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THE INFLUENCE OF REDUCTION OF THE NUMBER OF MEASUREMENTS ON DECISIONS CONCERNING DISTINCTNESS OF RED FESCUE (*FESTUCA RUBRA* L.) VARIETIES

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Summary

In a paper the problem of reduction of number of measurements in DUS (distinctness, uniformity and stability) trials on red fescue varieties is discussed. All consideration are based on the results of DUS trials performed by The Research Centre for Cultivar Testing in the years 2005 to 2009. All trials were performed at Variety Testing Experimental Station at Słupia Wielka. It has been shown that reduction in the number of measurements from 60 to 30 will have very limited impact on decisions concerning distinctness of tested varieties

Keywords and phrases: DUS trials, number of measurements, red fescue

Classification AMS 2010: 62K99, 62P10

1. Introduction

Every new variety of any cultivated species before being accepted (e.g. listed in National List of Varieties) must pass a set of tests called distinctness, uniformity and stability trials (DUS tests). International Union for the Protection of New Varieties of Plants (UPOV) coordinates internationally research related to DUS trials. Countries, members of UPOV, are obliged to perform their DUS trials according to the Guidelines for the Conduct of Test for Distinctness, Uniformity and Stability, issued by UPOV. As every new (candidate) variety must be distinct from every other known variety (so-called variety of common knowledge), therefore the number of tested varieties in one trial is often very large (often larger than 100). The number of observed characteristics is dependent on species and is often large (for some species larger than 50). The so-called measured characteristics (reversely than visually assessed ones) need special equipment and time of specialized person to make measurements. The number of measurements concerning plants or their parts (for every tested variety) is usually not smaller than 30. In all species of grasses (therefore also for red fescue) the number of measurements is, according to UPOV guidelines (see TG/67/4, 1990) equal to 60. There were some optimization efforts undertaken within Technical Working Group TWC of UPOV (see documents TWC/25/14 and TWC/29/26). All consideration concentrated on reduction of the number of reference varieties (the varieties to which new variety is similar and potentially indistinct). The other proposal was to compare candidate variety with different sets of reference varieties in different years of testing (cyclic planting). Similar considerations performed by Pilarczyk and Kowalczyk (2011) related to DUS testing of ryegrass varieties showed that reduction in number of measurements had very limited impact on decisions concerning distinctness decisions, in particular on decisions after three years of testing. In this paper the influence of reduction of number of measurements on distinctness decisions in DUS trials on red fescue varieties is undertaken.

2. Data

The results of five DUS trials performed by The Research Centre for Cultivar Testing in years 2005-2009 form basis of the considerations. All the trials were established at Variety Testing Experimental Station at Słupia Wielka near Poznań. The trials were organized as randomized complete block experiments with six replicates. There were ten plants chosen at random from every plot, giving in total 60 measurements for each characteristic and every variety. There were the following characteristics included:

whole plant characteristics:

- natural height (coded RNWN),
- leaf width (LSRS),
- length of longest stem (ZDNZ),
- upper internode length (ZDGM),

flag leaf characteristics:

- length (LFD),
- width (LFS),
- size (LFW),
- shape (ratio of length to width – LFK),

inflorescence characteristic:

- length (KD).

All the measurements were taken at proper plant development stage as indicated in official UPOV TG/67/5 document.

3. Method

All considered characteristics (traits) were analyzed in turn one by one. The analysis of variance was the main tool used for statistical interpretation of results. For yearly results (single trials), the adopted mixed model of observation has been of the form (Oktaba, 1980):

$$y_{ijk} = \mu + b_i + t_j + \eta_{ij} + e_{ijk} \tag{3.1}$$

where y_{ijk} denotes *k*-th measurement of analyzed characteristic concerning *j*-th variety within *i*-th replicate (complete block). The remaining symbols denote respectively:

μ – general mean, b_i – the random effect of *i*-th complete block (replicate), t_j – the fixed effect of *j*-th variety, η_{ij} – the plot error and e_{ijk} – the measurement error.

After analysis of variance, all pairs of tested varieties were compared using Fisher's LSD (least significant difference) at α=0.05 significance level (Guenther, 1964). It is worth to mention that this method of multiple comparisons does not fulfill requirements for being the simultaneous test procedure. But this method is officially adopted by UPOV and Poland, like all other members states, is obliged to use this method.

After three (sometimes after two) years of testing, the 'multi-years" analysis of series of trials is performed using the mixed model as follows:

$$y_{ij} = \mu + r_i + t_j + (rt)_{ij} + \bar{e}_{ij} \tag{3.2}$$

where y_{ij} denotes *i*-th variety mean value obtained in *j*-th year and the remaining symbols mean respectively:

μ – the general mean, r_i – the random effect of *i*-th year, t_j – the fixed effect of *j*-th variety, $(rt)_{ij}$ – the random interaction effect of *i*-th year and *j*-th variety, $\bar{e}_{ij}$ – the pooled error (weighted mean of errors from single trials).

In this model (when interaction is significant, which is the case in majority of all analyzed trials and characteristics), the significance of differences among varieties is tested against the mean square for interaction (Talbot, 2000). All pairs of varieties are again compared using LSD approach but now the mean square for interaction plays the role of error.

All the calculation has been performed twice with use DUST package (Weatherup, 1992). First time all available data were used. In the next step, only randomly chosen half of data were involved and the same calculation was performed. For every characteristic the number of cases were counted that pairs of varieties were declared distinct (different at 0.05 significance level). The characteristic that distinguishes the largest number of pairs is declared as one possessing the highest discriminating power (and is ranked 1). The other characteristic that distinguishes smaller number of pairs than that ranked 1, but larger number than all other characteristics is ranked 2, and so on. All characteristics are also ranked according to so-called relative discriminating power. The characteristic that distinguishes the largest number of pairs is possessing also rank 1 according the relative discriminating power. The characteristics that distinguishes the second largest number of pairs but after excluding all pairs already distinguished by characteristic with rank 1 obtains rank 2, and so on. In that way all characteristics are ranked according to power of discrimination in all single (one year trials), in two years series and in three years series. All the calculations were performed for full dataset and for reduced dataset, therefore the dependence of conclusions on number of measurements could be observed.

4. Results

In Table 1 the results of yearly analyses for all data are given, while in Table 2, the same results for reduced data are presented. As expected, the number of not distinct pairs of varieties slightly increased for reduced data both in one-year analyses and in three-years analyses. For example in year 2005 the number of indistinct pairs of varieties increased from 207 (for all data) to 266 (for reduced data). The difference is 59 pairs, but it is less than 1.4% of total number of tested pairs.

Table 1. Absolute and relative discriminating power of characteristics, yearly results – full dataset

Characteristic	Year (number of distinguished pairs) 2005				2006				2007				2008				2009				Sum of ranks	
	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Rela-tive
plant: LSRS	2458	5	55	5	4803	7	58	5	3014	2	292	3	2640	2	46	5	90	9	5	9	25	27
RNWW	-	-	-	-	5228	1	5228	1	3201	1	3201	1	2876	1	2876	1	1894	5	568	2		
ZDNZ	3258	1	3258	1	4648	8	7	7	2754	3	115	4	2572	3	10	7	1752	6	132	4	21	23
ZDGM	2573	4	191	3	4867	5	342	3	2310	6	31	6	2355	7	109	4	1452	8	24	6	30	22
flag leaf: length (LFD)	2736	3	86	4	4958	3	4	8	2434	5	10	8	2453	6	1	8	2427	3	221	3	20	31
width (LFS)	1853	7	10	7	4839	6	3	9	2001	8	19	7	658	9	0	9	2830	1	2830	1	31	33
shape (LFK)	1594	8	28	6	3975	9	108	4	1219	9	36	5	2473	5	676	2	1685	7	21	7	38	24
size (LFW)	2380	6	3	6	4944	4	16	6	2249	7	1	9	2340	8	17	6	2562	2	9	8	27	37
inflorescence: length (KD)	2868	2	440	2	5197	2	965	2	2666	4	571	2	2550	4	214	3	2273	4	71	5	16	14
number of varieties	93				117				96				90				96					
number of pairs	19720		4278		43459		6786		21848		4560		20917		4005		16965		4560			
number of distinct pairs	19720		4071		43459		6731		21848		4276		20917		3949		16965		3881			
number of indistinct pairs			207				55				284				56				679			

Table 2. Absolute and relative discriminating power of characteristics, yearly results – reduced data

Characteristic	Year																				Sum of ranks	
	2005				2006				2007				2008				2009					
	number of distinguished pairs																					
	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rank	Absolute	Relative
plant: LSRS	2280	5	72	5	4138	8	36	6	2535	3	265	3	2664	2	138	4	172	9	2	9	27	27
RNWW	-	-	-	-	4952	1	4952	1	2974	1	2974	1	2690	1	2690	1	1654	5	618	2		
ZDNZ	3164	1	3164	1	4530	6	19	7	2661	2	84	5	2387	3	12	7	1650	6	161	4	18	24
ZDGM	2520	4	183	3	4518	7	1058	2	2164	7	120	4	2232	6	286	3	1384	8	20	7	32	19
flag leaf: length (LFD)	2601	3	92	4	4660	5	13	8	2236	5	7	8	2334	5	4	8	2280	3	292	3	21	31
width (LFS)	1813	7	18	7	4916	2	189	4	1589	8	6	9	1826	9	28	6	2547	1	2547	1	27	27
shape (LFK)	1525	8	40	6	3436	9	50	5	1102	9	59	6	2098	7	70	5	1479	7	42	6	40	28
size (LFW)	2248	6	4	8	4732	4	2	9	2173	6	19	7	2077	8	1	9	2460	2	18	8	26	41
inflorescence: length (KD)	2756	2	439	2	4892	3	363	3	2469	4	600	2	2352	4	74	2	2206	4	79	5	17	14
number of varieties	93				117				96				90				96					
number on pairs	18907		4278		40774		6786		19903		4560		20660		4005		15832		4560			
number of distinct pairs	18907		4012		40774		6682		19903		4134		20660		3933		15832		3779			
number of indistinct pairs			266				104				426				72				781			

Table 3. Absolute and relative discriminating power of characteristics in three years series – full dataset

Characteristic	Years												Sum of ranks	
	2005-2007				2006-2008				2007-2009					
	number of distinguished pairs													
	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rrank	Absolute	Rank	Relative	Rank	Absolute	Relative
plant:														
leaf width (LSRS)	2235	1	2235	1	1643	2	205	2	1671	2	178	3	5	6
natural height (RNWW)	-	-	-	-	2004	1	2004	1	1872	1	1872	1		
length of longest stem (ZDNZ)	1383	6	21	5	1264	6	34	5	1465	4	281	2	16	12
upper internode length (ZDGM)	495	8	1	8	567	8	10	7	1168	6	29	6	22	21
flag leaf:														
length (LFD)	1856	2	38	4	1390	4	60	4	1401	5	104	4	11	12
width (LFS)	1556	5	10	6	1295	5	7	8	980	7	2	8	17	22
shape (LFK)	790	7	65	3	754	7	147	3	740	8	51	5	22	11
size (LFW)	1726	4	2	7	1521	3	18	6	1611	3	16	7	10	20
inflorescence:														
length (KD)	1820	3	219	2	92	9	1	9	88	9	1	9	21	20
number of varieties	75				76				76					
number of pairs	11861		2775		10530		2850		10996		2850			
number of distinct pairs	11861		2591		10530		2486		10996		2534			
number of indistinct pairs			184				364				316			

Similar figures are observed for other years, the largest difference in number of indistinct pairs appeared in year 2007, it was 3.1% of total number of tested pairs of varieties, the smallest in year 2008, only 0.40% of total number of pairs. Similar phenomenon is observed in two- and three-years series of trials, see Table 3 and Table 4. The results for two-years series are not presented for practical reasons. Usually the so-called "early decisions" are taken after first year of testing and the final decisions after three years. In series from years 2005-2007, the number of indistinct pairs increased for 0.90% of total number of tested pairs, while – rather unexpectedly – in years 2006-2008 and 2007-2009, the number of indistinct pairs was higher respectively for 3.0% and 3.7% for full set of data than for reduced one. At least partly this phenomenon can be justified by fact, that in series of DUS trials, differences among varieties are tested against the mean square for variety by year interaction while in single trials

against the mean square for plot error. The mean square for interaction depends more on the number of years than on the number of measurements while the mean square for plot error depends on the number of replicates (here always 6) and on the number of measurements. Therefore larger differences in numbers of indistinct pairs were observed in single trials than in series of trials. Also the rankings of characteristics according to their absolute and relative discriminating power, see figures in all tables from 1 to 4, are very similar for analysis with use of full and reduced set of data. For example in yearly analyses, both for full data set and for reduced data set, the highest discriminating power revealed characteristic KD (length of inflorescence). On the other hand, characteristics LFK and LFW had the lowest discriminating power in two considered versions of analysis (full and reduced dataset).

Table 4. Absolute and relative discriminating power of characteristics in three years series – reduced data

Characteristic	Years												Sum of ranks	
	2005-2007				2006-2008				2007-2009					
	number of distinguished pairs													
	Absolute	Rank	Relative	Rank	Absolute	Rank	Relative	Rrank	Absolute	Rank	Relative	Rank	Absolute	Relative
plant:														
leaf width (LSRS)	2218	1	2218	1	1640	3	81	4	1598	4	105	4	8	9
natural height (RNWW)	-	-	-	-	1949	1	1949	1	1810	1	1810	1	2	2
length of longest stem (ZDNZ)	1366	6	17	6	1240	7	20	6	1406	6	39	6	19	18
upper internode length (ZDGM)	483	8	0	8	584	9	8	7	1161	8	12	7	25	22
flag leaf:														
length (LFD)	1725	3	50	3	1705	2	53	2	1784	2	131	3	7	11
width (LFS)	1485	5	22	5	1289	6	4	9	1223	7	4	9	18	23
shape (LFK)	666	7	37	4	859	8	119	3	968	9	55	5	24	12
size (LFW)	1685	4	3	7	1536	5	5	8	1552	5	6	8	14	23
inflorescence:														
length (KD)	1814	2	219	2	1609	4	333	2	1709	3	477	2	9	6
number of varieties	75				76				76					
number of pairs	11442		2775		12411		2850		13211		2850			
number of distinct pairs	11442		2566		12411		2572		13211		2639			
number of indistinct pairs			209				278				211			

4. Conclusion

Performed analysis allow to conclude, that looking for more optimal planning of DUS trials on grasses, apart from methods proposed in literature (reduced the reference set of varieties or their cyclic planting) also the reduction in the number of measurements should be seriously taken into consideration.

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