Journal of Experimental Agriculture International

41(3): 1-12, 2019; Article no.JEAI.48269
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Path Coefficient Analysis of Some Prominent Agronomic Traits in Castor *(Ricinus communis* L.*)* Germplasm

Destaw Mullualem Atinafu[1*], Shiferaw Alemu Alayachew[2] and Zerihun Jida[2]

[1]Department of Applied Biology, College of Natural and Computational Sciences, Injibara University, Ethiopia.
[2]Department of Applied Biology, College of Natural and Computational Sciences, Wolkite University, Ethiopia.

Authors' contributions

This work was carried out in collaboration among all authors. Author DMA proposed the study, develop the proposal, the manuscript, techniques and all steps of the research until final submission. Author SAA designed the study, wrote the proposal, collected the data, compiled, analyzed the data, interpreted the result and wrote the first draft and the revised versions of the manuscript. Author ZJ supervised the study design, data collection and reviewed the manuscript and supervised the research activity. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v41i330401
Editor(s):
(1) Dr. Tancredo Souza, Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Portugal.
(2) Dr. Mohamed Fadel, Professor, Microbial Chemistry, Department Genetic Engineering and Biotechnology, Division National Research Center, Egypt.
Reviewers:
(1) F. J. Owuna, Usmanu Danfodiyo University, Sokoto, Nigeria.
(2) Schirley Costalonga, Universidade Federal do Espírito Santo, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/48269

Original Research Article

Received 15 February 2019
Accepted 26 April 2019
Published 28 October 2019

ABSTRACT

Background and Objective: Castor (*Ricinus communis* L.) is a diploid plant with chromosome number of 2n=20 which belongs to family of Euphorbiaceous and genus Ricinus. Correlation alone is not efficient for variability studies. So, it should be in conjugation with Path co- efficient analysis to know the direct and indirect effects. This study was conducted to assess the role of evaluating path coefficient analysis in castor.
Materials and Methods: A Field experiment was carried out to determine direct and indirect effects of yield and its components in castor accessions at Melkassa, central rift valley of Ethiopia under irrigation in 2014. The experiment was conducted using a randomized complete block design with 3 replications and a total of 48 castor accessions were evaluated.

**Corresponding author: E-mail: Destaw.mullualem@gmail.com;*

Results: Number of capsules per plant, number of primary branches per plant, length of inter node and hundred seed weight had exerted positive direct effect for both at phenotypic and genotypic path analysis.Phenotypic and genotypic path analysis showed that the number of capsules per plant, number of secondary branches per plant, length of inter node, days to 50% second flowering and seed yield exhibited positive direct effect on oil content.
Conclusion: Thus, traits like number of capsules per plant, number of secondary branches per plant, length of inter nod and days to 50% second flowering should be given emphasis in improving seed yield.

Keywords: Germplasm; melkassa; Ricinus communis; path analysis; oil content.

1. INTRODUCTION

Castor *(Ricinus communis L.*) is not important as consumption purpose for human being in Ethiopia due to the presence of ricin oleic acid in its seed oil. It is a diverse and economically important family of flowering plants in the family of *Euphorbiaceous*. It is a diploid plant with the set of chromosome numbers 2n=20 which is cultivated from lowlands to highlands [1]. Castor was initially believed to have four centers of origin: East Africa (Ethiopia), Northwest and South West Asia and Arabian Peninsula, India, and China. However, Ethiopia is believed to be the most probable center of diversity and origin because of the presence of high diversity [2]. Oil is a valuable component of a fully mature seed. Thus; the economic value of an oilseed is often related directly to its oil content. High oil content is a common goal of breeding programs in several oil crops including castor. Unlike other oilseeds that synthesize their oil in their embryo, castor seed deposits its oil in the endosperm. Therefore, the oil content of castor is greater than most oilseeds and only exceeded by coconut. In Ethiopia, the oil content of castor accessions varies from 29-58% [3]. Castor oil is non-edible and has been used almost entirely for pharmaceutical and industrial applications. Castor is a valuable oilseed crop that provides almost the entire world's supply of hydroxy fatty acids. It is used in varnish, paints, detergent, pharmaceuticals, and synthetic polymer industries. Its oil does not freeze even at high altitudes and it is one of the best lubricants for jet engines [4]. If there is genetic correlation between traits in the case of direct selection of one trait, this can cause change in another trait. Most of the time, traits are correlated and knowledge of the relationships among various quantitative and qualitative traits is an essential aid to the choice of appropriate parameters to be used as selection indices [5]. Correlation studies provide the association of quantitative characters, especially of seed yield and its attributes. Path co-efficient analysis measures the direct influence of one variable upon another and permits the separation of correlation coefficients into direct and indirect effects [6]. The polygenic inheritance of yield components makes selection more difficult. Moreover, these complex traits are highly influenced by environment, which reduces the progress to be achieved through direct selection. In such cases, there is another option to hasten the genetic improvement, which is known as indirect selection for yield. Yield, being a complex character, is composed of several components some of which affect the yield directly, while, others affect indirectly [7].

The essence of this approach is selection of elite genotypes on the basis of yield attributes rather than the yield. This selection criterion takes into account the information on interrelationship among agronomic traits, their relationship with yield as well as their direct influence on yield [8]. In Ethiopia there are adequate amount of castor genetic resource which needs repeated experiment. However, there was limited study regarding to castor and its importance. So that, by considering the knowledge of the relationships among various quantitative and qualitative traits and the breeding strategy to derive high yielding cultivar this study was conducted to assess the role of evaluating path coefficient analysis in castor.

2. MATERIALS AND METHODS

The study was conducted at Melkasa Agricultural Research Center, situated in Central Rift Valley of Oromiya region, Ethiopia during the off season under irrigation in 2014. Melkasa is located at 8^{o} 24'N , 39^{o} 12'E ,1550 m. a.s.l in the hot to warm sub- moist rift valley in the central part of the country and receives an average annual rainfall of 680 mm.

2.1 Experimental Design

Forty eight accessions of castor that were available at Melkasa Agricultural Research Centers were planted at the experimental farm of

Melkassa Research Center. Plot size was four rows spaced at 80 cm apart, 60 cm between plants and six meters long. The design of the experiment was randomized complete block design (RCBD) with three replications. The experimental plots were plowed twice and harrowed once and ridges were made at 80 cm using tractor. Seeds were planted at two seeds per holl and thinned to a single plant after growth. No fertilizer or pesticide was applied. All plots received the required irrigation every 7 days until maturity.

2.2 Data Collection

Data was collected based on an average of five randomly selected plants and plot basis. Five representative plants per plot were randomly selected from the central rows excluding the two border rows and tagged for observations.

1. **Height (PH):** The distance measured in cm from the soil surface to the tip of the top most leaf.
2. **Length of main Inflorescence (LMI):** the length of main inflorescence in cm.
3. **Number of capsules per plant (CP):** Total number of capsules per plant recorded at physiological maturity.
4. **Number of seeds per plant (SP):** The average number of seeds per plant.
5. **Number of primary branches per plant (PB):** The number of branches extending from the main stem .
6. **Number of secondary branches per plant (SB):** The number of branches extending from the primary branches that will be recorded on some randomly taken plants from each experimental unit.
7. **Number of Inflorescence per plant (IP):** The number of inflorescence counted on each randomly selected plant.
8. **Length of inter node (LIN):** the length of the inter nodes measured in cm.
9. **Days to 50% flowering (DF):** Is the number of days from planting to when about 50% of the plants on the plot produce flowers on about 50 % of their main inflorescence.
10. **Days to 50% second flowering (DSF):** Is the number of days from planting to when about 50% of the plants on the plot produce flowers on about 50% of their secondary inflorescence.
11. **Days to first maturity 50% (DFM):** The actual number of days from planting to main inflorescence maturity.
12. **Days to second maturity 50% (DSM):** The actual number of days from planting to secondary inflorescence maturity.
13. **Hundred Seed weight (HSW**): The weight of 100 seeds in grams.
14. **Oil Content (OC):** Oil content of oven dried seed as determined by the NMR.
15. **Seed yield per plot (SY):** Dry seed yield from harvestable rows of each experimental plot.

Path coefficient analysis was conducted to determine the direct and indirect effect of various traits on oil content using the general formula of [9]. In path coefficient analysis, seed yield per plant was taken as the dependent variable while the rest of the traits considered as independent variables. The direct and indirect effects of the independent traits on seed yield per plants were estimated by the simultaneous solution of the following general formula suggested by [9].

$$r_{ij} = p_{ij} + \sum r_{ik}\, p_{jk}$$

where:

r_{ij} = is the association between independent variables (i) and dependent variables (j) as measured by phenotypic and genotypic correlation coefficient.

Pij= is component of direct effect of independent variable (i) as measured by the phenotypic and genotypic path coefficient

$\sum r_{ik}\, p_{jk}$ = is the summation of components of indirect effect of a given independent variable (i) on a given dependent variable (j) via all other independent traits.

3. RESULTS

3.1 Phenotypic and Genotypic Path Coefficient Analysis of Seed Yield with Other Quantitative Traits

Path coefficient analysis was carried out both at phenotypic and genotypic levels considering seed yield as dependent character and yield attributes as independent characters. Each component has two path actions in relation to direct effect on seed yield and indirect effect through components which are not revealed by correlation studies. Relationship between yield and yield contributing characters were studied in details through path coefficient analysis. Path coefficient analysis performed to disclose the causes and effects of chain relationships of different yield contributing characters with yield [10]. Thus, specification of causes and

Table 1. Materials used for this study

Entry no.	Accessio n no.	Obtained From	Entry no.	Accession no.	Obtained From	Entry no.	Accession no.	Obtained From
1	200361	MARC	17	106559	MARC	33	200363	MARC
2	200365	MARC	18	106578	MARC	34	219619	MARC
3	200367	MARC	19	203642	MARC	35	208950	MARC
4	200370	MARC	20	208628	MARC	36	200353	MARC
5	200371	MARC	21	208630	MARC	37	203645	MARC
6	200377	MARC	22	219640	MARC	38	106550	MARC
7	200380	MARC	23	219684	MARC	39	106595	MARC
8	200381	MARC	24	200354	MARC	40	219618	MARC
9	200389	MARC	25	200355	MARC	41	203640	MARC
10	200390	MARC	26	200360	MARC	42	212871	MARC
11	200391	MARC	27	200376	MARC	43	106501	MARC
12	200393	MARC	28	200386	MARC	44	212772	MARC
13	203651	MARC	29	106594	MARC	45	106564	MARC
14	203653	MARC	30	219637	MARC	46	219689	MARC
15	208619	MARC	31	219691	MARC	47	219623	MARC
16	212989	MARC	32	200358	MARC	48	Abaro	MARC

MARC= Melkasa Agricultural Research Centers

measuring the relative importance of each of the yield components can be achieved by using the method of path analysis, as a mean of separating the direct effects from the indirect ones through other characters [11] .

Phenotypic path analysis of the direct and indirect effects revealed that number of capsules per plant (0.036),number of seeds per plant (0.271),number of primary branches per plant (0.348),number of secondary branches per plant (0.135),length of inter node (0.167),days to 50% second flowering (0.011),hundred Seed weight (0.040) had positive direct effect on seed yield.

Whereas, negative direct effect was observed for plant height (-0.205), Length of main Inflorescence (-0.042), number of inflorescence per plant (-0.114), days to 50% first flowering (-0.013), days to first maturity 50 %(-0.138), days to second maturity 50 %(-0.065), oil content (-0.006).

The genotypic path analysis of direct and indirect effects revealed that plant height (0.011), number of capsules per plant (0.117), number of primary branches per plant, (0.876), length of inter node, (0.152), days to 50% first flowering (0.211), days to second maturity (0.020), hundred seed weight (0.182) and oil content (0.297) exerted direct positive effects on fruit yield. The direct effect of length of main inflorescence (-0.223), number of seeds per plant (-0.265), number of secondary branches per plant (-0.185), number of inflorescence per plant (-0.241), days to 50% second flowering (-0.319) and days to first maturity 50 %(-0.418) were negative.

3.2 Phenotypic and Genotypic Path Analysis of Oil Content with Other Characters

Plant height (0.052), length of main inflorescence (0.105), number of capsules per plant (0.159), number of secondary branches per plant (0.142), length of inter node (0.056), days to 50% second flowering (0.094), hundred Seed weight (0.042) and seed yield (0.042) had exerted positive direct effect on oil content at phenotypic level. However, number of seeds per plant (-0.041), number of primary branches per plant (-0.078), number of inflorescence per plant (-0.312), days to 50% first flowering (-0.069) and days to second maturity 50%(-0.027) had showed negative direct effects on oil content.

The genotypic direct and indirect effect of different characters on oil content showed that length of main inflorescence (0.337), number of capsules per plant (0.218), number of seeds per plant (0.384), number of secondary branches per plant (0.017), length of inter node(0.145), days to 50% second flowering(0.373), days to first maturity 50%(0.078), days to second maturity 50%(0.406) and seed yield(0.422) had exerted positive directs effect on oil content. However, plant height (-0.233), number of primary branches per plant (-0.305), number of inflorescence per plant (-0.175), days to 50% first flowering (-0.324) and hundred seed weight (-0.121) had showed negative direct effects on oil content.

Table 2. Estimates of phenotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of traits via other independent traits on seed yield of 48 castor accessions

	PH	LMI	CP	SP	PB	SB	IP	LIN	DFF	DSF	DFM	DSM	HSW	OC	rp
PH	**-0.205**	-0.012	0.008	0.082	0.124	0.017	-0.022	0.101	0.001	-0.002	0.012	0.004	-0.005	-0.0003	0.105
LMI	-0.060	**-0.042**	0.002	0.008	0.038	0.007	-0.017	0.059	0.002	-0.003	0.024	0.016	-0.006	-0.0005	0.027
CP	-0.047	-0.002	**0.036**	0.161	0.108	0.033	-0.046	0.053	0.001	-0.001	0.014	0.012	-0.004	-0.0004	0.318
SP	-0.062	-0.001	0.022	**0.271**	0.123	0.026	-0.034	0.036	0.002	-0.002	0.026	0.017	-0.010	0.0000	0.413
PB	-0.073	-0.005	0.011	0.096	**0.348**	0.071	-0.048	0.063	0.004	-0.003	0.016	0.012	-0.005	0.0002	0.488
SB	-0.025	-0.002	0.009	0.051	0.182	**0.135**	-0.036	0.043	-0.002	-0.002	0.016	0.006	0.000	-0.0002	0.376
IP	-0.040	-0.006	0.015	0.080	0.146	0.042	**-0.114**	0.026	0.002	-0.002	0.021	0.010	-0.002	0.0012	0.180
LIN	-0.125	-0.015	0.012	0.058	0.133	0.035	-0.018	**0.167**	0.003	-0.004	0.022	0.015	-0.003	-0.0006	0.279
DFF	0.020	0.007	-0.002	-0.036	-0.099	-0.025	0.017	-0.036	**-0.013**	0.008	-0.076	-0.037	0.012	-0.0002	-0.260
DSF	0.035	0.011	-0.004	-0.046	-0.100	-0.020	0.021	-0.055	-0.010	**0.011**	-0.089	-0.038	0.010	-0.0004	-0.275
DFM	0.018	0.007	-0.004	-0.051	-0.040	-0.016	0.018	-0.026	-0.007	0.007	**-0.138**	-0.040	0.008	-0.0007	-0.264
DSM	0.014	0.010	-0.007	-0.070	-0.064	-0.012	0.018	-0.039	-0.008	0.007	-0.085	**-0.065**	0.013	0.0000	-0.288
HSW	0.025	0.007	-0.004	-0.066	-0.042	0.002	0.004	-0.013	-0.004	0.003	-0.029	-0.021	**0.040**	0.0002	-0.099
OC	-0.012	-0.004	0.002	0.000	-0.012	0.005	0.026	0.003	0.000	0.001	-0.003	0.000	-0.001	**-0.006**	-0.001

Where, PH: plant height, LMI: length of main inflorescence, CP: number of capsules per plant ,PB: number of primary branches per plant , SB: number of secondary branches per plant , LIN: length of inter node, IP: number of inflorescence per plant , DFF: Days to 50% first flowering, DSF: Days to 50% second flowering, DFM: Days to first maturity 50%, DSM: Days to second maturity 50%, SP: Number of seeds per plant, HSW: Hundred Seed weight, OC: Oil content

Table 3. Estimates of genotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of traits via other independent traits on seed yield of 48 castor accessions

	PH	LMI	CP	SP	PB	SB	IP	LIN	DFF	DSF	DFM	DSM	HSW	OC	rg
PH	**0.011**	-0.090	0.055	-0.153	0.376	-0.023	-0.059	0.106	-0.024	0.072	0.023	-0.004	-0.032	0.056	0.313
LMI	0.004	**-0.223**	0.017	-0.016	0.207	-0.020	-0.086	0.058	0.043	0.088	0.083	-0.005	-0.034	0.007	0.123
CP	0.005	-0.033	**0.117**	-0.177	0.307	-0.079	-0.090	0.082	0.003	0.029	0.056	-0.006	-0.019	0.110	0.304
SP	0.006	-0.014	0.078	**-0.265**	0.434	-0.068	-0.055	0.072	-0.040	0.075	0.082	-0.006	-0.054	0.112	0.355
PB	0.005	-0.053	0.041	-0.131	**0.876**	-0.095	-0.091	0.048	-0.071	0.097	0.023	-0.006	-0.044	0.055	0.654
SB	0.001	-0.024	0.050	-0.098	0.450	**-0.185**	-0.042	0.050	-0.037	0.048	0.050	-0.004	0.008	0.097	0.366
IP	0.003	-0.075	0.043	-0.060	0.329	-0.032	**-0.241**	0.037	-0.039	0.114	0.119	-0.006	-0.001	-0.047	0.143
LIN	0.008	-0.085	0.063	-0.125	0.278	-0.061	-0.058	**0.152**	0.040	0.102	0.080	-0.007	-0.025	0.052	0.414
DFF	-0.001	0.046	0.002	0.051	-0.295	0.036	0.045	-0.029	**0.211**	-0.265	-0.276	0.015	0.090	0.030	-0.342
DSF	-0.002	0.062	-0.011	0.062	-0.265	0.028	0.086	-0.049	0.175	**-0.319**	-0.311	0.015	0.082	0.055	-0.392
DFM	-0.001	0.044	-0.016	0.052	-0.049	0.022	0.069	-0.029	0.139	-0.237	**-0.418**	0.015	0.063	0.039	-0.308
DSM	-0.002	0.059	-0.034	0.083	-0.265	0.041	0.076	-0.055	0.161	-0.248	-0.316	**0.020**	0.066	0.039	-0.376
HSW	-0.002	0.042	-0.012	0.079	-0.213	-0.008	0.001	-0.021	0.104	-0.143	-0.144	0.009	**0.182**	-0.020	-0.147
OC	0.002	-0.005	0.043	-0.100	0.162	-0.060	0.039	0.027	0.023	-0.059	-0.054	0.003	-0.012	**0.297**	0.304

Where, PH: plant height, LMI: length of main inflorescence, CP: number of capsules per plant ,PB: number of primary branches per plant , SB: number of secondary branches per plant , LIN: length of inter node, IP: number of inflorescence per plant , DFF: Days to 50% first flowering, DSF: Days to 50% second flowering, DFM: Days to first maturity 50%, DSM: Days to second maturity 50%, SP: Number of seeds per plant, HSW: Hundred Seed weight, OC: Oil content

Table 4. Estimates of phenotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of traits via other independent traits on oil content of 48 castor accessions

	PH	LMI	CP	SP	PB	SB	IP	LIN	DFF	DSF	DFM	DSM	HSW	SY	rp
PH	**0.052**	0.031	0.037	-0.013	-0.028	0.017	-0.061	0.034	0.007	-0.016	-0.015	0.002	-0.005	0.001	0.06
LMI	0.015	**0.105**	0.007	-0.001	-0.009	0.007	-0.046	0.02	0.012	-0.024	-0.028	0.006	-0.007	0.013	0.084
CP	0.012	0.004	**0.159**	-0.025	-0.024	0.034	-0.125	0.018	0.003	-0.011	-0.016	0.005	-0.004	0.017	0.064
SP	0.016	0.003	0.095	**-0.041**	-0.027	0.027	-0.092	0.012	0.009	-0.016	-0.031	0.007	-0.01	0.02	0.000
PB	0.019	0.012	0.049	-0.015	**-0.078**	0.074	-0.131	0.021	0.019	-0.027	-0.019	0.005	-0.005	0.016	-0.035
SB	0.006	0.005	0.039	-0.008	-0.041	**0.142**	-0.098	0.015	-0.013	-0.014	-0.02	0.002	0.001	0.008	0.037
IP	0.01	0.015	0.064	-0.012	-0.032	0.044	**-0.312**	0.009	0.01	-0.017	-0.025	0.004	-0.002	0.012	-0.225
LIN	0.032	0.037	0.051	-0.009	-0.03	0.037	-0.05	**0.056**	0.015	-0.031	-0.026	0.006	-0.003	-0.011	0.117
DFF	-0.005	-0.018	-0.007	0.006	0.022	-0.026	0.047	-0.012	**-0.069**	0.07	0.09	-0.015	0.012	-0.011	0.029
DSF	-0.009	-0.027	-0.018	0.007	0.022	-0.021	0.057	-0.019	-0.051	**0.094**	0.107	-0.016	0.011	-0.011	0.074
DFM	-0.005	-0.018	-0.016	0.008	0.009	-0.017	0.048	-0.009	-0.037	0.061	**0.165**	-0.016	0.009	-0.012	0.119
DSM	-0.004	-0.025	-0.031	0.011	0.014	-0.012	0.048	-0.013	-0.039	0.055	0.101	**-0.027**	0.013	-0.004	-0.001
HSW	-0.006	-0.017	-0.017	0.01	0.009	0.002	0.012	-0.004	-0.02	0.024	0.035	-0.027	**0.042**	0.042	-0.03
SY	0.005	0.003	0.051	-0.017	-0.038	0.053	-0.056	0.016	-0.018	-0.026	-0.043	-0.009	0.042	**0.042**	**-0.001**

Where, PH: plant height, LMI: length of main inflorescence, CP: number of capsules per plant ,PB: number of primary branches per plant , SB: number of secondary branches per plant , LIN: length of inter node, IP: number of inflorescence per plant , DFF: Days to 50% first flowering, DSF: Days to 50% second flowering, DFM: Days to first maturity 50%, DSM: Days to second maturity 50%, SP: Number of seeds per plant, HSW: Hundred Seed weight, SY: Seed yield per plot

Table 5. Estimates of genotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of traits via other independent traits on oil content of 48 castor accessions

PH	PH	LMI	CP	SP	PB	SB	IP	LIN	DFF	DSF	DFM	DSM	HSW	SY	rg
	-0.233	0.135	0.102	0.222	-0.131	0.002	-0.043	0.101	0.037	-0.084	-0.004	-0.089	0.021	0.132	0.188
L MI	-0.094	**0.337**	0.032	0.024	-0.072	0.002	-0.062	0.055	-0.067	-0.103	-0.015	-0.107	0.023	0.052	0.022
CP	-0.109	0.050	**0.218**	0.257	-0.107	0.007	-0.065	0.078	-0.005	-0.034	-0.010	-0.119	0.012	0.128	0.370
SP	-0.135	0.021	0.146	**0.384**	-0.151	0.006	-0.040	0.068	0.062	-0.087	-0.015	-0.127	0.036	0.150	0.377
PB	-0.100	0.079	0.076	0.190	**-0.305**	0.009	-0.066	0.046	0.109	-0.113	-0.004	-0.123	0.029	0.276	0.185
SB	-0.028	0.036	0.094	0.142	-0.157	**0.017**	-0.031	0.048	0.056	-0.057	-0.009	-0.090	-0.005	0.154	0.327
IP	-0.057	0.113	0.081	0.087	-0.115	0.003	**-0.175**	0.035	0.060	-0.133	-0.022	-0.128	0.001	0.060	-0.160
LIN	-0.162	0.128	0.118	0.181	-0.097	0.006	-0.042	**0.145**	-0.062	-0.119	-0.015	-0.147	0.017	0.175	0.176
DFF	0.027	-0.069	0.003	-0.073	0.103	-0.003	0.032	-0.027	**-0.324**	0.310	0.051	0.311	-0.059	-0.144	0.101
DSF	0.053	-0.093	-0.020	-0.090	0.092	-0.003	0.062	-0.046	-0.269	**0.373**	0.058	0.316	-0.054	-0.165	0.185
DFM	0.013	-0.067	-0.029	-0.075	0.017	-0.002	0.050	-0.028	-0.214	0.277	**0.078**	0.306	-0.042	-0.130	0.130
DSM	0.051	-0.089	-0.064	-0.120	0.092	-0.004	0.055	-0.052	-0.248	0.290	0.059	**0.406**	-0.043	-0.159	0.133
HSW	0.041	-0.063	-0.022	-0.114	0.074	0.001	0.001	-0.020	-0.159	0.167	0.027	0.177	**-0.121**	-0.062	-0.068
SY	-0.073	0.043	0.066	0.136	-0.200	0.006	-0.025	0.060	0.111	-0.146	-0.024	-0.150	0.018	**0.422**	0.304

Where, PH: plant height, LMI: length of main inflorescence, CP: number of capsules per plant ,PB: number of primary branches per plant , SB: number of secondary branches per plant , LIN: length of inter node, IP: number of inflorescence per plant , DFF: Days to 50% first flowering, DSF: Days to 50% second flowering, DFM: Days to first maturity 50%, DSM: Days to second maturity 50%, SP: Number of seeds per plant, HSW: Hundred Seed weight, SY: Seed yield per plot

Table 6. Phenotypic correlation (above diagonal) and genotypic correlation (below diagonal) of yield and yield related 15 quantitative traits of 48 castor accessions grown at Melkassa in 2014 during the off season

	PH	LMI	CP	SP	PB	SB	IP	LIN	DFF	DSF	DFM	DSM	HSW	SY	OC
PH	**1.000**	0.295**	0.230**	0.304**	0.357**	0.122*	0.194	0.609**	-0.096	-0.168*	-0.089	-0.069	-0.120	0.105	0.060
LMI	0.402**	**1.000**	0.042	0.029	0.110	0.052	0.146	0.355**	-0.168*	-0.257**	-0.172*	-0.241**	-0.158	0.027	0.084
CP	0.469**	0.149	**1.000**	0.594**	0.310**	0.242**	0.399**	0.321**	-0.047	-0.114	-0.098	-0.192*	-0.106	0.318*	0.064*
SP	0.578**	0.062	0.669**	**1.000**	0.354*	0.189**	0.295**	0.215**	-0.133	-0.168*	-0.187*	-0.257**	-0.245**	0.413**	0.000
PB	0.429 **	0.236	0.350*	0.495**	**1.000**	0.523**	0.419**	0.381**	-0.284**	-0.288**	-0.116	-0.185*	-0.120	**0.488****	-0.035
SB	0.122	0.106	0.430**	0.370**	0.514**	**1.000**	0.314**	0.261**	0.186*	-0.149	-0.119	-0.086	0.012	0.376**	0.037
IP	0.244	0.355**	0.372**	0.227	0.376**	0.176	**1.000**	0.159	-0.149	-0.184*	-0.154	-0.155	-0.039	0.180*	-0.225**
LIN	0.697**	0.380**	0.540**	0.471**	0.317*	0.331*	0.241	**1.000**	-0.216**	-0.332**	-0.156*	-0.233**	-0.077	0.279**	0.117
DFF	-0.114	0.206	0.015	0.192	-0.337*	-0.174	-0.185	0.192	**1.000**	0.744**	0.547**	0.570**	0.293**	-0.260**	0.029
DSF	-0.226	-0.276	-0.090	0.234	0.303*	-0.152	-0.357*	-0.320*	0.831**	**1.000**	0.647**	0.583**	0.258**	-0.275**	0.074
DFM	-0.054	-0.198	-0.133	0.195	0.056	-0.119	-0.285*	-0.191	0.659**	0.743**	**1.000**	0.616**	0.212*	-0.264**	0.119
DSM	-0.219	-0.264	0.294*	-0.314*	0.302*	-0.223	-0.315	-0.363*	0.766**	0.778**	0.755**	**1.000**	0.320**	-0.288**	-0.001
HSW	-0.178	-0.187	0.102	0.299*	0.244	0.045	-0.005	-0.138	0.492**	0.449**	0.344*	0.360**	**1.000**	-0.099	-0.030
SY	0.313**	0.123	0.304**	0.355*	**0.654****	0.366*	0.143*	0.414**	-0.342*	0.392**	0.308*	-0.376**	-0.147	**1.000**	-0.001
OC	0.188	0.022	0.370**	0.377**	0.185	0.327*	0.160	0.176	0.101	0.185	0.130	0.133	0.068	0.304*	**1.000**

***and* indicate significant differences at 1% and 5%, respectively*

Where: PH: plant height, LMI: length of main inflorescence, CP: number of capsules per plant , SP: Number of seeds per plant, PB: number of primary branches per plant , SB: number of secondary branches per plant, IP: number of inflorescence per plant , LIN: length of inter node, DFF: Days to 50% first flowering, DSF: Days to 50% second flowering, DFM: Days to first maturity 50%, DSM: Days to second maturity 50%, HSW: . Hundred Seed weight, SY: Seed yield per plot, OC: Oil content

4. DISCUSSION

4.1 Phenotypic and Genotypic Path Coefficient Analysis of Seed Yield with Other Quantitative Traits

Correlation, indicated by a correlation coefficient, is a measure of a linear association between traits. So, correlation is the baseline for explanation of path coefficient analysis. As the correlation coefficients are insufficient to explain true relationship for an effective manipulation of the characters, path coefficients were worked out. This work is continuous from the existing data from [4]. (Table 6) was correlation works for this data which is important to perform path analysis. This (Table 6) showed that both correlation and path analysis confirmed that number of primary branches per plant was the key contributors of seed yield with maximum direct effects. It is to mean that primary branches per plant was highly and positively correlated (0.488**) at phenotypic level and (0.654**) genotypic level (Table 6). In the case of path analysis again primary branches per plant had exerted the highest positive effects phenotypic path analysis (0.348, Table 2) and genotypic path analysis (0.876 Table 3) that is why primary branches per plant were the key contributors. According to the result reported by [12] primary branches per plant were contributed direct positive effect on seed yield which was in agreement with this study. The positive direct effect of days to 50% second flowering (0.011)and capsules per plant(0.036) at the phenotypic path analysis level with seed yield in this study (Table 2) was in agreement with [13]. Eventhough the value is not exactly similar positive direct effect was recorded in both cases. The positive values for days to 50% flowering (0.166) and capsules per plant (0.441) were reported by [13]. The direct effects of these characters on seed yield indicated that, improvement on these traits will increase seed yield.

Whereas the negative value as observed in (Table 2) indicates that the contribution of these traits for seed yield was reduced. A negative direct value recorded from days to 50% flowering (-0.013) in this study was analogous with the study of [14] (-0117). Even though traits like plant height had exerted negative direct effect on seed yield, it had positive indirect effects *via* number of primary branches per plant. Number of primary branches per plant showed the highest positive direct effects (0.348) on seed yield and exerted positive indirect effect through traits like number of secondary branches per plant, Days to maturity, oil content, days to first flower and number of capsules per plant (Table 2). The residual (0.601) indicated that characters which are included in the phenotypic path analysis explained 99.39% of the total variation in seed yield. The residual effect implies that the unexplained variation of the dependent variable that is not accounted by path coefficient analysis. (Table 2).

At the genotypic path analysis level with seed yield also, the direct positive value indicates that the true relationship between these traits as good contributors to seed yield and could be considered as most important components for selection in breeding program for higher seed yield (Table 3). As a result, these traits could be considered as important traits for selection in a breeding program for higher seed yield of the Castor advanced lines. These finding were in agreement with the result reported by [13] who observed direct positive effects on days to 50% first flowering (0.568), number of capsules per plant (0.540) and oil content (0.222).They also reported negative direct effects on days to first maturity 50 %(-0.016).However, number of seeds per plant (0.434), number of secondary branches per plant (0.450) (Table 3)contributed to seed yield mainly via their highest and positive indirect effects with number of primary branches per plant. The positive direct effect of seed yield with plant height (0.011), days to maturity (0.02) and 100- seed weight (0.182) (Table 3) in this study were in line with the study of [14] with the observed values of plant height (0.027), days to maturity (0.08) and 100- seed weight(0.06) in the study of previous authors. Howe ever, negative direct values recorded from days to % flowering (-0117) in their study was disagreement with the present study. The direct positive effect of plant height with seed yield was also in line with the study reported by [10]. The residual (0.311) indicated that characters which included in this genotypic path analysis explained (99.69%) of the total variation in seed yield (Table 3).

The significant positive relationship between seed yield and oil yield suggests that this trait tend to produce higher oil yield. This finding was in agreement with the result which was reported by [15] seed yield (0.092), hundred seed weight (0.373). But, traits like days to first maturity contributed indirect positive effects for number of seeds per plant, number of primary branches per plant and number of inflorescence per plant. The residual (0.87) indicated that characters which are included in the phenotypic path analysis explained 99.13% of the total variation in oil content (Table 4).From the results obtained (Table 4) and (Table 5) it would be reasonable to suggest that a breeder engaged in the improvement of castor oil yield should give emphasis on common traits like length of main inflorescence, days to maturity, capsules per plant, secondary branches per plant, length of inter node and seed yield. Selection for these traits will therefore increase oil yield. The observed values of plant height (-0.233), number of primary branches per plant (-0.305), number of inflorescence per plant (-0.175), days to 50% first flowering (-0.324) and hundred seed weight (-0.121) had showed negative direct effects on oil content (Table 5).Similar results were obtained by[15] for plant height (-0.136) and days to maturity (0.071).The residual (0.57) indicated that characters which are included in the phenotypic path analysis explained 99.430% of the total variation in oil content(Table 5).

5. CONCLUSIONS AND RECOMMENDATIONS

In this study the result of path coefficient analysis of seed yield with other quantitative traits showed that number of primary branches per plant had exerted the highest direct positive effects both at the genotypic(0.348) and phenotypic(0.876) levels. Therefore, path analysis confirmed that number of primary branches per plant was the key contributors of seed yield with maximum direct effects. Whereas, path analysis of oil content with other characters showed that seed yield (0.422) had exerted the highest direct positive effects. For further improvement of castor breeding program, there should be more than one location for clear information of variability studies of this oil seed crop and since the study was done in the off seasons, it is suggested to undertake the experiment in both dry season and during the main season. Awareness creation for different research institutions and farmers is also vital order to get the required benefit from this oilseed crop. Doing this experiment both at phenotypic level and molecular level by using molecular marker is the important one.

6. SIGNIFICANCE STATEMENT

This study provides basic information for this oil seed crops to evaluate its variability. Since correlation alone is inadequate to generate important information for the genetic resource of castor in Ethiopia, it is vital to guide those researches in different institutions as a base line. The study of its phenotypic variability along with path analysis plays a great role for those interested researchers to do further by showing the right path they would like to do since a lot has not been done about the path analysis of castor seed yield and its oil content. It also indicates direction for further improvement.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Goodarzi FR, Darvishzadeh A, Hassani , Hassanzaeh A. Study on genetic variation in Iranian castor bean (*Ricinus communis* L.) accessions using multivariate statistical techniques. Journal of Medicinal Plants Research. 2012;6:1160-1167.
2. Anjani K. Castor genetic resources: A primary gene pool for exploitation. J .Ind. Crops Prod. 2012;35:1–14.
3. MARC (Melkassa Agriculture Research Center).2011, Progress Report for the Period; 2010.
4. Destaw M, Getinet A, Yohannes Pand Shiferaw A. Phenotypic variability and association of traits among yield and yield-related traits in Castor (*Ricinus communis L*.) accessions at Melkassa, Central Rift Valley of Ethiopia. African Journal of Agricultural Research. 2017;12:3562-3568.
5. Abimiku OE, Azagaku ED and Ndor E. Genetic Variability and Correlation Studies in Some Quantitative Characters in Castor (*Ricinus cummunis*. L) Accessions. Asian Journal of Agricultural Sciences. 2012;4: 368-372.
6. Dapke JS, Naik MR, Singh AP, Baraskar VV, Narwade AV, Indivar Prasad. Genetic association yield with different agronomic traits in castor (*Ricinus communis* L.) International Journal of Biology Research; 2016.
7. Baldaniya JD, Kale BH, Mungra KS, Patel HN,Lad MD, Chauhan DA. Genetic variability, correlation and path analysis for morphological and quality traits in pigeonpea [*Cajanus cajan* (L.) Millsp.]. International Journal of Chemical Studies. 2018;6(5):2584-2587;6(5). [ISSN: 2349–8528]
8. Singh MA, Tomar CN, Mishra , Srivastava SBL. Genetic parameters and character

association studies in Indian mustard. Journal of Oilseed Brassica. 2011;2:35-38.
9. Dewey DR, KH Lu. A correlation and path coefficient analysis of components of Crested wheat grass seed production. Agronomy J. 1959;51:515-518.
10. Dhedhi KK, Ghelani YH, Joshi HJ , Dangaria CJ. Correlation and Path Co-Efficient Analysis in Castor (Ricinus Communis L.) Over Environments. Junagadh Agricultural University, Jamnagar-361 006, India. Agric. Sci. Digest. 2010;30:286-289.
11. Ibrahim AH, Abdalla E , Abdel R, Naim M. Path Coefficient and Selection Indices in Sixteen Guar (Cyamopsis Tetragonoloba L.)Genotypes under Rain-fed. International Journal of Agriculture and Forestry. 2012; 2:79-83.
12. Patel JK, Nakarani DB. Character association and path analysis in castor (*Ricinuscommunis* L.). International Journal of Agricultural Sciences; 2016. DOI:10.15740/HAS/IJAS/12.1/22-27
13. Tewari N, Mishra A. Correlation and Path Coefficient Analysis of Castor (*Ricinus communis* L.) in non-traditional area of central Uttar Pradesh. International Journal of Genetic Engineering and Biotechnology. 2013;4:1-9.
14. Dapke JS, Naik MR, Singh AP, Baraskar VV, Narwade AV, Indivar P. Genetic association yield with different agronomic traits in castor (*Ricinus communis* L.). International Journal of Biology Research. 2016;1(1):47-49. [ISSN: 2455-6548]
15. Adeyanju AO, Usman A, Mohammed SG. Genetic Correlation and Path- Coefficient Analysis of Oil Yield and its Components in Castor. Libyan Agriculture Research Center Journal International. 2010;1:60-64.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/48269