Effects of the water based plant care concentrate, Mineral, on winter wheat

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"Plant care" products applied to foliage have a variety of uses for plant protection, plant nutrition and other purposes. Field study was set (2007-2009) to identify the effects of a foliar application of 12 ml 5.0 m^{-2} (24 l ha^{-1}) of the water based product, Mineral, on the winter wheat cultivar, Soissons. Mineral is recommended in organic production. The applications were provided during the BBCH 05, BBCH 21/23, BBCH 32/33, and BBCH 47/49 growth stages of winter wheat at the University of Maribor Agricultural Centre. An additional treatment at a dose of 80 l ha^{-1} was performed in 2009. The data show no significant effects of Mineral on the yield ($P \geq 0.05$) compared with a control treatment. On the other hand, treated plants had the most intensively green leaves. Although there were no significant differences among the treatments and control in morphological parameters (spike length, spikelet's per spike, kernel weight per spike and kernels per spike), some improvements of a higher dose of Mineral application were apparent. The application of Mineral in experimental circumstances had some beneficial effects on plant (less damage caused by cereal leaf beetle), but no significant effect on yield. The results of a higher dose of Mineral application in 2009 suggest the value of further investigations.

Key words: plant growth regulators, growth stimulators, plant protection, winter wheat, yield response functions, Mineral

INTRODUCTION

If it can be shown that the foliar application of non-synthetic agents have positive effects on wheat growth and development, then such treatments should form an important part of wheat production systems. In 2008, 160,279 tonnes wheat was grown on 35,413 ha of arable land in Slovenia (Food and Agriculture Organization of the United Nation 2010). In 2007, wheat was grown under organic management on 280 ha of arable land in Slovenia and on 56 ha of arable land under conversion (Willer and Klicher 2009).

High yields of well-filled grains are currently of primary importance in the wheat market. The quality and quantity of a wheat yield depend on environment, plant genotype, the system of cultivation and their interactions (Bavec et al. 2009b). The environmental factors which cause plants the most biotic stress are extremes of temperature (summer heat and winter frost), extremes of water availability (drought and excessive rainfall), mineral deficiency, oxidative stress, excess salinity, and various other extremes of weather such as hail.

As in the EU, two groups of growth regulators and other plant care agents are registered for use in improving cultivated crops in Slovenia (Commission Regulation (EC) No. 889/2008, Council Regulation (EC) No. 834/2007) (Bavec et al. 2009a). The first group includes seaweed extracts (Algacifo 300, Bio Plantella Topgreen, Bio Plantella Vrt, Biofa Algenextrakt, Gomar BM 86), plant extracts (Biocin-F), peptide and amino acid agents (Aminovital, Bio Plantella Vita, Multi-pepton, Poly-Amin, and Protifert LMW), agents based on mixed trace elements (Cifo Mikrom, Masquol, and Micro Combi), calcite from sea sediments (Megagreen), and various others (Bio Plantella humin, Borogreen, Coralite KR+, Curapid, Fer 6 Plus, Ferapid, Kelagreen, Lithovit, Manrapid, New Cal, N-G-K Plus-9-Frucht, N-G-K Blatt, Oligogreen, Vitaven, and Vit-Org). The second group includes seaweed extracts (Algaren, Algo Vital Plus), extracts from the field horsetail, *Equisetum arvense* L. (Biofa Equisetum Plus, Bio Plantella Super-F-R, and Bio Plantella Natur-F) (Bavec at el. 2009b). It is quite likely that some of these preparations enhance certain physiological processes in plants, especially protein synthesis. They may help to stimulate the metabolism of the plant, or increase growth parameters and yield (Smith-Freatanaby and Staden 1983, Owusu 2000; Heo et al. 2005; Kannan et al. 2007; Parrado et al. 2008; Sivansankari et al. 2006; Rayorath et al. 2008; Uppal et al. 2008; Jayaraj et al. 2008; Rathore et al. 2009).

Mineral is a special water-based concentrate similar to saline mineral water having a mild salinity and beneficial effects on plants according to description of AS AN d.o.o. (Planet of health 2010). Preparat has permission in organic farming (Bavec et al. 2009b).

The Institute for Bioelektromagnetics and New Biology reported that treatment with "water fertilizer" (which we suspect may be similar to Mineral) had a positive effect on the germination of cucumbers seeds, although beans plants showed no significant resulting increase in stem length (The report of water fertilizer research of AS AN d.o.o 2005). It was also found that Mineral Red (is not the same like Mineral) has a herbicide effect on grass, reducing seed germination, but no effect on the resistance of bean plants to lice, or of roses to mildew (The report of product Mineral 2007).

The aim of this research is analysed the effects of Mineral application on growth rate of winter wheat (*Triticum*

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aestivum ssp. *vulgare*) and its morphological parameters (spike length, the number of spikelet's per spike, kernel weight per spike and the number of kernels per spike) and final yield in field conditions under pests control.

MATERIAL AND METHODS

The trial site

The field trials were conducted from 2007 to 2009 at the University of Maribor Agricultural Centre, at an elevation of 282 m above sea level and between 46° 39'E and 15° 39'N. We used the winter wheat cultivar, Soissons, experimentally sprayed with the proprietary agent Mineral, which is a water based concentrate of 75 minerals (Table 1).

The experiment was designed in random blocks with five replications. Each experimental unit consisted of a 5.5 m^{-2} plot (5.5 m long x 1 m wide) with spaces of 0.125 m between the seed rows. In spring, the edges of the plots were shortened in length to 5 m due to a possible overlap during sowing. So that the final area of each unit was 5.0 m^2.

In the first, second and third experimental years, wheat was sown on October 27^{th} (2006), at the end of October (2007) and 21^{st} (2008), using a Wintersteiger mobile planting device.

Mineral was applied in four foliar applications, each with a total amount of 12 ml per 5 m^2 plot, i.e. 24 l ha^{-1}. The wheat plants were sprinkled with a foliar fertilizer sprayer. The Mineral was diluted to one part of concentrate per 100 parts water, following the manufacturer's instructions. The four treatments were applied at key growth stages (based on the cereal code developed by Witzenberger et al. 1989 and Lancashire et al. 1991) at emergence (BBCH 05, beginning or Mid-November); 2) at tillering (BBCH 21/23, on14 March); 3) at stem elongation (BBCH 32/33, on 20 April); and 4) at the start of booting (BBCH 47/49, on 23 May).

The previously crop was maize in all the years.

In 2009, an extra treatment was included using a higher dose of Mineral (20 l ha^{-1} for each of four applications, to make a total dose of 80 l ha^{-1}) following the manufacturer's recommendations (Planet of health 2010).

Soil characteristics of the trial site

The soil phosphorus and potassium contents were determined using the Egner et al. (1960) AL-method and were found to be at the optimal C level in 2007-2008 and at the B level in 2009. Humus content in the experimental plots was fairly uniform at 3.22% in 2007, 2.90% in 2008, and 1.81% in 2009. The soil was slightly acidic at a pH of 6.1 in 2007, 6.0 in 2008, and 5.9 in 2009 (determined by pH meter and pH indicator following Yamada by Foster and Gruntfest 1937).

According to the Slovenian soil classification system (1991), the experimental sites are prevailingly Dystric Cambisols overlying hard carbonate rocks (subtype Gleysoils). These are in the cambic B-horizon group and fall into the Cambic soils class with A – $(B)_v$ – C profile. These soils are "culluvial dystric brown soils" and are characterised by seasonal water surpluses originating from the shallow groundwater table (Vrščaj 2005). These soils are very suitable for the production of cereals, maize fodder catch crops, and slightly less for sugar beet and potatoes. In years with high precipitation, their productivity is reduced because crops grown on them are susceptible to disease caused by excessive soil saturation.

Measurements

In 2007-2009, we compared the height and color of wheat plants at the second node stage (BBCH 32) and weighed the seed yield in the laboratory, determined moisture content (SIST ISO 711:1997), and hectolitre kernel weight (SIST ISO 7971-2:1997). Prior to harvesting, the

Table 1. Chemical composition of Mineral

Na	>3500000 µg/L	Ni	1390 µg/L	Pd	< 10 µg/L	Eu	< 0.1 µg/L	Au	< 0.2 µg/L
Li	100 µg/L	Cu	140 µg/L	Ag	< 20 µg/L	Gd	< 0.1 µg/L	Hg	< 20 µg/L
Be	< 10 µg/L	Zn	< 50 µg/L	Cd	< 1 µg/L	Tb	< 0.1 µg/L	Tl	< 0.1 µg/L
Mg	1260000 µg/L	Ga	< 1 µg/L	In	< 0.1 µg/L	Dy	< 0.1 µg/L	Pb	1 µg/L
Al	< 200 µg/L	Ge	< 1 µg/L	Sn	< 10 µg/L	Ho	< 0.1 µg/L	Bi	< 30 µg/L
Si	< 20000 µg/L	As	135 µg/L	Sb	< 1 µg/L	Er	< 0.1 µg/L	Th	< 0.1 µg/L
K	334000 µg/L	Se	510 µg/L	Te	< 10 µg/L	Tm	< 0.1 µg/L	U	3.2 µg/L
Ca	350000 µg/L	Br	65100 µg/L	I	100 µg/L	Yb	< 0.1 µg/L	Na	9340 mg/L
Sc	< 100 µg/L	Rb	112 µg/L	Cs	0.4 µg/L	Lu	< 0.1 µg/L	F	< 2 µg/L
Ti	< 10 µg/L	Sr	7830 µg/L	Ba	< 10 µg/L	Hf	< 0.1 µg/L	Cl	20200 mg/L
V	< 10 µg/L	Y	< 0.3 µg/L	La	< 0.1 µg/L	Ta	< 0.1 µg/L	NO_2	< 2 mg/L
Cr	< 50 µg/L	Zr	< 1 µg/L	Ce	< 0.1 µg/L	W	< 2 µg/L	Br	66 mg/L
Mn	< 10 µg/L	Nb	< 0.5 µg/L	Pr	< 0.1 µg/L	Re	< 0.1 µg/L	NO_3	< 2 mg/L
Fe	2000 µg/L	Mo	< 10 µg/L	Nd	< 0.1 µg/L	Os	< 0.2 µg/L	PO_4	< 4 mg/L
Co	< 0.5 µg/L	Ru	< 1 µg/L	Sm	< 0.1 µg/L	Pt	< 30 µg/L	SO_4	2800 mg/L

Source: http://www.planetzdravja.com/.

morphological parameters of the crop were measured (2008-2009). In 2008 and 2009, we also tried to monitor the overwintering characteristics of plants (number of overwintered wheat plants per m^2 – i.e. difference between plants in autumn and spring), such as the number of stems per unit area of wheat and the tillering factor (number of tillers per plant). We evaluated the number of wheat plants at the beginning of spring by counting them in marked areas (1 x 1 m) on each experimental plot. From these data the number of overwintered wheat plants per m^2 was calculated. In the booting stage (47/49 BBCH), we estimated cereal leaf beetle (*Olema melanopus* L.) damage. In each plot we randomly selected 40 spikes before harvest, for subsequent analysis in the laboratory. Each wheat spike was measured (mm), and the number of spikelets, the number kernels per spike, and the weight of the kernels (g) were recorded. Experiments were harvested on 18th July 2007, 29th July 2008, and 21st July 2009. The samples from all treatments were analysed for grain protein content (SIST ISO 1871:1995), falling number (SIST ISO 3093:2005) and sedimentation value (SIST ISO 5529:1997).

Grain properties, such as proteins (determined using the Kjeldahl method), sedimentation value (determined using the Zeleny sedimentation test), falling number (following Sven Hagberg 1960, and approved by ISO 3093 in 1982) and hectolitre weight (determined using the standard Schopper Chondrometer methodology), were analysed.

We considered a plant to have reached a particular developmental stage, when the stage became apparent in 75% of the plant. We measured leaf colour using a modified Munsell Color Chart for Plant Tissues (1977), with five colour intensity classes: 1) extremely bright green; 2) bright green; 3) green; 4) dark green; and 5) extremely dark green.

Plant damage caused by the cereal leaf beetle was scored on a graded scale (modified non-linear scale used for estimating formal field trials in Slovenia and followed by EPPO standards PP1/236(1): 2004): 1) no damage; 2) slightly damaged – up to 10% leaf area damaged; 3) medium damage – 10-20% leaf area damaged; 4) strong damage - 20-35% leaf area damaged; and 5) very strong damage - over 50% leaf area damaged.

Wheat is classified into classes A, B or C, based on the crude protein content, falling number, specific weight, and the sedimentation value. These classes are recognised between Slovenian wheat producers and buyers, and minimum values of the parameters for each class are listed in Table 2.

The data were analysed using the Statgraphics Centurion XV Professional statistical package (Statgraphics 2005). The results were subjected to Analysis of Variance (ANOVA). Homogeneity of the variance was analysed with Cochran's test. Significant differences between means at $P \leq 0.05$ (*) and $P \leq 0.01$ (**) was tested using the 95.0% Tukey's HSD method. The means are presented with their standard error (SE).

Table 2: Wheat classification system in Slovenia

Parameter	Quality class A	Quality class B	Quality class C	EU intervention purchase
Protein (%)	14	12	10.3	10.5
Falling number (s)	280	250	220	220
Hectolitre weight (kg)	78	76	74	73
Sedimentation (ml)	45	35	30	-

Source: http://www.furs.si/Publications/Seme/OSL_zita_2008_internet.pdf/

Table 3: The effect of Mineral on overwintered wheat plants and number of tillers at the University Agricultural Centre in 2008-2009

	Average number of overwintered wheat plants (m^{-2})		Average number of plant tillers (m^{-2})	
	2008-2009	**2009**	**2008-2009**	**2009**
Year (A)	*		**	
Treatment (B)	ns	ns	ns	ns
Interaction A x B	ns		ns	
Year				
2008	297.6±43.4[a]		396.4±13.6[a]	
2009	235.9±30.3[b]		296.6±13.6[b]	
Treatment				
Control	264.0±55.5	228.0±45.5	333.0±59.1	283.6±37.1
Mineral	269.5±53.2	243.8±36.6	360.0±76.9	309.6±49.3
Higher Mineral dose		223.2±28.1		284.0±13.3

Values are expressed as mean ± SD; Significant: ** $P \leq 0.01$; * $P \leq 0.05$; ns – $P \geq 0.05$; Different letter indicate statistical differences.

RESULTS AND DISCUSSION

The application of Mineral had no effect on number of tillers per plant and number of overwintered plants. However, the Mineral application resulted in higher value. According to obtain results, we could not assert that Mineral application in autumn increased low temperatures resistance. But significant effects were seen between years, demonstrating that low tillering capacity was due to the period of unusually low temperature and high rainfall in March 2009 at the BBCH 21/23 stage (Table 3).

As reported by Majathoub (2003) the effect of Vigro agent might be due to plant growth promoters which maintain the activity of endogenous phytohormones and improve plant growth during the tillering growth stage (BBCH 21/23).

Only in 2009 the application of Mineral significantly affected the intensively of green colour of leaves in comparison to the control (Table 4). Consequently, the increase of more intense colour of plant could be explainable by the minerals action with nutrients composition. The above-average warm weather at BBCH 32 (in April) clearly promoted plant development. However, the morphological differences in leaf stem and spike measurements after several treatments were not observed.

Table 4: The effect of Mineral on the intensity of green of wheat plants at the second node stage (BBCH 32) at the University Agricultural Centre in 2007-2009

	Colour intensity of wheat plants BBCH 32 2007-2009	Colour intensity of wheat plants BBCH 32 2009
Year (A)	**	
Treatment (B)	ns	**
Interaction A x B	ns	
Year		
2007	1.2±0.84[b]	
2008	1.0±0.82[b]	
2009	1.6±0.83[a]	
Treatment		
Control	1.1±0.26	1.0±0.00[b]
Mineral	1.5±0.64	1.8±0.50[a]
Higher Mineral dose		2.2±0.44[a]

Values are expressed as mean ± SD; Significant: ** $P \leq 0.01$; * $P \leq 0.05$; ns – $P \geq 0.05$; Different letter indicate statistical differences

Treatment with Mineral had little overall effect on grain yield. Comparing data between 2007 *vs*. 2009 and 2009 showed significant differences in yield, although 2009 differed from neither 2007 nor 2008. Consequently, the yield in 2008 was affected by unusually high temperatures in May and drought stress in April (with temperatures slightly above the long-term average and rainfall at only 50% of the long-term average). This resulted in seed development occurring too early, before the crops had reached their optimal height. The quantity and quality of the yield was further reduced by July storms (The Environmental Agency of the Republic of Slovenia 2010). For example, the quantity of the yield was 3.2±0.4 compared to the 2007 (4.6±0.4). In 2009 there was no difference in yield between the lower and higher dosages of Mineral, though both were higher compared to the control (Table 5).

However, in 2009 our results were comparable to several studies investigated the effects of saline and alkaline waters used for irrigation on wheat productivity (Singh et al. 2009).

Investigation of treatment with proprietary Agat 25 K, applied to oats at the tillering stage (BBCH 21/23), showed a significant increase in yield from 0.7 t ha^{-1} to 1.2 t ha^{-1}, depending on variety (Batalova and Budina 2008).

Table 5: The effect of Mineral on wheat grain yield (t ha^{-1}) at the University Agricultural Centre in 2007-2009

	Grain yield (kg 10 m^{-2} or t ha^{-1}) 2007-2009	Grain yield (kg 10 m^{-2} or t ha^{-1}) 2009
Year (A)	*	
Treatment (B)	ns	**
Interaction A x B	ns	
Year		
2007	4.6±0.4[a]	
2008	3.2±0.4[b]	
2009	3.9±0.4[ab]	
Treatment		
Control	3,87±0.3	3.5±0.13[b]
Mineral	3,95±0.3	4.2±0.13[a]
Higher Mineral dose		4.1±0.13[a]

Values are expressed as mean ± SD; Significant: ** $P \leq 0.01$; * $P \leq 0.05$; ns – $P \geq 0.05$; Different letter indicate statistical differences

In June 2009, the high temperatures and frequent rainfall at the grain filling stage caused stressful conditions for plants which resulted in poor crop development. Heavy rainfall in July led to waterlogged soil and mechanical difficulties with the wheat harvest. The grain quality was reduced through sprouting grain in the spikes (The Environmental Agency of the Republic of Slovenia 2010). It might be that plants treated with Mineral are more resistant to high and low temperatures.

There were no significant differences among spike parameters (spike length, number of spikelet's per spike, number of kernels per spike, and kernel weight per spike) between the treatment and the control within years, except for spike length and kernels per spike in 2009, under the higher Mineral dose treatment. The effect of year predominated (Table 6). The increase in the number of kernels per spike at the higher Mineral dose was similar to the effect of Vigro agent reported by Majathoub (2003).

Table 6: The effect of Mineral on spike characteristics at the University Agricultural Centre in 2008-2009

	Spike length (cm)		Spikelet's per spike (No)		Kernels per spike (No)		Kernel weight per spike (g)	
	2008-2009	2009	2008-2009	2009	2008-2009	2009	2008-2009	2009
Year (A)	**	*	**	ns	ns		**	ns
Treatment (B)	ns		ns		ns	*	ns	
Interaction AxB	ns		ns		ns		ns	
Year								
2008	6.7±0.41^{a}		14.4±0.92^{b}		34.1±3.6		1.7±0.2^{a}	
2009	5.8±0.35^{b}		22.8±3.06^{a}		31.1±3.0		1.0±0.1^{a}	
Treatments								
Control	6.1±0.49	5.7±0.15^{a}	18.0±0.7	22.0±2.8	32.8±3.6	30.8±1.3^{a}	1.4±0.45	1.0±0.09
Mineral	6,3±0.64	5.8±0.69^{a}	19.1±0.7	23.5±3.5	32.5±3.8	31.5±4.4^{a}	1.3±0.33	1.0±0.19
Higher Mineral dose		5.1±0.14^{b}		23.4±1.8		26.4±1.5^{b}		1.1±0.05

Values are expressed as mean ± SD; Significant: ** $P \leq 0.01$; * $P \leq 0.05$; ns – $P \geq 0.05$; Different letters indicate statistical differences.

ANOVA showed significant differences between treatments and their interaction (Mineral and control plots) for plant damage due to cereal leaf beetle attack (Table 7). In 2009 we found no increased wheat plant damage caused by cereal leaf beetle attack at the higher Mineral dose (at the booting stage, 47/49 BBCH).

There were clearly significant interaction effects between year and treatment on plant height (Table 7). The highest plants were recorded in 2009 (56.2±11.9), compared to the control treatment (53.9±9.6).

Table 7: The effect of Mineral on plant damage caused by cereal leaf beetle and plant height at harvest time at the University Agricultural Centre in 2008-2009

	Plant damage caused by cereal leaf beetle	Plant height at harvest time (cm)
	2008-2009	2008-2009
Year (A)	ns	**
Treatment (B)	*	*
Interaction A x B	*	*
Year		
2008	1.5±0.71	45.5±3.17^{b}
2009	1.5±0.47	64.6±4.88^{a}
Treatment		
Control	1.75±0.63^{a}	53.9±9.6^{b}
Mineral	1.25±0.43^{b}	56.2±11.9^{a}
Higher Mineral dose		

Values are expressed as mean ± SD; Significant: ** $P \leq 0.01$; * $P \leq 0.05$; ns – $P \geq 0.05$; Different letter indicate statistical differences.

Table 8: The effect of Mineral on kernel moisture (%) and hectoliter kernel weight (kg hl^{-1}) at University Agricultural Centre in 2007-2009

	Kernel moisture (%)		Hectoliter kernel weight (kg hl^{-1})	
	2007-2009	2009	2007-2009	2009
Year (A)	**		ns	
Treatment (B)	ns	*	ns	*
Interaction A x B	ns		ns	
Year				
2007	11.0±0.24^{a}		75.7±1.29	
2008	13.1±0.22^{b}		75.4±0.53	
2009	14.7±0.92^{b}		74.0±2.51	
Treatment				
Control	13.2±0.54	14.9±0.54^{b}	74.6±3.47	73.5±3.47^{b}
Mineral	13.0±0.71	14.6±0.62^{ab}	75.5±3.34	74.5±2.90^{ab}
Higher Mineral dose		14.2±0.17^{a}		75.9±1.69^{a}

Values are expressed as mean ± SD; Significant: ** $P \leq 0.01$; * $P \leq 0.05$; ns – $P \geq 0.05$; Different letter indicate statistical differences.

Table 9: Wheat yield quality classification in each treatment in 2008 and 2009

	Protein (%)		Falling number (s)		Hectoliter weight (kg)		Sedimentation (ml)	
	2008	2009	2008	2009	2008	2009	2008	2009
Control	B	C	A	B	C	C	C	C
Mineral	B	C	A	B	B	C	C	C
Higher Mineral dose	/	A	/	B	/	B	/	B

Grain moisture content varied between years, and differed at the higher Mineral dose. Hectoliter kernel weight did not vary between years and treatments except in 2009 at the higher Mineral dose (Table 8). However it might be results of the influence of Mineral physiological pathways of plants. In this way, the parameters of quality improvement, such as increase dry matter because of decrease grain moisture which are shown could not be explained with our experiment.

The wheat yield from each treatment was assessed based on quality parameters which classify grain into particular classes. In 2008, the Mineral treatment resulted in a higher hectoliter weight. In 2009, the higher Mineral dose increased the protein content, hectoliter weight and sedimentation (Table 9), but 2009 was without any dry weather periods at the grain development stages, which could also have influenced the quality of the grain.

CONCLUSION

We conclude that the experimental use of Mineral in field circumstances not caused beneficial effects on growth, but no significant effect on yield at low concentration (24 l ha^{-1}) in all these experimental years. The others parameters have not responded because of strong weather effects. The application of Mineral led to more intense leaf colour and less leaf damage caused by cereal leaf beetle, although the mechanisms behind this are unknown. Moreover, we can expect high grain yield (hectoliter kernel weight, protein, sedimentation) and increase dry matter. Yield quality (hectoliter kernel weight) increased in 2009 just at the higher Mineral dose (80 l ha^{-1}), for those are suggest further investigation into higher dose treatments.

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