Effect of planting density on yield and yield components in different castor beans varieties (*Ricinus communis* L.)

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Abstract: This study was conducted to evaluate the effects of different planting density (100×100 cm, 60×60 cm, 30×30 cm) on yield and yield components of three varieties (Buan-1, Changwon-1 and Yunnam-1) varieties of castor beans (*Ricinus communis* L.). It was observed that number of branch per plant, number of seed per plant and weight of seeds per plant were decreased with the increasing planting density, but 100-seed weight was not significantly different in all three varieties of castor beans. As plant density increased, yield of castor beans increased as the number of branch per unit area and 100-seed weight. In Buan-1, number of seed per unit area was increased with the increase in planting density. However, Changwon-1 and Yunnam-1 were decreased by the increase of planting density. As planting density increased, contribution of main stem in term of weight grain of panicle and no. of grain increased. However 1st branch contribution was decreased after the increase of planting density. Highest seed yield was recorded at 30×30 cm of planting density.
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1. Introduction

The castor bean is an economically importance oilseed of the family *Euphorbiaceae* and is also known as caster plant. It has been documented that castor bean has been originated from East Africa and Ethiopia (Moshkin, 1986). It is cultivated mainly in subtropical regions and has a high adaptability in cultivation even in bad environment. India is the largest producer of castor beans, followed by China and Brazil, while in South Korea, it is cultivated on small area.

The seed of castor beans contain ricin, ricinine and other allergen that are toxic to humans and animals (Olsnes, 2004). However, it is used in inks and industrial lubricants, cosmetics, pomades, artificial leather, paints, and new materials such as plastics and synthetic fibers (Winch, 2006). In South Korea, the leaves, seeds and roots have been traditionally used as medicinal material of oriental medicine and civilian medicine for homeostasis, purgative, swelling, bruising, and diarrhea (Kim, 1993).

Recently, castor bean is being recognized as a potential biodiesel crop because they contain more oil substances as compared to other crops (Comar et al., 2004; Wang et al., 2008). Research on utilizing castor beans as biodiesel crop are being carried out (Wang et al., 2008; Comar et al., 2004) in different aspects such as development of castor sprouts for biodiesel production and to explore its genetic diversity (Gerard et al., 2008; Wang et al., 2008; Baldanzi et al., 1998; Bhardwaj et al., 1996).

The adjustment of plant density is a simple method with low input but has a significant impact on yield (Soratto et al., 2012). A high plant population may favor overgrown plants (Carvalho et al., 2010) which ultimately lead towards lodging, whereas a low plant density may result weed growth, late flowering, long lateral branches, and big stems, which disturb mechanical harvesting (Severino et al., 2012). However, Beltrão et al., (2007) reported that the behavior of castor bean to the changing plant density is very complicated and consider diferent ecophysiological aspects, since it causes many changes in growth and development.

In South Korea, since the climate change prevails, the development of bioenergy crops is in demand in order to transform it into a low-carbon social structure. However, there is a lack of research on domestic crops for biodiesel production. So there is a need to develop high-quality biodiesel crops. Therefore, this study was carried out in order to evaluate the effects of different plant population arrangement on agronomic and yield components of local varieties of castor bean from South Korea.

2. Material and Methods

2.1. Materials

Three varieties; two domestic (Buan-1, Changwon-1) and one foreign (Yunnam-1) of castor beans (*Ricinus communis* L.) were collected from National Agrobiodiversity center, Jeonju, South Korea. This study was carried out in National Sunchon University farm (N 35° 00′05.4″, E 127° 30′30.5″) in order to analyze growth characteristics and quality components based on varying planting densities (100×100 cm, 60×60 cm, 30×30 cm), and find out the adequate planting density. The soil used in the experiment has a physico-chemical composition of pH 6.7, which makes it a weak acidic. The soil had also contained little amount of organic matters, comparably large amount of phosphate, potassium, and magnesium. The soil also had with low calcium content and low nutrient holding capacity.

2.2. Processing method

There were three varying planting densities: 30×30 ㎝ (10,800 plant/10 a), 60×60 ㎝ (2,500 plant/10 a), 100×100 ㎝ (1,000plant/10 a). For each density group, 2~3 seeds were seeded with the direct seeding method, and in the third stage of foliage leaf, no. of seedling was adjusted to one plant per spot. The soil was fertilized prior to sowing, for each 10a, 1,000kg of composts and chemical fertilizers including 4kg of nitrogen, 3kg of phosphate and 2kg of potassium (N-P_2O_5-K_2O = 4-3-2 ㎏/10 a) were scattered evenly. Standard cultivation method was followed as specified by the Rural Development Administration. (RDA, 1997). The testing field was 300m^2 long, and the experiment was arranged in randomized block design with three replication.

2.3. Growth Investigation

The parameters such as no. of branch per plant; no. of seed per branch, no. of seed per plant, weight of seeds per plant, total grain number, and grain weight, were investigated three times manually. Using the data, per panicle spike rate of grain weight and rate of grain number were calculated. In each replication, one hundred seed weight were weighed three times, one hundred seed at each time. All investigation methods followed the Agricultural Science and Technology Research Survey and Analysis Standard (RDA, 2004) and Agricultural Research and Survey Standard (RDA, 1983). Test results were analyzed using MYSTAT.

3. Results

The plant density had a greater impact on plant survival. Low plant density provided better conditions for plant growth and development than high plant density. As it is evident from the results that number of panicle, number of grain/plant single plant seed weight and 100-seed weight were decreased as the planting density increased (Table 1). The largest panicle number was 8.8, which was found in the lowest planting density 100 × 100 ㎝ in Buan-1 followed by Changwon-1 (8) and Yunnam–1 (6.9). There was no significant difference between the 100 × 100 ㎝ and the 60 × 60 ㎝ planting densities. However, a significant drop was found in 30 × 30 ㎝ in all three varieties (Table 1). This may be the result of competition for water, light and nutrients between individual plants (Park et al., 2006). These results are in line with the finding of Kwon (2004). Soratto et al. (2012) also noted low survival rate of castor plants because of increasing plant density. Similarly the largest number of grain (235.21) per plant was found in Buan-1 followed by Changwon-1 (206.77) and Yunnam–1 (200.04). at 100 × 100cm plant density (Table 1). Single plant seed weight also decreased as the planting density increased in all three varieties, which is in accordance with the tendency found in number of branches per plant and. It was 60.99g, which is the largest at 100 × 100cm plant density in Changwon-1 followed by Buan-1 (59.74g) and Yunnam–1 (43.14) (Table 1). Non significant difference was observed in case of 100-seed weight at different plant densities in all three varieties. However there was a slight tendency of 100-seed weight increasing, as planting density increased. This is because nutrients are concentrated in the panicle of primary branch and the main stem, which facilitates growth and grain saturation. Therefore, compared to other densities, 30 × 30 cm had high rate of no. of grains of the main stem and primary branch experienced an increase in 100-seed weight, because the accumulation of nutrients were concentrated in the main stem and primary branch. These results are in line with the Lee et al. (2000), they suggested that variation of individual plants due to change in environment was minimum between relatively low planting densities.

Correlation analysis between yield components and Buan-1 and Changwon-1, which are domestic accessions, were relatively sensitive towards planting density. The no. of panicle and 100-seed weight showed a meaningful positive correlation with planting density. Yield of the foreign accession Yunnam 1 was not sensitive towards planting density, but still showed a positive correlation. All three accessions showed a negative correlation of yield and no. of panicle against planting density. Therefore, for castor plant, no. of panicle had the strongest influence on yield. Regarding castor plant cultivation, certain degree of increase in planting density is helpful, if too densely planted; it decreased no. of panicle, which does not help to increase output (Table 2).

All domestic and foreign collected accessions showed an increase in no. of panicle and yield per unit area with the increasing planting densities. Changwon-1' (domestic) at 30 × 30 cm plant density had the largest no. of panicle (46.46) per unit area followed by Buan 1 (domestic) (42.14) and Changwon-1 (foreign) (34.570) (Table 3). No. of grain per panicle in different planting densities varied across different accessions. In domestic accession, Buan 1, first decreased and then increased as planting density increased. On the other hand no. of grain per panicle of other two accessions, Changwon-1 (domestic) and Yunnam-1 (foreign), gradually decreased as planting density increased. Yield per unit area was the largest at 30 × 30 cm: in Buan-1 (domestic) (316.10 kg) followed by Changwon-1 (261.84 kg) and Yunnam-1 (196.47 kg) while 100 × 100 cm had the smallest amount of yield in Buan 1 (67.22 kg), Changwon-1 (60.95 kg) and Yunnam-1 (43.11 kg) (Table 3). These results are in line with finding of Cha and Lee (1979) and Kim et al. (1981). They concluded that no. of branch, no. of pod, and no. of grain increases in the low-density environment while no. of pod, weight of pod and weight of grain per unit area increases in the high-density environment.

Table 1. Effect of different planting densities on no. of branch per plant, no. of seed per plant and seed weight per plant of three castor beans varieties

Varieties	**Density (plants/10a)**	**NO. of branch**	**NO. of seed**	**No. of seed per plant**			**100-seed weight (g)**	**Weight of seeds³⁾ (g) 1st branch**
				main stem	**1st branch**	**2nd branch**	**main stem**	
Buan-1	100×100 cm (1,000)	8.8a	235.21a	58.03a	151.84a	25.35a	58.03a	151.84a
	60×60 cm (2,500)	7.5b	180.33b	40.85b	123.14b	16.39b	40.85b	123.14b
	30×30 cm (10,800)	3.9c	100.69c	29.29c	61.73c	9.68c	29.29c	61.73c
Changwon 1	100×100 cm (1,000)	8.0a	206.77a	60.18a	133.60a	33.09a	26.86ns	60.99a
	60×60 cm (2,500)	6.9b	169.05b	43.55b	107.10b	18.40b	26.49ns	45.01b
	30×30 cm (10,800)	4.3c	90.02c	30.23c	47.71c	12.08c	26.90ns	24.22c
Yunnam 1	100×100 cm (1,000)	6.9a	200.04a	36.01a	150.10a	13.95a	21.53ns	43.14a
	60×60 cm (2,500)	5.0b	140.88b	20.08b	112.70b	8.10b	21.84ns	30.69b
	30×30 cm (10,800)	3.2c	82.50c	12.57c	66.02c	3.92c	22.01ns	18.23c

Table 2. Correlation of between yield components and varieties.

Varieties	**No. of branch**	**No. of seed[1)]**	**100-seed weight**
Buan 1	0.91**	-0.72	0.81*
Changwon 1	0.83*	-0.69	0.76
Yunnam 1	0.75	-0.32	0.64

1) No. of seed per branch

	Density (plants/10a)	No. of branch (×1,000 ea/10a)	No. of seed	100-seed weight (g)	Seed yield (kg/10a)
Buan-1	100×100 cm (1,000)	8.82	26.74	28.50	67.22
	60×60 cm (2,500)	19.21	24.06	28.55	132.01
	30×30 cm (10,800)	42.14	25.64	29.04	316.10
Changwon-1	100×100 cm (1,000)	8.0	28.36	26.86	60.95
	60×60 cm (2,500)	17.65	24.54	26.49	114.75
	30×30 cm (10,800)	46.46	20.95	26.90	261.84
Yunnam-1-	100×100 cm (1,000)	6.9	29.02	21.53	43.11
	60×60 cm (2,500)	12.80	28.19	21.84	78.89
	30×30 cm (10,800)	34.57	25.81	22.01	196.47

Contribution of main Stem and other branches to yield.

The influence of planting density on main stem's yield components and yield is shown in Table 4. As planting density increased, weight grain of panicle and no. of grain of main stem increased. The contribution of main stem in term of weight grain of panicle increased as planting density increased: in Buan-1 (30.84 to 34.24%), Changwon-1 (31.50 to 35.13%) and Yunnam (33.92 to 35.51%). The average comparison rate of all 100-seed weight was steady in Buan-1 and Yunnam-1 despite of increase in planting density. However, in Changwon-1, the average comparison rate increased slightly and then decreased (Table 4). In all accessions, contribution of primary branch was over 60%, regardless of accessions and planting density (Table 5). Weight of grain also showed a similar tendency as no. of grain regarding the contribution of primary branch. Buan-1 had the rate of over 60%, while Yunnam-1 had a relatively low rate (58~56 %) of contribution. In case of 100-seed weight, all three accessions decreased consistently (100.10~96.07%) as planting density increased, which is different from the main stem (Table 5). Lee et al. (2000) concluded that involucrum plant grows more on the lower node when they were cultivated under high-density as compared to low-density. This is because low-density allows plants to have more space. As planting density increased, the weight of seed, no. of seed and 100-seed weight decreased. The contribution of secondary branch in the yield was very low compared to main stem and primary branch (Table 6). However, In Buan-1, weight of seed decreased as planting density increased, while in Changwon-1 and Yunnam-1 first decreased and then increased (Table 6). Ko et al. (1998) reported that main stem contribution to 100-seed weight tends to decrease as planting density increase, while they did not find correlation between no of branch and planting density.

Table 4. Effect of different planting densities on main branch contribution to yield of three castor beans varieties.

Varieties	**Density (plant/ 10a)**	**Weight of seed (g)**	**Branch contribution (%)**	**No. of seed**	**Branch contribution (%)**	**100-seed weight (g)**	**branch/plant (%)**
Buan 1	100×100 cm (1,000)	18.42	30.84	81.15	32.05	28.75	100.88
	60×60 cm (2,500)	16.49	32.01	61.60	34.16	28.86	101.08
	30×30 cm (10,800)	10.15	34.24	35.59	35.35	29.43	101.34
Changwon 1	100×100 cm (1,000)	19.21	31.50	72.30	31.88	26.86	100.11
	60×60 cm (2,500)	15.17	33.70	55.84	33.03	27.09	102.27
	30×30 cm (10,800)	8.51	35.13	31.60	35.10	27.42	101.93
Yunnam 1	100×100 cm (1,000)	14.63	33.92	63.81	31.90	22.07	102.51
	60×60 cm (2,500)	10.70	34.85	45.89	32.57	22.55	103.25
	30×30 cm (10,800)	6.47	35.51	27.26	33.04	22.71	103.18

Table 5. Effect of different planting densities on 1st branch contribution to yield of three castor beans varieties.

Varieties	Density (plant/ 10a)	Weight of seed (g)	Branch contribution (%)	No. of seed	Branch contribution (%)	100-seed weight (g)	branch/plant (%)
Buan 1	100×100 cm (1,000)	38.19	63.93	162.51	64.18	28.53	100.10
	60×60 cm (2,500)	33.34	64.72	117.30	65.05	28.19	98.74
	30×30 cm (10,800)	18.45	63.08	63.62	63.19	27.90	96.07
Changwon 1	100×100 cm (1,000)	39.39	64.58	147.83	65.19	26.86	100.01
	60×60 cm (2,500)	30.10	66.88	110.56	65.40	26.14	98.68
	30×30 cm (10,800)	15.31	63.22	58.39	64.86	26.33	97.89
Yunnam 1	100×100 cm (1,000)	25.37	58.80	133.57	66.77	21.40	99.35
	60×60 cm (2,500)	18.34	59.77	94.46	67.05	21.22	97.16
	30×30 cm (10,800)	10.38	56.93	55.16	66.86	21.31	96.82

Table 6. Effect of different planting densities on 2st branch contribution to yield of three castor beans varieties.

Varieties	Density (plant/ 10a)	Weight of seed (g)	Branch contribution (%)	No. of seed	Branch contribution (%)	100-seed weight (g)	branch/plant (%)
Buan 1	100×100 cm (1,000)	3.12	5.23	8.87	3.77	23.90	83.86
	60×60 cm (2,500)	1.68	3.27	1.44	0.80	23.80	83.36
	30×30 cm (10,800)	0.78	2.68	1.47	1.46	21.80	75.07
Changwon 1	100×100 cm (1,000)	2.39	3.92	6.64	2.93	22.25	82.84
	60×60 cm (2,500)	2.61	5.80	2.65	1.57	21.08	79.58
	30×30 cm (10,800)	3.99	16.50	0.37	0.41	20.01	74.39
Yunnam 1	100×100 cm (1,000)	3.11	7.20	2.66	1.33	13.01	60.04
	60×60 cm (2,500)	1.65	5.38	0.53	0.38	11.45	52.43
	30×30 cm (10,800)	1.38	7.56	0	0.01	9.28	42.16

It is concluded that yield of castor beans increased as the plant density. In domestic variety (Buan-1), number of seed per unit area was increased with the increase in planting density. Contribution of main stem as compared to other branches was more in yield. Maximum seed yield was recorded at 30×30 cm of planting density.

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