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Multivariate Statistical Analysis of Yield, its Components and Characters above the Flag Leaf Node in Spring Rye[1]

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Summary. The relationships between yield and its components and structures above the flag leaf node were studied in an 8 × 8 diallel of spring rye (*Secale cereale* L.) by the use of multivariate statistical procedures. Stepwise multiple regression analysis showed that flag leaf characters did not account for significant amounts of variability in yield or its components. Principal component analysis showed no association between yield (and its components) and flag leaf characters while the canonical correlation between the two sets of characters was significant.

Introduction

Thorne (1966) in reviewing the evidence available regarding the physiological aspects of grain yield in cereals concluded that characters above the flag leaf node and yield were closely associated. Hsu and Walton (1971) working with hard red spring wheat showed that flag leaf sheath length, flag leaf width and ear length influenced grain yield by affecting some of the generally accepted components of yield, i.e. weight per grain, number of grains per spike and number of spikes per plant. Similar findings for wheat were also reported by Simpson (1968), Smocek (1969), and Volfeng and Simpson (1967). The present study was undertaken to study the relationships between grain yield, its components and characters above the flag node in the material resulting from the diallel crossing of eight cultivars of spring rye (*Secale cereale* L.) by utilising multivariate statistical procedures.

Materials and Methods

The eight cultivars obtained from CIMMYT in Mexico were: Apicazo, Argentine, Centenio de Alto, Explorer, Marco Juarez, Merced, Prolific and Zoapila. These cultivars were crossed in all possible combinations with the reciprocal families being bulked to yield 28F_1 families. Twelve seeds of each family were planted per row. The distance between seeds and between rows was 30 cm. The experiment was laid out in a randomized block design with four replicates. Each plot consisted of one row.

The following characters were measured:

1. Yield per plant (g)
2. Yield per plot (g)
3. Number of plants per plot
4. Number of tillers per plant
5. Number of spikes per plant
6. Number of seeds per spike
7. Number of spikelets per spike
8. Number of seeds per spikelet
9. 250 kernel weight (g)
10. Flag leaf length (cm)
11. Flag leaf width (cm)
12. Flag leaf sheath length (cm)
13. Length of the extrusion of the spike from the flag leaf sheath
14. Spike length

Characters 1 to 9 were measured after harvest while the rest were measured at maturity. Values were averaged over each plot before analysis. Principal component analysis according to Cattell (1965) was performed with the matrix rotated by the varimax method.

Results

Simple correlations

There was no significant correlation between yield and any of the flag leaf morphological characters (Table 1). The classical yield components were significantly correlated with yield per plant. On a plot basis, plants per plot, number of tillers and spikes per plant and 250 kernel weight were significantly correlated with yield. The number of spikes per plant was negatively correlated with flag leaf length and extrusion length. The number of seeds per spike was positively correlated with kernel weight, flag leaf width, and the characters associated with fertility and spike density. No correlation was found between kernel weight and any of the flag leaf characters.

Canonical correlation

The coefficient of canonical correlation between yield and its components and the characters associated with the flag leaf was highly significant (coefficient of canonical correlation = 0.44; Wilk's lambda = 0.59; Chi-square = 71.51 with 45 degrees of freedom). Yield per plot (coefficient = 2.63) and flag leaf width (coefficient = 0.68) exerted the most influence in determining the correlation between the two sets of characters. Other than this natural division of the characters into two groups no other subsets showed significant canonical correlation.

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Table 1. *Simple phenotypic correlation coefficients*

	Components of yield								Morphological characters				
									Flag leaf				
	Plot yield	Plants per plot	Tillers per plant	Spikes per plant	Seeds per spike	Spikelets per spike	Seeds per spikelet	250 Kernel weight	length	width	sheath length	Extrusion length	Spike length
Plant yield	0.83**	0.04	0.59**	0.58**	0.19*	0.05	0.19*	0.30**	0.00	0.12	0.02	0.14	0.11
Plot yield		0.57**	0.40**	0.43**	0.08	−0.08	0.01	0.22**	−0.01	0.12	0.01	0.24**	0.01
Plants/plot			0.11	−0.06	−0.11	−0.21*	−0.09	0.01	−0.05	0.03	−0.08	0.19	−0.20*
Tillers/plant				0.93**	−0.09	−0.07	−0.05	−0.00	−0.13	0.02	−0.01	−0.01	−0.07
Spikes/plant					−0.09	−0.06	−0.08	−0.04	−0.16*	−0.07	−0.15	−0.44**	−0.13
Seeds/spike						0.50**	0.88**	0.17*	0.14	0.16*	0.12	0.06	0.23**
Spikelets/spike							0.11	−0.02	0.02	0.05	−0.03	−0.02	0.14
Seeds/spikelet								0.19*	0.12	0.11	0.17*	0.09	0.19*
250 Kernel weight									0.01	0.06	0.10	0.11	0.15
Flag leaf length										0.69	0.53**	0.22**	0.45**
Flag leaf width											0.34**	0.12	0.35**
Sheath length												0.11	0.53**
Extrusion length													0.25**

n = 144. — * significant at 5%. — ** significant at 1%.

Stepwise multiple regression analysis

Multiple regression analysis using the measured yield per plot as the dependent variable showed the importance of the classical components of yield (Table 2). Although some of the morphological characters were entered into the regression equation early (Table 2) their inclusion did not improve its predictive value by much. All characters together accounted for 97.61% of the variability present in yield. The five morphological characters accounted for only 5.71% of the variability in yield per plot when used alone in the regression equation. Furthermore they did not account for significant amounts of variability when the dependent variable was any of the classical yield components. The classical yield components on the other hand accounted for 97.30% of the variability observed in yield per plot.

Factor analysis

Using principal components analysis 8 factors were isolated (Table 3) which accounted for 91.58% of the variability present in the data. The factors were named on the basis of the characters having high loadings on them as follows: Factor 1 — Flag leaf area; factor 2 — tillering ability; factor 3 — fertility; factor 4 — production units per unit area; factor 5 — kernel weight; factor 6 — spike density; factor 7 — extrusion length; and factor 8 — spike length.

Discussion

The methods used provided complementary information. Thus both stepwise multiple regression and principal components analysis showed that there was no association between yield and any of its components and the characters associated with the flag leaf. The significant canonical correlation between the two sets of the variables and the significant simple correlations between some of the morphological characters and yield components however indicate that some of these characters covary consistently. It is to be expected that yield and its components will be influenced by the photosynthetic capability of the plant (Thorne, 1966; Walton, 1971); the present statistical approach failed to detect such relationships. However, the combination of multiple regression and principal component analysis was successful in detecting the relationships between yield and its components. Whether the failure to demonstrate any relationship between the characters associated with the flag leaf and yield and its components lies with the methods or whether such a relationship does not exist will have to be answered by further experiments. Although such relationships have been demonstrated in wheat (Walton, 1971) the present author could not show their existence in hexaploid triticale, the amphidiploid between tetraploid wheat and rye (Kaltsikes, unpublished).

Table 2. *Regression coefficients for all characters in the order introduced to the stepwise multiple regression* ($R^2 = 97.7^{***}$)

Character	Regression coefficient
Yield per plant	9.46***
Plants per plot	9.54***
Flag leaf sheath length	0.81*
Extrusion length	0.51*
Number of seeds per spike	−0.54**
Seeds per spikelet	12.81**
Spikelets per spike	0.61*
250 Kernel weight	−0.97
Flag leaf width	5.22
Flag leaf length	−0.42
No. of heads per plant	−0.64
No. of tillers per plant	0.55
Length of head	−0.15

*, **, *** denote significance at the 5%, 1% and 0.1% level of probability, respectively.

Table 3. *Rotated factor matrix (loadings* $\times 10^3$*) for yield, its components and characters above the flag leaf node in spring rye*

Character*	Factor								Communality
	1	2	3	4	5	6	7	8	
1.	35	768	169	313	339	−125	85	87	0.862
2.	35	558	85	757	221	−18	132	72	0.965
3.	00	−122	−73	930	−66	128	75	−6	0.916
4.	00	945	−54	−75	−61	65	−69	−62	0.917
5.	−67	944	−68	−36	−89	44	−9	−100	0.922
6.	86	−20	913	−9	68	−356	13	74	0.979
7.	16	−32	169	−109	−29	−962	−15	21	0.969
8.	35	5	982	−19	79	60	37	99	0.987
9.	35	16	105	20	968	30	43	63	0.957
10.	822	−94	45	−70	−89	45	−10	−101	0.923
11.	932	41	65	74	12	−48	00	139	0.902
12.	253	−59	81	−51	19	133	−49	851	0.823
13.	88	−9	38	128	48	16	973	105	0.987
14.	187	−27	90	36	69	−177	184	817	0.783

* See text for designation of characters.

Zusammenfassung

Das Verhältnis von Ertrag und Ertragskomponenten zur Struktur oberhalb des letzten Halmknotens wurde in einer 8×8 diallelen Kreuzungsserie mit Sommerroggen (*Secale cereale* L.) untersucht. Dabei wurden multivariate statistische Methoden angewandt. Stufenweise mehrfache Regression zeigte, daß alle gemessenen Eigenschaften des Fahnenblattes keinen signifikanten Einfluß hatten, weder auf die Variabilität des Gesamtertrages noch auf die der Ertragskomponenten. Eigenvektor-Faktorenanalyse zeigte keinen Zusammenhang zwischen Ertrag und Ertragskomponenten zu Eigenschaften des Fahnenblattes, während eine kanonische Korrelation zwischen diesen beiden Eigenschaftsgruppen signifikante Beziehungen aufwies.

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