TOOLS FOR EVALUATION OF WEED COMPETITIVENNESS OF WHEAT

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Abstract

This study is concentrated on the testing of methods of weed competitiveness evaluation. There were used simple scoring methods (tuft shape, the length of the plant) and compared with indirect methods based on LAI (SunScan Devices - Canopy Analysis Sytem) and soil coverage evaluation (multispectral image data analyzes by software MultiSpecW32). When evaluating parameter LAI, there were positive correlations with the length of the plant in all stages of measuring (BBCH 33-36, 55, 69). When assessing ground cover vegetation in BBCH 29, there were possitive correlation with the length of plants in all stages of the evaluation (BBCH 33-36, 55, 69). After evaluating the characters contributing to the weed competitiveness of varieties, we can´t find variety with the highest weed competitiveness. But the results of our experiment shown that tools based on LAI and soil coverage measurements could be use for proposal of varieties with better weed competitiveness.

Key words: methods of evaluation, wheat, weed competitiveness.

INTRODUCTION

Weed plants are one of the main factors limiting the level of agricultural yield (ANDREW ET AL., 2015). In comparison with pests and diseases, weeds have the potential to incur the greatest yield loss, through competition with the crop and decreasing yield quality, and can, therefore, incur high costs of control (OERKE, 2006). Because of the availability of herbicides in the last 50 years, the natural competitiveness of field crops to weeds has been overlooked (LAMMERTS VAN BUEREN, 2002). Application of herbicides have also significant environmental impact. While i.e. the volume of greenhouse gases emissions caused by the application of pesticides has decreased during the time (MOUDRÝ ET AL., 2013A), and is currently on low values (MOUDRÝ ET AL., 2013B; MOUDRÝ ET AL., 2013C), the ecotoxicity of pesticides is often high.

Many cultural control methods may be employed by farmers to reduce weed populations, including delayed drilling, increased seed rate and rotational ploughing (LUTMAN ET AL., 2013). Competitive cultivars are a potentially attractive option in comparison, because they do not incur any additional costs (ANDREW ET AL., 2015). Cereal cultivars having a high degree of crop competitive ability, especially against aggressive weeds, are highly beneficial in organic farming as well as in other farming systems that aim to limit the use of herbicides (HOAD ET AL, 2008; MASON ET AL., 1990). Morphological, physiological, and biochemical traits are thought to control plant competitiveness. A competitive crop ideotype for spring wheat should include taller plants, with fast early season growth, early maturity, and increeased fertile tiller number (MASON ET AL., 1990; KÖPKE 2005; KRUEPL ET AL 2006).

Early interest in competitive cultivar traits mainly focussed on maximum canopy height. Although the advantages of plant height in terms of shading weeds are clear, it cannot, alone, explain variation in competitive ability (ANDREW ET AL., 2015). Early vigour of a cultivar is related to crop establishment and the rate at which aboveground material is produced and has been correlated with morphological leaf traits such as leaf area in the earliest phases of growth (REBETZKE & RICHARDS, 1999). Tillering capacity in wheat contributed to suppression of dry matter production in mixed flora assemblages (KORRES & FROUD- WILLIAMS, 2002). In wheat, leaf area index at early growth phases was associated with suppression (HUEL & HUCL, 1996; HOAD ET AL., 2006; HANSEN ET AL., 2008).

The competitiveness against weed is not targeted by breeding of modern wheat cultivars (KONVALINA ET AL., 2014). We cannot consider the newly bred plants are naturally competitive to weed plants, because it has not confronted any important competitive weed plant during the breeding process (LAMMERTS VAN BUEREN, 2002).

Methods for determination of the ability to suppress weeds must be practical and stable enough to be employed in the breeding selective process and in the evaluation of new lines and cultivars. Selection of the ability to suppress weeds can be made at weeded plots directly, or, according to BERTHOLDSSON (2005), it can be made indirectly – by selection of characteristics (features) related to the competitiveness.

This study aims to verify practical possibilities for the employment of modern methods, which are based on a detailed analysis of image, or a measurement of leaf area. We can study natural wheat competitiveness against weeds by using these methods and techniques. This work partly aims to evaluate correlations of the above-mentioned methods with classical evaluation techniques, which are based on evaluation of particular morphological characteristics.

MATERIALS AND METHODS

Eight spring wheat varieties (Anabel, Astrid, Dafne, Izzy, Quintus, KW Scirocco, SG – S833 – 11, and SW Kadrilj) were grown on the test plots in České Budějovice and Zvíkov. The experiment was carried out in compliance with organic farming standards.

Characteristic of the test plot in České Budějovice is as follows: altitude of 385 metres above sea level, grain-growing region, land type – sand and earth, gley brown soil. Beans (Faba vulgaris) as forgoing crops. Harrowing (protection against weeds) was carried out once a growing season.

Characteristic of the test plot in Zvíkov is as follows: altitude of 485 metres above sea level, grain-growing region, land type – earth, brown soil. Mixture of legumes and cereals as a forgoing crop. Harrowing (protection against weeds) was carried out once a growing season.

Evaluating the wheat competitiveness against weeds, we studied the following characteristics:

- Tuft shape (the methodology reference) in BBCH 29;
- Length of plants (the methodology reference) measured in three different periods (BBCH 33–36, BBCH 51–55, BBCH 69);
- Flag leaf position (the methodology reference) in BBCH 51–55;
- Vegetation cover was measured with the Multi-SpecW32 software instrument during the periods of BBCH 29 and BBCH 33–36;
- LAI analysis was carried out with the SunScan (Canopy Analysis System) instrument during three different periods (BBCH 33–36, BBCH 51–55, BBCH 59).

The statistical data analysis was carried out with the STATISTICA 9.1 (StatSoft, Inc. USA) program. We used the analysis of variance (ANOVA) in order to evaluate an impact of the locality, variety or both on every assessed characteristic. Tukey HSD test was carried out as well. We measured average figures of every variety at both stations. We also measures average figures of every characteristic at both stations. Correlations were employed there; they showed closeness strength) of relations between the variables.

RESULTS AND DISCUSSION

Official variety tests do not deal with the competitiveness of cereals against weeds. Some of the recommended characteristics are evaluated there, they are not interpreted anyway (their relation to the competitiveness against weeds is not interpreted there). This is e.g. the length of plant (HOAD ET AL., 2006). Therefore, our article aims to describe relations (correlations) between the individual characteristics that influence the competitiveness against weeds. At the same time, we have to tell genetically determined characteristics apart. We have to tell characteristics influencing the environment apart as well.

Tab. 1 shows the results of analysis of variance for every factor. The results have shown the length of plant is influenced by the locality (it was strongly influenced in every measured and tested case). Varieties of cereals with long stalks are much more competitive than varieties with short stalks (CUDNEY ET AL., 1991). The other way around, the tuft shape and the position of flag leaf were influenced by the variety, not the locality in our tests (see Tab. 2). The vegetation cover rate was strongly influenced by the locality in our tests. It is one of the most significant characteristics for the competitiveness against weeds (LEMERLE ET AL., 1996).

Tab. 1. – Analysis of factor influence (ANOVA**)**

Factor	DF	LAI BBCH 36		LAI BBCH 49		LAI BBCH 55		Plant length BBCH 33-36		Plant length BBCH 55		Plant length BBCH 69	
		MS	%	MS	%	MS	%	MS	%	MS	%	MS	%
Variety (1)	7	1.7178	16.2***	0.694	1.63ns	1.20	1.91***	48	16.2**	74	0.26***	470	1.87***
Locality (2)	1	7.6002	71.7***	38.07	89.5***	60.30	96.0***	31827	71.7***	28203	99.6***	2456	97.82***
1x2	7	0.9226	8.7*	3.171	7.46***	1.070	1.70***	31	8.69*	38	0.13**	76	0.30**
Eror	176	0.389	-	0.595	-	0.268	-	13	-	11	-	27	-
Note: P < 0.05; **P < 0.01; P < 0.001; ns - no significant													

Tab. 2. – Analysis of factor influence (ANOVA)

Factor	DF	Uncovered soil BBCH 29		Uncovered soil BBCH 33-36		Soil coverage BBCH 29		Soil coverage BBCH 33-36		Tuft shape		Flag leaf position	
		MS	%	MS	%	MS	%	MS	%	MS	%	MS	%
Variety (1)	7	152	5***	111	6***	152	5***	111	6***	44.1	88**	46**	87
Locality (2)	1	2860	93***	1604	89***	2869	93***	1604	89***	3.0	6**	0**	0
1x2	7	74	2**	80	5***	75	2**	80	5***	3.0	6**	7**	12
Eror	176	21	-	18	-	21	-	18	-	0.0	-	0	-
Note: P < 0.05; **P < 0.01; P < 0.001; ns - no significant													

Tab. 3. – Variety evaluation results I

Variety	LAI BBCH 36	LAI BBCH 49	LAI BBCH 55	Plant length BBCH 33-36	Plant length BBCH 55	Plant length BBCH 69
Anabel	1.76±15.1ab	2.66±13.9a	3.13±11.5a	35.25±15.0a	47.67±13.9a	74.25±11.5a
Astrid	1.95±12.8ab	3.05±11.9a	3.39±14.3ab	32.83±12.8a	52.58±11.9a	81.63±14.3ab
Dafne	2.24±14.2ab	2.86±10.4a	3.14±12.1ab	33.83±14.2a	51.29±10.4a	81.20±12.1ab
Izzy	2.33±13.0b	2.91±12.5a	3.51±11.3ab	34.66±13.0a	52.79±12.5a	88.70±11.3b
Quintus	1.66±15.3a	3.00±13.0a	3.83±10.1b	33.20±15.3a	51.37±13.0a	78.33±10.1ab
KW Scirocco	1.73±11.7a	2.97±13.5a	3.40±14.1ab	37.17±11.7a	50.71±13.5a	84.29±14.1ab
SW Kad-rilj	1.68±13.0a	2.90±12.9a	3.27±12.7ab	33.25±13.6a	53.25±13.8a	84.75±14.4ab
SG S 833	2.12±13.6ab	3.26±13.8a	3.34±14.4ab	34.38±13.0a	50.63±12.9a	79.50±12.7ab
Note: Statistically different at P < 0,05 (Tukey HSD test).						

Tab. 3 and 4 show the results of evaluated parameters of every tested variety. The results have shown a considerable variability of characteristics among tested varieties. We can choose a variety which has more preferable characteristic in more likely to be competitive against weeds.

Tab. 4. – Variety evaluation results II

Variety	Uncovered soil BBCH 29	Uncovered soil BBCH 33-36	Soil coverage BBCH 29	Soil coverage BBCH 33 - 36	Tuft shape BBCH 29	Flag leaf position BBCH 55
Anabel	42.02±7.3ab	32.89±5.5ab	57.98±7.9ab	67.11±5.6ab	3.00±0.0a	5.00±0.0b
Astrid	40.58±5.3a	29.75±3.8b	59.42±5.3a	70.25±3.8b	3.00±0.0a	3.00±0.0a
Dafne	39.14±6.7a	31.80±5.5ab	60.86±6.7a	68.20±5.5ab	5.00±0.0b	3.00±0.0a
Izzy	46.83±.4b	36.01±3.4a	53.17±5.4b	63.98±3.4a	1.00±0.0c	3.00±0.0a
Quintus	43.83±4.7ab	33.46±5.6ab	56.17±4.7ab	66.53±5.6ab	5.00±0.0b	5.00±0.0b
KW Scirocco	40.69±5.5a	34.99±6.0a	59.31±5.5a	65.01±6.0a	3.00±0.0a	5.00±0.0b
SW Kadrilj	40.78±6.3a	33.99±3.0ab	59.22±6.3a	66.01±3.0ab	3.00±1.0d	3.00±0.0a
SG S 833	44.20±6.8ab	360.3±7.8a	55.85±6.9ab	63.96±7.8a	3.00±0.0a	7.00±1.0c
Note: Statistically different at P < 0,05 (Tukey HSD test).						

Assessing the practical employment of the weed competitiveness evaluation methods and techniques, we carried out and assessed the correlation analysis (see Tab. 5). Measuring the leaf area index (LAI) in BBCH 49, we found positive correlations with the length of plant in every measured period (BBCH 33–36, 55, 69). LAI is one of the main factors that influence the competitiveness to weeds (Huel and Hucl, 1996). The length of plant we measured in BBCH 33–36, 55 and 69, correlated with the leaf area LAI (BBCH 55). The length of plant in BBCH 55 related obviously to the length of plant in BBCH 33–36 and BBCH 69. We also found a correlation between the vegetation cover in BBCH 29 and the length of plant in BBCH 33–36, 55 and 69. LAI figures in BBCH 55 correlated with the vegetation cover in BBCH 33–36. We found a correlation in every stage of evaluation. Such a finding has been supported by NEUHOFF ET AL. (2005) who also say that the total LAI correlates to the vegetation cover. Crop stands with well-established photosynthetic apparatus are more likely to reach higher LAI values, even in later stages of growth. The other way around, plants with smaller leaf area in early stages of growth do not reach larger leaf area or higher yield rate during the rest of the growing season either (DREWS ET AL., 2004).

Tab. 5. – Correlation analysis

Parameter	Mean	SD	LAI BBCH 33-36	LAI BBCH 49	LAI BBCH 55	Plant length BBCH 33- 36	Plant length BBCH 55	Plant length BBCH 69	Uncovered soil BBCH 29	Uncovered soil BBCH 33 -36	Soil coverage BBCH 29	Soil coverage BBCH 33-36	Tuft shape BBCH 29	Flag leaf position BBCH 55
LAI BBCH 36	1.93	0.702												
LAI BBCH 49	2.95	0.943	0.13*											
LAI BBCH 55	3.38	0.803	0.25*	0.34*										
Plant length BBCH 36	34.32	13.47	0.25*	0.46*	0.68*									
Plant length BBCH 55	51.29	12.72	0.27*	0.47*	0.69*	0.95*								
Plant length BBCH 69	81.58	13.15	0.27*	0.44*	0.61*	0.88*	0.92*							
Uncovered soil BBCH 29	42.26	6.523	-0.10*	-0.24*	-0.36*	-0.55*	-0.52*	-0.47*						
Uncovered soil BBCH 33 -36	33.65	5.615	-0.12*	-0.19*	-0.40*	-0.46*	-0.49*	-0.41*	0.58*					
Soil coverage BBCH 29	57.73	6.527	0.10*	0.25*	0.36*	0.55*	0.52*	0.47*	-1.00*	-0.58*				
Soil coverage BBCH 33-36	66.38	5.615	0.12*	0.19*	0.40*	0.46*	0.49*	0.41*	-0.58*	-1.00*	0.58*			
Tuft shape	3.13	1.320	-0.11^{ns}	0.01^{ns}	-0.01^{ns}	-0.11^{ns}	-0.13^{ns}	-0.26*	-0.12^{ns}	-0.12^{ns}	0.12^{ns}	0.12^{ns}		
Flag leaf position	4.25	1.396	-0.15*	0.97^{ns}	0.06^{ns}	0.06^{ns}	-0.07^{ns}	-0.13^{ns}	0.01^{ns}	0.11^{ns}	-0.01^{ns}	-0.11^{ns}	0.19*	

Note: *Statistically significant. ^{ns}Not significant

CONCLUSIONS

This study was concentrated on the evaluation of competitive ability of spring wheat varieties by selected characteristics affecting competitiveness against weeds. It also included the practical verification of image analysis methods and LAI index measurement that were employed and the natural wheat competitiveness against weeds was tested and assessed. The results have shown close correlations between the above-mentioned methods and the classical evaluation of characteristics, which is based on a plant morphology. If the cereal variety testing includes the weed competitiveness testing in the future, a combination of methods will be employable there – the plant morphology and the (crop stand) vegetation cover.

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