ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Path-coefficient analysis of seed yield and its components in linseed (*Linum usitatissimum* L.) - A review

*** Bhima Sen Naik[1], Janakinath Dash[2] and Uma Ballav Mohapatra[3]**

1. Orissa University of Agriculture and Technology- Chiplima Campus, Regional Research and Technology Transfer Station, Chiplima, Sambalpur-768 025, Odisha, India .
2. Nayagarh Autonomous College, Nayagarh-752 069, Odisha, India.
3. Government of Odisha - Science and Technology Department, Bhubaneswar-751 001, Odisha, India.

Manuscript Info

Manuscript History:

Received: 14 January 2016
Final Accepted: 25 February 2016
Published Online: March 2016

Key words:
Components of seed yield, linseed, oil flax, path analysis, seed yield

***Corresponding Author**

Bhima Sen Naik.

Abstract

In this article we have reviewed the works on path coefficient analysis of seed (grain) yield and yield contributing characters in linseed under normal sown, late sown and soil stress conditions. The dependent variable was seed yield, and independent variables were yield contributing characters such as days to 50% flowering, days to maturity, plant height, technical height, tiller number, number of primary and secondary branches, number of capsules, number of seeds per capsule or plant, 100 or 1000- seed weight, etc. Under normal sown condition, mostly number of capsules is the trait that has very high or high positive direct effect on seed yield across different sets of plant genetic resources and environments conferring it to be the most important selection criterion for improvement of seed yield. Under late sown condition, basing on different plant materials number of capsules is the most promising selection criterion for improvement of seed yield. Path analysis work under soil stress condition is inadequate.

Introduction:-

Linseed or oil flax (*Linum usitatissimum* L., 2n= 30, X = 15) belongs to the order Malpighiales, the family Linaceae, and the tribe Lineae. It is popularly known as *atasi, pesi, phesi* or *tisi* in Odia. It is the second most important winter oilseed crop and stands next to rapeseed-mustard in area and production in India. Although linseed plants have several utilities, it is commercially cultivated for its seed, which is processed into oil and after extraction of oil, a high protein livestock feed is left. Linseed oil content varies from 33-45% and has been used for centuries as a drying oil. About 20% of the total linseed oil produced in India is used by the farmers and the rest about 80% goes to industries for the manufacture of paints, varnish, oilcloth, linoleum, printing ink etc.

Linseed has an important position in Indian economy due to its wide industrial utility. But, the national average productivity of linseed is quite low. As per FAOSTAT (2014), India ranks 4th among world's linseed producing countries. However, in terms of productivity, India (392 kg/ha) is far below than Switzerland (2647 kg/ha), Tunisia (2633 kg/ha), U.K. (2600 kg/ha), France (2121 kg/ha) and New Zealand (1853 kg/ha). In India, during 2013-14 linseed is grown in an area of 292.1 thousand hectares with annual production of 141.2 thousand tonnes and productivity of 484 kg/ha. Out of 15 linseed growing states, the major are Madhya Pradesh (110.4 thousand ha), Maharashtra (31.0 thousand ha), Chhattisgarh (26.2 thousand ha), Uttar Pradesh (26.0 thousand ha), Jharkhand (25.5 thousand ha), Odisha (22.9 thousand ha) and Bihar (18.7 thousand ha). In Odisha, the annual production is 11 thousand tonnes with productivity of 478 kg/ha (Anonymous, 2015a, b).

The ultimate criterion of productivity in an oilseed crop is the oil yield, which depends on seed yield and oil content. Although improvement in oil content is possible, there appears to be much greater scope of increasing seed yield potential. Yield, however, is a polygenically controlled complex character and is determined by a number of multiplicative character components, which are also quantitatively inherited. The primary objective of linseed breeder is to increase the seed yield. Generally, yield represents the final character resulting from many developmental and biochemical processes which occur between germination and maturity. Before yield improvement can be realized, the linseed breeder needs to identify the cause of variability in seed yield and acquire information on the nature and magnitude of variation in the available materials in any given environment, since fluctuations in environment generally affects yield through its components. Knowledge of heritability and genetic advance of the characters is a pre-requisite for the improvement through selection. The study of correlation among the traits is important for assessing the feasibility of joint selection of two or more traits. Positive correlation between two desirable traits makes the job of the plant breeder easy for improving both traits simultaneously. On the other hand, negative correlation expressed between two desirable traits makes it impossible to achieve a significant improvement in both the traits. However, simple correlation does not give an insight into the true biological relationship of these traits with seed yield. The path coefficient analysis developed by Wright (1921,1960) and described by Dewey and Lu (1959), which is a standardized partial regression analysis, allows partitioning of correlation coefficient into direct and indirect effects of various traits (independent variables) towards dependent variable (seed yield), and thus helps in assessing the cause effect relationship as well as effective selection. If the correlation between the seed yield and a character is due to the direct effect of the character, it shows the true relationship between them. So, selection can be focused on this character to improve seed yield. If the correlation is due to indirect effect of the character through another component trait, the selection would be based on later trait through which indirect effect is exerted. Equipped with such information, a linseed breeder can devise more precise and effective breeding programme. Considerable research on this aspect has been done, and the researchers have emphasized the importance of different traits for improvement seed yield, that has been reviewed below.

Path coefficient analysis:-

The concept of path coefficient analysis was originally developed by Wright (1921), but the technique was first used for plant selection by Dewey and Lu (1959). Several studies including perennial grasses (Dewey and Lu, 1959; Das *et al*., 2004; Wu *et al*., 2006) have demonstrated that partitioning correlation coefficients into direct and indirect effects provides more useful information. In linseed, this technique was first applied by Badwal *et al*. (1970). Subsequently, a number of workers did path coefficient analyses of seed yield and its components in linseed with different sets of plant genetic resources and agro-climatic environments. They studied seed yield as dependent variable, and component characters of seed yield as independent variables such as days to 50% flowering, days to maturity, plant height, technical height, tiller number, number of primary and secondary branches, number of capsules, number of seeds per capsule or plant, 100 or 1000- seed weight, etc. While reviewing, the path coefficient values are re-casted following the scale of Lenka and Mishra, 1973 (0.00 to 0.09 = negligible, 0.10 to 0.19 = low, 0.20 to 0.29 = moderate, 0.30 to 0.99 = high, >1.00 = very high) wherever possible. As it is more precise and accurate to estimate path-coefficients based on genotypic correlations, mostly the genotypic path coefficient analyses have been discussed depending upon availability of information.

Under normal sown conditions:-

A. Number of capsules with positive direct effect:-

Genotypic path coefficients were worked out by Badwal et al. (1970) to determine the true components of a complex character like yield. Capsule number, 1000-seed weight, tiller number and primary branches were found to have high magnitude of positive correlations with seed yield. An examination of the path coefficients revealed that capsule number had very high direct effect on seed yield. The other characters like l000-seed weight, plant height and days to 50 % flowering, in addition to high direct effect, also influenced the yield through capsule number per plant. Tiller number and primary branches influenced the yield mainly through capsule number. It is concluded that capsule number and l000-seed weight are the major factors which directly contribute to seed yield. These characters, therefore, are important selection criteria for linseed improvement.

Chandra (1978) worked out path coefficients and showed that capsule number and 1000-seed weight had the highest direct effect on seed yield.

Kumar and Chauhan (1979) examined the relationships of seed yield with other characters by path coefficient analysis. Number of branches per plant, number of capsules per plant and 1000-seed weight had large positive direct effects on yield, while plant height and tiller number had negative direct effects. Seeds per capsules had very little direct effect on yield but it had large negative indirect effect on yield through 1000-seed weight. This indicated that number of branches per plant, number of capsules per plant and 1000-seed weight were the major yield determining characters.

The genotypic path coefficient analysis indicated moderate positive direct effect of number of branches per plant, high positive direct effect of number of capsules per plant, very high positive direct effect of seeds per capsule and high positive direct effect of 1000- seed weight on seed yield. Seed yield is negatively associated with the 1000-seed weight. This would mean that it is not possible to select for large seed weight without affecting the number of seeds per capsule. The capsules are borne on secondary and tertiary branches and therefore, larger numbers of secondary and tertiary branches are important in the model plant type (Patil *et al.* 1980).

Analysis of the association among yield and its components by Kapoor and Chawla (1983) in twenty varieties of linseed showed that number of capsules per plant and 1000-seed weight *h*ad large direct effect on seed yield, while plant height and tiller numbers had large indirect effects through capsules per plant.

Path analysis studies revealed that number of capsules followed by secondary branches and 1000-seed weight were the major components influencing seed yield. Selection indices based on primary branches, secondary branches, number of capsules, 1000-seed weight and seed yield per plant were 203.83 % superior to direct selection for seed yield (Rao and Singh, 1983).

At genotypic level, both capsules per plant and seeds per capsule had high positive direct effects on seed yield and their indirect effects *via* other characters were negligible. Seed weight and days to flowering had low and moderate positive direct effect on seed yield respectively while days to maturity showed high negative direct effect on seed yield. Thus yield improvement can be achieved through selection for more capsules per plant, more seeds per capsule and moderate seed weight accompanied with synchronous flowering and early maturity (Satapathi *et al* (1987).

Path coefficient analysis at genotypic level by Muduli and Patnaik (1994) revealed very high positive direct effect of capsules per plant, and high positive direct effect of seeds per capsule and 1000-seed weight on seed yield. However, 1000-seed weight had high negative indirect effect *via* capsules per plant and seeds per capsule leading to highly significant negative correlation with seed yield. So, capsules per plant and seeds per capsule are the major components determining seed yield, and they should be improved for improving seed yield.

Mirza *et al*. (1996) partitioned the association of yield components with yield into direct and indirect effects, through path coefficient analysis and observed that days to flowering, capsules per plant and harvest index had the highest positive direct effect on seed yield.

Mahto and Mahto (1997) reported high positive direct effect of number of capsules per plant, number of primary branches per plant, days to maturity, days to 50% flowering, plant height and number of secondary branches per plant on seed yield. Number of capsules per plant and number of primary branches per plant had a highly significant positive association with seed yield and in multiple regression equation 68.59 % contribution to seed yield per plant; it revealed their importance. Hence, they must be taken into consideration while making a programme for linseed improvement.

Path analysis for 13 yield and quality influencing characters was worked out. Seed yield per plot showed a positive and significant genotypic correlation with number of capsules per plant, number seeds per capsule, 100-seed weight and oil content. The genotypic associations of seeds per capsule and 100-seed weight with seed yield per plot were positive and significant but they had direct negative path towards seed yield per plot. Days to flowering and plant height had negative genotypic correlation with seed yield per plot but they had a positive direct effect towards seed yield per plot. For reliable selection index, number of capsules per plant and oil content were the characters of prime importance (Rashid *et al*., 1998).

Mahto and Rahaman (1998) worked out the direct and indirect effects of different characters using path coefficient analysis in respect of seed yield at phenotypic level. The results revealed high positive direct effect of number of capsules per plant, and low positive direct effect of number of primary branches and number of secondary branches per plant. It may be mentioned that these characters also indicated highly significant positive correlation both at genotypic and phenotypic levels. This suggests true relationship of these characters with seed yield. From the above results it may be suggested that a linseed breeder should lay greater emphasis on capsules per plant and number of branches per plant as selection criteria for seed yield.

Mishra and Yadav (1999) in a study for partitioning correlation with yield into direct and indirect effects indicated that seeds per plant and capsules per plant had a high positive direct effect on seed yield.

Path coefficient analysis revealed that number of capsules per plant had the greatest direct effect on seed yield. It is concluded that number of capsules per plant is the most important selection criterion for linseed yield improvement followed by 1000-seed weight (Tolba, 2000).

Chimurkar *et al*. (2001) in a correlation coefficient study using 43 genotypes indicated that yield improvement could be achieved by selection for number of primary branches per plant and number of capsules per plant either directly or indirectly.

Yadav (2001) in a study of partitioning association of twelve quantitative traits with yield by path coefficient analysis showed that the number of capsules per plant exhibited the greatest direct positive effects on seed yield per plant followed by 1000-seed weight, harvest index and plant height.

Genotypic path coefficient analysis revealed high positive direct effect of number of seeds per capsule, moderate positive direct effect of number of capsules per plant and low positive direct effect of 1000-seed weight on seed yield. Therefore, improvement of seed yield in the material is possible by using appropriate breeding strategy through selection for number of seeds per capsule, number of capsules per plant and 1000-seed weight (Akbar *et al*., 2001).

Akbar *et al*. (2003) found very high positive direct effect of number of capsules per plant, high positive direct effect of plant height, and low positive direct effect of 1000-seed weight and number of branches per plant on seed yield at genotypic level.

Sarkar (2005) observed at phenotypic level large positive direct effect of number of capsules per plant,1000-seed weight and seeds per capsules. A close examination of all the direct and indirect effects of the component traits of yield indicated the presence of enough scope for yield improvement through selection for more number of capsules per plant, seeds per capsule and moderate seed weight with synchronous flowering and early maturity.

Copur *et al.* (2006) reported phenotypically high positive direct effect of number of capsules per plant, and low positive direct effect of plant height, number of primary branches and 1000-seed weight on seed yield. According to these findings, breeding for high yielding linseed varieties, number of capsules should be considered firstly followed by plant height, number of primary branches and 1000-seed weight.

Rao (2007) observed very high positive direct effect of number of capsules per plant, and high positive direct effect of 1000-seed weight and number of seeds per capsule on seed yield at genotypic level. The association of these characters with seed yield was also positive indicating the importance of these traits for improving seed yield. In the present study, number of secondary branches per plant, capsules per plant and 1000-seed weight having high heritability and moderate to high genetic advance, positive correlation with high direct effects could be considered as selection criteria for improving seed yield in linseed.

Path coefficient analysis identified biological yield per plant, number of capsules per plant, harvest index and test weight as important components having direct effects, and number of seeds per capsule and number of capsules per plant *via* biological yield per plant showed indirect effects on seed yield (Kant *et al*., 2008).

The main source of plant seed yield variation in order of relative importance was the direct effect of number of capsules per plant (33.15 % and its negative joint effect with seed index (16.35 %) followed by its joint effect with number of fruiting branches per plant (12.65 %) and its joint effect with length of fruiting zone (3.07 %). Hence, number of capsules per plant totally contributes seed yield per plant by 49.2 % out of 98.27 % total contribution of the four traits fractionated in this study (Ottai *et al*., 2011).

Path analysis revealed high positive direct effect of capsule number and primary branch per plant, plant height and 1000-seed weight on seed yield. To breed high yielding oil flax varieties, capsule number per plant, primary branch per plant, plant height and 1000-seed weight should firstly be considered (Rahimi *et al.* 2011).

Gauraha and Rao (2011) found high positive direct effect of number of capsules per plant on seed yield at genotypic level. The number of primary branches per plant showed low positive direct effect and number of secondary branches per plant, number of seeds per plant and 1000-seed weight exhibited moderate direct effect towards seed yield per plant. Path coefficient analysis revealed the importance of number of capsules per plant as major yield contributing component in linseed. Hence, direct selection for the number of capsules per plant, number of primary branches per plant, number of secondary branches per plant, number of seeds per plant and 1000-seed weight may ultimately lead to the development of high yielding linseed genotypes.

Savita *et al*. (2011) reported high positive direct effect of number of capsules per plant, number of total branches per plant, 1000-seed weight and number of primary branches per plant on seed yield per plant at genotypic level.

Tewari et al. (2012) observed high positive direct effect of capsules per plant, seeds per capsule and 1000-seed weight on seed yield. It is concluded that capsules per plant and seeds per capsule should be given due consideration during selection programme for higher seed yield of linseed.

Pali and Mehta (2013) found high positive direct effect of number of capsules per plant at genotypic level.

Path coefficient analysis revealed that direct and indirect effects of genotypic path coefficients were higher in magnitude than the corresponding phenotypic path coefficients. Number of capsules per plant showed a high and positive direct effect on seed yield (Iqbal *et al.,* 2013).

Path coefficient analysis revealed that direct and indirect effects of genotypic path coefficients were higher in magnitude than the corresponding phenotypic path coefficients. Number of capsules per plant showed high positive direct effect on seed yield (Reddy *et al*.2013).

Tariq *et al*. (2014) observed high positive direct effect of number of capsules per plant and l000-seed weight, moderate positive direct effect of number of seeds per capsule, and low positive direct effect of number of primary branches per plant and plant height on seed yield at genotypic level. Thus, breeding for high seed yielding cultivars of linseed, number of capsules per plant should be kept in mind firstly followed by 1000-seed weight, number of seeds per capsule, number of primary branches per plant and plant height.

Phenotypic path analysis indicated that number of capsules per plant exhibited high positive direct effect on seed yield signifying the importance of this trait while selecting for improvement of seed yield of linseed (Rajanna *et al*., 2014).

Genotypic path coefficient analysis indicated that number of capsules per plant and 1000-seed weight showed high positive direct effect on seed yield per plant. These traits having positive direct effect on seed yield can be considered as suitable selection criteria for evolving high yielding linseed varieties (Tewari and Singh, 2014).

In a path analysis study, Singh and Tewari (2015) found positive direct effect of number of capsules per plant, 100-seed weight, plant height, number of seeds per capsule and number of primary branches per plant on seed yield. So, for breeding of high seed yielding cultivars of linseed, number of capsules per plant should be kept in mind firstly followed by 100-seed weight, plant height, number of seeds per capsule and number of primary branches per plant.

B. Others with positive direct effect:-

Chawla and Singh (1983) observed high positive direct effects of biological yield and harvest index on seed yield at genotypic level. Though number of capsules per plant had negligible positive direct effect, it increased manifold *via* biological yield and harvest index leading to highly significant correlation.

Singh and Mahto (1994) partitioned the correlation coefficient into direct effect of each component and its indirect effect *via* other yield components. The results indicated very high positive direct effect of straw yield, and high positive direct effect of technical height and harvest index on seed yield.

Khan and Gupta (1995) carried out genotypic path coefficient analysis of seed yield and observed high negative direct effect of plant height and high positive direct effect of days to maturity and 1000-seed weight. The number of capsules per plant had negligible positive direct effect on seed yield but moderate and high positive indirect effect *via* plant height and days to maturity, respectively. Thus, reduced plant height, and increased days to maturity and 1000-seed weight are the major yield contributing characters and selection for these characters in most of the breeding programmes would be effective for yield improvement.

In a genotypic path coefficient analysis Malik and Singh (1995) found biological yield to have very high positive direct effect on seed yield per plot. Again, it emerged as the single most important trait to influence seed yield per plot directly as well as indirectly.

Pal *et al*. (2000) while partitioning character association of four yield components with yield in 18 linseed genotypes observed that plant height exhibited negative direct effect on seed yield.

Awasthi and Rao (2005) in a genotypic path coefficient analysis reported very high positive direct effect of number of seeds per plant, high positive direct effect of 100-seed weight, moderate positive direct effect of number of primary branches per plant and low positive direct effect of number of secondary branches per plant on seed yield. The negative direct effect on seed yield was observed in number of capsules per plant, number of seeds per capsule, plant height, days to maturity and days to 50%. Thus, in order to increase seed yield, attributes like number of seeds per plant, 100-seed weight, number of primary branches per plant and number of secondary branches per plant seem to be more important.

Path coefficient analysis revealed that 1000-seed weight exhibited highest direct effect on seed yield per plant followed by harvest index and days to flowering. Indirect effect of harvest index on seed yield *via* 1000-seed weight was positive and more than that of direct effect (Nagaraja *et al*., 2009).

Path analysis indicated that harvest index and biomass were the main determinants of yield per plot at both Sinana and Robe. Analysis over locations also supported that harvest index and biomass are the main determinant of seed yield per plot (Tadesse *et al.*, 2009)

Path coefficient analysis revealed that harvest index exhibited highest positive direct effect on seed yield per plant followed by number of branches per plant. Indirect effects of number of branches per plant and number of capsules per plant *via* harvest index was positive, but indirect effect was more than that of the direct effect on seed yield (Dandigadasar *et al*., 2011).

Phenotypic path coefficient analysis revealed very high positive direct effect of dry matter of capsules and biological yield, and high positive direct effect of harvest index, dry matter of branches, dry matter of main stem and dry matter of leaves on seed yield per plant, and selection for these characters would lead to increase in yield (Sinha and Wagh, 2013).

Path coefficient analysis revealed that harvest index followed by biological yield per plant and plant height emerged as most important indirect yield components. They may be considered in formulating selection strategy in linseed for developing high yielding varieties (Chaudhary *et al*., 2014).

Path coefficient analyses at phenotypic level revealed that biological yield per plot had the greatest positive direct effect on seed yield per plot in both the seasons. Selection for biological yield per plot followed by capsules per plant and seeds per capsule would be the most effective means of indirectly selecting for higher seed yield (Paul *et al*., 2015).

Under late sown conditions:-

The North Central Plateau Zone of Odisha comprising the districts of Mayurbhanj and Keonjhar contributes to about 50.6 % of the total linseed area of the state of Odisha (Anonymous, 2015b). However, a significant number of farmers are forced to sow linseed one month late due to excess moisture in the field. Seed setting is highly affected due to higher temperature during later phase of growth decreasing seed yield significantly (Dash *et al*., 2011). So, the crop was sown about one month late and evaluated.

Partitioning genotypic correlation into direct and indirect effects (Naik and Satapathy, 2002) showed very high positive direct effect of number of capsules per plant followed by high positive direct effects of number of seeds per capsule and 1000-seed weight, and moderate positive direct effect of number of primary branches per plant. The high positive direct effect of number of seeds per capsule was reduced remarkably by its negative indirect effects *via* number of capsules and number of primary branches per plant. The ultimate correlation of number of seeds per capsule with seed yield turned to negative and non-significant. The moderate positive direct effect of number of primary branches per plant increased manifold mainly by its high positive indirect effect *via* number of capsules per plant resulting in significant correlation with the seed yield. However, number of capsules and primary branches per plant are the most promising selection criteria for improvement of seed yield on the basis of genotypic coefficient of variation (GCV), heritability in broad sense (H), genetic advance, correlation and path coefficient analysis.

Dash *et al*. (2011) observed very high positive direct effects of number of capsules per plant and number of seeds per capsule; high positive direct effects of 1000-seed weight and number of primary branches per plant on seed yield at genotypic level. The positive direct effect of number of primary branches per plant increased manifold mainly by its high positive indirect effect *via* number of capsules per plant resulting in highly significant positive correlation with seed yield. Basing on GCV, genetic advance, correlation and path coefficient analysis, number of capsules and primary branches per plant are the most promising selection criteria for improvement of seed yield.

At the genotypic level, very high positive direct effects of days to 50% flowering, numbers of capsules per plant and 1000-seed weight were found. The direct effect of days to 50% flowering was increased by its very high positive indirect effect *via* number of capsules per plant and number of seeds per capsule. Again, the direct effect of number of capsules per plant was also increased by its very high positive indirect effect *via* days to 50% flowering. The direct effect of 1000-seed weight was increased by its very high positive indirect effect *via* number of seeds per capsule. On the basis of genotypic coefficient of variation (GCV), heritability in broad sense (H), genetic advance, correlation and path coefficient analysis, for improvement of seed yield the selection criteria should be more days to 50% flowering and higher number of capsules per plant with moderate 1000-seed weight (Dash *et al*., 2016).

Under soil stress conditions:-

Singh (1980) worked out path coefficients in linseed varieties for sodic soil (pH 9.1 and ESP 24) as well as for normal soil conditions to determine the true components of a complex character like yield. Path coefficients revealed that days to 50 % flowering and plant height had very high and high direct effect on yield, respectively under sodic soil conditions but plant height had negative direct effect on yield in normal soil conditions. In sodic soil conditions tiller number per plant and capsule number per plant exerted a negative direct effect on yield but influenced the yield via days to 50 % flowering and 100 seed weight. The positive correlation between 100-seed weight and yield in sodic soil conditions was mainly due to its indirect effect via plant height, tiller number per plant, capsule number per plant and days to maturity. Days to maturity had high and negative direct effect on yield under both the soil conditions.

Conclusion:-

Under normal sown condition, mostly number of capsules is the trait that has very high or high positive direct effect on seed yield across different sets of plant genetic resources and environments conferring it to be the most important selection criterion for improvement of seed yield. Under late sown condition, basing on different plant materials number of capsules is the most promising selection criterion for improvement of seed yield. Path analysis work under soil stress condition is inadequate. So, in a new environment and plant materials tentatively number of capsules may be considered as selection criterion for improvement of seed yield under normal and late sown conditions till detailed character association study is carried out.

References

1. Akbar, M., Khan, N.I. and Sabir, K.M. (2001): Correlation and path coefficient studies in linseed. On line J. Biol. Sci., 1 (6): 446-447.
2. Akbar, M., Mahmood, T., Anwar, M., Ali, M., Shafiq, M. and Salim, J. (2003): Linseed improvement through genetic variability, correlation and path coefficient analysis. Int. J. Agric. Biol., 5 (3): 303-305.
3. Anonymous (2015a): Annual Report 2014-15, All India Coordinated Research Project on Linseed, Project Coordinating Unit (Linseed), C. S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, pp.269.
4. Anonymous (2015b): Odisha Agriculture Statistics 2013-14, Directorate of Agriculture and Food Production, Bhubaneswar, Odisha, India,pp.65.

5. Awasthi, S.K. and Rao, S.S. (2005): Selection parameters for yield and its components in linseed (*Linum usitatissimum* L.). Indian J. Genet., 65 (4): 323-324.
6. Badwal, S.S., Gill, K.S. and Singh, H. (1970): Path coefficient analysis of seed yield in linseed. Indian J. Genet., 30 (3): 551-556.
7. Chandra, S. (1978): Studies of interrelationship between seed yield and its components in some exotic strains of linseed (*Linum usitatissimum*). Acta Agron. Hung., 27: 7 4-80.
8. Chaudhary, M., Verma, P.N., Shweta, Rahul, V.P., Singh, V. and Chauhan, M.P. (2014): Character association and path coefficient analysis for seed yield and oil content in linseed (*Linum usitatissimum* L.). Trends Biosci., 7(10): 879-882.
9. Chawla, B.K. and Singh, P. (1983): Associations among agronomical and quality traits in linseed (*Linum usitatissimum* L.*).* Madras Agric. J., 70 (4): 228-232.
10. Chimurkar, H.C., Patil, S. and Rathod, D.R. (2001). Character association studies in linseed. Annals Plant Physiol., 15 (1): 72-76.
11. Copur, O., Gur, M.A., Karakus, M. and Demirel, U. (2006). Determination of correlation and path analysis among yield components and seed yield in oil flax varieties (*Linum usitatissimum* L.). J. Biol. Sci., 6 (4): 738-743.
12. Dandigadasar, B., Tattimani, M., Danaraddi, C.S., Biradar, S.B. and Dandagi, M.R. (2011): Genetic variability, correlation and path analysis in linseed (*Linum usitatissimum* L.). Asian J. Bio Sci., 6(2): 218-222.
13. Das, M.K., Fuentes, R.G. and Taliaferro, C.M. (2004): Genetic variability and trait relationships in switchgrass. Crop Sci., 44: 443-448.
14. Dash, J., Naik, B.S. and Mohapatra, U.B. (2011): Path coefficient analysis for seed yield in linseed (*Linum usitatissimum* L.) under late sown conditions. J. Oilseeds Res., 28 (1): 45-47.
15. Dash, J., Naik, B.S. and Mohapatra, U.B. (2016): Variability, *correlation* and path-coefficient analysis in linseed (*Linum usitatissimum* L.) under late sown conditions in the north central plateau zone of Odisha in India. Int. J. Adv. Res., 4 (1): 799-811.
16. Dewey, D.R. and Lu, K.H. (1959): A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J., 51: 515-518.
17. FAOSTAT (2014): http://faostat3.fao.org
18. Gauraha, D. and Rao, S.S. (2011): Association analysis for yield and its characters in linseed (*Linum usitatissimum* L.). Res. J. Agric. Sci., 2 (2): 258-260.
19. Iqbal, J., Hussain, F., Ali, M., Iqabl, M.S. and Hussain, K. (2013): Trait association of yield and yield components of linseed (*Linum usitatissimum* L.). Int. J. Mod. Agric., 2(3): 114-117.
20. Kant, R., Chauhan, M.P., Srivastava, R.K. and Maurya, K.N. (2008): Correlation and path coefficient analysis of seed yield and yield components of linseed (*Linum usitatissimum* L.). Int. J. Pl. Sci., 3(2): 323-325.
21. Kapoor, C.J. and Chawla, B.K. (1983): Genetic parameters and associations among yield and yield components in linseed. Madras Agric. J., 70 (6): 401-403.
22. Khan, M.N. and Gupta, S.C. (1995): Character association and path analysis in linseed. J. Oilseeds Res., 12 (2): 309-311.
23. Kumar, S and Chauhan, B.P.S. (1979): Association analyses in the segregating populations of linseed. Indian J. Genet., 39 (3): 506-510.
24. Lenka, D. and Mishra, B. (1973): Path coefficient analysis of yield in rice varieties. Indian J.Agric. Sci.**,** 43: 376-379.
25. Mahto, C. and Rahaman, M.H. (1998): Correlation and path analysis of some quantitative characters in linseed. J. Oilseeds Res., 15 (2): 348-351.
26. Mahto, R.N. and Mahto, J.L. (1997): Correlation, regression and path coefficient analysis in rainfed linseed. Madras Agric. J., 84 (2): 84-86.
27. Malik, B.P.S. and Singh, S. (1995): Genetic variability, correlation and path analysis in linseed. J.Oilseeds Res., 12 (1):1-4.
28. Mirza, S.H. and Daulotun, N. and Islam, S. (1996): Genetic studies of interrelationships between seed yield and its components in linseed. Bangladesh J. Bot., 25 (2): 197-200.
29. Mishra, A.K and Yadav, L. N. (1999): Genetic parameters and association analysis in linseed. Indian J. Agric. Res., 33 (2): 113- 118.
30. Muduli, K.C. and Patnaik, M.C. (1994): Character association and path coefficient analysis in linseed (*Linum usitatissimum* L.). Orissa J. Agric. Res., 7 (Suppl.): 6-11.
31. Nagaraja, T.E., Ajit, K.R. and Golasangi, B.S. (2009): Genetic variability, correlation and path analysis in linseed. J. Maharashtra Agric. Univ., 34 (3): 282-285.
32. Naik, B.S. and Satapathy, P.C. (2002): Selection strategy for improvement of seed yield in late sown linseed. Res. Crops, 3 (3): 599-605.
33. Ottai, M.E.S., Al-Kordy, M.A.A. and Afiah, S.A. (2011): Evaluation, correlation and path coefficient analysis among seed yield and its attributes of oil flax (*Linum usitatissimum* L.) genotypes. Australian J. Basic Appl. Sci., 5 (11): 252-258.

34. Pal, S.S., Gupta, T.R. and Singh, I. (2000): Genetic determination of yield in linseed. Crop Improv., 27 (1): 109-110.
35. Pali, V. and Mehta, N. (2013): Studies on genetic variability, correlation and path analysis for yield and its attributes in linseed (*Linum usitatissimum* L.). Pl. Arch., 13 (1): 223-227.
36. Patil, V.D., Makne, V.G. and Chaudhari, V.P (1980): Association analysis in linseed. Indian J.Genet., 40 (1): 235-237.
37. Paul, S., Bhateria, S. and Kumari, A. (2015): Genetic variability and interrelationships of seed yield and yield components in linseed (*Linum usitatissimum* L.). SABRAO J. Breed. Genet., 47(4): 375-383.
38. Rahimi, M.M., Zarei, M.A. and Arminian, A. (2011): Selection criteria of flax (*Linum usitatissimum* L.) for seed yield, yield components and biochemical compositions under various planting dates and nitrogen. Afr. J. Agric. Res., 6 (13): 3167-3175.
39. Rajanna, B., Biradar, S.A. and Ajithkumar, K. (2014): Correlation and path coefficient analysis in linseed (*Linum usitatissimum* L.). The Bioscan (Suppl. Genet. Pl. Br.), 9(4): 1625-1628.
40. Rao, S.K. and Singh, S.P. (1983): Analysis of yield factors in segregating populations and their implications in selection of flax (*Linum usitatissimum* L.). Canadian J. Genet. Cytol., 25(5): 495-501.
41. Rao, S.S. (2007): Genetic variability and path analysis for seed yield in linseed, *Linum usitatissimum* L. J. Oilseeds Res., 24 (1): 190-192.
42. Rashid, M., Gilani, M.M. and Khan, F.A. (1998): Path coefficient analysis of some yield and quality influencing characters in linseed (*Linum usitatissimum* L.). J. Animal Pl. Sci., 8 (3-4): 103-106.
43. Reddy, M.P., Reddy, B.R., Arsul, B.T. and Maheshwari, J.J. (2013): Character association and path coefficient studies in linseed. Int. J. Curr. Microbiol. App. Sci., 2 (9): 250-254.
44. Sarkar, T.K. (2005): Genetic variability and character association in linseed (*Linum usitatissimum* L.). M.Sc.(Ag.) Thesis, Orissa University of Agriculture & Technology, Bhubaneswar, Odisha, India.
45. Satapathi, D., Mishra, R.C. and Panda, B.S. (1987): Variability, correlation and path coefficient analysis in linseed. J. Oilseeds Res., 4: 28-34.
46. Savita, S.G., Kenchanagoudar, P.V., Parameshwarappa, K.G. and Rudranaik, V. (2011): Correlation and path coefficient analysis for yield and yield components in linseed (*Linum usitatissimum* L.) germplasm. Karnataka J. Agric. Sci., 24 (3): 382-386.
47. Singh, A. and Tewari, N. (2015): Predictors of linseed improvement identified through correlation and path coefficient analysis. Curr. Adv. Agric. Sci., 7(2): 114-116.
48. Singh, K.N. (1980): Path analysis in linseed under sodic conditions. Indian J. Genet. , 40 (2): 385-387.
49. Singh, S.N. and Mahto, J. L. (1994): Path coefficient analysis in linseed. J. Oilseeds Res., 11 (1): 115-117.
50. Sinha, S. and Wagh, P. (2013): Genetic studies and divergence analysis for yield, physiological traits and oil content in linseed. Res. J. Agric. Sci., 4(2): 168-175.
51. Tadesse, T., Singh, H. and Weyessa, B. (2009): Correlation and path coefficient analysis among seed yield traits and oil content in Ethiopian linseed germplasm. Int. J. Sustain. Crop Prod., 4 (4): 8-16.
52. Tariq, M.A., Hussain, T., Ahmad, I. Saghir, M., Batool, M. and Safdar, M. (2014): Association analysis in linseed (*Linum usitatissimum* L.). J. Biol. Agric. Healthcare, 4(6): 60-62
53. Tewari, N. and Singh, A. (2014): Genetic architecture of yield contributing traits in linseed (*Linum usitatissimum* L.). J. Oilseeds Res., 31(2): 167-169.
54. Tewari, N., Singh, N. and Shweta (2012): Selection parameters for seed yield and its components in linseed (*Linum usitatissimum* L.). Curr. Adv. Agric. Sci., 4(2): 149-151.
55. Tolba, A.M. (2000): Effect of gamma radiation on some characters of flax (*Linum usitatissimum* L.). Annals Agric. Sci. (Cairo), 45(1): 215-227.
56. Wright, S. (1921): Correlation and causation. J. Agric. Res., 20: 557-587.
57. Wright, S. (1960): Theory of path coefficient and regression; alternative or complementary concepts. Biometrics, 16: 189-202.
58. Wu, Y.Q., Taliaferro, C.M., Martin, D.L., Goad, C.L. and Anderson, J.A.(2006): Genetic variability and relationships for seed yield and its components in Cynodon accessions. Field Crops Res., 98: 245-252.
59. Yadav, R.K. (2001): Association studies over locations in linseed characters and its variability in different environments. J. Agric. Sci., 140 (3): 283-296.