Examination of nutrient reaction of winter wheat after sunflower forecrop

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SUMMARY

We tested the fertilizer reaction of four different winter wheat varieties in three different crop years, on chernozem soil, in long-term experiment. We examined the optimum fertilizer requirements and the maximum yield of the varieties. According to our results there were significant differences among the years: the yield of the winter wheat varieties changed between 1.4–6.1 t ha^{-1} in 2013, 3.8–8.6 t ha^{-1} in 2014 and 3.2–8.6 t ha^{-1} in 2015. The yield increasing effect of fertilization was significantly different in the tested years. The optimum level of fertilization was determined by, besides the genetic differences among the varieties, the crop year and the extent of fertilization. In milder winter months, due to the higher average temperatures, yields of winter wheat increased compared to an average crop year.

Keywords: *winter wheat, yield, nutrient reaction, fertilization, genotype*

ÖSSZEFOGLALÁS

Tartamkísérletben vizsgáltuk három különböző évjáratban csernozjom talajon négy különböző őszi búza fajta trágyareakcióját. Vizsgáltuk a fajták optimális műtrágyaigényét és a maximális termésmennyiséget. Eredményeink szerint az évek között jelentős különbségeket tapasztaltunk, az őszi búza fajták termése a 2013. évben 1,4–6,1 t/ha között, 2014. évben 3,8–8,6 t/ha, 2015. évben 3,2–8,6 t/ha között változott. A trágyázás termésnövelő hatása a vizsgált években jelentősen eltért. Az optimális műtrágyaszintet a fajták közötti genetikai különbség mellett az évjárat és a műtrágyázás mértéke határozta meg. Enyhébb téli hónapokban köszönhetően az őszi búza termésmennyiségei átlagos évjárathoz képest nőttek.

Kulcsszavak: *őszi búza, termés, tápanyag-reakció, műtrágyázás, genotípus*

INTRODUCTION

In the crop production of the world, one of the most important plants is the winter wheat. According to Slafer et al. (1994), winter wheat is one of the most widely grown cereals, it is grown in all regions of the world. According to Satorre and Slafer (1999), winter wheat is grown on one-sixth of the arable area of the world. According to Chen et al. (2012) winter wheat is one of the main protein sources for humankind, it has a higher protein content than maize or rice. Winter wheat is grown in dry or semi-dry areas. According to Braun et al. (2010) winter wheat provides 20% of the required amount of protein and 21% of the daily calorie consumption for 4.5 billion people in 94 developing countries. Winter wheat production of the world is nearly 700 million tonnes. According to Rajaram and Braun (2008), by 2020 the winter wheat utilization of the world will reach 840–1000 million tonnes. According to Richards (2000), compared to the previous century the yield of winter wheat has doubled. Increase in yield could be achieved by the development of several factors. According FAO (2013) data, in the world, sunflower is grown on 25.6 million hectares and winter wheat is grown on 218.4 million hectares. In our country, winter wheat is grown on 1.11 million hectares, and sunflower is grown on 0.5936 million hectares. In Hungary, with winter wheat in 2014 (4.73 t ha^{-1}) and in 2015 (5.14 t ha^{-1}) average yield was achieved KSH (2015). The production of cereal plants is strongly influenced by the type of the forecrop, the time of its harvest, its effect on the soil and its water consumption. According to Ruzsányi and Lesznyák (2003) as an effect of the forecrops, after plants with favourable and unfavourable water management, differences of 200 mm can occur in the water content of the soil. According to Pepó (2009), the domestic production of arable crops is very unilateral, 60–70% of wheat sowings takes place after unfavourable forecrops (the wheat itself, maize, sunflower). The balanced nutrient supply has high importance. According to Márton (1985), compared to the effect of NPK fertilization with total active agent content, the yield of wheat in the average of 7 years was increased 2% by the NK fertilization, and was decreased by 6% by the NP, by 13% by the PK, by 22% by the P, by 28% by the K and by 38% by the one-sided N fertilization. According to Harmati and Szemes (1985) to meet the nitrogen requirement of wheat varieties in production, an active nitrogen substance of 120–200 kg ha^{-1} is needed, depending on the variety, the available NPK content of the soil, the forecrop and the water supply of wheat. According to Bocz and Győri (1985), with unfavourable forecrops, in the average of the varieties, the optimum dose of nitrogen increases to 180 kg ha^{-1}. According to the data of Debreceni (1994) gained in Nagyhörcsök, the optimal crop year proves to be the most favourable both in the yield and in the fertilizer reaction. His data are contradicted by Kadlicskó (2009), since yield results show intense fluctuation: extremely high average yield occurs also in draughty years and average or less yield occurs also in rainy years. Anomalies can imputable to agrotechnical elements. There are significant differences between the varieties in production. According to Pepó (2002), wheat varieties with different genotypes could utilize the favourable agroecological conditions and elements of production technology on different extents. According to Szabó (2013), less modern varieties with older genotypes produced lower maximum yields in every crop year and they also had considerably weaker nutrient reaction. According to Pepó (2004), variety GK Öthalom has a moderate, while variety Mv Csárdás has a weak natural nutrient utilization ability. According to Pepó (2001), also with incomplete or reduced fertilization, we must necessarily be careful with the choice of the genotype, as significant differences occur between the varieties in their natural nutrient utilization ability.

MATERIAL AND METHODS

Our field research took place on the Látókép test farm of Agricultural Science Centre of University of Debrecen, Centre for Agricultural and Applied Economic Sciences, on calcareous chernozem soil, in long-term experiment, in growing seasons of years 2013–2015. Our experimentation on winter wheat took place after sunflower forecrop, arranged in split bands. We examined winter wheat varieties GK Öthalom, GK Csillag, Mv Csárdás and Mv Toldi. 100% of P and K fertilizer doses were applied in autumn, 50% of the N fertilizer doses were applied in autumn and the other 50% in spring. Fertilizer doses applied with the different nutrient levels are shown in *Table 1*. We analysed the nutrient reaction of winter wheat varieties by polynomial regression function. We determined the optimum values Sarlangue et al. (2007) from the equations of the regression, with the help of the following formula: $y=a+bx+cx^2$, where $x=-b/(2*c)$. The yield was harvested by Sampo plot combine. Our results were demonstrated by Microsoft Excel. The aim of our researches was to determine the crop rotation, the yield and the optimum fertilization after sunflower forecrop. Based on the measured values of precipitation and temperature *(Table 2)* we detected significant differences between the crop years.

Table 1

Fertilizer doses applied in the experiment (Debrecen, 2012–2015)

Applied fertilizer doses	N	P_2O_5	K_2O
	(kg ha^{-1})		
0	0.0	0.0	0.0
1	30.0	22.5	26.5
2	60.0	45.0	53.0
3	90.0	67.5	79.5
4	120.0	90.0	106.0
5	150.0	115.5	132.5

Winter wheat is a plant which well reacts to weather conditions, but during its long growing season its stands can face several favourable and unfavourable effects. According to our date, in the analysed years the vegetative development of winter wheat was affected mainly by the water supply and the temperature conditions *(Table 2)*. In growing season 2012/2013 the amount of rainfall was more (+79.3 mm) than the average of 30 years. In growing seasons 2013/2014 and 2014/2015 the total amount of rainfall was significantly less than the average of 30 years. According to our weather data, the average values of temperature measured in the vegetative periods of the analysed years considerably exceeded the 30 year average (6.93 ^{o}C). According to our temperature data, the average temperature of winter months (January and February) exceeded the 30 year average, thus the vegetative development was more intensive in winter.

Table 2

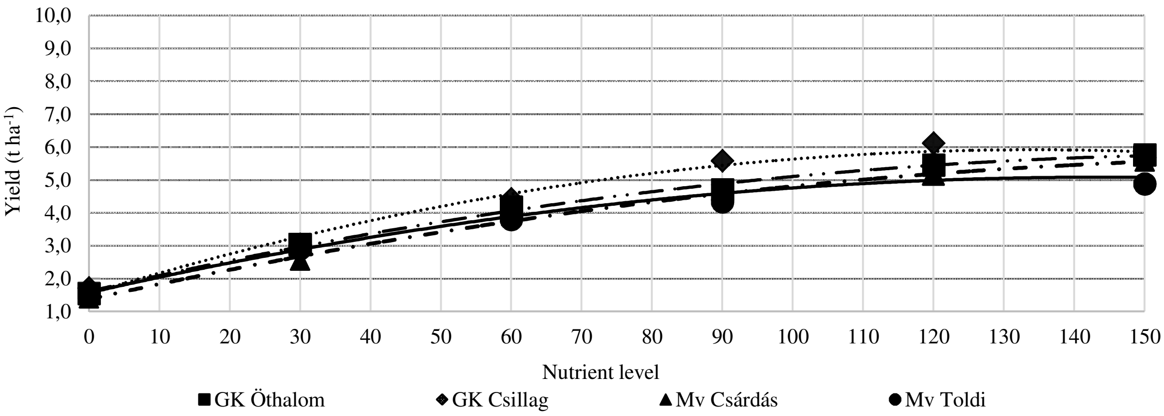
Monthly values of the precipitation (mm) and the temperature (^{o}C) in the vegetative period of winter wheat (Debrecen, 2012–2015)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Marc.	Apr.	May	Jun.	
	Precipitation (mm)									Total
2012/2013	22.4	16.6	65.8	38.7	52.9	136.3	48.0	68.7	30.8	480.2
2013/2014	39.1	51.5	0.0	39.2	26.0	11.3	39.6	69.4	7.9	284.0
2014/2015	88.6	20.8	37.9	39.5	18.6	10.2	21.9	52.9	60.5	350.9
30 year average	30.8	45.2	43.5	37.0	30.2	33.5	42.4	58.8	79.5	400.9
	Temperature (^{o}C)									Average
2012/2013	11.1	7.2	-1.2	-1.0	2.3	2.9	12.0	16.6	19.6	7.72
2013/2014	11.8	7.6	0.5	2.0	7.8	8.9	12.3	15.4	19.0	9.48
2014/2015	11.2	6.4	2.4	1.0	1.5	6.2	10.1	15.8	19.9	8.28
30 year average	10.3	4.5	-0.2	-2.6	0.2	5.0	10.7	15.8	18.7	6.93

RESULTS AND DISCUSSION

In our long-term filed experiments we examined the effect of sunflower forecrop and fertilization on the optimum fertilizer reaction of different winter wheat genotypes *(Table 2)*. In growing season of 2012/2013, the dry period of autumn and the extremely rainy (136.3 mm) months of spring were unfavourable to the early development of the varieties. The amount of precipitation (79.3 mm) exceeded the 30 year average, however, its distribution had a negative effect on the yield. In 2013, yields results of the tested treatments (control, N_{30}+PK, N_{60}+PK, N_{90}+PK N_{120}+PK, N_{150}+PK) changed between 1.55–5.77 t ha^{-1} with GK Öthalom, 1.71–5.68 t ha^{-1} with GK Csillag, 1.41–5.56 t ha^{-1} with Mv Csárdás, 1.60–4.87 t ha^{-1} with Mv Toldi *(Figure 1)*.

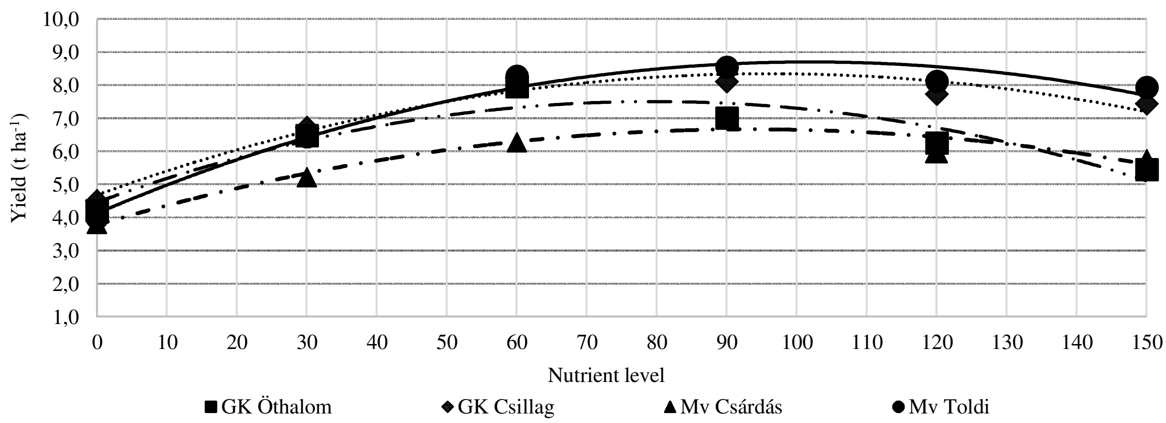
Figure 1: **Fertilizer reaction of winter wheat varieties after sunflower forecrop (Debrecen, 2012–2013)**



The fertilizer treatment that produced the maximum yield was N_{150}+PK with genotypes GK Öthalom, GK Csillag and Mv Csárdás, and it was N_{120}+PK with genotype Mv Toldi.

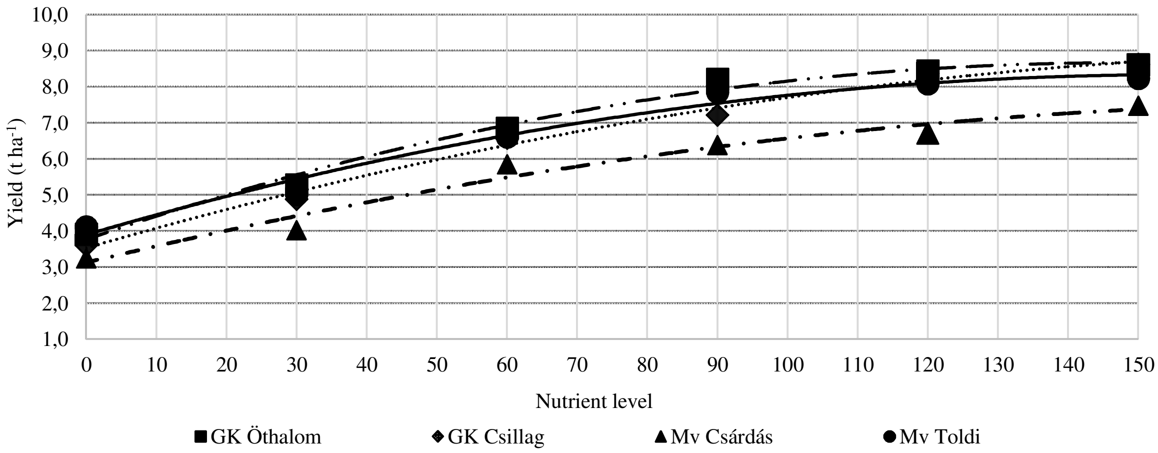
The growing season of 2013/2014 was very different from that of 2012/2013. The months of winter were extremely mild – exceeding the average temperature of many years – which had a positive effect on the yield. The favourable weather conditions helped the development of the vegetative organs, and also the chernozem soil, which can have favourable amount of available N, provided appropriate conditions for the development of winter wheat stands. In the growing season of 2014, the yield produced with the tested treatments *(Figure 2)* changed between 4.21–5.45 t ha^{-1} with GK Öthalom, 4.51–7.44 t ha^{-1} with GK Csillag, 3.81–5.76 t ha^{-1} with Mv Csárdás and 4.00–7.93 t ha^{-1} with Mv Toldi. In the growing season of 2014, the fertilizer treatments that resulted in maximum yields were N_{77}+PK and N_{112}+PK treatments. Due to the conditions that occurred at the end of the growing season, because of infectious pressure, significant decrease in the yield was detected with genotypes Mv Csárdás and Mv Toldi with N_{90}+PK–N_{150}+PK interval of fertilizer treatments *(Figure 2)*.

Figure 2: **Fertilizer reaction of winter wheat varieties after sunflower forecrop (Debrecen, 2013–2014)**



The growing season of 2015 is considered as favourable based on the measured temperature and precipitationdata. In December, January and February we measured average temperatures which exceeded the average of many years, but the precipitation conditions of the months at the end of winter and in spring were unfavourable for the development of the vegetative organs. In growing season of 2015 the intervals of yields with the different fertilizer treatments *(Figure 3)* changed between: 3.91–8.60 t ha^{-1} with GK Öthalom, 3.62–8.61 ha^{-1} with GK Csillag, 3.23–7.47 t ha^{-1} with Mv Csárdás and 4.12–8.23 t ha^{-1} with Mv Toldi. The maximum yield was achieved with the high dose N_{150}+PK fertilizer treatment, it changed in an interval of 7.42–8.60 t ha^{-1} between the varieties. During our 3-year research period we evaluated the yield of the varieties in the average of the tested treatments. The best variety was GK Csillag (6.03 t ha^{-1}), followed by Mv Toldi 5.90 t ha^{-1}, GK Öthalom 5.74 t ha^{-1}, and Mv Csárdás 5.05 t ha^{-1}. We averaged the maximum yields of the three tested years. According to our observations, the maximum average yield was reached by GK Csillag 7.65 t ha^{-1}, followed by GK Öthalom 7.44 t ha^{-1}, Mv Toldi 7.41 t ha^{-1}, and Mv Csárdás produced the lowest yield (6.69 t ha^{-1}) among the varieties.

Figure 3: **Fertilizer reaction of winter wheat varieties after sunflower forecrop (Debrecen, 2014–2015)**



Our research data have confirmed the genetic differences between the varieties during the analysis of yield, also in unfavourable crop year. According to our results, the crop year influenced the optimal fertilizer optimum of the varieties, which varieties reacted to in different ways.

We determined the optimum fertilizer requirements of winter wheat varieties with different genotypes for maximum yields, by polynomial regression function *(Table 3)*. Based on our research data, we detected significant differences between the favourable fertilizer levels of the tested year.

In the growing season of 2012/2013 the maximum yield was gained on the ($N_{122–150}K_{91.5–112.5}P_{107.8–132.5}$) fertilizer level with increased doses. In the growing season of 2013/2014, due to the much higher monthly average temperatures of winter months, the different genotypes reached the maximum yield on a much lower fertilizer level ($N_{77–112}K_{57.5–84.2}P_{67.7–99.2}$) In the growing season of 2014/2015, the maximum yields were gained on the fertilizer level with increased doses. As per our results, the maximum yield was determined, besides by the genotype and the fertilizer treatment, by the characteristics of the crop year. To the weather conditions the different winter wheat varieties reacted in a way that is specific to the variety and the adaptive ability of the varieties were significantly different.

Table 3

The fertilizer optimum of the winter wheat varieties in the tested years (Debrecen, 2013–2015)

Year	Variety	Sunflower forecrop				
		N	P_2O_5	K_2O	Maximum yield	Equations of the polynomial regression function
		(kg ha^{-1})			(t ha^{-1})	
2012–2013	GK Öthalom	150	112.5	132.5	5.8	$y = -0.0001x^2 + 0.0498x + 1.6116$ $R^2 = 0.9954$
	GK Csillag	150	112.5	132.5	6.1	$y = -0.0002x^2 + 0.0652x + 1.5419$ $R^2 = 0.9852$
	Mv Csárdás	150	112.5	132.5	5.6	$y = -0.0001x^2 + 0.0473x + 1.3753$ $R^2 = 0.9962$
	Mv Toldi	122	91.5	107.8	5.5	$y = -0.0002x^2 + 0.0488x + 1.5736$ $R^2 = 0.9651$
2013–2014	GK Öthalom	77	57.5	67.7	8.0	$y = -0.0005x^2 + 0.0766x + 4.4565$ $R^2 = 0.8800$
	GK Csillag	95	71.5	84.2	8.2	$y = -0.0004x^2 + 0.0763x + 4.6763$ $R^2 = 0.9528$
	Mv Csárdás	108	81.1	95.5	7.1	$y = -0.0004x^2 + 0.0865x + 3.0348$ $R^2 = 0.9820$
	Mv Toldi	112	84.2	99.2	8.6	$y = -0.0004x^2 + 0.0898x + 4.1220$ $R^2 = 0.9735$
2014–2015	GK Öthalom	150	112.5	132.5	8.6	$y = -0.0002x^2 + 0.0663x + 3.7640$ $R^2 = 0.9896$
	GK Csillag	150	112.5	132.5	8.6	$y = -0.0001x^2 + 0.0562x + 3.5248$ $R^2 = 0.9917$
	Mv Csárdás	150	112.5	132.5	7.5	$y = -0.0004x^2 + 0.0865x + 3.0348$ $R^2 = 0.9820$
	Mv Toldi	142	106.7	125.7	8.2	$y = -0.0002x^2 + 0.0569x + 3.8926$ $R^2 = 0.9778$

CONCLUSIONS

In long-term field experiment, in Hajdúság on calcerous chernozem soil, in three different crop years (2013–2015) we examined the fertilizer optimum with four different winter wheat genotypes (GK Öthalom, GK Csillag, Mv Csárdás, Mv Toldi). The results of the polynomial regression function *(Figures 1–3)* proved that the optimum fertilization level is determined mostly by the crop year and the effect of fertilization. According to our experimental data, the warmer winter months have high importance for the yield of winter wheat, as winter wheat stands can grow intensively, thus produce higher yields with lower optimum fertilization requirement. Difference between varieties is significant even with unfavourable effect of the crop year. The adaptive ability of the varieties is different, which is determined, besides the genotype, by the characteristics of the crop year. As per our research data, GK Csillag has proven to be the best variety, and the yield of Mv Toldi and GK Öthalom changed in a similar interval. In the tested years the yield of Mv Csárdás was the lowest.

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