WEED COMPETITIVENNESS OF WINTER AND SPRING WHEAT IN ORGANIC FARMING

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Abstract

Weed plants are one of the main factors limiting the level of agricultural yield. Damages are very important in organic farming now. Because of the availability of herbicides in the last 50 years, the natural competitiveness of field crops to weeds during breeding process and also VCU testing has been overlooked. Many control methods may be used by farmers to reduce weed populations, including harrowing and hoeing or increased seed rate. The simple and the cheapest solution will be use natural weed competitiveness ability of varieties. Our study is concentrated on the testing of methods of weed competitiveness evaluation. There were used some simple scoring methods (tuft shape, the length of the plant). These methods were compared with indirect methods based on LAI (SunScan Devices - Canopy Analysis Sytem) and soil coverage evaluation (multispectral image data analyzes by software MultiSpec W32). There were used spring and winter varieties of wheat. Small plot trials were grown on organic certified experimental area. In case of 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 correlations 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 didn´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 potential of better weed competitiveness.

Key words: organic farming, weed competitiveness, wheat

Weed plants are one of the main factors limiting the level of agricultural yield (Andrew *et al,* 2015). Because of the availability of herbicides in the last 50 years, the natural competitiveness of field crops to weeds has been overlooked. The competitiveness against weed is not targeted by breeding of modern wheat cultivars (Konvalina P. *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 E.T., 2002).

Many weed control methods may be used by farmers to reduce weed populations, including harrowing, increased seed rate and rotational ploughing (Lutman P.J.W. *et al,* 2013). Competitive cultivars are a potentially attractive option in comparison, because they do not incur any additional costs (Andrew I.K.S. *et al,* 2015). Cereal cultivars having a high degree of crop competitive ability, especially against aggressive weeds, are highly beneficial in organic farming (Hoad S.P. *et al,* 2008). Morphological, physiological, and biochemical traits are thought to control plant competitiveness (Mason M.G. *et al,* 1990; Köpke U., 2005; Kruepl C. *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 I.K.S *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 G.J. and Richards R.A., 1999). Tillering capacity in wheat contributed to suppression of dry matter production in mixed flora assemblages (Korres N.R. and Froud- Williams R.J., 2002). In wheat, leaf area index at early growth phases was associated with suppression (Hansen P.K. *et al,* 2008).

Our study aims to verify practical possibilities for the use of modern methods in wheat competitiveness against weeds, which are based on a detailed analysis of image, or a measurement of leaf area. Our work also evaluates

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correlations of the above-mentioned methods with classical evaluation techniques, which are based on evaluation of particular morphological characteristics.

MATERIAL AND METHOD

Small plot trials were grown in two locations – Faculty of Agriculture, University of South Bohemia in České Budějovice (48.9750572N, 14.4451039E) and organic farm in Zvíkov (48.9720044N, 14.6209550E).

Characteristic of the test plot in České Budějovice is as follows: altitude of 400 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 500 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.

Used varieties:

Deset odrůd ozimé pšenice (Bohemia, Diadem, Ekolog, Element, Energo, Penalta, Scaro, Sultan, SE 304/11, SE 770/09) and eight spring wheat varieties (Anabel, Astrid, Dafne, Izzy, Quintus, KW Scirocco, SG S833/11, SW Kadrilj) were grown. The experiment was carried out in compliance with organic farming standards.

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 MultiSpecW32 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 DISCUSSIONS

Cereals are highly weed competitive crops and are very useful for the organic farming (Lemerle D. *et al,* 2001). As far as our experiment is concerned, five characteristics influencing weed competitiveness were observed: a tuft shape, a flat leaf position, a coverage rate, a LAI and a length of plant. The weed competitiveness is profoundly influenced by agronomical factors, as a width of row, a density of seeding, climatic conditions affecting growth and evolution of a cultural and weed plant as well. Our experiment has confirmed this fact. Winter varieties did not have good conditions for growth of the crop plant during the growing season. There was water shortage and a lack of nutrients in autumn and spring months. It provoked sparse and short crop plants. There was even no crop plant in several locations.

A semi-upright (or a semi-vertical) and an upright (or a vertical) tuft contributes to higher weed competitiveness. As far as the spring varieties are concerned, Dafne and Quintus varieties had semi-upright tufts. Anabel, Astrid, KW Scirocco, SW Kadrilj and SG S 833 varieties had upright tufts (see *table 3*). As far as the winter varieties are concerned, Diadem, Ekolog and Penalta varieties had upright tufts, whereas Bohemia, Energo, Element, Scaro and Sultan varieties had semi-upright tufts (see *table 5*). Izzy variety had a very upright tuft. SE 770/09 and SE 304 winter varieties also tended to grow like that. The shape of tuft was mostly influenced by a variety factor (the spring and the winter varieties as well) (see *tables 1* and *4*). If the varieties with very upright tufts are grown organically, they become very risky. If the varieties with very upright tufts are well-established, they tend to be as weed competitive as the varieties with upright or semi-upright tufts (Hoad S.P. *et al,* 2006).

The soil coverage rate was another observed characteristic. It had a high correlation with the LAI and the length of plant (see *table 6*). The experiment showed significant correlations between them in every evaluation stage. The crop stands with a well-established photosynthetic apparatus are more likely to attain higher LAI values in later stages of growth. On the other hand, if the crop stands are covered with a few leaves in early stages of growth, they attain neither high values of the leaf coverage nor high values of the yield rate for the rest of the growing season. Wheat varieties can cover more land and have longer plants as well. Longer plants catch more sunshine and they protect the land against weeds (Drews *et al,* 2004).

The LAI index may influence the weed competitiveness as well. The optimum situation is as follows: the crop stand plants attain the value of

LAI equal to 1 as soon as possible, and they stay in the optimum situation as long as possible (Huel D.G. and Hucl P., 1996). All the evaluated varieties attained higher values in the BBCH 36 stage (higher than LAI 1). A high correlation with the length of plant was also evident there. The LAI had a significant correlation with the length of plant in every evaluated stage (see *table 6*). The higher the LAI was, the longer the plant was.

The length of plant was also evaluated there. It had a positive correlation with the land coverage rate (see *table 6*). Varieties with longer stalks can catch more light and sunshine and they suppress weeds better than varieties with shorter stalks – wheat cultivars (Cudney D.W. *et al,* 1991). All the spring wheat varieties grown in Zvikov had mid-long stalks (see *table 2*). The following varieties of Anabel, Astrid, Dafne, Quintus, KW Scirocco and SG S 833 grown in Ceske Budejovice had short stalks (see *table 2*).

The position of flat leaf was evaluated there as well. An upright or a horizontal flat leaf contributes to higher weed competitiveness (Hoad S.P. *et al,* 2006). The following spring wheat varieties had horizontal flat leaves: Anabel, Quintus, and KW Scirocco. The following varieties had upright flat leaves: Astrid, Dafne, Izzy, and SW Kadrilj. Varieties having overhanging flat leaves are unsuitable for the weed competitiveness. Variety called SG S 833 had overhanging flat leaves (see *table 3).*

CONCLUSIONS

Our experiment has produced the following results. The variety had the most significant effect on the tuft shape and the flat leaf position. There was not any correlation between the tuft shape, the flat leaf position and the other parameters. Varieties with semi-upright and upright tufts proved to be the most suitable for the organic farming system. Most of the evaluated varieties produced such results. As far as the flat leaf position is concerned, varieties with very upright, upright (vertical) and horizontal flat leaves are the most suitable for the organic farming system. Such flat leaves prevailed in case of the evaluated plants. As far as the length of plant is concerned, the most of the evaluated varieties proved to be suitable for the organic farming system. The LAI parameter had a positive correlation with the length of plant in every stage of the experiment. Our experiment has produced the following results. Particular characteristics can provide us with a prediction of the wheat competitiveness against weeds.

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REFERENCES

Andrew I.K.S, Storkey J., Sparkes DI., 2015 - *A review of the potential for competitive cereal cultivars as a tool in integrated weed Management*. Weed Research 55:239-248.

Cudney, D.W., JORDAN, L.S., HALL, A.E. 1991 - *Effect of wild oat (Avena fatua) infestations on light interception and growth rate of wheat (Triticum aestivum).* Weed Sci. 39:175-179.

Drews, S.D., Neuhoff Köpke U., 2004 - *Optimizing fading ability of winter beat stand as a method of weed control*. J. Plant Dis. Prot. 19:545-552.

Hoad, S., Topp, C., Davies, K. 2008 - *Selection of cereals for weed suppression in organic agriculture: a method based on cultivar sensitivity to weed growth*. Euphytica 163:355–366.

Huel, D.G., Hucl, P., 1996 - *Genotypic variation for competitive ability in spring wheat*. Plant Breed. 115:325-329.

Hansen P.K., Kristensen, K., Willas, J., 2008 - *A weed suppressive index for spring barley (Hordeum vulgare) varieties.* Weed Research 48:225-236.

Konvalina, P., Stehno, Z., Capouchová, I., Zechner, E., Berger, S., Grausgruber, H., Janovská, D., Moudry, J., 2014 - *Differences in grain/straw ratio, protein content and yieldin landraces and modern varieties of different wheat species under organic farming*. Euphytica 199:31-40.

Köpke, U., 2005 - Crop ideotypes for organic cereal cropping systems. In: Lammerts Van Bueren, E. T., Østergård, H. (Eds.). *Proceedings of the COST SUSVAR/ECO-PB Workshop on Organic plant Breeding Strategies and the use of Molecular Markers*, pp. 13-16. Louis Bolk Institute, Driebergen, Netherlands.

Korres, N.E., Froud-Williams, R.J. 2002 - *Effects of winter wheat cultivars and seed rate on the biological characteristics of naturally occurring weed flora.* Weed Res. 42:417-428.

Kruepl, C., Hoad, S., Davies, K., Bertholdsson, N.O., Paolini, R. 2006 - *Weed competitivness*. In: Donner, D., Osman, A. (Eds.). *Handbook cereal variety testing for organic low input agriculture*. COST860-SUSVAR, pp. W1-W16, Risø National Laboratory, Denmark.

Lammerts Van Bueren, E.T., 2002 - *Organic plant breeding and propagation: concepts and strategies*. [Ph.D. thesis.]. Wageningen University, Netherlands, pp. 38-61.

Lemerle, D., Verbeek, B., Cousens, R.D., Coombes, N.E., 1996 - *The potential for selecting wheat varieties strongly competitive against weeds*. Weed Res. 36:505-513.

Lutman P.J.W., Moss S., Cook S.K., Welham S.J., 2013 - *A review of the effects of crop agronomy on the management of Alopecurus myosuroides*. Weed Research 53:299-313.

Mason, M.G., Rowland, I.C. 1990 - *Nitrogen fertiliser response of wheat in lupin-wheat, subterranean clover-wheat and continuous wheat rotations*. Australian journal of experimental agriculture 30: 231-236.

Rebetzke, G.J., Richards, R.A. 1999 - *Genetic improvement of early vigour in wheat.* Aust. J. Agric. Res. 50:291-301.

Table 1

Analysis of factor influence (ANOVA) – spring varieties of wheat

Factor	DF	LAI BBCH 36		LAI BBCH 49		Plant length BBCH 33-36		Plant length BBCH 55		Uncovered soil BBCH 33 -36		Soil coverage BBCH 33-36	
		MS	%	MS	%	MS	%	MS	%	MS	%	MS	%
Variety (1)	7	1.7178	16.2***	0.694	1.63ns	47.7	16.2**	74.4	0.26***	111.2	6.19***	111.2	6.19***
Locality (2)	1	7.6002	71.7***	38.074	89.5***	31827.0	71.7***	28202.8	99.6***	1604.3	89.34***	1604.3	89.34***
1x2	7	0.9226	8.7*	3.171	7.46***	31.0	8.69*	38.2	0.13**	80.3	4.47***	80.3	4.47***
Eror	176	0.389	-	0.595	-	13.2	-	10.8	-	17.5	-	17.5	-

Note: P < 0.05; **P < 0.01; P < 0.001; ns - no significant

Table 2

Variety evaluation results – spring varieties of wheat

Locality	LAI BBCH 36	LAI BBCH 49	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
JCU	1.74±0.83a	2.51±0.70a	21.45±3.06a	39.17±4.01a	70.28±5.83a	46.11±5.33b	36.50±4.45b	53.88±5.33a	63.49±4.43a	3.25±1.21a	4.25±1.40a
Zvíkov	2.13±0.47b	3.40±0.96b	47.20±4.57b	53.40±3.48b	92.89±7.46b	38.40±5.20a	30.73±5.18a	61.62±5.20b	69.26±5.18b	3.00±1.42a	4.25±1.40a

Note: Statistically different at P < 0.05 (Tukey HSD test).

Table 3

Individual variety evaluation results – spring varieties of wheat

Variety	LAI BBCH 36	LAI BBCH 49	Plant length BBCH 33-36	Plant length BBCH 55	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	1.76±15.08ab	2.66±13.96a	35.25±15.08a	47.67±13.96a	42.02±7.39ab	32.89±5.56ab	57.98±7.93ab	67.11±5.56ab	3.00±0.00a	5.00±0.00b
Astrid	1.95±12.87ab	3.05±11.97a	32.83±12.87a	52.58±11.97a	40.58±5.31a	29.75±3.85b	59.42±5.31a	70.25±3.85b	3.00±0.00a	3.00±0.00a
Dafne	2.24±14.27ab	2.86±10.49a	33.83±14.27a	51.29±10.49a	39.14±6.72a	31.80±5.56ab	60.86±6.72a	68.20±5.56ab	5.00±0.00b	3.00±0.00a
Izzy	2.33±13.04b	2.91±12.57a	34.66±13.04a	52.79±12.57a	46.83±.48b	36.01±3.44a	53.17±5.48b	63.98±3.44a	1.00±0.00c	3.00±0.00a
Quintus	1.66±15.36a	3.00±13.06a	33.20±15.36a	51.37±13.06a	43.83±4.76ab	33.46±5.65ab	56.17±4.76ab	66.53±5.65ab	5.00±0.00b	5.00±0.00b
KW Scirocco	1.73±11.71a	2.97±13.52a	37.17±11.71a	50.71±13.52a	40.69±5.54a	34.99±6.02a	59.31±5.54a	65.01±6.02a	3.00±0.00a	5.00±0.00b
SW Kadrilj	1.68±13.02a	2.90±12.98a	33.25±13.60a	53.25±13.85a	40.78±6.35a	33.99±3.06ab	59.22±6.35a	66.01±3.06ab	3.00±1.02d	3.00±0.00a
SG S 833	2.12±13.60ab	3.26±13.85a	34.38±13.02a	50.63±12.98a	44.20±6.87ab	360.3±7.88a	55.85±6.91ab	63.96±7.88a	3.00±0.00a	7.00±1.02c

Note: Statistically different at P < 0.05 (Tukey HSD test).

Table 4

Analysis of factor influence (ANOVA) – winter wheat varieties

Factor	DF	LAI BBCH 51 -55		LAI BBCH 59		Plant length BBCH 37		Plant length BBCH 51-55		Uncovered soil BBCH 29		Uncovered soil BBCH 33-36		Soil coverage BBCH 29		Soil coverage BBCH33-36	
		MS	%	MS	%	MS	%	MS	%	MS	%	MS	%	MS	%	MS	%
Variety	9	0.8655	87.530***	0.6543	80.97***	100.88	90.613***	453.0	93.576***	92.0	78.90***	151.4	82.91***	92.3	78.95***	149.4	82.81***
Eror	39	0.1234	12.439**	0.1547	0.1915***	10.45	9.3865***	31.1	6.424***	24.6	21.1**	31.2	17.08***	24.6	21.04**	31.0	17.18***

Note: :* P < 0.05; **P < 0.01; P < 0.001; ns - no significant

Table 5

Variety evaluation results – winter varieties of wheat

Variety	LAI BBCH 51-55	LAI BBCH 59	Plant length BBCH 33-36	Plant length BBCH 51-55	Uncovered soil BBCH 29	Uncovered soil BBCH 33-36	Soil coverage BBCH 29	Soil coverage BBCH 33-36
Bohemia	0.87±0.28ac	2.03±0.61ab	19.50±4.10 ab	47.08±9.72ab	51.95±5.59abc	41.82±3.53abc	48.05±5.59abc	58.17±3.53abc
Diadem	1.73±0.42b	1.90±0.36ab	16.83±2.37b	41.58±6.35a	58.47±5.25b	40.95±4.88abc	41.53±5.25a	59.05±4.88abc
Ekolog	1.37±0.28ac	1.81±0.41ab	26.33±6.93c	54.67±6.73c	53.72±5.36abc	43.27±2.07abc	46.27±5.36abc	56.72±2.07abc
Element	1.45±0.47ab	1.52±0.22a	22.16±2.66ab	53.17±2.79bc	52.57±4.21abc	41.62±1.07abc	47.42±4.21abc	58.37±1.07abc
Energo	1.22±0.41ac	1.66±0.34ab	22.67±1.83ab	58.08±2.81c	55.18±5.63ab	36.12±2.61b	44.82±5.63ab	63.87±2.61c
Penalta	1.10±0.33ac	1.54±0.33a	18.75±1.71ab	41.08±2.81a	47.95±7.73c	38.55±11.51bc	52.05±7.73c	52.05±11.51bc
Scaro	1.37±0.25ab	2.16±0.57b	20.91±2.07ab	46.08±4.72ab	51.97±5.61abc	44.07±5.72ac	48.02±5.61abc	55.02±5.72ab
SE 304	1.71±0.45b	1.91±0.38ab	17.41±2.64b	51.83±5.20bc	51.82±1.10ac	42.70±4.11abc	48.17±1.10bc	48.17±4.11abc
SE 770/09	1.73±0.29c	1.53±0.23a	22.83±2.33ab	57.00±4.61c	53.85±4.00abc	47.30±8.31a	46.00±4.02abc	52.85±8.17a
Sultan	1.51±0.24ab	1.55±0.28a	19.17±1.99ab	45.83±6.10ab	55.12±0.73ab	47.75±3.60a	44.87±0.73ab	52.25±3.60a

Note: Statistically different at P < 0.05 (Tukey HSD test).

Table 6

Corelation analysis – all spring varieties

Parameter	Mean	SD	LAI BBCH 33-36	LAI BBCH 49	Plant length BBCH 33- 36	Plant length BBCH 55	Uncovered soil BBCH 33 -36	Soil coverage BBCH 33-36	Tuft shape BBCH 29
LAI BBCH 36	1.93	0.702							
LAI BBCH 49	2.95	0.943	0.13*						
Plant length BBCH 36	34.32	13.47	0.25*	0.46*					
Plant length BBCH 55	51.29	12.72	0.27*	0.47*	0.95*				
Uncovered soil BBCH 33 -36	33.65	5.615	-0.12*	-0.19*	-0.46*	-0.49*			
Soil coverage BBCH 33-36	66.38	5.615	0.12*	0.19*	0.46*	0.49*	-1.00*		
Tuft shape	3.13	1.320	-0.11^{ns}	0.01^{ns}	-0.11^{ns}	-0.13^{ns}	-0.12^{ns}	0.12^{ns}	
Flag leaf position	4.25	1.396	-0.15*	0.97^{ns}	0.06^{ns}	-0.07^{ns}	0.11^{ns}	-0.11^{ns}	0.19*

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