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Assessment of salt tolerance ability in maize genotypes at seedling stage

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Abstract: Screening of salt tolerant genotypes of agricultural crops is a necessary aspect for future food security. In this study, ten genotypes of maize were used to analyze their performance under saline condition. An experiment was performed as factorial under Completely Randomized Design (CRD) with three replications. At seedling stage all of the genotypes were used for correlation analysis between leaf temperature, chlorophyll contents, shoot fresh weight, shoot dry weight, root fresh weight, and root dry weight. Fresh root length had positive and highly significant correlation with fresh root weight, root density and dry root weight. Root length has negative and highly significant correlation with dry shoot weight. Chlorophyll content had negative and highly significant correlation with leaf temperature. Leaf temperature had negative and highly significant correlation with chlorophyll content and root density but positive and significant correlation was present with dry shoot weight and dry root weight both at genotypic and phenotypic level. Fresh root length had positive and highly significant correlation with fresh root weight, root density and dry root weight. Root length has negative and highly significant correlation with dry shoot weight. Genotypic and phenotypic correlation of fresh shoot weight with fresh root shot ratio, dry root shoot ratio was negative and highly significant. Results presented that fresh shoot weight was positive and in significant correlation with fresh root weight, root density, dry root weight at both genotypic and phenotypic level.
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Key words: Salinity, maize, correlation analysis, genotypic correlation, phenotypic correlation

1. Introduction

Maize (*Zea Mays L.*) is a cereal crop, belongs to family poaceae. In Canada and USA, it is known as corn. It is annual cross-pollinated crop having erect, thick and strong culms or stalk, with nodes and internodes (Kynast 2012). It is a multipurpose crop that is used as food, fodder and commercial products like jellies, starch, corn oil, grain cake and alcohol. Maize can be categorized in two types on the basis of sowing times in Pakistan. Spring maize is sown in January-February while autumn crop is sown in August to November-December (Talha et al., 2020). Maize is grown in wide range of environment from high altitude of KPK to planes areas of Punjab. Spring crop is grown for grain purpose while autumn crop fulfills the fodder Production. Salinity is a Global environmental issue. It is a common factor which seriously affects crop production particularly in arid and semi-arid regions (Iqra et al., 2020). Salinity is the main cause of soil degradation and reduction in crop production (Lee et., al 2013). It is one of the major factors which affect cell metabolism of crop plants and causes reduction in productivity (Talha et al., 2020). In Pakistan, approximately 6.8 million hectares land is salt affected. More than 100 million hectares of agricultural land remains uncultivated due to salinity stress. Saline soil is producing more adverse effect elements (P, Zn, Mn, Na+ Cl-) as compared to essential elements (K and Fe) which are not necessary for plant growth and better yield (Turan et al., 2009). Salinity affects plant growth, seed germination and disturbs water uptake by plant. Presence of excessive NaCl concentrations in soil has a negative impact on crop production. Salinity inhibits plant growth thus causing reduction in production. Accumulation of salts in roots and shoots areas blocks water transport and produces drought conditions for plant (Shrivastava, 2015). It reduces the available water concentration for crop (Jabeen et al., 2019). High levels of salinity may result in plant's death. Transpiration rate and cell turgidity are also affected. Because of salts accumulation cells death may occur. Salinity also adds to other problems for example plant weakened due to salinity is more volatile to diseases as compared to healthy plant (Tahir et al., 2018).

Just like many other crops maize is also sensitive to salinity. Salinity has negative impact on maize production. Maize crop grown under saline condition can have low production and weak growth. Maize seed germination may reduce because of NaCl's presence in the soil. Yellowing of leaves, weak appearances, low germination rate may be result of salinity (Chaudhary et al., 2017).

The effects of salinity on plant are difficult to determine, for example salinity affects plant physiology and it is hard to define directly from plant physiology. So, for precise description plant detectable traits like Na^+ and K^+ ions concentrations in cell, root and shoot weight, and chlorophyll contents etc are focused. These are traits which shall be observed to determine salinity tolerance (Negrão *et al.,* 2017). With the use of selection and breeding techniques, improvement in salt tolerance in different plant species would be possible (Shoukat et al., 2018). Therefore, the purpose of the present study was to generate information on the genetic variability for salinity tolerance at early seedling and late morphological stage in maize genotypes.

2. Material And Methods

The experiment was performed out at greenhouse in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad.

The Experimental material was consisted of 10 elite genotypes of maize namely as:

L-32	L-33	L-34	L-35	L-42
L-43	L-44	L-45	L-52	L-53

These genotypes were sown in sand filled polythene bags in green house. Each polythene bag was consisted of 500g of sand by using Completely Randomized Design in Factorial experiments with three replications. Two seeds were sown in each polythene bag to avoid any missing in germination. Three treatments were applied: One was normal and other two were saline. Normal treatment was consisted of 0mM salt concentration and other two salt stress contain 50mM and 100mM NaCl concentration in each treatment each genotype was consisted of five plants per replication. After 21 days of sowing seedling data was recorded on following morphological and physiological seedling traits like Fresh shoot length, Fresh root length, Root density, Fresh shoot weight, Fresh root weight, Dry root weight, Dry shot weight, Fresh root shoot ratio, Dry root shoot ratio, Leaf Temperature, Leaf chlorophyll content.

Statistical Analysis

For all the measured traits the data was analyzed statistically by using analysis of variance technique given by (Steel *et al.* 1997).

Correlation Analysis

To determine the relationship among different traits under study genotypic and phenotypic correlations were estimated by using the following statistical techniques designed by Kwon and Torrie, 1964.

i.) Genotypic Correlation Coefficient was calculated by following formula.

$r_{G=} Cov_{gij} / \sqrt{(Var_{gi}) (Var_{gj})}$

Where,

$r_{G= Genotypic}$ correlation Coefficient

CoVgij = Genotypic covariance of ith, jth characters.

Vargi = Genotypic variance of ith characters.

Vargj = Genotypic variance of jth characters.

ii.) Phenotypic correlation coefficient was calculated by following formula:

$r_p = Covpij / \sqrt{(Varpi) (Varpj)}$

Where,

r_p= the estimate of phenotypic correlation coefficient.

CoVpij = Phenotypic covariance of ith and jth trait.

Var pi = Phenotypic variance of ith trait.

Varpj = Phenotypic variance of jth trait.

Significance test for genotypic and phenotypic correlation.

Statistical importance of genotypic correlation coefficient was checked by the method of Reeve (1955). Genotypic correlation coefficient was significantly considered if its value exceeded twice of its standard error.

$SE (r_g) = (1- r_g^2 / \sqrt{2}) + (\sqrt{[(SEh^2i / h^2i) (SEh^2j / h^2)]})$

Where,

$SE (r_g)$ = Standard error of genotypic correlation coefficient

r_g = Genotypic correlation coefficient.

h^2 = Heritability

SEh^2 = Standard error of heritability

The estimated values of genotypic correlation coefficient and heritability were assumed significant if their values exceeded twice of their standard error.

Statistically significant values of phenotypic correlation coefficients were calculated by using t-test according to Steel *et al.* (1997). The value of correlation was considered significant if "t" tabulated was less than "t" calculated.

The value of "t" calculated was calculated by using following formula:

$t_{cal} = r / [\sqrt{(1-r^2_p)} / (n-2)]$

Where,

r = the phenotypic correlation coefficient
n = total number of observation
n-2 = correlation error degree of freedom

Path coefficient Analysis: The procedure of path coefficient analysis was followed as described by Dewey and Lu (1959) by the solution of simultaneously equation to estimate the direct and indirect effects of individual seedling characters to the fresh shoot length using genotypic correlations. For this purpose fresh shoot length was used as resultant variable (effect) and other seedling characters as casual variables (causes).

3. Results and discussion

The analysis of variance showed that all the genotypes have significant difference for understudied traits.

Table 1. Analysis of variance for understudied traits

Source	DF	LT	CC	FSL	FRL	RFW	SFW	RDW	SDW	RD
Genotype	9	53.02**	26.08**	35.04**	45.25**	121.44**	12.63**	21.62**	24.77**	16.11**
Treatment	2	434.33**	267.73**	1598.72**	1417.02**	2321.94**	338.88**	2972.76**	2242.6**	1146.08**
G*T	18	28.87*	7.9	7.49	14.22	100.86	7.92	23.25	19.2	10.11
Error	30									
Total	59									

*, ** =significant at 5% and1% levels of significance respectively. FSW= fresh shoot weight, FRW= fresh root weight, FSL=fresh shoot length, FRL=fresh root length, RD=root density, DSW=dry shoot weight, LT=leaf temperature, CC=chlorophyll content, F.RS=fresh root shoot ratio, D. RS=dry root shoot ratio, DRW=dry root weight.

Correlation

Correlation is the measure of range of relationship occurring between two or more independent variables. Correlation analysis in plant breeding shows the relative importance of different plant traits, which can be value in a crop breeding programs. Correlation analysis between yield and other various quantitative traits is the logical step in making sense about the contribution of these traits to yield per plant. The estimates of genotypic correlation refer to the association between two plant traits due to the genetic components of plant, while phenotypic correlation means the correlation between the phenotypic appearance of the plant for certain pair of plant traits. This shows greater contribution of genotypic factors in the development of association.

Correlation between chlorophyll content and other traits

On observing phenotypic correlation and genotypic correlation between different traits in. (Tables 2 & 3) the data showed that chlorophyll content had negative and highly significant correlation with leaf temperature. Correlation of chlorophyll content with root density was negative and non-significant. Chlorophyll content was associated positive and significantly with shoot length. While the association with Fresh root weight, Fresh shoot weight, dry root weight, dry shoot weight, root shoot ratio fresh and root shoot ratio dry was non-significant and positive. Results of present study were according to the described results of Mustafa *et al.* (2013) and Ali *et al.* (2011) for chlorophyll content.

Correlation between leaf temperature and other traits:

On observing phenotypic correlation and genotypic correlation between different traits in (Tables 2 & 3) the data describe leaf temperature had negative and highly significant correlation with chlorophyll content and root density but positive and significant correlation was present with dry shoot weight and dry root weight both at genotypic and phenotypic level. Significant and positive correlation was shown by leaf temperature with fresh root weight, fresh shoot length and fresh and dry root shoot ratio respectively. For leaf temperature Mustafa *et al.* (2013) and Ali *et al.* (2011) reported similar findings as presented above.

Correlation between fresh root length another trait

On observing phenotypic correlation and genotypic correlation between different traits in (Tables 2 & 3) results revealed that fresh root length had positive and highly significant correlation with fresh root weight, root density and dry root weight. Root length has negative and highly significant correlation with dry shoot weight. Fresh shoot length, Fresh root shoot ratio and dry root shoot ratio have positive and non-significant correlation with root length. According to the findings reported by Xianju *et al.* (2004) and Mustafa *et al.* (2013) similar results were obtained from above study.

Correlation between fresh shoot length and other traits

On observing phenotypic correlation and genotypic correlation between different traits in all treatment 0 mM,50mM and 100 mM. Results presented in (Tables 2 & 3) revealed that fresh shoot length had positive and highly significant correlation with fresh shoot weight while shoot length has negative and non-significant correlation with fresh and dry root shoot ratio. Root length and dry root eight were positively and non-significantly correlated to each other. Non-significant positive genotypic and phenotypic correlation was present between fresh shoot length and chlorophyll content. Similar results were reported by Ali *et al.* (2011), and Mustafa *et al.* (2013).

Correlation between fresh root weight and other traits

On observing phenotypic correlation and genotypic correlation between different traits in (Table 2 & 3) results showed that fresh root weight was positive and high significantly correlated at genotypic and phenotypic level with fresh root length, root density and dry root weight. While positive and non-significant correlation with chlorophyll content at both genotypic and phenotypic level. Results of this study were according to the results of Xianju *et al.* (2004), Mustafa *et al.* (2013) and Mehdi and Ahsan (2000).

Correlation between fresh shoot weight and other traits

On observing phenotypic correlation and genotypic correlation between different traits in (Table 2 & 3) results showed that the genotypic and phenotypic correlation of fresh shoot weight with fresh root shot ratio, dry root shoot ratio was negative and highly significant. Results presented that fresh shoot weight was positive and in significant correlation with fresh root weight, root density, dry root weight at both genotypic and phenotypic level. Fresh shoot weight had highly significant and positive genotypic correlation with leaf temperature. Fresh shoot weight and fresh root shoot ratio had significantly negative correlation with each other and genotypic and phenotypic level. Same results were obtained from findings of Ali *et al.* (2011).

Correlation between root density and other traits

On observing phenotypic correlation and genotypic correlation between different traits in all treatment 0 mM,50mM and 100 mM. In (Table 2 & 3) results shows that positive and highly significant correlation at genotypic and phenotypic level was observed between root density with dry shoot weight, chlorophyll content, dry root weight and fresh root weight. Root density showed negative and highly significant genotypic and phenotypic correlation with leaf temperature. Genotypic correlation of root density with fresh shoot length was negatively significant but phenotypic correlation was positively significant. Results were according to the findings of Ali *et al.* (2011) Mustafa *et al.* (2013).

Correlation between dry shoot weight and other traits

On observing phenotypic correlation and genotypic correlation between different traits in the results showed that dry shoot weight had positive and highly significant correlation with leaf temperature, dry root weight, fresh shoot weight and root density. Dry shoot weight was in non-significant correlation with chlorophyll content. Dry shoot weight was in positive and at high significance at genotypic level with fresh shoot length and fresh root length but positively significant at phenotypic level. Genotypic and phenotypic correlation of dry shoot weight with fresh root weight was significantly positive. Genotypic and phenotypic correlation association of dry shoot weight with fresh and dry root shoot ratio was negatively significant and negative highly significant respectively. Similar findings were reported by Ali *et al.* (2011) and Mustafa *et al.* (2013) as presented in above study.

Correlation between dry root weight and other traits

On observing phenotypic correlation and genotypic correlation between different traits in (Table 2 & 3) the results showed that dry shoot weight had positive and highly significant correlation with dry root shoot ratio and fresh root shoot ratio. Dry root weight has positive and highly significant correlation with root length and fresh root weight. with dry root weight, fresh shoot weight and root density. Dry root weight was in non-significant correlation with chlorophyll content and leaf temperature. Dry root weight was positive and significantly correlated with root density. Similar findings were reported by Ali *et al.* (2011) and Mustafa *et al.* (2013) as presented in above study.

Correlation between fresh root shoot ratio and other traits

On observing phenotypic correlation and genotypic correlation between different traits in (Table 2 & 3) the results showed that fresh root shoot ratio was positively and significantly correlated with dry root shoot ratio and leaf temperature but positive and highly significant correlation with fresh shoot length and dry root weight. Fresh root shoot ratio had negatively significant correlation with fresh shoot weight, fresh root weight and root density at both genotypic and phenotypic level. A negative and significant association observed between fresh root shoot ratio and dry shoot weight at genotypic level but positively highly significant at phenotypic level. Correlation between fresh root shoot ratio and fresh root length was negatively significant at genotypic level and highly significant at phenotypic level. Fresh root shoot ratio was non-significant in correlation with chlorophyll content at genotypic level and negatively non-significant at phenotypic level. Findings of Mustafa *et al.* (2013) and Mehdi and Ahsan (2000) and Ali *et al.* (2011) for fresh root shoot ratio were according to the findings of present results.

Correlation between dry root shoot ratio and other traits

On observing phenotypic correlation and genotypic correlation between different traits in (Table 2 & 3) Results showed that dry root shoot ratio had positive and highly significant association with dry root weight. Dry root shoot ratio was correlated negatively with fresh shoot weight and fresh root weight at genotypic level but negatively non-significant at phenotypic level. Significant positive correlation was observed of dry root shoot ratio with leaf temperature and fresh root shoot ratio. Non-significant association was with chlorophyll content. Highly Significant and positive correlation was seen with fresh shoot length at genotypic but only significant at phenotypic level. With fresh root length correlation of dry root shoot ratio was negatively significant while non-significant and negative at phenotypic level but negative and significant with root density and dry shoot weight at genotypic and highly significant at phenotypic level respectively. Similar findings were reported by Mehdi and Ahsan (2000), Ali *et al.* (2011) and Mustafa *et al.* (2013) for dry root shoot ratio.

Table 2. Genotypic correlation

	CC	**L.T**	FRL	FSL	FRW	FS	**R.D**	DRW	DSW	F.RS	D. RS
CC											
L.T	-0.72**										
FRL	0.25	0.03									
FSL	0.51*	-0.03**	0.12								
FRW	0.30	0.03	0.29**	0.12							
FSW	0.32	-0.06*	-0.12	0.77*	0.02						
R.D.	-0.15	0.16	0.45**	0.10	0.34**	0.14					
DRW	0.43	0.01	0.37**	0.16	0.53**	0.12	-0.10*				
DSW	0.57	0.36	-0.37**	-0.40*	0.07	0.01**	-0.44	-0.23			
F.RS	0.021	0.08*	0.24	-0.41	0.69**	-0.69**	0.37	-0.24	0.001		
D. RS	0.62876	-0.24**	0.09	0.30	-0.44	-0.12	0.23**	0.79**	-0.76**	-0.17	

Table 3. phenotypic correlation

	CC	**L.T**	FRL	FSL	FRW	FSW	**R.D**	DRW	DSW	F.RS	D. RS
CC											
L.T	-0.69**										
FRL	0.18	0.03									
FSL	0.45*	-004**	0.02*								
FRW	0.28	0.05	0.11**	-0.13							
FSW	0.22	0.02	-0.11	0.68**	-0.01						
R.D.	0.06	0.14	0.36	0.07	0.28*	0.10					
DRW	0.32	0.01	0.24**	-0.12	0.50*	-0.09	-0.14				
DSW	-0.50	-0.34	-0.48	-0.35 *	0.03	0.03*	-0.37	-0.26			
F.RS	0.075	0.01**	0.12**	-0.33 *	0.71**	-0.70**	-0.29	0.24**	-0.02**		
D. RS	0.49	0.21**	0.14**	0.26	0.39**	-0.10**	0.15	0.80**	-0.77**	-0.15	

*, ** =significant at 5% and1% levels of significance respectively. FSW= fresh shoot weight, FRW= fresh root weight, FSL=fresh shoot length, FRL=fresh root length, RD=root density, DSW=dry shoot weight, LT=leaf temperature, CC=chlorophyll content, F.RS=fresh root shoot ratio, D. RS=dry root shoot ratio, DRW=dry root weight

Path coefficient analysis

When several quantitative variables especially crop yield and its components are mutually correlate in some complex ways. Simple correlation provides in complete information about the nature of association. Thus, on the basis of simple correlation co efficient breeder searching for high degree components of yield upon which his entire struggle for success for a specific program is based may not be able to make right decision. Path analysis can be applied by partitioning correlation co-efficient pathways) using genotypic correlation for different traits.

Chlorophyll content vs. fresh shoot length

The results summarized in table 4 showed that on fresh shoot length the direct effect of chlorophyll content was negative (-1.2). The indirect effect on fresh shoot length through root length (-0.33) shoot length root shoot ratio fresh (-0.027) root shoot ratio dry (0.81) was negative. The indirect effect on shoot length through root density (0.19) and shoot weight dry (0.741) was positive. The negative direct effect of chlorophyll content on fresh shoot length suggested that selection would be ineffective in this way. Ali *et al.* (2011) described that chlorophyll content was in negative direct effect with fresh shoot length.

Leaf temperatures vs. fresh shoot length

The results summarized in table 5 showed that on shoot length the direct effect of leaf temperature on shoot length was positive (2.29). The indirect effect on fresh shoot length through chlorophyll content (1.3) root length (0.27) Dry shoot fresh (0.74) root density (1.04) was positive. The indirect effect on fresh shoot length through (-0.15) shoot weight dry (-1.34) root shoot ratio (-0.54) was negative. The positive direct effect of leaf temperature on fresh shoot length suggested that selection would be effective in this way. Mustafa *et al.* (2013) also reported that leaf temperature had direct positive effect on fresh shoot length.

Fresh root length vs. fresh shoot length

The results summarized in table 6 showed that on shoot length the direct effect of root length was positive (1.73). The indirect effect on shoot length through chlorophyll content (0.44), leaf temperature (0.21), fresh root weight (0.51), root density (0.79), fresh root shoot ratio (0.42) was positive. The indirect effect on shoot length through fresh shoot weight (-0.21) dry root weight (-0.6) and shoot weight dry (-0.916) was negative. The positive direct effect of fresh root length on shoot length shows that selection would be effective in this way. Mustafa *et al.* (2013) also recorded same direct positive effect of fresh root length on fresh shoot length as describe here also.

Fresh root weight vs. fresh shoot length

The results indicated in table 7 showed that on root length the direct effect of fresh root weight was negative (-1.709). The indirect effect on shoot length through chlorophyll content (-0.514) leaf temperature (-0.514) root length (-0.5) fresh shoot weight (-0.03) dry shoot weight (-0.12) root shoot ratio fresh (1.1) was negative. The indirect effect on shoot length through root density (0.59) and dry root weight (0.92) was positive. The negative direct effect showed that selection would be ineffective in this way. Results of fresh root weight were contradictory to the results of Mustafa *et al.* (2013) who reported positive direct effect of fresh root weight on fresh shoot length.

Fresh shoot weight vs. fresh shoot length

The results indicated in table 8 showed that on shoot length the direct effect of fresh shoot weight was positive (1.19). The indirect effect of chlorophyll content (0.38) leaf temperature (0.385) root length (0.144) root weight fresh (0.02) root density (0.17) dry shoot weight (0.01) was positive. The indirect effect on shoot length through fresh root shoot ratio (0.82) dry root shoot ratio (0.140 and dry root weight (0.14) was negative. The positive direct effect showed that selection would be effective in this way.

Root density vs. fresh shoot length

The result summarized in table 9 showed that direct effect of root density on shoot length was negative (-2.1). The indirect effect on shoot length through dry root weight (0.22), dry shoot weight (0.93), fresh root shoot ratio (0.79) fresh root weight (0.73) and root length (0.95) was positive. The indirect effect on shoot length through leaf temperature (0.96) was negative. the negative direct effect indicate that the selection would be ineffective in this way. Results presented here above were contradictory to the findings of Ali *et al.* (2011) and Mustafa *et al.* (2013) who reported root density was in direct positive effect on fresh shoot length.

1. Dry root weight vs. fresh shoot length

The results summarized in table 10 showed that direct effect of dry root weight on shoot length was positive (5.4). the indirect effect of chlorophyll content (2.4) leaf temperature (2.17) root shoot ratio dry (4.34) was positive. The indirect effect of root length (2.04) fresh root weight (2.95) fresh shoot weight (0.68) was negative. The positive direct effect indicated that selection would be effective in this way. Results are in contrast with the results of Mustafa *et al.* (2013) and Ali *et al.* (2011) who recorded positive direct effect of dry root weight on fresh shoot length

Dry shoot weight vs. fresh shoot length

The result summarized in table 11 showed that the direct effect of dry shoot weight on shoot length was negative (5.29). The indirect effect of chlorophyll contents (2.4) leaf temperature (2.17) and dry root shoot ratio (4.34) was positive. The indirect effect of root density (0.58) fresh root weight (2.95) fresh shoot weight (0.68) was negative. The positive direct effect showed that selection would be ineffective in this way. Results are in contradictory with the results of above study as Ali *et al.* (2011) and Mustafa *et al.* (2013) mentioned positive direct effect of dry shoot weight on fresh shoot length.

Fresh root shoot ratio vs. fresh shoot length

The results summarized in table 12 showed that direct effect of fresh root shoot ratio was positive (0.71). The indirect effect on shoot length through chlorophyll content (-0.07) leaf temperature (0.17) fresh shoot weight (0.49) root density (0.273) was negative. The indirect effect of dry shoot weight on shoot length was positive. The positive direct effect showed that selection would be effective in this way. Results mentioned above were contradictory to the results of Mustafa *et al.* (2013) and Ali *et al.* (2011)

who also described same findings that fresh root shoot ratio was in direct negative effect to fresh shoot length.

Dry root shoot ratio vs. fresh shoot length

The results summarized in table 13 showed that direct effect of dry root shoot ratio was negative on shoot length. The indirect effect of chlorophyll content (5.61) leaf temperature (5.69) root length (0.87) root density (2.09) was negative. The indirect effect of fresh root weight (3.95) and dry shoot weight was positive. The positive direct effect showed that the selection would be effective in this way. Results mentioned above were according to the results of Mustafa *et al.* (2013) and Ali *et al.* (2011) who also reported same findings that dry root shoot ratio was in direct negative effect to fresh shoot length.

Table-4: Direct and indirect effects of chlorophyll content on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	**-1.288**	
Indirect effect via:		
Leaf temperature		-0.73 0.06
Fresh root length		-0.33
Fresh root weight		-0.38
fresh shoot weight		-0.42
Root density		0.19
Dry root weight		-0.56
Dry shoot weight		0.74
fresh root shoot ratio Dry root shoot ratio		-0.02 -0.8

Table-5: Direct and indirect effects of leaf temperature on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	**2.296**	
Indirect effect via:		
Chlorophyll content		0.019 0.06
Fresh root length		0.27
Fresh root weight		-0.15
fresh shoot weight		0.074
Root density		1.04
Dry root weight		0.909
Dry shoot weight		-1.34
fresh root shoot ratio Dry root shoot ratio		-0.54 1.46

Table-6: Direct and indirect effects of fresh root length on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	1.73	
Indirect effect via:		
Chlorophyll content		0.447
Leaf temperature		0.21
Fresh root weight		0.51
fresh shoot weight		-0.21
Root density		0.79
Dry root weight		-0.64
Dry shoot weight		-0.91
fresh root shoot ratio Dry root shoot ratio		0.42 0.17

Table-7: Direct and indirect effects of fresh root weight on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	1.69	
Direct Effect	**-1.709**	
Indirect effect via:		
Chlorophyll content		0.51
Leaf temperature		-0.51
Fresh root length		-0.5
fresh shoot weight		-0.03
Root density		0.59
Dry root weight		0.92
Dry shoot weight		-0.12
fresh root shoot ratio Dry root shoot ratio		-1.1 0.75

Table-8: Direct and indirect effects of fresh shoot weight on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	1.191	
Indirect effect via:		
Chlorophyll content		0.38
Leaf temperature		0.38
Fresh root length		-0.114
fresh root weight		0.02
Root density		0.17
Dry root weight		-0.14
Dry shoot weight		0.01
fresh root shoot ratio Dry root shoot ratio		-0.8 -0.14
Total		-0.023

Table9-: Direct and indirect effects of root density on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	-2.1	
Indirect effect via:		
Chlorophyll content		0.32
Leaf temperature		-0.96
Fresh root length		-0.95
fresh root weight		0.73
Fresh shoot weight		-0.3
Dry root weight		-0.22
Dry shoot weight		0.93
fresh root shoot ratio Dry root shoot ratio		0.798 -0.49

Table-10: Direct and indirect effects of dry root weight content on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	5.4	
Indirect effect via:		
Chlorophyll content		2.4
Leaf temperature		2.1
Fresh root length		-2.04
fresh root weight		-2.95
Fresh shoot weight		-0.68
Root density		-0.58
Dry shoot weight		-1.2
fresh root shoot ratio Dry root shoot ratio		-1.34 4.34

Table-11-: Direct and indirect effects of dry root shoot ratio on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	-5.9	
Indirect effect via:		
Chlorophyll content		3.04
Leaf temperature		3.1
Fresh root length		2.79
fresh root weight		-0.39
Fresh shoot weight		-0.07
Root density		2.34
Dry root weight		1.2
Fresh root shoot ration Dry root shoot ratio		-0.007 -0.007

Table-12: Direct and indirect effects of fresh root shoot ratio on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	0.71	
Indirect effect via:		
Chlorophyll content		-0.007
Leaf temperature		-0.17
Fresh root length		0.17
fresh root weight		0.503
Fresh shoot weight		-0.49
Root density		-0.273
Dry root weight		-0.176
Dry shoot weight Dry root shoot ratio		0.001 -0.128

Table-13: Direct and indirect effects of dry root shoot ratio on fresh shoot length

Path association	Direct path coefficient (p)	Indirect path coefficient (pr)
Direct effect	-8.93	
Indirect effect via:		
Fresh shoot weight		-5.61
Fresh root weight		-5.69
Fresh root length		-0.87
Root density		3.95
Dry shoot weight		1.07
Leaf temperature		-2.09
Chlorophyll content		-7.08
Fresh root shoot ratio Dry root shoot ratio		6.87 1.59

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