ISSN 1392-3196
Zemdirbyste / Agriculture, vol. 93, No. 4 (2006), p. 306-313
UDK 633.22

STUDIES OF INTERTRAIT CORRELATIONS IN COCKSFOOT (*DACTYLIS GLOMERATA* L.)

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Abstract

Economically valuable traits such as dry matter (DM) yield of the first cut and aftermath, plant height, days to heading, leafiness, digestibility, crude protein and crude fibre contents were studied for 18 varieties and breeding populations of cocksfoot (*Dactylis glomerata* ssp. *glomerata* L.) at the Lithuanian Institute of Agriculture (Dotnuva) during the period 2002-2003. Application of genotypic and phenotypic coefficients of correlation and principal component analysis were studied. Positive, high genotypic correlations ($P < 0.01$) of DM yield of the first cut were noted to plant height (0.780) as well as to crude fibre content (0.828). Negative high genotypic correlations ($P < 0.01$) were found between yield and forage quality traits such as digestibility and crude protein content. Using the principal component method two factors covering more than 85 % from the total variance of traits was revealed. The obtained structure of components from factor 1 allowed us to reveal two groups of correlating traits. The first group includes traits defining DM yield: plant height, crude fibre and DM yield of the first cut. The second group includes traits defining forage quality: days to heading, leafiness, digestibility and crude protein. DM yield of aftermath (factor 2) is not related to other traits studied. As a simple index for selecting plants combining productivity and quality, digestible dry matter (DDM) yield is suggested. The highest DDM yield was shown by the cultivar 'Regenta' (4.0 t ha^{-1}), populations Nos. 1262 (3.79 t ha^{-1}), 1316 (3.76 t ha^{-1}) and 1927 (3.72 t ha^{-1}).

Key words: coksfoot (*Dactylis glomerata L.)*, correlations, principal component analysis.

Introduction

Breeding work with cocksfoot has been in progress since 1924 in Lithuania; five cultivars 'Asta', 'Anksta', 'Aukštuolė', 'Regenta' and 'Dainava' have been developed.

The high coefficients of trait genotypic correlation imply the prevalence of genetic variation in their general phenotypic variation and thus favour a more effective selection of plants according to the genotype /Nyquist, 1991; Smith et al., 1998/.

Intensification of the breeding process, transition from analytical to synthetical breeding techniques requires the knowledge of intertrait correlation allowing a more rational use of the breeding methods.

The main applications of principal components analysis (PCA) analytic techniques are: 1 – to reduce the number of variables, 2 – to detect structure in the relationships between variables that is to classify variables. Therefore, PCA is applied as a data reduction or structure detection method. Principal component analysis (PCA) is a ubiquitous technique for data analysis and processing, but one which is not based upon a probability model. The coordinates of points of variables are defined by their loads on the factors. The purpose of factor analysis is to discover simple patterns in the pattern of relationships among the variables. In particular, it seeks to discover if the observed variables can be explained largely or entirely in terms of a much smaller number of variables called factors.

The correlations among the traits are widely used in the breeding process for selection of the desirable genotypes. The genotypic and phenotypic correlations among the traits in cocksfoot have been discussed by several authors. Kalton et al., (1952) reports on the presence of strong positive correlations among the spring vigour of plants, leafiness and panicle number with forage mass yield. Carlson & Moll (1962) studied the correlations among 8 traits in breeding lines and noted that the genotypic correlations always somewhat exceeded the phenotypic ones. Particularly high positive correlations have been found among leafiness and summer regrowth as well as between summer regrowth and the autumnal vigour of plant development. Correlations between earliness and leafiness were low, if any. A strong negative correlation was found between yield and plant pests /Casler, 1991; Casler et al., 2002/.

The aim of the present study was to elucidate the relationship and correlations among eight economically valuable traits of cocksfoot in order to intensify the process of selection and development of new cultivars.

Materials and methods

As the study material we used four cocksfoot cultivars and 14 breeding populations developed over the recent years at the Lithuanian Institute of Agriculture. The experiments were carried out in 2002-2003 in Dotnuva on a sod gleyic moderately heavy drained loam soil.

The cocksfoot was sown on 8.37 m^{-2} plots in four replications in the first half of June without a cover crop. In the year of use, the herbage was cut three times with a Hege 212 field mower, and 0.5 kg herbage samples were taken for dry matter content analysis. The varieties studied were divided into three groups of earliness according to the beginning of plant heading. The first cut was taken at the beginning of heading for each group of varieties.

Aftermath (2nd and 3rd cuts) was cut 45-55 days following the previous cut.

In the autumn of each year of use, phosphorus and potassium fertilizers ($P_{60}K_{90}$) were applied. Nitrogenous fertilizers (N_{150}) were applied each year of herbage utilization in several applications: in spring N_{60} and N_{45} after the first and second cut. As a standard, the 'Aukštuolė' cocksfoot cultivar was used.

Meteorological conditions during the experimental years varied rather significantly. In 2002, the second half of summer was droughty; consequently the dry matter yield of the aftermath was lower. In 2003, the conditions during the growing season were conducive to cocksfoot growth and development.

Alongside the DM yields of the first cut and aftermath, the varieties and breeding populations were assessed for plant height, number of days from spring regrowth to paniculation and leafiness. The contents of digestible matter, crude protein and crude fibre were determined for the plants of the first cut on a NIRS-6500 spectrometer at the laboratory of chemical tests /Butkute B., 2003/.

Digestible dry matter (DDM) yield can be used as a simple breeding index for selection. $Breeding\ index = \dfrac{DMyields.t/ha \times digestibility.\%}{100\%}$

For analysis of all system of correlations between traits we used a principal components method /Čekanavičius & Murauskas, 2002/. For the improvement of a solution rotation of a system principal components variance maximizing (varimax) rotation of the original variable space was used. As a result of varimax rotation the large loads were enlarged and small reduced, due to which the interpreting principal of components was facilitated. Thus the contributing principal components in a total variance do not vary.

The experimental data were processed by the covariation analysis and principal components analysis method with the application of the breeding-oriented software from the AGROS ver. 2.06 and STATISTICA ver. 5.5 packages.

Results and discussion

The genotypic and phenotypic correlations are measures of the degree of closeness of the linear relationship between the pairs of variables.

The knowledge of the intertrait correlations facilitates the choice of the breeding strategy in developing a new cultivar. The value of the genotypic correlation depends on the pleiotropic effect of genes and on the heritability coefficients of both traits /Falconer, 1985/. The phenotypic and genotypic correlations among seven traits in cocksfoot plants of the first cut are shown in Table 1. In all cases the correlations on the genotypic level exceeded those on the phenotypic level. In three cases, the phenotypic correlations were very weak and statistically insignificant (Table 1).

Positive high genotypic correlations ($P < 0.01$) were identified between DM yield of the first cut and plant height (0.780) and crude fibre content (0.828). The negative high correlations were revealed among DM yield of the first cut and the number of days before paniculation (-0.828), leafiness (-0.825), digestibility (-0.887) and crude protein content (-0.904). Dry matter digestibility positively correlated with leafiness (0.936) and crude protein content (0.827), and negatively correlated with crude fibre content (-0.985).

Phenotypic correlation is not a precise criterion for assessing the interrelations among the traits, as it ignores the influence of environmental conditions on the degree to which the traits are expressed. The reason for a genotypical correlation to arise is based on the manifestation of the pleiotropic action of genes or conjugation among the blocks of genes decisive for the traits. The genotypical correlation will be close to the phenotypical correlation and have the same sign if the medium correlation between the traits is insignificant or negligible. For breeders working on the improvement of both traits, the positive genotypical correlation between the traits will be desirable, whereas the negative correlation will be an obstacle for attaining the desirable goal. It is rather difficult to explain unequivocally the reason for the appearance of different types of correlations. For instance, a higher genotypical correlation as compared to phenotypical implies a weak influence of environmental factors on the traits or a manifestation of the additive action of genes. The results of the study of genotypical correlations can be interpreted from the two points of view. On the one hand it is possible to consider an appreciable genotypical variance in the common correlation variability of the traits, investigated by us. On the other hand the increased correlation coefficient can be linked with delection of nonlinearity, using analysis of covariance for calculation /Falconer, 1985/.

Table 1. Genotypic and phenotypic coefficients of correlations between studied traits
1 lentelė. *Genotipinių ir fenotipinių koreliacijų koeficientai tarp tirtų požymių*

Traits, number *Požymiai, numeris*	Type of correlation *Koreliacijos tipas*	Number of trait *Požymio numeris*					
		2	3	4	5	6	7
DM yield of the 1st cut t ha^{-1}	G	0.780**	0.828**	0.825**	0.887**	0.904**	0.828**
I pjūties saus. medž. derlius t ha^{-1}	P	0.732**	0.683**	0.708**	0.177ns	0.819**	0.193ns
Plant height cm	G		0.888**	0.923**	0.918**	0.770**	0.894**
Augalų aukštis cm	P		0.793**	0.804**	-0.465*	0.593**	0.470*
Earliness days	G			0.917**	1.025ns	0.699**	-0.957**
Ankstyvumas dienomis	P			0.840**	0.691**	0.487*	-0.655**
Leafiness %	G				0.936**	0.762**	-0.825**
Lapuotumas %	P				0.567**	0.574*	-0.549*
Digestibility %	G					0.827**	-0.985**
Virškinamumas %	P					0.034ns	-0.911**
Crude protein %	G						-0.857**
Žali baltymai %	P						0.035ns
Crude fibre %	G						
Žalia ląsteliena %	P						

ns – nonsignificant / *nepatikima*
G – genotypic correlation / *genotipinė koreliacija*
P – phenotypic correlation / *fenotipinė koreliacija*
*, ** – $P < 0.05$ and $P < 0.01$, respectively / $P < 0,05$ ir $P < 0,01$, *atitinkamai*

Results of principal component analysis for 7 traits of cocksfoot is shown in Table 2.

The factor 1 is dominant; it has more than 69 % of variance, while factor 2 has only 16 % of variance. Two factors reflecting more than 85 % from the total variance of traits were revealed (Table 2). Apparently, the first factor is generally more highly correlated with the variables than the second factor. This is to be expected because, as previously described, these factors are extracted successively and will account for less and less variance overall. The better structure of components is shown in Figure 1.

Table 2. Results of principal component analysis for studied traits of cocksfoot
2 lentelė. *Paprastųjų šunažolių tirtų požymių analizės rezultatai, taikant pagrindinių komponentų metodą*

Trait / *Požymiai*	Principal components / *Pagrindiniai komponentai*	
	Factor 1 *1 faktorius*	Factor 2 *2 faktorius*
DM yield of the 1st cut t ha^{-1} *I pjūties saus. medž. derlius t ha^{-1}*	**-0.828348**	0.300124
DM yield of aftermath t ha^{-1} Atolo saus. medž. derlius t ha^{-1}	0.022838	**0.973818**
Plant height cm / *Augalų aukštis* cm	**-0.908095**	-0.246794
Earliness days / *Ankstyvumas dienomis*	**0.947716**	0.027095
Leafiness % / *Lapuotumas %*	**0.910805**	-0.121288
Digestibility % / *Virškinamumas %*	**0.957459**	0.030723
Crude protein % / *Žali baltymai %*	**0.705157**	-0.404275
Crude fibre % / *Žalia ląsteliena %*	**-0.932844**	0.032551
Total sum of squares / *Bendra kvadratų suma*	5.523222	1.280189
% of variance / *Variansu %*	69.04	16.00

Bold loadings - > 0.7 / *Paryškintos reikšmės - > 0,7*

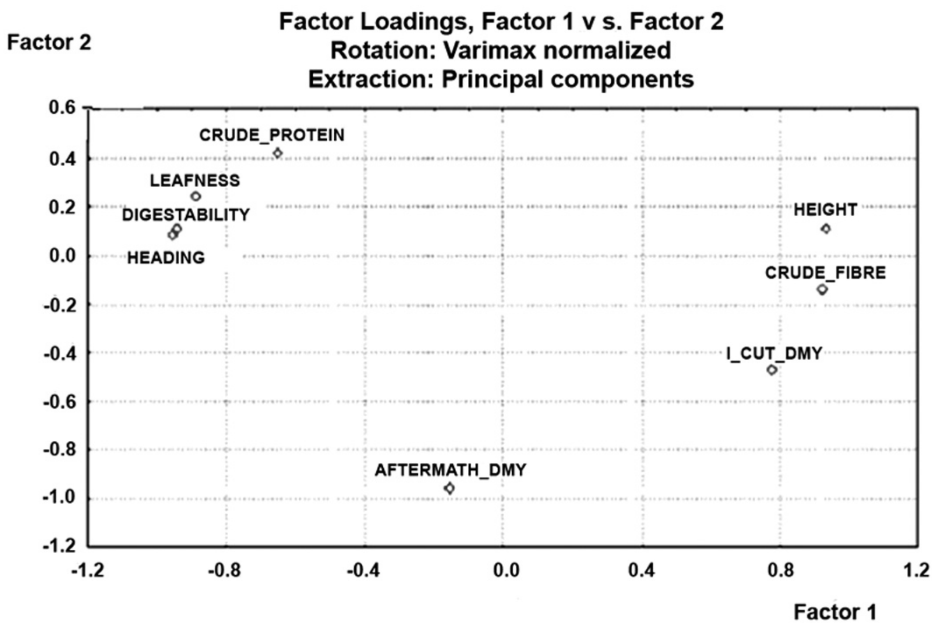


Figure 1. Allocation of traits in a plane of 1 and 2 factors
1 paveikslas. *1 ir 2 faktorių požymių erdvinis išsidėstymas*

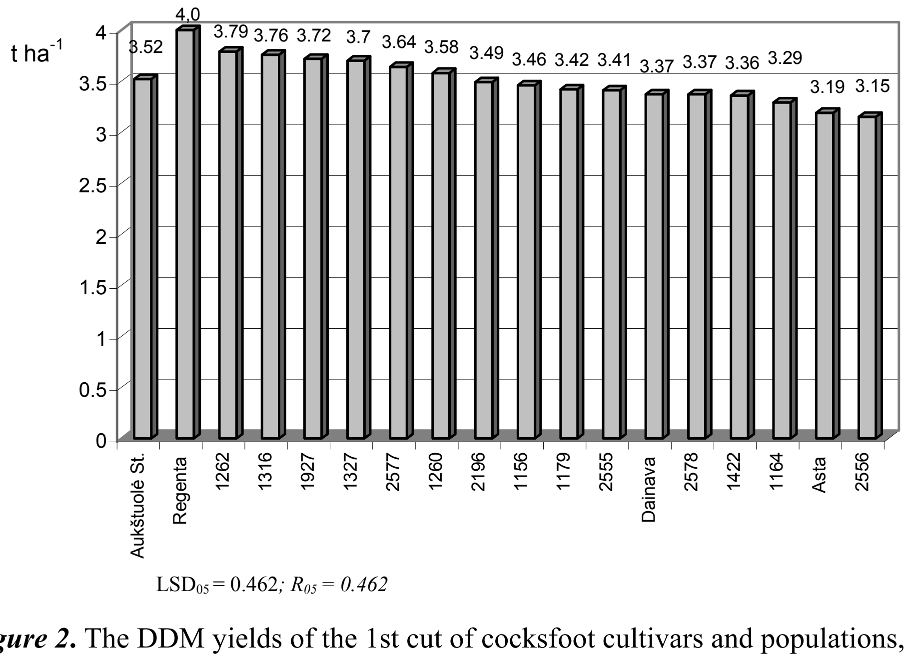
The structure of components from factor 1 allowed us to reveal two groups of linked traits (Figure 1). Every group is seen separately in the right space and in the left space, at the bottom – separately located trait – DM yield of aftermath.

The first group from factor 1 includes traits defining DM yields: plant height, crude fibre and DM yields of the first cut (Figure 1). The second group includes traits defining forage quality: days to heading, leafiness, digestibility and crude protein.

As second factor was revealed only significant trait of DM yield of aftermath. Other traits for factor 2 were not significant (Table 2).

The above-explained facts allow considering that the variance of correlation variability for cocksfoot is stipulated by the genotypical determination permitting to carry out reliable breeding for investigated traits. The main drawback of cocksfoot is a low quality of forage mass compared to other grasses /Kanapeckas, Lemežienė, Tarakanovas et al., 1999/. A correlative analysis confirmed a negative relation on the genotypic level between the first cut yield and the indices of its quality. The late-ripening cultivars of cocksfoot can be regarded as a reserve for raising its quality as a forage /Collins, Casler, 1990/. The processes of ageing in them are slower than in the earlier cultivars. By cutting late-ripening cultivars together with early ones it is possible to gain in digestible matter yield /Paplauskienė, Tarakanovas, 2000/.

The strategy of developing a high-yielding cocksfoot cultivar with a high quality of fodder should be based on a compromise between DM yield and DDM yield. As a simple breeding index for selection, DDM yield can be used. Figure 2 shows DDM yield in cocksfoot cultivars and population. The highest DDM yield was recorded for cultivar 'Regenta' (4.0 t ha^{-1}), Nos. 1262 (3.79 t ha^{-1}), 1316 (3.76 t ha^{-1}) and 1927 (3.72 t ha^{-1}).



$LSD_{05} = 0.462$; $R_{05} = 0.462$

Figure 2. The DDM yields of the 1st cut of cocksfoot cultivars and populations, t ha^{-1}
2 paveikslas. *Paprastųjų šunažolių veislių ir populiacijų I pjūties virškinamųjų sausųjų medžiagų derlius t ha^{-1}*

Conclusions

1. Using the principal of the main components two factors covering more than 85 % from the total variance of traits were revealed. The obtained structure of components from factor 1 allowed us to reveal two groups of linked traits. The first group includes traits defining DM yields: plant height, crude fibre and DM yield of the first cut. The second group includes traits defining forage quality: days to heading, leafiness, digestibility and crude protein. DM yield of aftermath (factor 2) is not related with other studied traits.

2. Positive, high, genotypic correlations ($P < 0.01$) were found between the yield of the first cut and plant height (0.780), as well as crude fibre content (0.828). Negative, high, genotypic correlations ($P < 0.01$) were observed between the forage quality indicators and the yield of the first cut.

3. As a simple index of breeding, for selection of plants combining productivity and quality, digestible dry matter yield is suggested. The highest digestible matter yield of the 1st cut was exhibited by the cultivar 'Regenta' (4.0 t ha^{-1}), Nos. 1262 (3.79 t ha^{-1}), 1316 (3.76 t ha^{-1}) and 1927 (3.72 t ha^{-1}).

Received 07 09 2006
Accepted 20 11 2006

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ISSN 1392-3196
Žemdirbystė, t. 93, Nr.4 (2006), p. 306-313
UDK 633.22

PAPRASTŲJŲ ŠUNAŽOLIŲ POŽYMIŲ KORELIACINIŲ RYŠIŲ TYRIMAS

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Santrauka

Lietuvos žemdirbystės institute 2002-2003 metais įvertinta 18 paprastųjų šunažolių veislių ir selekcinių numerių pagal šiuos požymius: I pjūties bei atolo sausųjų medžiagų derlių, vegetacijos periodo trukmę iki plaukėjimo, lapuotumą, žalius baltymus, virškinamumą ir ląstelieną. Tarp visų požymių apskaičiuoti genotipinės ir fenotipinės koreliacijos koeficientai. Pozityvinė aukšta genotipinė koreliacija ($P < 0,01$) nustatyta tarp I pjūties sausųjų medžiagų derliaus ir augalų aukščio (0,780), taip pat tarp I pjūties sausųjų medžiagų derliaus ir ląstelienos kiekio (0,828). Negatyvinė aukšta genotipinė koreliacija ($P < 0,01$) nustatyta tarp I pjūties sausųjų medžiagų derliaus ir pašaro kokybės požymių, tokių kaip virškinamumas ir žalių baltymų kiekis. Naudojant pagrindinių komponentų metodą, nustatyti du veiksniai, apjungiantys daugiau kaip 85 % šių veiksnių reikšmių nuo bendros variacijos. Tai leido nustatyti dvi tarpusavyje susijusias grupes pagal atitinkamus požymius. Pirmąją grupę apjungia kiekybiniai požymiai, lemiantys sausųjų medžiagų derlių: augalų aukštis, ląstelienos kiekis ir I pjūties sausųjų medžiagų derlius. Antrąją grupę apjungia požymiai, lemiantys pašarų kokybę: vegetacijos periodo trukmė iki plaukėjimo, lapuotumas, žali baltymai ir virškinamumas. Atolo sausųjų medžiagų derlius (faktorius 2) nėra susijęs su kitais nagrinėjamais požymais. Kaip selekcinį indeksą, apjungiantį produktyvumą ir kokybę, galima vartoti virškinamųjų sausųjų medžiagų derlių. Pagal šį indeksą išsiskyrė veislė ‘Regenta’ (4,0 t ha^{-1}) bei selekciniai numeriai 1262 (3,79 t ha^{-1}), 1316 (3,76 t ha^{-1}) ir 1927 (3,72 t ha^{-1}).

Reikšminiai žodžiai: paprastoji šunažolė (*Dactylis glomerata* L.), koreliacijos, pagrindinių komponentų metodas.