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ORIGINAL PAPER

RESPONSE OF SPRING WHEAT TO DIVERSIFIED MINERAL FERTILIZATION

Wacław Jarecki, Jan Buczek, Dorota Bobrecka-Jamro

Department of Plant Production
University of Rzeszow

Abstract

The quantity and quality of spring wheat grain yield is dependent on appropriate cultivation practices, including mineral fertilization. Nutrients can be applied both to soil, on seeds and on leaves. For new cultivars, determination of the optimal doses and timings of fertilization with nitrogen and other mineral elements should be considered as particularly important. A controlled field experiment with the spring wheat cultivar Katoda was carried out in 2013-2015, at the Experimental Station of the University of Rzeszow in south-eastern Poland. The first experimental factor was the fertilization system (soil, seed, foliar or combined seed x foliar system), the second factor was the dose of soil nitrogen applied (80 vs. 120 kg ha^{-1}) and the third factor was the year of cropping (2013, 2014, 2015). The highest grain yield was obtained after the combined application of the seed fertilizer Primus B and foliar Basfoliar 36 Extra. The difference obtained in comparison with the control amounted to 0.87 t ha^{-1}. Increasing the nitrogen dose from 80 to 120 kg ha^{-1} caused an increase in the SPAD (Soil Plant Analysis Development) index, the number of spikes prior to harvest, TGW (*thousand grain weight*) and grain yield by 0.5 t ha^{-1}, respectively. Both the foliar fertilizer and a higher nitrogen dose effected an increase in the total protein content in the grain. The highest fibre content was obtained after the use of the seed fertilizer and in the control seeds, and the highest ash content occurred after the use of the foliar fertilizer. An increase in the content of Mg, Fe and Mn in grain was caused by foliar fertilization, while a higher K content resulted from the application of a higher nitrogen dose.

Keywords: *Triticum aestivum* L. seed fertilizer, foliar fertilizer, nitrogen, SPAD values, nutrition, grain yield.

dr inż. Wacław Jarecki, Department of Plant Production, University of Rzeszow, Zelwerowicza St. 4, 35-601 Rzeszów, Poland, e-mail: waclaw.jarecki@wp.pl

INTRODUCTION

Mineral fertilization of spring wheat modifies the grain yield (Nadim et al. 2012) and has an effect on its quality (Ali et al. 2013, Blandino et al. 2016). The previous studies (Bly, Woodard 2003, Dewal, Pareek 2004) indicated that mineral fertilization of wheat modifies plant growth and development, yield components and the quantity and quality of yield. Bly and Woodard (2003) showed that post-pollination foliar N gave higher grain protein and was most effective when the planned yield goal was exceeded. Dewal, Pareek (2004) proved that nutrient uptake increased up to the highest level of P, S and Zn, although P uptake was reduced at the highest level of zinc, and Zn uptake was reduced at the highest level of phosphorus.

Nitrogen is the most important nutrient. A deficit of this element limits plant growth and development, thereby affecting negatively the yield-forming ability of crops, including wheat. An excess of nitrogen in turn has a negative effect on field crops and, additionally, it poses a threat to the natural environment (Liang et al. 2011, Wang et al. 2011). Nitrogen fertilization should be planned according to the needs of a cultivated crop, at appropriate doses, proportions and times. Apart from nitrogen, rational fertilization with other nutrients is also important. Macro- and microelements can be applied to soil (Nadim et al. 2012, Ali et al. 2013), on leaves (Ducsay et al. 2007, Wróbel 2009, Rawashdeh, Sala 2014) or on seeds (Farooq et al. 2012).

Mineral fertilization may be synchronized by the use of modern measuring techniques. Performing measurements of SPAD is useful for determination of fertilization dosage during plant growth (Martínez, Guiamet 2004, Barutçular et al. 2015). For wheat, the results of SPAD allow for optimizing fertilization, particularly with nitrogen, and predicting the grain yield (Vidal et al. 1999, Islam et al. 2014). A SPAD chlorophyll meter is useful for rapid analysis of chlorophyll and nitrogen status of crops, while it has not been established how strongly the meter readings are correlated with grain yield under variable field conditions (Islam et al. 2014).

The aim of this study was to assess the effect of soil nitrogen, seed and foliar fertilization on chosen plant characteristics, the SPAD index and the quantity and quality of grain yield of cv. Katoda spring wheat.

MATERIAL AND METHODS

Field experiment

Over 2013-2015, a controlled field experiment was carried out at the Experimental Station of the University of Rzeszow in Krasne (50°03′N, 22°06′E), Poland. This was a two-factorial experiment conducted with four replications in the split-plot design. The test plant was the spring wheat cultivar Katoda (breeder Danko Sp. z o.o., Poland). Katoda is a cultivar with very good fertility and grain quality.

The first tested factor was composed of seed and foliar fertilization systems (Primus B vs. Basfoliar 36 Extra) and the second factor comprised two nitrogen doses (80 and 120 kg ha^{-1}). The seed fertilizer Primus B is manufactured by Intermag Sp. z o.o. (Poland) and the foliar fertilizer Basfoliar 36 Extra is made by Adob Sp. z o.o. (Poland). The seed fertilizer was applied on the seed material at a dose of 0.2 dm^3 100 kg^{-1} of grain. The chemical composition of this fertilizer included in g dm^{-3}: 19.5 N, 5.67 P, 10.79 K, 14.11 Mg, 10.4 S, 2.6 B, 2.6 Cu, 11.7 Fe, 3.9 Mn, 0.78 Mo, 5.2 Zn and 1.95 Ti. The foliar fertilizer was applied as a single dose at the BBCH 39 stage, at a dose of 10 dm^3 ha^{-1} applied with a hand sprayer. The amount of working liquid was 300 dm^3 ha^{-1}. Isolation belts between the plots were 2 m wide. The chemical composition of the foliar fertilizer included in g dm^{-3}: 363.2 N, 25.93 Mg, 0.27 B, 2.7 Cu, 0.27 Fe, 13.5 Mn, 0.067 Mo and 0.13 Zn.

Soil nitrogen fertilization (ammonium nitrate 34%) at a total dose of 80 N kg ha^{-1} was split into two doses: pre-sowing 50 N kg ha^{-1} and as top dressing 30 N kg ha^{-1}. The amount of 120 N kg ha^{-1} was also divided into the pre-sowing 80 N kg ha^{-1} and top dressing 40 N kg ha^{-1} doses (Table 1). Fertilization with phosphorus (superphosphate 19%) and potassium (potassium salt 60%) was applied in autumn in amounts of 40 P kg ha^{-1} and 100 K kg ha^{-1}. The herbicide Chwastox Extra 300 SL (3.5 dm^3 ha^{-1}), insecticide Sumi-Alpha 050 EC (0.25 dm^3 ha^{-1}), fungicide Juwel TT 483 SE (1.5 dm^3 ha^{-1}) and growth regulator Cerone 480 SL (0.75 dm^3 ha^{-1}) were used to protect wheat plants.

Table 1

Fertilization design

Factor	Fertilizers, dose	Application time, dose		
		before sowing	BBCH 21	BBCH 39
Soil application	80 N kg ha^{-1}	50 N kg ha^{-1}	30 N kg ha^{-1}	–
	120 N kg ha^{-1}	80 N kg ha^{-1}	40 N kg ha^{-1}	–
Seed application	Primus B	0.2 dm^3 100 kg^{-1} seeds	–	–
Foliar application	Basfoliar 36 Ex	–	–	10 dm^3 ha^{-1}
Combined seed x foliar application	Primus B + Basfoliar 36 Ex	0.2 dm^3 100 kg^{-1} seeds	–	10 dm^3 ha^{-1}

BBCH scale (Bleinholder et al. 2001)

Sowing dressed seeds (dressing Sarox 75 WS at a dose of 200 g 100 kg^{-1} of grain) was performed on: 16 April 2013, 1 April 2014 and 8 April 2015. The seeding rate was 450 seeds m^{-2}. Cultivation practices were performed in accordance with the recommendations of the Research Centre for Cultivar Testing (COBORU, Poland) for spring wheat crops. The previous crop was winter oilseed rape. The area of plots for sowing was 11.5 m^2, and for harvesting – 10 m^2. Grain harvest was performed with a plot combine harvester during the first ten days of August.

Weather conditions at the study site

The weather conditions were given according to the data of the Meteorological Station of the University of Rzeszow. In 2015, the lowest total precipitation during the plant growth period was recorded as compared with the long-term data (Table 2). High total precipitations occurred in June 2013 and in July 2014. Air temperatures were also diverse in the years of the study. The highest monthly temperatures were recorded in July 2014 and in August 2015 (Table 3).

Table 2

Total monthly precipitation (mm)

Years	Months					Total
	April	May	June	July	August	
2013	33.9	87.5	143.4	19.2	11.0	295.0
2014	29.9	92.2	48.1	112.4	46.8	329.4
2015	25.7	85.1	8.9	52.4	6.1	178.2
1956-2012	48.3	78.1	85.8	90.6	62.7	–

Table 3

Mean monthly air temperature (°C)

Years	Months					Mean
	April	May	June	July	August	
2013	9.39	9.84	18.48	19.33	19.58	15.32
2014	10.10	14.10	16.30	20.10	18.10	15.74
2015	8.60	13.00	17.60	19.90	21.40	16.10
1956-2012	8.89	13.74	17.20	19.14	18.35	–

Soil conditions

The soil of the experimental area was classified as Haplic Cambisol (FAO 2015) and had the texture of silt, according to the classification by the IUSS Working Group WRB. The soil reaction was slightly acidic, the humus content was high and N_{min} was very low or low. The soil was characterized by a high content of assimilable P, moderate content of K, high or very high content of Mg and low content of S. The content of microelements was generally average (Table 4).

Analytical methods

The analyses involved the measurements of soil plant analysis development – SPAD (Süss et al. 2015), yield structure as well as the quantity and quality of grain yield. Data regarding thousand grains weight (TGW) were recorded by counting randomly selected 1000 grains from each sub-plot and weighed on a sensitive electronic balance.

Measurements of SPAD with the apparatus 502 P Konica Minolta

Table 4

Physicochemical soil properties, (spring before sowing, layer 0-30 cm)

Specification	2013	2014	2015
Soil reaction (1 mol dm^3 KCl)	5.59	6.07	5.83
Humus (%)	2.80	2.76	2.82
N_{min} 0-60 cm (kg ha^{-1})	50.2	48.5	55.4
Content of available nutrients in soil (mg kg^{-1})			
P	183	189	190
K	185	189	185
Mg	88	92	78
-	0.50	0.47	0.54
Fe	1314.1	2506.2	1781.3
Mn	215.5	295.2	315.4
Zn	11.3	17.1	16.4
B	1.51	1.74	1.61
Cu	5.8	7.4	6.3

(Japan) were made twice, at the tillering (BBCH 25) and the shooting stage (BBCH 49), on 30 flag leaves of wheat.

The plants were counted at the stage of emergence (BBCH 12) and the number of spikes per m^2, prior to harvest (BBCH 89). Plants for biometric measurements were collected from an area of 0.5 m^2 from each plot at the stage of full maturity of grain (BBCH 89). The grain yield from the plots was calculated per 1 ha taking into consideration the grain moisture content of 14%.

The grain content of starch, protein, ash and fibre was determined with the NIRS method, on an FT NIR MPA Bruker (USA) spectrometer. Spectometry in near-infrared is one of the most frequently used methods for investigating agro-food products.

To determine macroelements and microelements, plant samples were mineralized in a mixture of concentrated acids HNO_3:$HClO_4$:HS_2O_4 in the ratio 20:5:1, in an open system, in the heating block Tecator. The content of Ca, K, Mg, Zn, Mn, Cu, Fe was determined in mineralisates with atomic absorption spectroscopy (FAAS) on a Hitachi Z-2000 apparatus (Japan), whereas P was determined with colorimetry, using a spectrophotometer UV-VIS Shimadzu (Japan).

Statistical analyses

The effect of individual research factors (fertilization, year) and their interactions were assessed by means of two-way ANOVA. Differences between the mean values were compared by the Tukey's method, where the significance level was α = 0.05 Statistica 10 Software (StatSoft, Inc., Tulsa, USA) was used for statistical analyses.

RESULTS AND DISCUSSION

Field and biometric measurements

The fertilizer Primus B increased the plant density after emergences and the number of spikes prior to harvest. Fertilization with Basfoliar 36 Extra increased the number of grains per spike and TGW as compared with the fertilizer Primus B and the control. The higher nitrogen dose effected an increase in the number of spikes prior to harvest and TGW as compared with the lower dose. The highest grain yield was obtained after the combined application of the seed and foliar fertilizers (Table 5). The resultant difference relative to the control was 0.87 t ha^{-1}, i.e. 11.8%. Fertilization with Basfoliar 36 Extra also increased the grain yield, but by 0.48 t ha^{-1}, i.e. 6.5% in relation to the control. The use of a 120 kg ha^{-1} nitrogen dose caused an increase in the grain yield as compared with the lower dose (80 kg ha^{-1}). The significant difference was 0.5 t ha^{-1}, i.e. 6.6%, on average. El-Habbal et al. (2010) and Akhter et al (2016) proved that increasing the nitrogen dose results in an increase in yield structure components and wheat grain yield. Wróbel (2009) and Zoz et al. (2016) obtained a favourable effect of fertilization of

Table 5

Grain yield, plant density and yield components

Fertilization		Grain yield (t ha^{-1})	Number of plants after emergence (pcs. m^{-2})	Number of ears (pcs. m^{-2})	Number of grains per ear	Mass of 1000 grains (g)
Fertilizer	N (kg ha^{-1})					
Control	80	7.21	389.1	520.5	35.3	39.3
	120	7.57	402.2	530.5	36.1	40.1
Primus B	80	7.34	406.4	535.2	35.2	39.5
	120	7.92	408.6	546.2	36.3	40.5
Basfoliar 36 Extra	80	7.54	390.2	519.8	35.8	41.1
	120	8.19	401.3	532.4	37.2	41.9
Primus B + Basfoliar 36 Extra	80	8.05	405.8	537.0	35.9	42.3
	120	8.47	409.5	545.1	37.0	42.5
Control		7.39^{c}	395.7^{b}	525.5^{b}	35.7^{b}	39.7^{b}
Primus B		7.63^{bc}	407.5^{a}	540.7^{a}	35.8^{b}	40.0^{b}
Basfoliar 36 Extra		7.87^{b}	395.8^{b}	526.1^{b}	36.5^{a}	41.5^{a}
Primus B + Basfoliar 36 Extra		8.26^{a}	407.7^{a}	541.1^{a}	36.5^{a}	42.4^{a}
80		7.54^{b}	397.9	528.1^{b}	35.6	40.6^{b}
120		8.04^{a}	405.4	538.6^{a}	36.7	41.3^{a}
2013		8.42^{a}	407.7^{a}	536.1	36.2	43.8^{a}
2014		7.89^{ab}	402.2^{ab}	529.4	36.3	41.5^{ab}
2015		7.05^{b}	395.0^{b}	534.5	35.8	37.4^{b}

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$).

wheat with B, and ALI et al. (2013) with B and Zn, on the grain yield and its structure components. ZOZ et al. (2016) proved that foliar fertilization of wheat with Ca and B had a favourable effect on the yield structure components and the grain yield, but it did not have an effect on TGW. The present experiment confirmed significant differentiation of grain yield, plant density after emergences and TGW in the years of the study. FAROOQ et al. (2012) concluded that micronutrient application through seed treatments improves the stand establishment, advances phenological events, and increases yield and micronutrient grain contents in most cases. In some instances, seed treatments are not beneficial; however, the negative effects are rare.

Measurements of indexes

The application of the higher nitrogen dose resulted in an increase in the SPAD index at both stages: BBCH 25 and BBCH 49. EL-HABBAL et al. (2010) also indicated that increasing the nitrogen dose leads to an increase in the SPAD index of wheat, on average from 43 (the control) to 48.8 (120 N kg ha^{-1}). The foliar fertilizer Basfoliar 36 Extra resulted in a significant increase in the SPAD index value at the stage BBCH 49 (Table 6). In 2013 and 2014, the SPAD index values were significantly higher than in 2015. RAWASHDEH and SALA (2014) obtained an increase in the chlorophyll content in the flag

Table 6

Measurements of SPAD indicator

Fertilization		BBCH 25	BBCH 49
Fertilizer	N (kg ha^{-1})		
Control	80	38.5	48.3
	120	39.4	49.5
Primus B	80	38.9	48.2
	120	39.8	49.6
Basfoliar 36 Extra	80	38.5	50.4
	120	39.2	50.8
Primus B + Basfoliar 36 Extra	80	38.8	50.6
	120	40.0	50.7
Control		39.0	48.9^{b}
Primus B		39.4	48.9^{b}
Basfoliar 36 Extra		38.9	50.6^{a}
Primus B + Basfoliar 36 Extra		39.4	50.7^{a}
80		38.7^{b}	49.4^{b}
120		39.6^{a}	50.2^{a}
2013		41.6^{a}	51.2^{a}
2014		40.2^{a}	50.4^{a}
2015		35.5^{b}	47.8^{b}

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$).

leaf within the range from 51.5 to 59.3 SPAD units owing to foliar fertilization with Fe.

Chemical composition of seeds

The application of the fertilizer Basfoliar 36 Extra and the higher nitrogen dose resulted in an increase in the total protein content in the grain. The fibre content was higher after the application of the fertilizer Primus B and in the control. The content of ash increased significantly after the application of the fertilizer Basfoliar 36 Extra as compared with the control treatment. The chemical composition of grain was varied in the years of the study (Table 7). El-Habbal et al. (2010) and Velasco et al. (2012) report that higher nitrogen doses result in an increase in the total protein content in wheat grain. Blandino et al. (2016) proved that the quality parameters of wheat grain depend on nitrogen fertilization, and the time and method of the fertilizer application is essential.

The applied fertilization hardly changed the content of macroelements in the grain. Only an increase in the Mg content was observed under the influence of foliar fertilization and the K content was modified under the influence of the higher N dose. The content of macroelements in the grain was significantly varied in the years of the study (Table 8). In the study by Wilczewski

Table 7

Basic chemical composition of grains (% DM)

Fertilization		Starch	Protein	Fiber	Ash
Fertilizer	N (kg ha^{-1})				
Control	80	61.2	14.5	1.35	1.85
	120	61.0	15.3	1.33	1.80
Primus B	80	61.3	14.3	1.34	1.86
	120	60.8	15.2	1.30	1.83
Basfoliar 36 Extra	80	60.9	14.8	1.28	1.89
	120	60.7	15.9	1.25	1.87
Primus B + Basfoliar 36 Extra	80	61.0	14.8	1.29	1.92
	120	60.9	16.2	1.27	1.90
Control		61.1	14.9^{b}	1.34^{a}	1.83^{b}
Primus B		61.1	14.8^{b}	1.32^{a}	1.85^{ab}
Basfoliar 36 Extra		60.8	15.4^{a}	1.27^{b}	1.88^{a}
Primus B + Basfoliar 36 Extra		61.0	15.5^{a}	1.28^{b}	1.91^{a}
80		61.1	14.6^{b}	1.32	1.88
120		60.9	15.7^{a}	1.29	1.85
2013		61.5^{a}	15.1^{ab}	1.18^{c}	1.92^{a}
2014		61.8^{a}	14.8^{b}	1.31^{b}	1.89^{a}
2015		59.7^{b}	15.5^{a}	1.42^{a}	1.78^{b}

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$).

Table 8

Macroelement content in grain (g kg^{-1} DM)

Fertilization		P	K	Ca	Mg
Fertilizer	N (kg ha^{-1})				
Control	80	4.25	4.51	0.12	1.35
	120	4.18	4.62	0.11	1.31
Primus B	80	4.23	4.52	0.10	1.36
	120	4.24	4.60	0.13	1.33
Basfoliar 36 Extra	80	4.27	4.59	0.09	1.45
	120	4.30	4.62	0.09	1.42
Primus B + Basfoliar 36 Extra	80	4.26	4.58	0.08	1.47
	120	4.28	4.62	0.08	1.46
Control		4.22	4.57	0.12	1.33^{b}
Primus B		4.24	4.56	0.12	1.35^{b}
Basfoliar 36 Extra		4.29	4.61	0.09	1.44^{a}
Primus B + Basfoliar 36 Extra		4.27	4.60	0.08	1.47^{a}
80		4.25	4.55^{b}	0.10	1.41
120		4.25	4.62^{a}	0.10	1.38
2013		4.22^{ab}	4.73^{a}	0.09^{b}	1.35^{b}
2014		4.12^{b}	4.18^{b}	0.13^{a}	1.54^{a}
2015		4.42^{a}	4.84^{a}	0.08^{b}	1.28^{b}

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$).

et al. (2013), the content of P and Mg in grain of spring wheat fertilized with nitrogen at doses 120 or 160 kg ha^{-1} was significantly higher than after the application of lower nitrogen amounts. The fertilizer Basfoliar 36 Extra caused an increase in the Fe and Mn content in grain. The content of the other microelements in grain was significantly varied in the years of the study, except for Fe (Table 9). Ali et al. (2013) indicated that there was an increase in Zn in wheat grain owing to the fertilization with this element.

CONCLUSIONS

In conclusion, it should be stated that it is justified to apply a higher nitrogen dose (120 kg ha^{-1}) in spring wheat cultivation as well as both the seed fertilizer Primus B as well as the foliar Basfoliar 36 Extra. This conclusion is supported by measurements of SPAD reflecting the nutritional status of wheat plants and the quantity and quality of grain yield. Moreover,

Table 9

Microelement content in grain (mg kg-1 DM)

Fertilization		Fe	Mn	Zn	Cu
Fertilizer	N (kg ha-1)				
Control	80	45.2	42.3	35.3	3.95
	120	44.3	43.1	35.8	4.01
Primus B	80	45.4	42.2	35.2	3.89
	120	45.2	43.5	35.6	4.08
Basfoliar 36 Extra	80	46.2	43.8	36.2	4.12
	120	46.0	43.8	36.8	4.15
Primus B + Basfoliar 36 Extra	80	46.4	43.9	36.4	4.11
	120	46.3	44.5	36.7	4.17
Control		44.8^{b}	42.7^{b}	35.6	3.98
Primus B		45.3^{b}	42.9^{b}	35.4	3.99
Basfoliar 36 Extra		46.1^{a}	43.8^{a}	36.5	4.14
Primus B + Basfoliar 36 Extra		46.4^{a}	44.2^{a}	36.6	4.14
80		45.8	43.1	35.8	4.02
120		45.5	43.7	36.2	4.10
2013		45.9	44.1^{a}	36.8^{a}	4.16^{a}
2014		45.7	43.2^{ab}	35.8^{b}	4.07^{ab}
2015		45.2	42.9^{b}	35.4^{b}	3.95^{b}

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$).

the presented effects of spring wheat fertilization were largely dependent on the weather conditions in the years of the study.

REFERENCES

Akhter M.M., Hossain A., Timsina J., Teixeira da Silva J.A., Islam M.S. 2016. *Chlorophyll meter – a decision-making tool for nitrogen application in wheat under light soils*. Int. J. Plant Prod., 10(3): 289-302.

Ali M.A., Tariq N.H., Ahmed N., Abid M., Rahim A. 2013. *Response of wheat (Triticum aestivum* L.) *to soil applied boron and zinc fertilizers under irrigated conditions*. Pak. J. Agric. Agric. Engin., Vet. Sci., 29(2): 114-125.

Barutçular C., Toptaş İ, Türkten H., Yildirim M., Koç M. 2015. *SPAD greenness to estimate genotypic variation in flag leaf chlorophyll in spring wheat under Mediterranean conditions*. Turk. J. Field Crops., 20(1): 1-8. DOI: 10.17557/.51440

Blandino M., Marinaccio F., Reyneri A. 2016. *Effect of late-season nitrogen fertilization on grain yield and on flour rheological quality and stability in common wheat, under different production situations*. Ital. J. Agron., 11(2): 107-113. DOI: http://dx.doi.org/10.4081/ija. 2016.745

Bleinholder H., Weber E., Feller C., Hess M., Wicke H., Meier U. 2001. *Growth stages of mono -and dicotyledonous plants*. BBCH Monograph. Germany, pp. 158. http://www.jki.bund.de/fileadmin/dam_uploads/_veroeff/bbch/BBCH-Skala_englisch.pdf

Bly A.G., Woodard H.J. 2003. *Foliar nitrogen application timing influence on grain yield and protein concentration of hard red winter and spring wheat*. Agron. J., 95(2): 335-338. DOI: 10.2134/agronj2003.3350

Dewal G.S., Pareek R.G. 2004. *Effect of phosphorus, sulphur and zinc on growth, yield and nutrient uptake of wheat (Triticum aestivum)*. Ind. J. Agron., 49(3): 160-162.

Ducsay L., Ložek O., Varga L., Lošák T. 2007. *Effects of winter wheat supplementation with selenium*. Ecol. Chem. Eng., 14(3-4): 289-294.

El-Habbal M.S., Ashmawy F., Saoudi H.S., Abbas I.K. 2010. *Effect of nitrogen fertilizer rates on yield, yield components and grain quality measurements of some wheat cultivars using SPAD--Meter*. Egypt. J. Agric. Res., 88(1): 211-223.

FAO 2015. *World Reference Base for Soil Resources*. World Soil Resources Report. Italy. 106. pp. 192. http://www.fao.org/3/a-i3794e.pdf

Farooq M., Wahid A., Siddique K.H.M. 2012. *Micronutrients application through seed treatments - A review*. J. Soil Sci. Plant Nutr., 12(1): 125-142. http: //dx.doi.org/10.4067/S0718-95162012000100011

Islam M.R., Haque K.M.S., Akter N., Karim M.A. 2014. *Leaf chlorophyll dynamics in wheat based on SPAD meter reading and its relationship with grain yield*. Sci. Agric., 8(1): 13-18. DOI: 10.15192/PSCP.SA.2014.4.1.1318

Liang X.Q., Xu L., Li H., He M.M., Qian Y.C., Liu J., Nie Z.Y., Ye Y.S., Chen Y. 2011. *Influence of N fertilization rates, rainfall and temperature on nitrate leaching from a rainfed winter wheat field in Taihu watershed*. Phys. Chem. Earth., 36(9-11): 395-400. DOI: 10.1016/j.pce.2010.03.017

Martínez D., Guiamet J. 2004. *Distortion of the SPAD 502 chlorophyll meter readings by changes in irradiance and leaf water status*. Agronomie, 24(1): 41-46. DOI: 10.1051/agro:2003060

Nadim M.A., Awan I.U., Baloch M.S., Khan E.A., Naveed K., Khan M.A. 2012. *Response of wheat (Triticum aestivum L.) to different micronutrients and their application methods*. J. Anim. Plant Sci., 22(1): 113-119.

Rawashdeh H., Sala F. 2014. *Influence of iron foliar fertilization on some growth and physiological parameters of wheat at two growth stages*. Sci. P. S. A. Agr., 57: 306-309.

Süss A., Danner M., Obster C., Locherer M., Hank T., Richter K. 2015. *Measuring leaf chlorophyll content with the Konica Minolta SPAD-502Plus – Theory, Measurement, Problems, Interpretation*. EnMAP Field Guides Technical Report, GFZ Data Services. DOI: http://doi.org/10.2312/enmap.2015.010

Velasco J.L., Rozas H.S., Echeverriá H. E., Barbieri P.A. 2012. *Optimizing fertilizer nitrogen use efficiency by intensively managed spring wheat in humid regions: Effect of split application*. Can. J. Plant Sci., 92(5): 847-856. DOI:10.4141/CJPS2011-146

Vidal I., Longeri L., Hétier J.M. 1999. *Nitrogen uptake and chlorophyll meter measurements in spring wheat*. Nutr. Cycl. Agroecosys., 55(1): 1-6. DOI: 10.1023/A:1009843813004

Wang D., Xu Z., Zhao J., Wang Y., Yu Z. 2011. *Excessive nitrogen application decreases grain yield and increases nitrogen loss in a wheat-soil system*. Acta Agr. Scand. B - S P Sci., 61(8): 681-692. DOI: 10.1080/09064710.2010.534108

Wilczewski E., Szczepanek M., Piotrowska-Długosz A., Wenda-Piesik A. 2013. *Effect of nitrogen rate and stubble catch crop on the concentration of macroelements in spring wheat grain*. J. Elementol., 18(3): 481-494. DOI: 10.5601/jelem.2013.18.3.12

Wróbel S. 2009. *Response of spring wheat to foliar fertilization with boron under reduced boron availability*. J. Elementol., 14(2): 395-404. DOI: 10.5601/jelem.2009.14.2.20

Zoz T., Steiner F., Seidel E.P., Castagnara D.D., de Souza G.E. 2016. *Foliar application of calcium and boron improves the spike fertily and yield of wheat*. Biosci. J., 32(4): 873-880. DOI: http://dx.doi.org/10.14393/BJ-v32n4a2016-29714