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THE POSSIBILITIES OF REDUCTION OF WINTER BARLEY CHEMICAL PROTECTION BY GROWING VARIETY MIXTURES. PART II. EFFECT ON YIELD

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Abstract: In the four-year experiment the impact of four different barley varieties and selected two- and three-component mixtures were tested. The studies were carried out at two sites: Experimental Station for Variety Testing Słupia Wlk. (Wielkopolska region) and Plant Breeding Station Bąków (Opole District) during four growing seasons (2001/2002–2004/2005). The aim of the studies was to evaluate the yield through growing barley variety mixtures in combination with reduced use of fungicide and application dose rates. Positive effects (1–15% yield increase in mixtures compared to pure stands) were observed. On the base of obtained results it can be stated that winter barley variety mixtures can constitute an alternative way of growing winter barley, especially at low-input and ecological agriculture.

Key words: pro-ecological agriculture, variety mixtures, yield, winter barley

INTRODUCTION

In Poland during the nineties, the use of variety mixtures (mainly in barley cultivation) has been widely introduced into agricultural practice. The main concentration has been on species mixtures and spring barley variety mixtures.

The mixtures are designed particularly for the control of powdery mildew, but more general recommendations for their use are:

- broader genetic variation, a more resistant variety can be a "barrier" for pathogens,
- yields of the mixtures are usually higher and more stable compared with the individual pure stands of the components e.g. yield of mixture "AB" is greater than both A and B,
- better overall disease performance resulting in reduced need for fungicides (lower costs and better environment impact),

– variety mixtures can be cultivated in the same agronomic and husbandry way as pure stands (Gacek et al. 1996).

The results of four years field experiments designed to evaluate epidemiological and economical effects of winter barley cultivar mixtures are presented. In this paper, the aim of the studies was to evaluate the yield through growing barley variety mixtures in combination with reduced use of fungicide and application dose rates.

MATERIALS AND METHODS

In the four growing seasons 2001/2002–2004/2005, experiments with winter barley variety mixtures combined with different treatments of fungicides were carried out at two sites, namely the Experimental Station for Variety Testing Słupia Wlk. (Wielkopolska District) and the Plant Breeding Station Bąków (Opole District).

During the growing season 2002/2003 the studies were carried out in one site, the Experimental Station for Variety Testing Słupia Wlk. The experiment at the Plant Breeding Station Bąków was completely destroyed by late frost in the spring (March). In the experiment at Słupia Wlk., in the 2002/2003 season, 25% of plots were destroyed also because of a late frost.

In the experiments, four different winter barley cultivars were sown in pure stands and selected from these were two and three-component mixtures (3 mixtures in all), composed of these varieties. These were grown and evaluated on 5 m² plots over four replicates. The winter barley cultivars: Bombay (BO), Gil (GI), Gregor (GR) and Bażant (BA), and the following mixtures: Bombay/Gil (BOGI), Bombay/Gregor (BOGR), and Gil/Gregor/Bażant (GIGRBA) were used.

On the experimental plots seven different treatments with fungicides were used, namely:

– untreated plots (control),
– single treatment application with ¼, ½ and full dosage of fungicides (at the beginning of shooting),
– treatments with ¼, ½ and full dosages of fungicides but applied twice over the growing season (at the beginning of shooting and at the full/end of shooting).

At the beginning of shooting mixture of two fungicides was used – Amistar 250 SC + Tilt Plus 400 EC. At the full/end of shooting Tilt Plus 400 EC was used.

The grain yield from all the experimental plots was measured and evaluated statistically.

RESULTS AND DISCUSSION

During four vegetation seasons only powdery mildew caused by *Blumeria graminis* f. sp. *hordei* was observed on winter barley plants (Tratwal et al. 2007).

The factors denoted for the analysis were Variety, Treatment, Site and Year, where 2002/2003 was excluded from the analysis since it was at one site only and data was not considered sufficiently reliable. In the UK no transformations on yield data are performed (Patterson and Silvey 1980) and so the raw data was used for all analysis.

The Analysis of Variance (ANOVA) was then carried out on all data.

All main factors were found to be significant at the 0.1% level ($p < 0.001$) and looking at the F-Ratio's it was found that the observed F-Ratios could be ordered in terms

of impact on the ANOVA. The order was, from the largest F-Ratio, Site > Site x Year >> Year > Treatment with lastly Variety being the weakest. In light of these results it was appropriate to undertake all further analyses using separate sites with data from Bąków and Słupia Wlk. The Variety x Treatment interactions were found to be not significant at any site.

Separating the sites for analysis gives a fairer comparison on what is being looked at i.e. do variety mixtures give better yields than comparable pure stands and what are the optimal levels of fungicides to apply and to compare results across the 2 sites. Tables 1 and 2 show the ANOVA's data from both sites.

Table 1. Analysis of variance dry matter yield dt/ha at @15% moisture content from Site 1 – Bąków Variate: Yield

Source of variation	Degree of freedom	Mean square	F statistic	P-value
Variety	6	385.35	10.14	< 0.001
Treatment	6	1385.76	36.46	< 0.001
Year	2	18287.10	481.19	< 0.001
Variety x Treatment	36	27.89	0.73	0.872
Variety x Year	12	158.13	4.16	< 0.001
Treatment x Year	12	181.23	4.77	< 0.001
Variety x Treatment x Year	72	13.50	0.36	1.000
Residual	441	38.00		
Total	587			

ns – not significant

Table 2. Analysis of variance dry matter yield dt/ha at @15% moisture content from Site 2 – Słupia Wlk. Variate: Yield

Source of variation	Degree of freedom	Mean square	F statistic	P-value
Variety	6	165.34	1.97	0.068
Treatment	6	1703.07	20.33	< 0.001
Year	2	59738.48	713.10	< 0.001
Variety x Treatment	36	35.97	0.43	0.999
Variety x Year	12	57.90	0.69	0.761
Treatment x Year	12	335.52	4.01	< 0.001
Variety x Treatment x Year	72	47.45	0.57	0.998
Residual	441	83.77		
Total	587			

ns – not significant

For site 2 (Słupia Wlk.) it appears variety is not significant and therefore there is no evidence that using variety mixtures would give sustainable higher yield. This is also true even depending on the treatment and year. However, there are higher significant differences (at 0.1% level) at Bąków between the different varieties. The interaction of interest is that of variety and treatment unfortunately appears to show no significance. The Treatment and Year interaction does appear to be highly significant at both sites (Słupia Wlk. and Bąków), particularly for the Year. What are very noticeable are the opposite effects that the yields have across years for the two sites, which is illustrated in Table 3 as annually differing weather, soil type and overall level of disease are potentially reasons why this observation has occurred.

Table 3. Average grain yield over years at Słupia Wlk. and Bąków

Site	Year	Average grain yield in dt/ha
Bąków	2001/2002	81.3
	2003/2004	73.3
	2004/2005	62.1
Słupia Wlk.	2001/2002	76.4
	2003/2004	90.7
	2004/2005	111.1

All respective paired year interactions are also highly significant (except for variety at Słupia Wlk. mentioned above) which suggests that across the years the treatments do behave differently and also the varieties effects at Bąków. Next, the individual year data was analyzed to see if the results obtained above would be the same, especially the variety and treatment interaction. It so happened that in the 2004/2005 season at both sites some results appeared to be slightly different. At Bąków the variety main effect was found to be not significant and therefore other factors such as disease may have contributed to more similar variety performance for yield. At Słupia Wlk. there appeared to be some evidence ($p = 0.109$) that there was a variety and treatment interaction, for example the yield for variety Bażant under the control treatment was not the lowest and actually the yield for 1 treatment full dose was the highest rather than the 2 treatments full dose. However, this could have been driven by the seasonal effects, which are not typical for the site.

However, as no years are the same and factors such as weather and growing season cannot be controlled then only the variety and treatment will be looked at more closely. Tables 4, 5 gives the variety by treatment means for both sites.

Looking at the overall Treatment effect it can be concluded that using the control (no fungicide) would not give as high a yield as any other fungicide treatment at both sites i.e. 65.09 dt/ha is more than 1.87 dt/ha and less than any other treatment mean at Bąków and likewise 85.03 dt/ha is at least 2.78 dt/ha lower than any other treatment

Table 4. Grain yield (dt/ha) in winter barley varieties and their mixtures over 3 years

Site	Chemical treatment	Grain yield dt/ha							
		Bombay	Gil	Gregor	Bażant	Bombay/ Gil	Bombay/ Gregor	Gil/Gregor/ Bażant	Average
Bąków	control	66.15	65.92	62.35	67.98	65.42	62.67	65.15	65.09
	1 treatment ¼ dose (1TQ)	70.13	72.57	69.07	76.67	72.67	71.50	72.12	72.10
	1 treatment ½ dose (1TH)	68.62	69.68	66.20	75.53	68.60	70.90	72.85	70.34
	1 treatment full dose (1TF)	70.25	74.00	71.12	76.28	72.32	69.65	73.02	72.38
	2 treatments ¼ dose (2TQ)	72.05	77.05	70.48	75.25	75.53	71.27	77.42	74.15
	2 treatments ½ dose (2TH)	70.50	72.85	72.47	78.68	70.90	70.32	75.28	73.00
	2 treatments full dose (2TF)	77.37	80.28	78.82	80.90	78.57	74.77	79.25	78.56
	average	70.72	73.19	70.07	75.90	72.00	70.15	73.58	72.23
Słupia Wlk.	control	81.83	83.45	82.93	89.18	85.53	85.80	86.48	85.03
	1 treatment ¼ dose (1TQ)	90.47	89.78	91.08	90.57	91.87	90.28	91.97	90.86
	1 treatment ½ dose (1TH)	90.67	86.70	94.83	93.02	89.70	89.93	91.92	90.97
	1 treatment full dose (1TF)	92.95	92.83	94.90	94.85	92.77	94.48	92.18	93.57
	2 treatments ¼ dose (2TQ)	92.87	94.77	93.42	90.97	91.13	93.17	96.55	93.27
	2 treatments ½ dose (2TH)	93.35	94.67	96.67	96.82	97.65	97.77	95.95	96.12
	2 treatments full dose (2TF)	96.77	97.18	103.85	103.90	98.98	96.80	97.67	99.31
	average	91.27	91.11	94.40	94.73	92.85	92.29	92.47	92.73

Table 5. Respective LSD at 5% significance

Group	Bąków	Słupia Wlk.
Variety	1.87	2.78
Treatment	1.87	2.78
Interaction	4.95	7.34

mean at Słupia Wlk. It can also be concluded that using 2 treatments at full dose does actually increase the yield more than any other treatment. The most interesting of the other comparisons are the ones between 1TH (explanation are in Tables 4, 5) and 2TQ along with 2TH and 1TF i.e. what effect does applying half dosage once and quarter dose twice actually have. One way is to compare the respective means in the above table. Considering the respective LSD at Słupia Wlk. there appears to be no difference between these respective fungicide variants which is what you would hope for. However, at Bąków the comparison of applying half dose once (1TH) with quarter dose twice (2TQ) actually gives a significant difference in yield (means highlighted in bold) giving an indication that applying less fungicide more often is better. This pattern is seen in all four of the comparisons mentioned but for the other three not at a significant level.

Other comparisons looked at were those between applying fungicide once and twice i.e. (1TQ, 1TH, 1TF with 2TQ, 2TH). Note that 2TF was found to give better yield than any other treatment combination so this was not used. It was found at both sites that, in general, applying fungicide twice over the season rather than once does increase the yields significantly (independently of variety).

If only looking at a single application of fungicide (1T) there are no significant differences in terms of grain yield when full, half or quarter dosage rates are applied.

For two separate applications of fungicide (2TQ, 2TH, 2TF), there is evidence at Słupia Wlk. that applying half dosage would give higher yields than a quarter dosage, but neither dosage would give as high yield as the full dosage. At Bąków, there is no apparent difference in yield between the half and the quarter dosage rate although the full dosage rate does give higher yields.

For variety there appears to be no evidence at Słupia Wlk. that using variety mixtures would give a better yield i.e. all variety means are within 2.78 dt/ha of the overall mean of 92.73 dt/ha.

At Bąków, there are significant differences between varieties. Regarding the aim of the experiment to see if variety mixtures gave a better yield than the individual components, contrasts were carried out e.g. comparing the mean of pure stands Bombay and Gil with the respective mixture Bombay/Gil. The ANOVA is summarised in Table 6.

Unfortunately no comparisons are found to be significant even across the various treatments and therefore it should be concluded that there is no difference in yield when using variety mixtures compared with the individual varieties.

There are no available papers aimed at influence of winter barley variety mixtures combined with different fungicide treatments on yield increase. In the experiment with spring barley variety mixtures (without fungicide control) other authors (Gacek 1986; Gacek and Czembor 1983; Gacek and Nadziak 2000) revealed 1–14% of yield in-

crease comparing to pure stands and 8–11% of yield increase in the experiment with winter barley variety mixtures (without fungicide control) (Gacek 1986).

Experiments with winter wheat variety mixtures (Gacek et al. 1997) showed that thanks to growing two-component and three-component winter wheat variety mixtures 2–10% yield increase were observed.

Table 6. Grain yield dt/ha – Contrasts of variety mixtures vs full-stands at Bąków – analysis of variance. Variate: Yield

Source of variation	Degree of freedom	Mean square	F statistic	P-value
Variety	6	385.35	10.14	< 0.001
BO and GI v BOGI	1	0.10	0.00	0.960
BO and GR v BOGR	1	3.37	0.09	0.766
GI,GR and BA v GIGRBA	1	17.60	0.46	0.497
Treatment x Variety	36	27.89	0.73	0.872
Treatment BO and GI x BOGI	6	5.43	0.14	0.990
Treatment BO and GR x BOGR	6	41.83	1.10	0.361
Treatment GI,GR and BA x GIGRBA	6	23.56	0.62	0.714

BO – Bombay
GI – Gil
GR – Gregor
BA – Bażant
BOGI – Bombay/Gil
BOGR – Bombay/Gregor
GIGRBA – Gil/Gregor/Bażant

CONCLUSIONS

1. For Słupia Wlk. it appears that variety is not significant and therefore there is no evidence that using variety mixtures would give sustainable higher yield. There are stronger significant differences (at 0.1% level) at Bąków between the different varieties
2. The Treatment and Year interaction does appear to be highly significant as shown at both sites (Słupia Wlk. and Bąków), particularly the Year.
3. Looking at the overall Treatment effect it can be concluded that using the control (no fungicide) would not give as high a yield as any other fungicide treatment as shown at both sites.
4. Using 2 treatments at full dose does actually increase the yield more than any other treatment.
5. It was found at both sites that, in general, applying fungicide twice over the season rather than once does increase the yields significantly (independently of variety).

6. If only looking at a single application of fungicide (1T) there are no significant differences in terms of grain yield when full, half or quarter dosage rates are applied.
7. For two separate applications of fungicide (2TQ, 2TH, 2TF), there is evidence at Słupia Wlk. that applying half dosage would give higher yields than a quarter dosage, but neither dosage would give as high yield as the full dosage.

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POLISH SUMMARY

MOŻLIWOŚĆ OGRANICZENIA CHEMICZNEJ OCHRONY JĘCZMIENIA OZIMEGO POPRZEZ UPRAWĘ MIESZANEK ODMIAN. CZĘŚĆ II. WPŁYW NA PLONOWANIE

W czteroletnim (2001/2002–2004/2005) doświadczeniu polowym w dwóch miejscowościach (Stacja Doświadczalna Oceny Odmian Słupia Wlk. – woj. wielkopolskie i Hodowla Roślin Smolice Oddział Bąków – woj. opolskie) badano możliwość integracji uprawy odmian jęczmienia ozimego w mieszankach w połączeniu ze stosowaniem fungicydów w różnych dawkach i liczbie zabiegów w celu poprawienia plonowania. Przyrosty plonów w poszczególnych latach, miejscowościach i kombinacjach ochrony wahały się od 1–15% w porównaniu do siewów czystych.

Na podstawie uzyskanych wyników można stwierdzić, że uprawa mieszanek odmianowych jęczmienia ozimego może być alternatywną formą uprawy jęczmienia ozimego, zwłaszcza w rolnictwie niskonakładowym i ekologicznym, gdyż dzięki ich uprawie notowano wzrost plonowania.