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RELATIONSHIP BETWEEN SEEDLING AND MATURE PLANT TRAITS RELATED TO STRESS TOLERANCE OF WHEAT

Muhammad Aslam Chowdhry, Asif Ali, Ghulam Mahboob Subhani and Ihsan Khaliq

Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan

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Studies were conducted on twenty five spring wheat varieties/lines in the greenhouse and the field, using completely randomized design and randomized complete block design, respectively. In the greenhouse soil water content and atmospheric relative humidity were controlled to achieve the following treatments:- 1) unstressed, 2) root stress, 3) aerial stress and 4) root plus aerial stress. In the field experiment the crop was grown under naturally occurring stress (about 50 mm of rain in crop season). Data were recorded on various seedling and mature plant traits to determine the extent of genetic variability among genotypes and interrelationships between the traits. The differences among the varieties/lines were highly significant for all the traits. Almost all the values of genotypic correlations were greater than phenotypic ones. In the least and most stressed treatments survival rate, flag leaf area, number of stomata and leaf venation were positively and significantly correlated with grain yield. In the root stress treatment survival rate, root volume, root-shoot ratio, hygrophilic colloids, epidermal cell size and osmotic pressure were negatively but non-significantly correlated with grain yield. Maximum and significant genotypic correlation (0.79) was found between survival rate at root + aerial stress and number of stomata followed by 0.57 between root volume and hygrophilic colloids. Path coefficient analysis showed that leaf venation had the maximum (0.73) direct association with grain yield followed by survival rate at no water stress (0.42). Epidermal cell size had maximum indirect effect on grain yield through leaf venation.

Key words: *Triticum aestivum*, Correlation, Path-coefficient analysis.

Introduction

Wheat (*Triticum aestivum* L. em. Thell) in Pakistan covers an area of 8.3 million hectares annually, bringing about 16.16 million tons which is merely sufficient to meet domestic food requirements (Govt. of Pakistan, 1993). Constant efforts to boost production are needed to keep pace with the ever increasing population.

About one third of this area is rainfed (average rainfall 311 mm and average grain yields (1.12 t/ha) are about half of irrigated yield (2.13 t/ha). Under such limitations, the wheat breeders are working hard to evolve the genotypes which could tolerate the serious soil and atmospheric moisture stress. Stress at various stages of plant development is likely to produce a variable impact [1]. Genotypes having mechanisms to avoid or overcome moisture stress at an early stage of development may also perform better during later stages of growth. It seems desirable however, to determine the relationship between characters related to grain yield. Such information is important to devise appropriate screening strategies for developing wheat cultivars adapted to stressful agro-climatic conditions.

Yield of grain is of primary importance and the most complex objective for the breeder. It is determined by expression of numerous genes and their interaction with the environment. Genotypic and phenotypic correlation within varieties/strains are of value to indicate the degree to which various morpho-physiological characters are associated with economic productivity. Path-coefficient analysis is one reliable statistical technique which provides a means not only to quantify the inter-relationships of different yield components but also indicates whether the influence is directly reflected in yield or takes some other pathway for ultimate effect.

Asim *et al.* [1] observed the negative correlation between grain yield per plant and root-shoot ratio. Ashok and Yadav [2] conducted a field experiment for two years under irrigation and without irrigation and reported that shoot survival percentage was the chief contributor to yield in wheat, whereas, positive and significant genotypic correlation between grain yield per plant and 1000-grain weight was reported by Chowdhry *et al.* [3]. Naseer [4] reported that correlation between leaf venation and grain yield was positive and highly significant both under irrigated and drought conditions. He also reported that leaf venation has positive direct effect on yield. Srivastava *et al.* [5] observed that yield was positively and significantly correlated with flag leaf area. Akhtar [6] reported that flag leaf area had the positive direct effect on grain yield, while Singh *et al.* [7] revealed that flag leaf area had a positive effect indirectly on grain yield through 1000-grain weight.

Materials and Methods

One experiment was carried out in a greenhouse (Drought chamber) and another under moisture stress conditions in field during 1992-93. Twenty five varieties/strains of wheat were studied for various mopho-physiological characters at seedling and mature plant stages.

Greenhouse experiment. These genotypes were evaluated for seedling traits in greenhouse (Drought Chamber) during December, 1992. Fresh river sand was filled in 18×9cm polythene bags (450 g/bag), after washing thoroughly with distilled water. One seed of each variety was sown in each bag at uniform depth of 3 cm and bags were irrigated daily with normal water. Each genotype comprised of ten bags per replication. A completely randomized design with three replications was used.

Field capacity was determined by saturating the oven dry sand. It was estimated that 148 ml of water was required to reach saturation for 450 g of oven dried sand. Therefore, 74 and 37 ml of water was applied for maintaining the optimal and low soil moisture in different treatments, respectively.

At three leaf stage adequate Hoagland's solution [8] was applied for maintaining the required level of soil moisture and nutrient supply to the seedlings. Then 10 seedling of each genotype in each replication were placed in drought chamber at 45°C under controlled condition. Soil moisture was replenished to the desired level by weighing the individual bag and restoring the deficit if any, by adding water. When seedlings were placed in drought chamber water was not applied to the seedlings. The following treatments were therefore, used to ascertain the precise response of the wheat plant to various components of drought.

1.	No water stress	Optimal soil moisture (50% FC) + Normal humidity (60-70%)
2.	Root stress	Low soil moisture (25% FC) + Normal humidity
3.	Aerial stress	Optimal soil moisture + low humidity (12%)
4.	Root and aerial stress	Low soil moisture + low humidity

After 10 days, (when 50% mortality was observed) the seedlings were taken out from drought chamber and Hoagland's solution was applied immediately to the seedlings which were then irrigated with normal water daily. The following plant measurements were taken:-

1. Survival rates. After 10 days, the number of live seedlings were counted for each genotype in each stress treatment (i.e., measuring after stress). The number of seedlings that survived were expressed as percentage of the total number of seedlings to obtain the survival rates for each stress treatment.

2. Root-shoot ratio. For root-shoot ratio a separate set of experiment was raised in polythene bags under normal moisture level. At three leaf stage five seedlings per genotype/strain were taken for root-shoot ratio from each replication. The roots of the randomly selected seedlings were washed gently with tap water taking care not to damage the seedling. Fresh roots and shoots were kept separately in kraft paper bags and dried at 60°C for 60 hrs in an electric oven to a constant weight. Later they were weighed and the ratio of dried roots and shoots was calculated.

3. Root volume. At three leaf stage five seedlings of each genotype were taken out from the polythene bag and washed with tap water to remove the adhesive soil. The root volume (in cm^3) was determined by taking the difference of water rise in the beaker before and after dipping the roots.

Field experiment. The same twenty five varieties/strains were space planted (30 cm × 15 cm) in field in triplicated randomized complete block design under moisture stress conditions (49.9 mm rainfall) during the crop season 1992-93. Each plot consisted of 3 rows of 5m length. Ten guarded plants from each plot were randomly selected to record the following traits.

(a) Stomatal frequency (10× microscopic field). The stomatal counts per unit area were made on upper surface of the third nodal leaf of the mother shoot of each randomly selected plant. Five strips were taken from the middle part of the leaf and dipped into Carnoy's solution to arrest the stomatal movement and removal of chlorophyll from the leaf tissue. After 24 hours, the strips were removed from the solution, washed in acetone and stored in formalin solution for further examination. Strips were peeled from lower side and two samples were examined under the microscopic field area.

(b) Leaf venation (4× microscopic field). The leaf strips taken for studying stomatal frequency were also used for recording leaf venation. The same strips were examined under microscope and veins were counted under this microscopic field area.

(c) Osmotic pressure (m Osm/Kg). The samples were collected in the morning hours when leaves were fully turgid and weather was clear. Disease free third nodal leaves were collected from ten plants in small polythene bags and immediately stored in a deep freezer for 24 hrs. The cell sap was extracted from these samples with a rotary hand press and then centrifuged at 6500 rpm for about seven mins. A portion of the centrifuged cell sap was immediately frozen for the determination of osmotic pressure by using an automatic micro osmometer.

(d) Epidermal cell size (micron). Upper epidermal cell length and breadth were measured in microns from the strip taken for stomatal frequency and leaf venation. Five cells from each strip were measured at random for length and breadth using an ocular micrometer and the average was calculated. The cell size was then calculated by multiplying these

length and breadth with standardized value of microscope.

(e) Hygrophilic colloids (mg). Hygrophilic colloids contents were estimated indirectly by leaf powder method to assess its possible relationship with drought tolerance. About thirty disease free third nodal leaves were collected for each treatment when the crop was fully grown. Leaves were made dust free and sun dried in bags. These leaves were then oven dried at 70°C and were ground to a fine powder with an electric grinder. Grinder was thoroughly cleaned before grinding the next sample to avoid mixture. Powders of leaves were placed in electric oven at 50°C to keep them dry. One gram powder of each sample was subjected to 100 percent relative humidity in small crucibles of known weight. After 24 hours the crucibles were weighed again, the absorbed moisture was noted and the absorption per gram calculated. Three such values were obtained for each genotype in each replication.

(f) Flag leaf area (cm^2). Flag leaf area of mother shoot of ten randomly selected plants in each replication was measured on an electric leaf area meter and then average was calculated.

(g) Grain yield per plant (g). Grain yield in grams from 10 randomly selected plants was recorded separately on electric balance, average yield was then computed.

The analysis of variance and covariance were run for all the characters studied using the method of Steel and Torrie [9]. Correlation coefficient and path coefficient analysis was calculated according to procedures as delineated by Dewy and Lu [10].

Results and Discussion

Means, mean squares and coefficient of variability for drought chamber and field experiment are presented in Table 1. The differences among the varieties/strains were highly significant between no water stress, root stress, root + aerial stress and aerial stress for survival rate. Root volume, root-shoot ratio, hygrophilic colloids, epidermal cell size, flag leaf area, number of stomata, leaf venation, osmotic pressure and grain yield per plant showed significant variation between different varieties/strains. Genotype 6549 exhibited the maximum survival rate (100%) for no water stress. The genotype 6549 and 6414 had the maximum survival rate of 93.3 percent for root stress, while the genotype 6200 and 6145 revealed 93.3 percent survival rate for root + aerial stress. The genotype 6414 and 6532 also had 93.3 percent survival rate for aerial stress. The genotype 6500 had the highest value of 1.038, 3197.81 and 4.10 for root-shoot ratio, epidermal cell size and leaf venation, respectively. The genotype 5039 showed maximum value of 2.0 and 21.99 for root volume and grain yield per plant, respectively. In case of hygrophilic colloids highest value of 0.14 was observed for genotype 6448 and 6546. The genotype 6145 (23.82), 6529-1 (5.40) and Rohtas 90 (848.67) indicated highest values for flag leaf area, number of stomata and osmotic pressure, respectively.

Genotypic (r_g) and phenotypic (r_p) correlation coefficients for all possible combinations are presented in Table 2. In most of the cases genotypic correlations were higher as compared to phenotypic correlations. A review of Table 2 shows that survival rate for no water stress and for root + aerial stress were positively and significantly correlated with grain yield. The correlation coefficient were positive and non-significant between survival rate for aerial stress and grain yield, while negative and non-significant association was observed between survival rate for root stress and grain yield. The pattern suggests that for increasing yield, survival rate should also be given importance. Similar findings were also observed by Ashok and Yadav [2], who reported that shoot survival percentage was the chief contributor to yield in wheat crop.

A negative and non-significant relationship was observed for root-shoot ratio, root volume with grain yield at genotypic level. High root-shoot ratio has been associated with lower yield in other studies [1]. Epidermal cell size exhibited negative and non-significant correlation at genotypic and phenotypic levels with grain yield. This suggests that the increase in cell size will not significantly decrease grain yield. Flag leaf area was positively and significantly associated with grain yield as also found by Srivastava *et al.* [5]. Number of stomata showed positive and significant correlation coefficient at genotypic level with grain yield. This indicates that the increase of stomatal frequency will also have the positive effect on grain yield. Leaf venation revealed a positive and significant association with grain yield agreeing with the findings of Naseer [4]. Osmotic pressure and hygrophilic colloids exhibited the negative and non-significant relationship with grain yield both at genotypic and phenotypic levels. Significantly positive correlation coefficients were observed between osmotic pressure and survival rate for root stress and aerial stress and leaf venation at genotypic level but non-significant at phenotypic level. Number of stomata showed negatively significant genotypic correlation with osmotic pressure. Root-shoot ratio was positively and significantly associated with osmotic pressure, indicating that by increasing osmotic pressure the root-shoot ratio will also increase.

Negative and non-significant genotypic and phenotypic correlations were observed between leaf venation and survival rate for no water stress, root stress and root + aerial stress, root volume, flag leaf area and number of stomata. This implies that if one trait increases the other will not decrease significantly. Positively significant genotypic correlation was found between leaf venation and epidermal cell size,

TABLE 1. MEAN, MEAN SQUARES (MS) AND COEFFICIENT OF VARIABILITY (CV%) OF DROUGHT RELATED CHARACTERS IN WHEAT.

Varieties	Experiment - I								Experiment - II				
	Survival rate for no water stress (%)	Survival rate for root stress (%)	Survival rate for aerial stress (%)	Survival rate for root + aerial stress (%)	Root-shoot ratio	Root Volume (Cm^3)	Hygro-philic colloids (mg)	Epidermal cell size (microns)	Flag leaf area (cm^2)	No. of stomata per unit area	Leaf venation per unit area	Osmotic pressure (m osm/Kg)	Grain yield/ plant (g)
6549	100.0	93.3	50.0	50.0	0.807	1.51	0.09	1659.77	11.13	3.43	2.87	299.00	15.08
6448	96.7	66.7	76.7	86.7	0.881	1.50	0.14	1621.40	17.93	4.77	2.30	543.00	18.18
Rohtas	96.7	76.7	66.7	66.7	0.997	1.07	0.10	1637.76	12.80	4.87	3.10	848.67	19.09
6414	93.3	93.3	93.3	80.0	0.872	1.51	0.12	1584.46	18.00	4.73	2.40	632.00	11.55
6549-1	93.3	76.7	70.0	66.7	0.773	1.49	0.11	1952.50	19.47	3.30	2.60	610.00	10.72
6150	90.0	56.7	43.3	66.7	0.900	1.36	0.11	1731.03	19.40	4.30	3.60	340.00	12.79
Lu26S	86.7	66.7	70.0	76.7	0.882	1.50	0.11	1753.47	9.20	4.53	2.13	625.33	12.19
6200	86.7	66.7	66.7	93.3	0.874	1.76	0.13	1667.92	23.3	3.60	2.73	202.67	16.34
6528	83.3	56.7	66.7	56.7	1.002	1.75	0.12	2498.61	9.60	4.20	3.10	537.00	10.35
6128	83.3	66.7	50.0	50.0	0.670	1.48	0.12	2225.09	20.47	3.30	2.73	191.67	17.76
6120	80.0	70.0	56.7	86.7	0.877	1.77	0.09	1716.21	11.07	3.97	3.17	263.33	15.81
6145	80.0	76.7	53.3	93.3	0.753	1.65	0.13	1783.11	23.87	4.43	3.53	398.00	19.72
5039	76.7	60.0	76.7	43.3	0.772	2.00	0.12	2152.23	20.53	3.20	3.00	265.67	21.99
6546	76.7	66.7	73.3	73.3	0.989	1.60	0.14	1887.88	21.60	3.63	2.50	521.67	11.02
Pasban	76.7	56.7	60.0	56.7	0.902	1.04	0.10	2746.40	12.60	4.10	3.77	568.00	17.23
6614	76.7	86.7	56.7	56.7	0.881	1.00	0.11	2314.75	10.73	2.87	2.40	333.33	12.64
6142	73.3	63.3	63.3	76.7	0.769	1.49	0.10	2437.15	13.27	4.17	2.20	292.00	12.73
6039	70.0	70.0	70.0	83.3	0.661	1.65	0.10	2883.3	21.60	5.10	2.63	302.00	15.87
6529-1	70.0	46.7	76.7	76.7	0.729	1.08	0.09	1906.1	16.20	5.40	2.83	581.33	21.08
6532	66.7	73.3	93.3	63.3	0.795	1.50	0.10	1753.7	20.33	4.43	2.30	287.67	12.66
6529-10	66.7	76.7	50.0	46.7	0.726	1.49	0.10	1455.82	21.13	2.53	2.73	628.67	14.12
4943	66.7	70.0	63.3	70.0	0.832	1.65	0.11	2561.70	13.13	4.53	2.50	690.67	14.16
6339	63.3	76.7	66.7	46.7	0.775	1.51	0.11	1613.28	15.93	4.40	2.73	630.00	15.09
6500	60.0	73.3	43.3	56.7	1.038	1.50	0.10	3197.81	10.60	4.00	4.10	550.00	12.89
6529-11	56.7	43.3	56.7	66.7	0.829	1.50	0.11	1677.70	13.80	4.20	2.63	524.67	10.12
MS	441**	448**	519**	665**	0.031**	0.17**	0.001**	650494**	66**	1.5**	0.76**	94618**	34.61**
CV%	7.61	7.65	7.59	7.83	1.64	2.48	13.89	10.63	9.10	17.58	15.64	7.52	9.97

** = P < 0.01

showing that increase in epidermal cell size was accompanied by increased leaf venation and vice versa. Survival rate for root + aerial stress and aerial stress had positively significant correlation between the number of stomata both at genotypic and phenotypic levels. Increased number of stomata was associated with increased survival rate of seedlings. Survival rate for root + aerial stress, root volume, hygrophilic colloids, epidermal cell size exhibited the positive and significant correlation with flag leaf area both at genotypic and phenotypic levels. It means if one variable increases the other will also increase significantly. A positive and significant genotypic correlation was observed between epidermal cell size. Root-shoot ratio had the positive and non-significant correlation with hygrophilic colloids, which reflects that increase in hygrophilic colloids will not significantly increase the root-shoot ratio. Survival rate for no water stress and for root +aerial stress showed the positive but non-significant association with root-shoot ratio both at genotypic and phenotypic levels, suggesting that increase in one trait will not significantly increase the other trait. Survival rate for root + aerial stress revealed the positive and significant genotypic correlation, whereas survival rate for aerial stress exhibited positive non-significant correlation with root volume which shows that increase in root volume will not considerably increase the survival rate. Survival rate for aerial stress manifested the positive and significant genotypic correlation with other three survival rates. Survival rate for root + aerial stress also showed the positive and significant genotypic correlation with survival rate for no water stress, while survival rate for root stress was positively correlated with survival rate for no stress. This implies that the varieties/ lines which tolerate root stress will also tolerate the other moisture stress treatment.

The path coefficient analysis provided an effective way of finding out direct and indirect source of correlation, using genotypic correlation of different characters. The direct and

TABLE 2. ESTIMATES OF GENOTYPIC (r_G) AND PHENOTYPIC (r_p) CORRELATIONS AMONG YIELD AND SOME MORPHO-PHYSIOLOGICAL CHARACTERISTICS.

		Survival rate for root stress	Survival rate for aerial stress	Survival rate for root+ aerial stress	Root-shoot ratio	Root Volume	Hygro-philic colloids	Epidermal cell size	Flag leaf area	No. of stomata per unit area	Leaf venation per unit area	Osmotic pressure plant	Grain yield/
Survival rate for no water stress	r_g	0.388	0.106*	0.236*	0.194	-0.064	0.348	-0.424	0.026	0.021	-0.122	-0.023	0.126*
	r_p	0.362**	0.105	0.219	0.191	-0.060	0.245*	-0.376	0.023	0.031	-0.076	-0.010	0.123
Survival rate for root stress	r_g		0.053*	-0.079	-0.007	-0.019	-0.145	-0.169	-0.006	-0.320	-0.176	0.037*	-0.122
	r_p		0.052	-0.072	-0.003	-0.002	-0.113	-0.165	0.001	-0.272*	-0.157	0.030	-0.117
Survival rate for aerial stress	r_g			0.270*	-0.057	0.117	0.560	-0.230	0.234*	0.520*	-0.667	0.160*	0.014
	r_p			0.256*	-0.058	0.115	0.374**	-0.219	0.219	0.410**	-0.567**	0.158	0.016
Survival rate for root+aerial stress	r_g				0.038	0.014	0.433	-0.150	0.242*	0.794*	-0.183	-0.082	0.065*
	r_p				0.035	0.138*	0.326**	-0.145	0.236*	0.630**	-0.172	-0.805	0.063
Root/shoot ratio	r_g					-0.131	0.266	0.115*	-0.488	0.113	0.379	0.368*	-0.344
	r_p					-0.129	0.199	0.111	-0.478**	0.085	0.331*	0.365**	-0.332**
Root volume	r_g						0.570	-0.017	0.311*	-0.113	-0.075	-0.373	-0.037
	r_p						0.399	-0.018	0.304**	-0.078	-0.081	-0.369**	-0.037
Hygrophilic colloids	r_g							-0.154	-0.854*	-0.002	-0.349	-0.004	-0.119
	r_p							-0.118	-0.579**	0.065	-0.234	-0.008	-0.054
Epidermal cell size	r_g								0.408*	-0.015	0.408*	-0.110	-0.038
	r_p								0.356*	0.006	0.356**	-0.099	-0.037
Flag leaf area	r_g									-0.005	-0.10	-0.310	0.286*
	r_p									-0.005	-0.087	0.305**	0.275*
No. of stomata	r_g										-0.064	-0.265*	0.259*
	r_p										-0.026	-0.224	0.201
Leaf venation	r_g											0.029*	0.285*
	r_p											0.012	0.264*
Osmotic pressure	r_g												-0.142
	r_p												-0.134

* = Significant, ** = Highly significant

indirect effects of different characters on grain yield are presented in Table 3. The direct effect of survival rate for no water stress on grain yield was positive (0.4163). The indirect effect via survival rate for aerial stress, epidermal cell size, flag leaf area and number of stomata were also positive, while indirect effects through survival rate for root stress and root + aerial stress, root volume, root-shoot ratio, hygrophilic colloids, leaf venation and osmotic pressure were negative. The direct effects of survival rate for root and for root + aerial stress were -0.1301 and -0.2120, respectively. Whereas, direct effect of survival rate for aerial stress on grain yield was positive (0.3927). The direct effect of root volume on grain yield was positive (0.0187). The indirect effects through survival rate for no water stress, root + aerial stress, hygrophilic colloids, number of stomata, leaf venation were negative, while indirect effects via survival rate for root stress and aerial stress, root-shoot ratio, epidermal cell size, flag leaf area and osmotic pressure were positive . The direct effects of root-shoot ratio, hygrophilic colloids, epidermal cell size and osmotic pressure were -0.5401, -0.1875, -0.0396 and -0.0519, respectively. The direct effect of flag leaf area on grain yield was 0.1864. Similar results were reported by Akhtar [6]. The direct effect of leaf venation on grain yield was positive and maximum (0.7336). Similar findings were reported by Naseer [4]. The direct effect of number of stomata on grain yield was 0.3037.

It is concluded that survival rate for no water stress and aerial stress are important components of yield, so the special attention should be given to it in selection programme. While selection for greater survival rate for root stress and root + aerial stress would be benefitted almost entirely through the traits with indirect effects, which will make grain vigorous and finally grain yield will be increased.

It is also concluded from the results that root volume, flag leaf area, leaf venation and number of stomata will increase the grain yield per plant. While traits with negative

TABLE 3. DIRECT (IN PARENTHESIS) AND INDIRECT EFFECTS OF DROUGHT RELATED CHARACTERS IN WHEAT.

	Survival rate for no water stress	Survival rate for root stress	Survival rate for aerial stress	Survival rate for root+ aerial stress	Root-shoot ratio	Root volume	Hygro-philic colloids	Epidermal cell size	Flag leaf area	No. of stomata per unit area	Leaf venation per unit area	Osmotic pressure	(r_g)
Survival rate for no water stress	(0.4163)	-0.0505	0.0417	-0.0499	-0.1046	-0.0650	-0.0650	0.0106	0.0048	0.0063	-0.0890	-0.0016	0.126*
Survival rate for root stress	0.1616	(0.1301)	0.0208	0.0167	0.0038	-0.0003	0.0272	0.0061	-0.0010	-0.0970	-0.1281	-0.0019	-0.121
Survival rate for aerial stress	0.0442	-0.0069	(0.3927)	-0.0573	0.0306	-0.0028	-0.1051	0.0091	0.0436	0.1579	-0.4894	-0.0083	0.013
Survival rate for root+aerial stress	0.0980	0.0102	-0.1060	(-0.2121)	-0.0209	0.0025	-0.0813	0.0059	0.0450	0.2410	-0.1339	0.0042	0.065*
Root/shoot ratio	0.0807	0.0009	-0.0223	-0.0082	(-0.5401)	-0.0024	-0.0498	-0.0045	-0.0910	0.0342	0.2781	-0.0190	0.344
Root volume	-0.0267	0.0024	0.0458	-0.0293	0.0705	(0.0187)	-0.1069	0.0006	0.0579	-0.0342	-0.0530	0.0193	-0.037
Hygrophilic colloids	0.145	0.0189	0.2200	-0.0918	-0.1453	0.0107	(-0.188)	0.0061	0.1592	-0.0004	-0.2558	0.0002	0.119
Epidermal cell size	-0.1764	0.0219	-0.0902	0.0318	-0.0621	-0.0032	0.0288	(-0.0396)	-0.0522	-0.0044	0.2993	0.0056	0.038
Flag leaf area	0.0108	0.0007	0.0919	-0.0513	0.2636	0.0058	-0.1602	0.0110	(0.1864)	-0.0139	-0.0751	0.0161	0.286*
No. of stomata	0.0086	0.0416	0.2043	-0.1684	-0.0608	-0.0021	0.0003	0.0006	-0.0085	(0.3037)	-0.0469	-0.0138	0.259*
Leaf venation	-0.0507	0.0227	-0.2621	0.0387	-0.2048	-0.0014	0.0654	-0.0161	-0.0190	-0.0194	(0.7336)	-0.0015	0.285*
Osmotic pressure	-0.0094	-0.0048	0.0627	-0.0173	-0.1987	0.0069	0.0008	0.0043	-0.578	0.0806	0.0215	(-0.0519)	-0.142

indirect effects might decrease the grain yield per plant. Whereas, selection for root-shoot ratio, hygrophilic colloids, epidermal cell size and osmotic pressure might decrease the grain yield per plant, while the selection through the traits having positive indirect effects would increase the grain yield per plant.

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