on the 100 seed weight in g of variety Hiruy grown at Arsi Negelle and Melkassa during 2010 and 2011.

Intra Row Spacing cm	Inter Row Spacing in cm 60	80	100	60	Mean 80
50	54.8 [a]	51.4[bcd]	52.2[abcd]	50.3[d]	52.2
60	54.3[ab]	52.9[abcd]	54.3[ab]	53.7[abc]	53.8
70	54.3[ab]	53.6[abc]	51.0[dc]	51.3[bcd]	52.6
80	51.7[abcd]	51.6[bcd]	51.7[abcd]	51.8[abcd]	51.7
Mean	53.8	52.3	52.3	51.8	52.5

Number of Capsules Per Plant

The number of capsules per plant were highest at 50 and 60 cm inter and 80 cm intra row spacing or 20,833 plants per hectare (Table 4). Both 50 cm and 60 cm plant spacing at 80 cm row spacing resulted the same value. Plant spacing of 100 cm and 120 cm resulted in the lowest number of capsules per plant probably due to many branches and shorter inflorescence per plant and in wider spacing castor plants tend to have many branches causing competition.

Table 4. Effect of row and plant spacing on number of Capsules per plant of castor Var. Hiruy grown at Arsi Negelle and Melkassa during 2010 and 2011.

Intra Row Spacing in cm	Inter Row Spacing in cm 60	80	100	120	Mean
50	83[EFGH]	108[AB]	62[J]	88[DEFG]	85
60	93[CDE]	108[AB]	60[J]	72[HIJ]	83
70	84[EFGH]	105[ABC]	68[IJ]	77[GHI]	83
80	100[CBD]	119[Ac]	78[FGHI]	92[CDEF]	97
Mean	69	110	67	82	82

Seed Yield

Seed yield along with oil content is the major product of castor crop. The seed yield of castor variety Hiruy reached 1.5 tones per ha at the 50 cm intra row 80 cm inter row spacing which is equivalent of 20,833 plants per hectare. However the 60 cm intra row and 60 cm inter row spacing or 27,000 plants per hectare resulted in 1.4 tones (Table 5). The castor variety Hiruy is top branching and mostly with single raceme and this plant population holds true for other top branching varieties in the Ethiopian Rift Valley. Castor plant compensates by producing more branches under wider spacing and less branches under narrow spacing. However the plant tends to produce more seeds with higher oil content in the main raceme than secondary racemes. Under the moisture limiting environments of the Central Rift Valley of Ethiopia, 1.5 tones per hectare of seed yield with oil contents 48% is profitable because castor has a low input and low seed rate. Plant spacing of 50 cm and row spacing of 80 cm is equivalent to about 12 kg/ha of seed rate assuming 100 germination percentages. Therefore, castor has low cost of seed and fertilizer rate. Preliminary studies at Melkassa showed that castor has very low N and P requirement in the Central Rift Valley of Ethiopia.

Table 5. Effect of row and plant spacing on seed yield in tones/ha of castor Var. Hiruy grown at Arsi Negelle and Melkassa during 2010 and 2011.

Intra Row	Inter Row Spacing in cm				Mean
Spacing in cm	60	80	100	120	
50	1.2383^{bcd}	1.5442^{a}	1.3192^{abcd}	1.45ab	1.3879
60	1.4050^{abc}	1.1575^{cd}	1.2058^{bcd}	1.3142^{abcd}	1.2706
70	1.1692^{bcd}	1.0292^{d}	1.3550^{abc}	1.2667^{abcd}	1.2050
80	1.3723^{abc}	1.4292^{abc}	1.2300^{bcd}	1.2100^{bcd}	1.3103
Mean	1.2962	1.2900	1.2700	1.3100	1.2934

Oil Content

The oil content of the castor Var. Hiruy from two locations and two years was 49.1 % (Table 6). Castor genotypes containing oil content of well over 55% are identified out of germplasm grown at Melkassa. In Ethiopia, castor has relatively higher oil content than other oilseeds such as linseed and noug. Oil content of 49 % from a crop grown in arid climate can be considered high. The international standard of grade 1 castor seed is oil content of 45%. In this study, oil content was not significantly affected by neither inter or intra row spacing and the difference among treatments was only slight. In similar study, the oil content of castor was not affected plant and row spacing (Kittock Williams 1970). Similarly, the oil content of four safflower varieties was not affected by five plant population levels (Gonzalez et al. 1994).

Table 6. Effect of row and plant spacing on oil content of castor Var. Hiruy grown at Arsi Negelle and Melkassa during 2010 and 2011.

Intra Row	Inter Row Spacing in cm				
Spacing cm	60	80	100	120	Mean
50	48.6^{b}	48.9^{ab}	48.8^{ab}	48.8^{ab}	48.8
60	49.0^{ab}	48.7^{ab}	49.7a	48.9^{ab}	49.0
70	49.2^{ab}	49.3^{ab}	48.7^{ab}	48.8^{ab}	49.2
80	49.3^{ab}	49.3^{ab}	49.3^{ab}	49.2^{ab}	49.3
Mean	49.0	49.0	49.1	48.9	49.1

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