Journal of Oilseed Brassica, 14 (2) : 142-147, July 2023

Correlation and path analysis in Indian mustard (*Brassica juncea* L) for morpho-physiological traits in early maturing genotypes

Ajay Pal Yadav[1*], Bhagirath Ram[2], Hariom Kumar Sharma[2], Bhupendra Singh Yadav[3], Mahipal Yadav[4]

[1]*Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj 211007, Uttar Pradesh, India*
[2]*ICAR-Directorate of Rapeseed-Mustard Research Bharatpur 321303, Rajasthan, India*
[3]*MJRP College of Agriculture, Jaipur 302019, Rajasthan, India*
[4]*College of Agriculture, SKN Agriculture University, Jobner 303328, Jaipur, Rajasthan, India*
**Corresponding author: shineajay@gmail.com*
(Received: 31 May 2023; Revised: 18 June 2023; Accepted: 29 June 2023)

Abstract

Thirty advanced progenies along with three check varieties of Indian mustard (*Brassica juncea*) were evaluated during *Rabi* 2019-20. The analysis of variance showed significant difference among genotype for all the characters. High estimate of heritability coupled genetic advance as percentage of mean was observed for 1000-seed weight, siliqua per plant and seed yield per plant. Medium heritability with medium genetic advance as percentage of mean was observed for water retention capacity of leaves, membrane stability index and secondary branches per plant. Correlation coefficient reflected that seed yield per plant showed positive and significant association with primary branches per plant (0.83), excised-leaf water loss (0.52), secondary branches per plant (0.52), siliqua per plant (0.44), days to 50 % flowering (0.35), main shoot length (0.32) and plant height (0.24). Path coefficient at genotypic level studied that secondary branches per plant (0.28), water retention capacity of leaves (0.21), main shoot length (0.19), excised-leaf water loss (0.15), days to maturity (0.09), primary branches per plant (0.08), siliqua per plant (0.07) had positive direct effect on seed yield per plant was observed. Thus, morphological and physiological characters confer the potentiality of particular genotype and association with yield is suitable for genotype selection.

Keywords: *Genotypes, correlation, Indian mustard, membrane stability index, path analysis, relative water content*

Introduction

Indian mustard [*Brassica juncea* (L) Czern & Coss] belongs to the family Cruciferae. Cytologically, *B. juncea* is an amphidiploid (2n=36) derived from interspecific cross of *B. nigra* (2n=16) and *B. rapa* (2n=20). Mustard is the major *Rabi* oilseed crop of India. Hall (1992) studied that most sensitive stage is flowering for temperature stress damage probably due to vulnerability during pollen development, anthesis and fertilization it will reduce crop yield. High temperature in *Brassica* enhanced plant development and caused flower abortion with appreciable loss in seed yield (Rao *et al*., 1992). High temperature prevailing at the time of sowing reduces seed germination and causes seedling mortality, resulting in poor crop stand and reduced seed yield (Azharudheen *et al.*, 2013). Wide variations in diurnal soil temperatures ranging from 28°C to 56°C at the surface and from 33°C to 37°C at 300 mm depth were observed in Rajasthan (Gupta, 1986). The correlation coefficient is a measure of the degree of association between two traits worked at the same time (Steel and Torrie, 1984). Based upon genotypic and phenotypic correlations, the breeder would be able to decide the breeding method to be used to exploit the desirable and break the undesirable associations. In such situation path coefficient analysis developed by Wright (1921) put forward the real importance of such characters of partitioning the correlation coefficient in to direct as well as indirect effects. Therefore, this study was designed to assess the correlation and path analysis for early maturing genotypes in the Indian mustard germplasm. Thermotolerant genotypes identified in the study would have important bearing on *Brassica* breeding programmes.

Materials and Methods

Thirty genotypes of Indian mustard were evaluated in a complete randomized block design with three replications under heat stress conditions at ICAR-Directorate of Rapeseed-Mustard Research, (DRMR) Bharatpur during 2019-20. Each genotype was grown in a plot of three rows, each row consisting with 5-meter length and plant to plant distance were maintained at 15 cm by thinning after 15-20 days of sowing. A fertilizer dose of 40:40:40 kg/ha (N: P_2O_5: K_2O) was applied at the time of sowing and 40 kg N/

ha was top dressed 3 days after first irrigation. Standard agronomic practices were followed to raise a good crop. Five competitive plants were randomly selected at the time of maturity (except the days to 50 per cent flowering and days to maturity which were recorded on plot basis) from each plot to record the following observations, i.e. plant height (cm), primary branches per plant, secondary branches per plant, main shoot length (cm), siliquae per plant, siliqua length (cm), seeds per siliqua, seed yield per plant, 1000-seed weight (g), days to 50% flowering, days to maturity, relative water content (%), membrane stability index (%), excised leaf water loss (%) and water retention capacity of leaves (%). The membrane stability index (MSI) was determined following the method of Premachandra *et al*. (1990) as modified by Sairam (1994). Leaf stripes (0.2 g) of uniform size were placed in test tubes containing 10 ml of double distilled water in two sets. Test tubes in one set were kept at 40°C in a water bath for 30 min and electrical conductivity of the water containing the sample was measured (C1) using a conductivity bridge. Test tubes in the other set were incubated at 100°C in boiling water in water bath for 15 min and electrical conductivity was measured as above (C2). The MSI was calculated using the following formula: MSI (%) = [1- C1/ C2] × 100

For determining excised-leaf water loss (ELWL), the leaves were weighed at three stages viz. immediately after sampling (fresh weight); after drying in an incubator at 28°C and 50 % relative humidity for 6 h; and after oven drying for 24 h at 70°C as suggested by Clarke, (1987). The ELWL was calculated using the following formula: ELWL (%) = [Fresh weight – Weight after 6 h) / (Fresh weight- Dry weight] × 100

The samples for relative water content (RWC) were also weighed immediately to obtain fresh weight (FW); 2 cm leaf sections were floated in distilled water for 4 h, blot-dried and weighed to obtain turgid weight (TW). The 2.0 cm leaf sections were oven dried at 60°C for 24 h and weighed to obtain dry weight (DW). The RWC was calculated using the formula of Barrs (1968): RWC (%) = [FW – DW) / (TW- DW] × 100

The water retention capacity of leaves (WRCL) was estimated by the method proposed by Ashraf and Ahmad (1998). The genotypic and phenotypic correlation coefficients were calculated from the phenotypic and genotypic components of variances and covariance as described by Singh and Choudhary (1985) and the estimation of direct and indirect effects was calculated by the path coefficients analysis as suggested by Wright (1921) and as elaborated by Dewey and Lu (1959) at both phenotypic and genotypic levels.

Results and Discussion

The analysis of variance showed significant difference among genotypes for all the characters (Table 1 and 2). The MSI (17.4) showed maximum genotypic coefficient of variation followed by siliquae per plant (16.1), seed yield per plant (15.3), WRCL (13.3), secondary branches per plant (12.2) (Table 3). The genotypic coefficient of variation was low for RWC (3.3). In all cases phenotypic coefficient of variation was higher than genotypic coefficient of variation. Heritability estimates were high for most of the characters. However, heritability estimates (broad sense) was maximum for 1000-seed weight (61.4), siliqua length (61.0), seed yield per plant (59.0), plant height (57.5) and siliquae per plant (56.7). Expected genetic advance as percent mean was maximum for siliquae per plant (25.0), MSI (24.3), seed yield per plant (24.2), WRCL (18.7) and secondary branches per plant (15.8).

Correlation studies were also great interest for plant breeders in determining the traits which are correlated with main breeding objectives. The genotypic and phenotypic correlations between the fourteen characters are also summarized (Table 4) at 1 % and 5 % significant level. The seed yield showed positive and significant associated with primary branches per plant (0.83), ELWL (0.52), secondary branches per plant (0.52), siliquae per plant (0.44), days to 50 % flowering (0.35), main shoot

Table 1: Analysis of variance (ANOVA) for morpho-physiological characters of Indian mustard

Source of variation	d.f.	Mean square							
		Days to 50 % flowering	Plant height (cm)	Primary branches	Secondary branches	Main shoot length (cm)	Siliquae / plant	Siliqua Length (cm)	Seeds per Siliqua
Replication	2	9.5	17.7	1.2	0.7	1.0	917.5	0.6	0.1
Treatment	29	23.1 **	124.4 **	0.6 **	10.1 **	25.6 **	7319.8 **	0.4 **	2.1 **
Error	58	4.6	24.6	0.4	3.4	11.4	1485.4	0.5	0.6

* and ** denotes significant at 5 % and 1 % level of significance, respectively

Table 2: Analysis of variance (ANOVA) for morpho-physiological characters of Indian mustard

Source of	d.f.	Mean square							
		Days to maturity	Seed yield per plant (g)	1000 seed weight (g)	Days to maturity	Relative water content (%)	Membrane stability index (%)	Excise leaf water loss (%)	Water retention capacity of leaves(%)
Replication	2	147.4	1.3	0.2	147.4	74.6	886.1	115.6	203.0
Treatment	29	316.8 **	50.9 **	0.9 **	316.8 **	44.2 *	217.3 **	8.6 **	83.7 **
Error	58	151.0	9.6	0.1	151.0	22.5	61.5	4.7	23.0

* and ** denotes significant at 5 % and 1 % level of significance, respectively

Table 3: Genetic variability of morpho-physiological characters of Indian mustard

Characters	Heritability (%)	Genotypic coefficient of variations	Phenotypic coefficient of variations	Genetic advance	Genetic advance as % of means
Days to 50% flowering	35.6	4.8	8.0	2.7	5.9
Plant height (cm)	57.5	3.5	4.6	9.0	5.5
Primary branch	8.7	3.8	12.8	0.1	2.3
Secondary branch	39.6	12.1	19.3	1.9	15.8
Main shoot length (cm)	28.7	3.6	6.7	2.4	3.9
Siliquae per plant	56.6	16.1	21.4	68.4	25.0
Siliqua length (cm)	61.0	7.8	10.0	0.5	12.6
Seeds per siliqua	46.7	5.3	7.7	0.9	7.4
Days to maturity	49.4	5.2	7.4	10.4	7.6
Seed yield per plant (g)	59.0	15.2	19.9	5.8	24.2
1000 seed weight (g)	61.4	10.5	13.4	0.7	16.9
RWC (%)	24.3	3.2	6.6	2.7	3.3
MSI (%)	45.7	17.4	25.7	10.0	24.3
ELWL (%)	21.5	6.0	13.0	1.0	5.8
WRCL (%)	46.8	13.3	19.4	6.3	18.7

length (0.32) and plant height (0.24), while a negative value of genotypic correlation was observed for siliqua length (-0.46), MSI (-0.41) and seeds per siliqua (-0.24). Plant height had positive and significant associated with secondary branches per plant (0.92), primary branches per plant (0.85), siliquae per plant (0.56), 1000-seed weight (0.34) and WRCL (0.34), where as a negative value of genotypic correlation was recorded with ELWL (-0.34) and MSI (-0.24). The phenotypic correlation coefficients among fifteen characters of thirty genotypes in Indian mustard have been presented in Table 4. The phenotypic correlation coefficient was in general similar in direction but high in magnitude then that of genotypic correlation coefficient. At phenotypic level, the seed yield per plant showed significant positive correlation with primary branches per plant (0.32), secondary branches per plant (0.42), siliquae per plant (0.41), siliqua length (0.32), main shoot length (0.24) and ELWL (0.26). Utilizing of different genotypes in Indian mustard, the results made by Mahla *et al*. (2003), Khan *et al*. (2014), Verma *et al*. (2016), Priyamedha *et al*. (2018), Chaurasiya *et al*. (2019).

The estimates of direct and indirect effects of different character on seed yield per plant have been presented in Table 5. A perusal of data revealed that secondary branches per plant (0.28), WRCL (0.20), main shoot length (0.19), ELWL (0.15), days to maturity (0.08), primary branches per plant (0.07) and siliquae per plant (0.07) had positive direct effect on seed yield per plant. The maximum negative direct effect on seed yield per plant was observed for siliqua length (-0.37), RWC (-0.23), seeds per siliqua (-0.14), 1000-seed weight (-0.10), plant height (-0.09), days to 50% flowering (-0.05) and MSI (-0.03). Thus, direct selection for secondary branches per plant, WRCL, main shoot length and ELWL will result in improvement of seed yield per plant. Because, other component characters correlated response in component characters will automatically be obtained. The present investigation

Table 4 Correlation between different morpho-physiological traits of Indian mustard (genotypic and phenotypic)

Characters		Seed yield per plant (g)	Plant height (cm)	Primary branch	Secondary branch	Main shoot length (cm)	Siliquae per plant	Siliqua length (cm)	Seeds per siliqua	1000 seed Weight (g)	Days to 50% flowering	Days to maturity	RWC (%)	MSI (%)	ELWL (%)	WRCL (%)
Seed yield per plant (g)	rg	1.00														
	rp	1.00														
Plant height (cm)	rg	0.24*	1.00													
	rp	0.15	1.00													
Primary branch	rg	0.83**	0.85**	1.00												
	rp	0.32**	0.42**	1.00												
Secondary branch	rg	0.52**	0.92**	0.37**	1.00											
	rp	0.42**	0.49**	0.62**	1.00											
Main shoot length (cm)	rg	0.32**	0.14	-0.15	0.12	1.00										
	rp	0.24*	0.36**	0.31**	0.16	1.00										
Siliquae per plant	rg	0.44**	0.56**	0.70**	0.76**	0.26*	1.00									
	rp	0.41**	0.40**	0.44**	0.75**	0.24*	1.00									
Siliqua length (cm)	rg	-0.46**	-0.16	-0.48**	-0.12	-0.11	-0.20	1.00								
	rp	-0.31**	0.00	-0.09	-0.01	-0.02	-0.07	1.00								
Seeds per siliqua	rg	-0.24*	0.17	-0.03	0.11	-0.27**	-0.06	0.27*	1.00							
	rp	-0.15	0.15	0.15	0.12	0.11	0.07	0.15	1.00							
1000 seed Weight (g)	rg	-0.15	0.34**	0.27*	0.03	-0.23*	-0.27*	-0.18	0.27**	1.00						
	rp	-0.12	0.08	0.10	0.03	-0.15	-0.17	-0.11	0.13	1.00						
Days to 50% flowering	rg	-0.04	0.12	-0.39**	-0.22*	-0.06	-0.25*	-0.47**	0.45**	0.61**	1.00					
	rp	-0.03	0.15	0.13	0.05	-0.04	0.03	-0.08	0.26*	0.19	1.00					
Days to maturity	rg	0.35**	-0.11	0.23*	0.07	-0.37**	-0.22*	0.05	-0.13	-0.04	0.04	1.00				
	rp	0.19	-0.03	0.18	0.17	-0.13	0.07	0.01	-0.09	0.12	0.04	1.00				
RWC (%)	rg	-0.12	0.03	-0.25*	0.15	0.29**	0.251*	-0.57**	0.19	0.18	0.13	-0.39**	1.00			
	rp	-0.14	0.10	0.09	0.00	0.13	0.04	-0.20	0.13	0.08	-0.04	-0.17	1.00			
MSI (%)	rg	-0.41**	-0.24*	-0.22*	-0.33**	-0.15	-0.16	-0.17	0.23*	0.15	0.41**	-0.11	-0.07	1.00		
	rp	-0.08	-0.06	-0.16	-0.19	0.07	-0.16	-0.07	0.07	-0.10	0.08	-0.20	-0.07	1.00		
ELWL (%)	rg	0.52**	-0.34**	0.19	0.06	0.37**	0.10	-0.14	0.09	-0.09	0.14	0.32**	0.07	-0.53**	1.00	
	rp	0.26*	-0.15	0.05	0.12	0.15	0.15	0.02	0.10	-0.12	0.07	0.23*	0.04	0.00	1.00	
WRCL (%)	rg	0.19	0.34**	0.19	0.31**	0.00	0.34**	-0.12	0.40**	0.32**	0.06	0.01	0.47**	-0.34**	0.20	1.00
	rp	0.11	0.32**	0.05	0.16	0.02	0.17	0.13	0.20	0.15	0.09	-0.10	0.15	-0.09	0.08	1.00

* and ** denotes significant at 5 % and 1 % level of significance, respectively

Table 5: Path analysis of different morpho-physiological traits of Indian mustard (genotypic)

Characters	Direct effect	Plant height (cm)	Primary branch	Secondary branch	Main shoot length (cm)	Siliquae per plant	Siliqua length (cm)	Seeds per siliqua	1000 seed weight (g)	Days to 50% flowering	Days to maturity	RWC (%)	MSI (%)	ELWL (%)	WRCL (%)	R with seed yield per plant
Plant height (cm)	-0.10	-0.10	0.03	0.14	0.07	0.03	0.00	-0.02	-0.01	-0.01	0.00	-0.02	0.00	-0.02	0.07	0.15
Primary branch	0.08	-0.04	0.08	0.17	0.06	0.03	0.04	-0.02	-0.01	-0.01	0.02	-0.02	0.00	0.01	0.01	0.32
Secondary branch	0.28	-0.05	0.05	0.28	0.03	0.05	0.00	-0.02	0.00	0.00	0.02	0.00	0.01	0.02	0.03	0.42
Main shoot length (cm)	0.19	-0.04	0.02	0.05	0.19	0.02	0.01	-0.02	0.02	0.00	-0.01	-0.03	0.00	0.02	0.00	0.24
Siliquae per plant	0.07	-0.04	0.03	0.21	0.05	0.07	0.03	-0.01	0.02	0.00	0.01	-0.01	0.01	0.02	0.04	0.41
Siliqua length (cm)	-0.37	0.00	-0.01	0.00	0.00	-0.01	-0.37	-0.02	0.01	0.00	0.00	0.05	0.00	0.00	0.03	-0.32
Seeds per siliqua	-0.15	-0.02	0.01	0.03	0.02	0.01	-0.05	-0.15	-0.01	-0.01	-0.01	-0.03	0.00	0.02	0.04	-0.15
1000 seed Weight (g)	-0.11	-0.01	0.01	0.01	-0.03	-0.01	0.04	-0.02	-0.11	-0.01	0.01	-0.02	0.00	-0.02	0.03	-0.12
Days to 50% flowering	-0.05	-0.02	0.01	0.02	-0.01	0.00	0.03	-0.04	-0.02	-0.05	0.00	0.01	0.00	0.01	0.02	-0.03
Days to maturity	0.09	0.00	0.01	0.05	-0.03	0.01	0.00	0.01	-0.01	0.00	0.09	0.04	0.01	0.03	-0.02	0.19
RWC (%)	-0.24	-0.01	0.01	0.00	0.02	0.00	0.07	-0.02	-0.01	0.00	-0.02	-0.24	0.00	0.01	0.03	-0.14
MSI (%)	-0.03	0.01	-0.01	-0.05	0.01	-0.01	0.03	-0.01	0.01	0.00	-0.02	0.02	-0.03	0.00	-0.02	-0.08
ELWL (%)	0.15	0.02	0.00	0.03	0.03	0.01	-0.01	-0.01	0.01	0.00	0.02	-0.01	0.00	0.15	0.02	0.26
WRCL (%)	0.21	-0.03	0.00	0.05	0.00	0.01	-0.05	-0.03	-0.02	0.00	-0.01	-0.04	0.00	0.01	0.21	0.11

Residual are 0.53

confirm the reports suggested by several workers in Indian mustard i.e. Patel *et al.* (2000), Lal *et al.* (2011), Lodhi *et al.* (2013), Khan and Amjad (2014), Singh *et al.* (2017) and Priyamedha *et al.* (2018). Holland (2006) observed that genetic correlations between traits are due to linkage and/ or pleiotropy. He also emphasized the relative efficiency of correlations in indirect selection of traits. The present finding indicated that since the traits are highly correlated, correlations-based selection may be practiced for indirect selections for higher seed yield potential (Ojaghi and Akhundova 2010). Ram *et al.* (2015) reported that the RWC showed significant negative correlation with ELWL (r= -0.39) under heat stress condition. To bring out the improvement in yield direct selection for seed yield per plant has been the most common method used by plant breeders in the self-pollinated crop. However, it is possible to achieve the selection efficiency for yield even by indirect selection especially. If secondary characters are highly correlated with yield and is easily measurable. Kumar *et al.* (1994) suggested that improvement of complex character such as yield might be accomplished through component breeding.

Conclusion

Considering the above, our findings it may concluded that improvement in the characters like primary branches per plant, siliquae per plant, days to maturity, main shoot length, days to maturity, main shoot length could be helpful in improving seed yield per plant in the Indian mustard directly and also indirectly.

References

Ashraf M and Ahmad MM. 1998. Relationship between water retention capability and osmotic adjustment in sorghum (*S. bicolor*) grown under drought stress. *Arid Soil Res Rehab* **12**: 255-262.

Azharudheen TPM, Yadava DK, Singh N, Vasudev S and Prabhu KV. 2013. Screening Indian mustard (*B. juncea*) germplasm for seedling thermo-tolerance using a new screening protocol. *Afr J Agric Res* **8**: 4755-4760.

Barrs HD. 1968. Determination of water deficits in plant tissues. In: TT Kozolvski (ed) Water deficits and plant growth, Vol 1, *Academic Press*, New Delhi 235-368.

Chaurasiya JP, Singh M and Tomar P. 2019. Genetic variability, heritability, genetic advance and character association of Indian mustard (*B. juncea*). *J Oilseed Brassica* **10**: 80-86.

Dewey DR and Lu KH. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron J* **51**: 515-518.

Hall AE. 1992. Breeding for heat tolerance. *Plant Breed Rev* **10**: 129-168.

Holland JB. 2006. Estimate genotypic correlations and their standard errors using multivariate restricted maximum likelihood estimated with SAS Proc MIXED. *Crop Sci* **46**: 642-654.

Khan Tahira, Rasid Abdul, Amjad MA and Muhammad. 2014. Seed yield improvement in mustard (*B. juncea*) viz genetic parameters, heritability, genetic advance, correlation and path coefficient analysis. *Int J Agric Innov Res* **3**: 727-731.

Kumar PR, Singh R and Mishra AK. 2004. Rapeseed-mustard. In: Dhillon BS, Tyagi RK, Saxena S, Agrawal A (eds) Plant Genetic Resource: Oilseed and Cash Crops., Narosa publishing House, New Delhi, India. 20-44.

Kumar S and Sangwan RS. 1994. Genetic variability, heritability, genetic advance in *Brassica spp*. under dry land conditions. *Agric Sci Dig* **14**: 172-176.

Lal Mohan, Singh DP and Bagadi DL. 2011. Path coefficient analysis of yield components in Indian mustard (*B. juncea*). *Ann Bio* **27**: 143-146.

Lodhi B, Thakral NK, Singh D, Avtar R. and Bahadur R. 2013. Genetic variability, association and path analysis in Indian mustard (*B. juncea*). *J Oilseed Brassica* **5**:26-30.

Mahla HR, Jambhulkar SJ, Yadav DK and Sharma R 2003. Genetic variability, correlation and path analysis in Indian mustard (*B. juncea*). *Ind J Genet Plant Breed* **63**: 172-2.

Ojaghi J and Akhundova E. 2010. Genetic diversity in doubled haploids wheat based on morphological traits, gliadin protein patterns and RAPD markers. *Afr J Agric Res* **5**: 1701-1712.

Patel KM, Patel PG and Pathak HC. 2000. Path analysis in Indian mustard (*B. juncea*). *Madras Agric J* **87**: 330-331.

Premachandra GS, Saneoka H and Ogata S. 1990. Cell membrane stability an indicator of drought tolerance as affected by applied nitrogen in soybean. *J Agric Sci* **115**: 63-66.

Priyamedha, Haider ZA, Kumar A, Ram B, Singh VV and Rai PK. 2018. Analysis of genetic parameters and correlation for yield and quality traits in Indian mustard (*B. juncea*). *J Oilseed Brassica* **9**: 146-150.

Ram B, Singh VV, Singh BK, Priyamedha, Kumar A, Singh D. 2015. Comparative tolerance and sensitive response of Indian mustard (*Brassica juncea* L. Czern. and Coss.) genotypes to high temperature stress. *Sabrao J Breed Genet* **47**: 315-325.

Sairam RK. 1994. Effect of moisture stress on physiological activities of two contrasting wheat genotypes. *Ind J Exp Biol* **32**: 593-594.

Singh R and Sharma SK. 2007. Evaluation, maintenance, and conservation of germplasm. In: Gupta SK, Delseny M, Karder JC. (eds) Advances in Plant Pathology., Rapeseed Breeding, *Elsevier Publications*, pp 465-481.

Singh RK and Choudhary BD. 1985. Variance and covariance analysis. Biometrical Method in Quantitative Genetic Analysis. *Kalyani Publisher*, Ludhiana, pp 39-68.

Steel RG and Torrie JH. 1984. Principles and procedure of statistics. 137-167.

Wright S. 1921. Correlation and causation. *J Agric Res* **1**: 557-5.