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Original scientific paper

GENETIC VARIABILITY AND TRAITS ASSOCIATION IN CASTOR BEAN (*Ricinus communis* L.)

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Genetic diversity of 12 castor bean accessions collected from different geographical regions of Iran was assessed in a randomized complete block design with three replications under filed condition. The data were recorded for 32 agro-morphological traits. Significant differences were observed among accessions for main stem length, main stem moist weight, main stem dry weight, 10-seeds weight on primary raceme, seed number on primary raceme, leaf area dry weight, female flower length, male flower length, secondary and tertiary raceme weight and oil percentage. A strongly positive correlation was observed between total seed weight on primary raceme as yield with seed number on primary raceme, female flower length, primary raceme length and main stem diameter. Path coefficient analysis indicated high direct effect of seed number on primary raceme (0.82) on seed yield. In addition, direct effect of primary raceme length on seed yield was negative (-0.13). Primary raceme length had the greatest indirect effect via seed number on seed yield (0.35).

Key words: agro-morphological traits, castor bean, correlation coefficient, genetic diversity, path coefficient analysis

INTRODUCTION

Castor bean (*Ricinus communis* L.) as an important non-edible oilseed crop (oil content from % 40 to %60), is a monotypic species in the family *Euphorbiaceae* which has a wide range

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of distribution in tropical and subtropical regions. High genetic diversity of *Ricinus communis* in Ethiopia imply that this species has been originated from Eastern Africa (VAVILOV, 1951). Meanwhile, there are several lands in tropical and subtropical regions undergoing the cultivation of this species. Castor bean is important due to resource of vegetable and medicinal oil. Its oil has several industrial and non-industrial applications (OGUNNIYI, 2006). Considering to increasing demands for castor bean usage in many countries, improvement of genotypes is drawing great attention from plant breeders (SUJATHA *et al.,* 2008). Obviously, genetic diversity is same as backbone of any breeding programs that play important role to achieving any success. According to literature, there are limited variability in castor bean for productivity traits and resistance to diseases and pests which led to limit progress in castor bean breeding programmes (WEISS, 2000). Hence, it is necessary to evaluate the genetic diversity present across *Ricinus communis* germplasm from different geographic regions (HINCKLEY, 2006).

Yield of castor bean is a quantitative trait that largely influenced by the environment and has a low heritability. Plant breeders prefer yield related traits that indirectly increase seed yield (SARWAR and CHAUDHRY, 2008). Determination of correlation and path coefficient analysis between yield and its related agro-morphological traits are important for selecting favorable plant types in castor bean. Correlation coefficients in general show associations among independent characteristics and the degree of linear relation between these characteristics. As correlation coefficients describe relationships in a simple manner, generally, a path coefficient analysis is needed to clarify relationships between traits. Path coefficient analysis shows the extent of direct and indirect effects of the causal components on the response component. This method was used to determine the nature of the relationships between yield and yield components in some other crops such as winter rapeseed (ALI *et al.,* 2003; RAUF *et al.,* 2004); melon (FEYZIAN *et al.,* 2009); tobacco (HATAMI MALEKI *et al.,* 2011) and sunflower (DARVISHZADEH *et al.,* 2011). There are some reports on application of this robust statistical technique in castor bean (MOSHKIN, 1986; KHORGADE *et al.,* 1994; MEHTA and VASHIL, 1998; SEVUGAPERUMAL *et al.,* 2000; RAMESH *et al.,* 2001; RAMESH and DURGA, 2002; YADAV *et al.,* 2004; RAMU *et al.,* 2005; SARWAR and CHAUDHRY, 2008; ADEYANJU *et al.,* 2010; SARWAR *et al.,* 2010). The aims of this study were to evaluate the genetic variability on some accessions of castor bean from Iran and identification of the interrelationships among agro-morphological traits and yield in castor bean.

MATERIALS AND METHODS

Plant Material and Experimental Design

Plant material used in this study comprised 12 accessions of castor bean (*Ricinus commonis*) provided by the Seed and Plant Improvement Institute (SPII), Karaj, Iran (Tab. 1). The experiment was conducted at Urmia Agricultural Research Center in 2011. The latitude and longitude of region is 37º 44´ N and 45º 10´ E, respectively. Climate of the region is semidry and the average rainfall and the area temperature according to 16 years statistics are 184 mm and 12°C, respectively. Soil type of the experimental site was clay loam with pH 7.0.

Accessions were evaluated in a randomized complete block design with three replications. Each plot comprised of 3 lines of 6.5 meters long. Row to row and plant to plant spacing was 0.60 and 0.50 meters, respectively. The data on 5 individuals (vying) in each plot were recorded for 32 agro-morphological traits. The agro-morphological traits evaluated in this study were presented in Tab. 2.

Table 1. Studied castor bean (Ricinus communis L.*) accessions collected from various locations of Iran*

Number	Code in Gene Bank	Location	Latitude	Longitude	Altitude (m)
1	80-23	Tafresh (Markazi state)	34º 24´	49º 43´	1735
2	80-31	Ashtian (Markazi state)	34º 30´	50º 04´	2450
3	80-25	Arak (Markazi state)	34º 20´	49º 49´	1753
4	80-12-1	Sahreza (Isfahan state)	32º 11´	51º 37´	1750
5	80-29	Toyserkan (Hamedan state)	36º30´	48º 16´	1910
6	80-18	Taft (Yazd state)	31º 32´	54º 15´	2000
7	80-16-1	Fasa (Fars state)	28º 58´	51º 41´	1382
8	80-17	Ashtian (Markazi state)	32º 24´	50º 14´	1775
9	80-7	Mehriz (Yazd state)	30º 05	54º 17´	1550
10	80-11-1	Sahreza (Isfahan state)	32º 14´	51º 32´	1750
11	80-4	Jiroft (Kerman state)	28º 40´	57º 44´	685
12	80-22	Tafresh (Markazi state)	34º 27´	49º 38´	1727

Table 2. Agro-morphological traits measured in castor bean accessions

x1= main stem length (cm)	X17= secondary and tertiary branch dry weight (g)
x2= secondary branch number	x18= secondary and tertiary racemes weight (g)
x3= tertiary branch number	x19= total primary raceme weight
x4= secondary branch length (cm)	x20= primary raceme weight without capsule and seed
x5= tertiary branch length (cm)	x21= capsule weight on primary raceme (g)
x6= primary raceme length (cm)	x22= total seed weight on primary raceme (g)
x7= secondary raceme length (cm)	x23= 10 seed weight on primary raceme (g)
x8= tertiary raceme length (cm)	x24=seed number on primary raceme
x9= female flower length (cm)	x25= hollow seed number on primary raceme
x10= male flower length (cm)	x26= leaf area per plant (cm2)
x11= leaf number	x27= lamina leaf dry weight (g)
x12= leaf dry weight (g)	x28= lamina leaf length (cm)
x13= main stem fresh weight (g)	x29= lamina leaf width (cm)
x14= main stem dry weight (g)	x30= petiole leaf length (cm)
x15= main stem diameter (cm)	x31= leaf length (cm)
x16= secondary and tertiary branch fresh weight (g)	x32= oil content of seed (%)

Data Analyses

Data were subjected to analysis of variance using general linear model (GLM) procedure in the SAS software (SAS Institute Inc., Cary, NC, USA) after normalization of each trait that had not normal distribution (STEEL and TORRIE, 1980). When there was not significant difference between experimental blocks, block source was pooled with error source. Duncan's multiple range tests was used for comparing mean performance of accessions. Pearson correlation coefficients were determined among studied traits using PROC CORR in the SAS software. The stepwise multiple regressions were performed using SPSS 16.0 software to select significant predictor variables on total seed weight on primary raceme as seed yield. Path analysis was done using important predictor variables to determine their direct and indirect effects on seed yield.

RESULT AND DISCUSSION

Genetic Variability

Analysis of variances revealed significant differences among caster bean accessions for majority of studied traits (Tab. 3) that is consistent with previous reports (MOSHKIN, 1986; MANIVEL and HUSSAIN, 1997; JOSHI *et al.,* 2002; SARWAR and CHAUDHRY, 2008; ANJANI, 2010). Genetic variability is the raw material of crop breeding industry on which selection acts to evolve superior genotypes. The higher amount of variation present for a character in the breeding materials, greater is the scope for its improvement through selection.

Table 3. Analysis of variance for 32 agro- morphological traits in castor bean (Ricinus communis L.*) based on CRD design.*

S. O. V	Df	MS															
		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
Pop	11	0.87*	0.27	0.85	108.68	35.72	61.09	25.49	27.80	58.04**	29.20**	41.63	425.86	0.05*	0.05*	0.07	2512.22
Error	24	0.34	0.14	0.97	78.71	54.39	33.88	26.22	19.00	17.97	7.50	44.66	426.88	0.02	0.02	0.06	2127.58

* and ** significant at 0.05 and 0.01 of probability level, respectively. X1= Main stem length (cm), x2= Secondary branch number, x3=Tertiary branch number, x4=Secondary branch length (cm), x5=Tertiary branch length (cm), x6=Primary raceme length (cm), x7=Secondary raceme length (cm), x8=Tertiary raceme length (cm), x9=Female flower length (cm), x10=Male flower length (cm), x11=Leaf number, x12= Leaf dry weight (g), x13=Main stem fresh weight (g), x14=Main stem dry weight (g),x15= Main stem diameter (cm), x16= Secondary and tertiary branch fresh weight (g)

Table 3. Continued

S. O. V	Df	MS															
		X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32
Pop	11	0.57	2639.55**	632.14	0.04	88.78	181.84	0.43*	2483.72*	23.13	88680.12	2.32*	7.97	9.88	11.65	24.87	1.44**
Error	24	1.21	661.75	576.64	0.04	75.08	103.38	0.17	822.22	16.10	66206.25	0.01	7.97	7.09	8.50	17.88	0.37

* and ** significant at 0.05 and 0.01 of probability level, respectively. X17= Secondary and tertiary branch dry weight (g), x18= Secondary and tertiary racemes weight (g), x19= Total primary raceme weight, x20= Primary raceme weight without capsule and seed, x21= Capsule weight on primary raceme (g), x22= Total seed weight on primary raceme (g), x23= 10 seed weight on primary raceme (g), x24=seed number on primary raceme, x25= Hollow seed number on primary raceme, x26= Leaf area per plant (cm^2), x27= Lamina leaf dry weight (g), x28= Lamina leaf length (cm), x29= Lamina leaf width (cm), x30= Petiole leaf length (cm), x31= Leaf length (cm), x32= Oil content (%)

Results pertaining to mean comparison showed that there was a great variability in main stem length among accessions that varied from 34.1 cm (accession 2) to 69.2 cm (accession 11). Among studied accessions, accession 11 had the maximum value for main stem fresh weight and main stem dry weight traits while accession 2 possess minimum value. Mean comparison manifested that the accessions had variable female flower length which varied from 29.6 cm (accession 1) to 13.5 cm (accession 2). Also, there was a greater variability for male flower length, which varied from 14.9 cm (accession 11) cm to 4.2 cm (accession 8). In accordance with WEISS (2000), the proportion of male and female flowers on each raceme was variable depending on accession.

Accession 5 present maximum values for secondary and tertiary racemes weight. Among studied accessions, 10 seed weight on primary raceme was variable from 2.1 g to 3.3 g while, BHARDWAJ *et al.* (1996) reported that castor bean 100-seed weight is variable from 10 g to 44 g. Accessions 5 and 11 have the maximum values of 10 seed weight on primary raceme and minimum values of seed number on primary raceme. Accessions 1 and 11 have the maximum and minimum value for seed number on primary raceme, respectively. Among other groups, accessions 2 and 11 had minimum values for lamina leaf dry weight. In this study, oil content was varied from 28.9% (accessions 4 and 8) to 73% (accession 6) (Tab. 4). According to WEISS (2000), the difference in oil content could be due to genotype or geographical latitude. DA SILVA RAMOS *et al.* (1984) by studying 36 Brazilians caster bean varieties reported that the oil content vary from 39.6% to 59.5%. BHARDWAJ *et al.* (1996) observed wide variability in oil content of 72 castor accessions collected from 16 countries. OKOH *et al.* (2003) reported that oil content of 6 Nigerian castor bean accessions varied from 36.6% to 53.85%.

Table 4. Mean comparison between several traits of 12 caster bean (Ricinus communis L.*) accessions using Duncan multiple range test. Means followed by the same letter are not significantly different.*

	x1		x9		x10		x13		x14		X18		x23		x24		x27		x32	
Pop 1	45.6	bcd	29.6	a	4.9	de	104.0	a	30.7	ab	51.1	b	2.8	ab	172.0	a	10.4	a	38	cde
Pop2	34.1	d	13.5	c	5.9	cde	45.3	c	14.1	c	50.4	b	2.3	b	115.9	bc	6.7	b	46.6	bcde
Pop3	44.3	bcd	15.8	bc	11.2	abc	88.9	ab	28.5	ab	70.4	b	2.9	ab	90.3	bcd	9.4	ab	33.4	de
Pop4	46.2	bcd	19.3	bc	10.3	abcd	99.0	a	29.9	ab	64.6	b	2.9	ab	108.6	bcd	10.9	a	28.9	e
Pop5	54.6	ab	17.6	bc	13.8	ab	128.3	a	38.9	a	144.8	a	3.3	a	71.5	cd	12.6	a	55.8	abcd
Pop6	36.9	cd	17.3	bc	6.8	cde	70.0	abc	20.0	bc	40.4	b	2.1	b	104.3	bcd	10.5	a	73	a
Pop7	50.4	abc	23.4	ab	8.4	cde	70.0	abc	23.6	abc	38.5	b	2.7	ab	138.7	ab	9.6	ab	42.52	bcde
Pop8	40.5	bcd	15.1	bc	4.2	e	70.3	abc	21.6	abc	50.9	b	2.4	b	122.7	abc	8.6	ab	28.9	e
Pop9	48.3	abcd	19.3	bc	8.1	cde	64.3	abc	21.4	abc	41.9	b	2.3	b	124.6	abc	8.9	ab	64.5	ab
Pop10	50.6	abc	18.2	bc	8.9	bcde	94.5	a	30.1	ab	54.8	b	2.4	b	120.2	abc	8.0	ab	44.5	bcde
Pop11	69.2	a	15.1	bc	14.9	a	136.7	abc	45.2	ab	52.1	b	3.3	a	54.3	d	17.8	a	61.1	abc
Pop12	39.0	bcd	15.3	bc	7.9	cde	47.3	bc	16.2	bc	29.7	b	2.8	ab	119.1	abc	6.7	b	43.88	bcde

X1= Main stem length (cm), x9=Female flower length (cm), x10=Male flower length (cm), x13=Main stem fresh weight (g), x14=Main stem dry weight (g), x18= Secondary and tertiary racemes weight (g), x23= 10 seed weight on primary raceme (g), x24=seed number on primary raceme, x27= Lamina leaf dry weight (g), x32= Oil content (%).

In the case of x13 and x14, the data were deviated from normal distribution. Analysis of variance and mean comparison were made on transformed data but the original mean (anti-transformed data) were reported in Table.

Correlation Analysis

Results of simple correlations among 32 agro-morphological traits were presented in Tab. 5. The highest value of correlation (r = 0.99) was observed between main stem fresh weight with main stem dry weight and between secondary and tertiary branch dry weight with secondary and tertiary branch fresh weight. Among studied traits, total seed primary raceme weight had an intermediate positive correlation with majority of studied traits. This trait was positively and significantly correlated with seed number on primary raceme (r=88). Also, this trait exhibited significant positive correlation with female flower length, primary raceme length and main stem diameter.

Table 5. Simple correlation between studied agro-morphological traits of castor bean (Ricinus communis L.).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31
X2	0.36																														
X3	-0.38	0.28																													
X4	0.31	0.42	0.32																												
X5	-0.31	-0.04	0.60	0.36																											
X6	0.51	0.43	0.10	0.55	0.21																										
X7	0.04	0.19	0.48	0.78	0.75	0.52																									
X8	-0.27	-0.07	0.48	0.21	0.86	0.21	0.58																								
X9	0.32	0.33	0.14	0.30	0.15	0.81	0.26	0.18																							
X10	0.58	0.35	-0.13	0.61	0.11	0.49	0.50	-0.02	-0.02																						
X11	0.00	0.63	0.54	0.36	0.41	0.34	0.44	0.26	0.30	0.17																					
X12	0.24	0.66	0.40	0.57	0.50	0.54	0.62	0.30	0.42	0.43	0.78																				
X13	0.60	0.62	0.21	0.65	0.35	0.72	0.62	0.21	0.56	0.57	0.55	0.82																			
X14	0.66	0.62	0.18	0.65	0.32	0.73	0.61	0.19	0.54	0.62	0.51	0.80	0.99																		
X15	0.20	0.45	0.45	0.51	0.65	0.65	0.69	0.53	0.55	0.38	0.61	0.81	0.84	0.80																	
X16	0.18	0.50	0.42	0.73	0.49	0.51	0.72	0.28	0.34	0.46	0.55	0.76	0.79	0.76	0.79																
X17	0.23	0.53	0.44	0.75	0.54	0.54	0.75	0.35	0.35	0.50	0.55	0.79	0.83	0.81	0.83	0.99															
X18	0.27	0.33	-0.06	0.34	0.23	0.33	0.45	0.11	0.18	0.44	0.35	0.45	0.55	0.54	0.48	0.60	0.58														
X19	-0.31	-0.30	0.28	0.04	0.53	0.03	0.38	0.49	0.13	-0.19	0.01	0.09	0.08	0.06	0.32	0.21	0.22	0.00													
X20	0.33	0.54	0.02	0.32	0.22	0.64	0.34	0.26	0.54	0.31	0.41	0.55	0.61	0.63	0.56	0.37	0.43	0.28	0.13												
X21	-0.30	-0.29	0.20	-0.07	0.47	0.03	0.28	0.47	0.14	-0.22	-0.05	0.01	0.02	0.00	0.25	0.10	0.11	-0.02	0.97	0.21											
X22	0.17	0.20	0.27	0.37	0.41	0.62	0.45	0.43	0.72	-0.01	0.30	0.44	0.54	0.54	0.62	0.47	0.51	0.19	0.55	0.52	0.51										
X23	0.34	0.25	-0.09	0.46	0.25	0.55	0.49	0.12	0.25	0.62	0.18	0.53	0.64	0.66	0.58	0.64	0.65	0.47	0.16	0.51	0.12	0.46									
X24	-0.03	0.08	0.36	0.23	0.37	0.43	0.30	0.48	0.65	-0.28	0.25	0.24	0.25	0.24	0.39	0.19	0.23	-0.10	0.58	0.32	0.56	0.88	0.05								
X25	0.06	0.02	-0.14	-0.25	-0.17	0.41	-0.18	-0.06	0.62	-0.29	-0.08	-0.06	0.05	0.02	0.17	-0.05	-0.07	0.09	0.15	0.21	0.20	0.43	0.05	0.38							
X26	0.03	0.14	0.04	0.33	0.29	0.49	0.42	0.21	0.41	0.26	0.42	0.51	0.38	0.33	0.49	0.46	0.40	0.40	0.23	0.26	0.17	0.34	0.40	0.23	0.26						
X27	0.54	0.71	-0.05	0.47	0.07	0.69	0.36	0.00	0.56	0.52	0.57	0.72	0.76	0.76	0.57	0.47	0.49	0.45	-0.17	0.66	-0.18	0.39	0.51	0.17	0.16	0.55					
X28	0.01	0.04	0.13	0.43	0.35	0.31	0.50	0.13	0.11	0.43	0.18	0.36	0.30	0.27	0.40	0.51	0.48	0.28	0.15	0.02	0.09	0.06	0.34	-0.09	0.05	0.60	0.26				
X29	-0.03	-0.06	0.11	0.37	0.27	0.28	0.44	0.05	0.08	0.40	0.10	0.26	0.22	0.19	0.34	0.47	0.42	0.21	0.16	-0.06	0.09	0.03	0.35	-0.11	0.01	0.58	0.15	0.91			
X30	0.27	0.21	0.02	0.61	0.18	0.42	0.55	-0.03	0.18	0.55	0.34	0.47	0.43	0.41	0.33	0.47	0.43	0.34	-0.03	0.07	-0.12	0.09	0.38	-0.03	-0.14	0.61	0.54	0.71	0.70		
X31	0.23	0.24	0.12	0.58	0.26	0.39	0.56	0.06	0.14	0.55	0.36	0.43	0.45	0.42	0.40	0.57	0.53	0.38	-0.05	0.07	-0.12	0.03	0.36	-0.11	-0.10	0.55	0.44	0.79	0.75	0.89	
X32	0.02	0.11	-0.21	0.05	-0.41	-0.11	-0.28	-0.48	-0.13	0.03	-0.13	-0.18	-0.16	-0.15	-0.32	-0.03	-0.10	0.07	-0.28	-0.25	-0.28	-0.21	-0.01	-0.21	-0.08	-0.15	-0.06	-0.14	-0.16	0.03	-0.04

X1= Main stem length (cm), x2= Secondary branch number, x3=Tertiary branch number, x4=Secondary branch length (cm), x5=Tertiary branch length (cm), x6=Primary raceme length (cm), x7=Secondary raceme length (cm), x8=Tertiary raceme length (cm), x9=Female flower length (cm), x10=Male flower length (cm), x11=Leaf number, x12= Leaf dry weight (g), x13=Main stem fresh weight (g), x14=Main stem dry weight (g), x15= Main stem diameter (cm), x16= Secondary and tertiary branch fresh weight (g), X17= Secondary and tertiary branch dry weight (g), x18= Secondary and tertiary racemes weight (g), x19= Total primary raceme weight, x20= Primary raceme weight without capsule and seed, x21= Capsule weight on primary raceme (g), x22= Total seed weight on primary raceme (g), x23= 10 seed weight on primary raceme (g), x24=seed number on primary raceme, x25= Hollow seed number on primary raceme, x26= Leaf area per plant (cm^2), x27= Lamina leaf dry weight (g), x28= Lamina leaf length (cm), x29= Lamina leaf width (cm), x30= Petiole leaf length (cm), x31= Leaf length (cm), x32= Oil content (%). r ≥ | ±0. 34 | is significant at 1% probability level.

There was non-significant negative correlation between total seed primary raceme weight trait with male flower length and oil content. Moreover, there was high positive correlation between primary raceme length and female flower length (r= 0.81). Female flower length showed significant positive correlation with some other traits comprising primary raceme weight without capsule and seed, total seed weight on primary raceme, seed number on primary raceme, and hollow seed number on primary raceme. There was non-signification positive correlation between female flower length with total primary raceme weight, capsule weight on primary raceme and 10 seed weight on primary raceme. The 10 seed weight on primary raceme had significant relation with most of studied traits such as main stem length, secondary branch length, primary raceme length, and secondary raceme length (Tab. 5). Positive association between seed yield with total length of primary raceme, total number of racemes per plant and 100-seed weight were reported by MOSHKIN (1986) and SARWAR and CHAUDHRY (2008). Correlation results manifested non significant relation of capsule weight on primary raceme with 10 seed weight on primary raceme (Tab. 5). SARWAR and CHAUDHRY (2008) found that capsule weight per plant showed a significant and positive correlation with seed yield. Oil content was another trait that showed a significant negative correlation with tertiary raceme length and tertiary branch length. In this research, there was not any significant correlation between oil content and studied agro-morphological traits therefore; none of recorded trait affects the oil content. Meanwhile, positive correlation between 100-seed weight and oil content was reported. As reported by ANJANI (2010), oil content had lower positive and significant correlation with plant height.

Path Coefficient Analysis

Regarding to stepwise regression analysis, five traits out of studied traits was significant. Path coefficient analysis, showed the positive direct effect of predictable variables including main stem fresh weight (0.2), 10 seed weight on primary raceme (0.36), seed number on primary raceme (0.82) and hollow seed number on primary raceme (0.15) on total seed weight on primary raceme as responsible variable (Tab. 6). The maximum positive direct effects were seen in seed number on primary raceme followed by 10 seed weight on primary raceme on yield. MOSHKIN (1986) reported the highest direct effect of number of seeds per plant on seed yield. In this study, primary raceme length showed negative direct effect on yield (-0.13), while it had high positive correlation (0.62) with seed yield. Primary raceme length possessed many indirect effects via main stem fresh weight, 10 seed weight on primary raceme, seed number on primary raceme and hollow seed number on primary raceme. RAMESH *et al.* (2001) revealed that plant height up to primary spike had high direct effect on seed yield. Meanwhile, MEHTA and VASHIL (1998) found that length of main raceme had the greatest direct effect on seed yield per plant followed by number of capsules in main raceme and 100-seed weight. DEEPIKA and TUMMALA (1981) indicated that both number of capsules per primary raceme and the number of secondary branches have large positive direct effects on castor bean yield per plant. Also, the maximum indirect effect was showed by primary raceme length via seed number on primary raceme. 10 seed weight on primary raceme had not any indirect effect via seed number while this trait exhibited positive intermediate direct effect on seed yield (0.36). Thus, we can inference that direct selection of seed number on primary raceme and 10 seed weight on primary raceme and indirect selection through primary raceme length can improve castor bean seed yield.

Table 6. Direct and indirect effects of agronomic traits on total seed weight on primary raceme as yield in castor bean (Ricinus communis L.*).*

Character	Correlation coefficient	Direct effect	Indirect effect				
			X1	X2	X3	X4	X5
X1	0.62	-0.13		0.14	0.2	0.35	0.06
X2	0.54	0.20	-0.09		0.23	0.20	0.02
X3	0.46	0.36	-0.06	0.12		0.00	0.01
X4	0.88	0.82	-0.05	0.04	0.03		0.06
X5	0.43	0.15	-0.05	0.00	0.03	0.32	

X1= Primary raceme length, X2 = Main stem fresh weight, X3 = 10 seed weight on primary raceme, X4 = seed number on primary raceme, X5 = Hollow seed number on primary raceme.

CONCLUSION

To sum up, there are both positive and negative relations among studied agro-morphological traits of castor bean. The highest value of simple correlation was seen between main stem fresh weight with main stem dry weight and between secondary and tertiary branch dry weight with secondary and tertiary branch fresh weight. Using stepwise regression, five traits including primary raceme length, main stem fresh weight, 10 seed weight on primary raceme, seed number on primary raceme and hollow seed number on primary raceme had significant relation with total seed weight on primary raceme as responsible variable. The maximum positive direct effects were possessed to seed number on primary raceme followed by 10-seed weight on primary raceme suggesting that selection based on these traits could improve the total seed weight on primary raceme of castor bean.

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GENETIČKA VARIJABILNOST I ASOCIJACIJA SVOJSTAVA KOD RICINUSA (*Ricinus communis* L.)

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Izvod

Vršena su ispitivanja genetičke divergentnosti kolekcije 12 genotipova ricinusa sakupljenih iz različitih geografskih regiona Irana. Ispitivane su 32 agromorfološke osobine. Utvrđene su značajne stističke razlike između pojedinih genotipova. Utvrđena je jaka pozitivna korelacija ukupne težine semena u primarnoj cvasti kao prinosa sa brojem semena na primarnoj cvasti, dužine ženskih cvetova, primarne dužine cvasti i prečnika glavne stabljike. Analiza *Path* koeficijenta ukazuje na direktan efekat broja semena na primarnoj cvasti i prinosa semena. Direktan efekat dužine primarne cvasti je bio negativan na prinos semena.

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