Int. Agrophysics, 2004, 18, 285-288

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Influence of some meteorological factors on fertilizer use efficiency in winter wheat growing

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Received December 1, 2003; accepted May 18, 2004

A b s t r a c t. A field experiment with winter wheat (*Triticum aestivum*) on Orthic Luvisol was conducted for a period of eleven years. This study gives the ground to establish correctly the fertilizer rates, especially nitrogen, in accordance with the moisture conditions of the year. Winter precipitation (October-March) plays an especially important role because of the fact that it coincides with the timing of early spring dressing and gives opportunity for more precise determination of the nitrogen fertilizer rates. It was established that application of nitrogen at 120 kg ha^{-1} was unprofitable when autumn-winter precipitation sums were below 250 mm. Nitrogen fertilizer rates of 180 kg ha^{-1} could be used only when autumn-winter precipitation exceeded 350 mm. In order to quantify the connection between meteorological conditions and fertilizer utilization efficiency, a statistical analysis was used.

K e y w o r d s: fertilization, dressing, autumn-winter precipitation, moisture index

INTRODUCTION

The effective utilization of fertilizers is closely connected with soil-climatic conditions. Many studies indicate the positive effect of applied fertilizers in regions with good moisture conditions and with high precipitation amounts (Petrova, 1984; Tosheva, 1993; Hristov, 1994; Stamboliev and Davidkov, 2000; Zarkov, 2002). To a great extent, maximum grain yields are determined by the autumn-winter precipitation amounts, which gives the opportunity for correct forecast and optimization of the applied fertilizer rates, respectively (Petrova, 1984; Hristov, 1994; Stamboliev and Davidkov, 2000).

The goal of this study is to establish the connection between different fertilizer rate use efficiency in wheat growing and moisture conditions.

MATERIAL AND METHODS

In the complex experimental station - Targovishte, a field experiment with soft winter wheat after grain maize has been conducted for 11 years. The experimental station is located in the Eastern part of the middle climatic region of the Danube plain in the moderate climatic subregion (Ludogorie), at an altitude of 224 m a.s.l. on dark-grey forest soil (Orthic Luvisol in FAO classification, FAO, 1997). Two highly productive cultivars -Sadovo-1 and Pliska – were used in the experiment. The trials were set up in accordance with the block method, in four replications, with an experimental area of 20 m^2. Four different nitrogen fertilizer rates (0, 60, 120, 180) and P_2O_5 (0, 40, 80, 120) kg ha^{-1} on background of 120 kg ha^{-1} K_2O were tested.

In terms of the physical properties and particle size, the dark-grey forest soil could be classified as sandy-clay through the whole soil profile, with favourable water and air conditions. The thickness of the humus layer was about 40 cm. Humus content in the top soil layer (0-25 cm) was 1.91% and the curve of its distribution through the soil profile shows a considerable decrease in the lower layers. This soil had a high cation exchange capacity, considerably high base cation saturation, and weakly acidic reaction (pH_{KCl}=5.1). Available phosphorus and potassium in the topsoil layer was 18.8 mg 100g^{-1} and 23 mg 100 g^{-1} soil, respectively. Available phosphorus was determined according to Egner-Rihm method (Agrochemical Methods of Soil Analysis, 1960) and available potassium according to Milcheva (1985).

The period of research included years with a rather varied combination of meteorological factors. Two years of

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the period could be defined as dry with respect to the received winter precipitation amounts, which ranged at 160-180 mm and are considered as low compared with the long-term average amounts (227 mm). In two of the years, high winter precipitation rates (438 and 391 mm) were registered. In the remaining years from the whole experiment period, the monitored precipitation sums were close to the long-term average (Fig. 1). During the spring-summer period of the wheat development (April-June) in five of the years, precipitation amounts lower than the long-terms average were recorded - 223 mm. Only in one year of the research period a rainfall sum which exceeded the average long-term by 100 mm was obtained (Fig. 1).

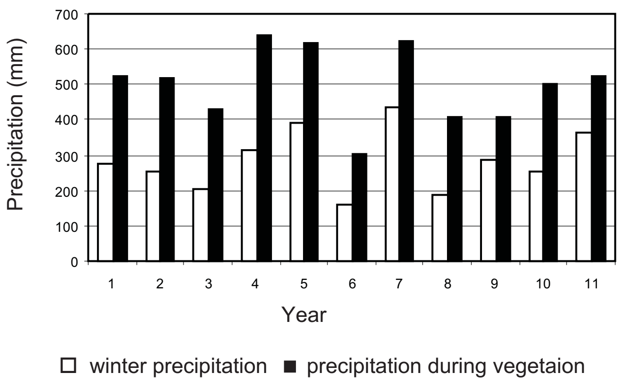

Fig. 1. Autumn-winter precipitation (October-march) and during vegetation period (October-June), mm for each year of research.

In this study, the moisture index was determined according to Ivanov's method (Climate in Bulgaria, 1991) which describes the relation between evapotranspiration, derived from average diurnal air temperatures, and average air humidity for the vegetation period and precipitation. The relation is shown in the following equation:

K = precipitation (October-March) 0.7 + precipitation (April-June)/evapotranspiration.

In order to determine the connection between the meteorological conditions and the fertilizer utilization efficiency, a statistical analysis was used.

RESULTS AND DISCUSSION

Average yield from the non-fertilized variant for the 11-year period was 2770 kg ha^{-1}. Yield increase with the application of 60 kg ha^{-1} of nitrogen fertilizer was by an average of 1470 kg ha^{-1}, in the increasing ranges from 750 to 2350 kg ha^{-1}. With the application of this rate, the increase was considerably stable within the limits of 1200-1900 kg ha^{-1}. Regressive equation for the influence of the winter precipitation on the effectiveness of nitrogen utilization shows a low value of r=0.53. Considerably equal values were received for the correlation between yields and precipitation during the vegetation period and the moisture index (r=0.48 and 0.60). These results confirm the stable increase of the yields with lower fertilizer rates, which in almost all of the cases was not limited by the meteorological conditions of the year.

The average increase in the yields with the application of nitrogen at 120 kg ha^{-1} , as compared with the yields obtained with the 60 kg ha^{-1} nitrogen rate, was 380 kg ha^{-1} grain. A great variation was observed between the yields throughout the years of the experiment (60-890 kg ha^{-1}) and it showed very well defined linear dependence on the moisture conditions (Table 1, Fig. 2). Yield increases by more than 700 kg ha^{-1} were obtained in years with high amounts of autumn-winter as well as vegetation period precipitation (above 300 mm). Good correlation between these two parameters was confirmed by the correlation values obtained (r=0.90, 0.86, and 0.66).

It should be mentioned that no increase in the yields was obtained with the application of the higher nitrogen dosage of 180 kg ha^{-1}. The average increase for the total 11-year period was 40 kg ha^{-1}. Yields above and near those received from the variants treated with nitrogen at the 120 kg ha^{-1} rate were observed only in years with greater amount of autumn-winter precipitation (391-438 mm - October-March

Table 1. Yields wheat increase in $N_{12}P_{10}K_{10}$ fertilizer application in comparison with $N_6P_5K_{10}$ rates in dependence on moisture index

Parameters	Autumn-winter precipitation October-March (mm)	Precipitation during vegetation period October-June (mm)	Moisture index	Yields increasing (kg ha^{-1})
	377	600	1.69	770
	314-438	526-637	1.58-1.98	590-890
Average	266	488	1.46	200
ranges	251-287	410-521	0.98-1.69	120-320
	185	381	0.98	100
	162-205	305-431	0.76-1.21	60-140

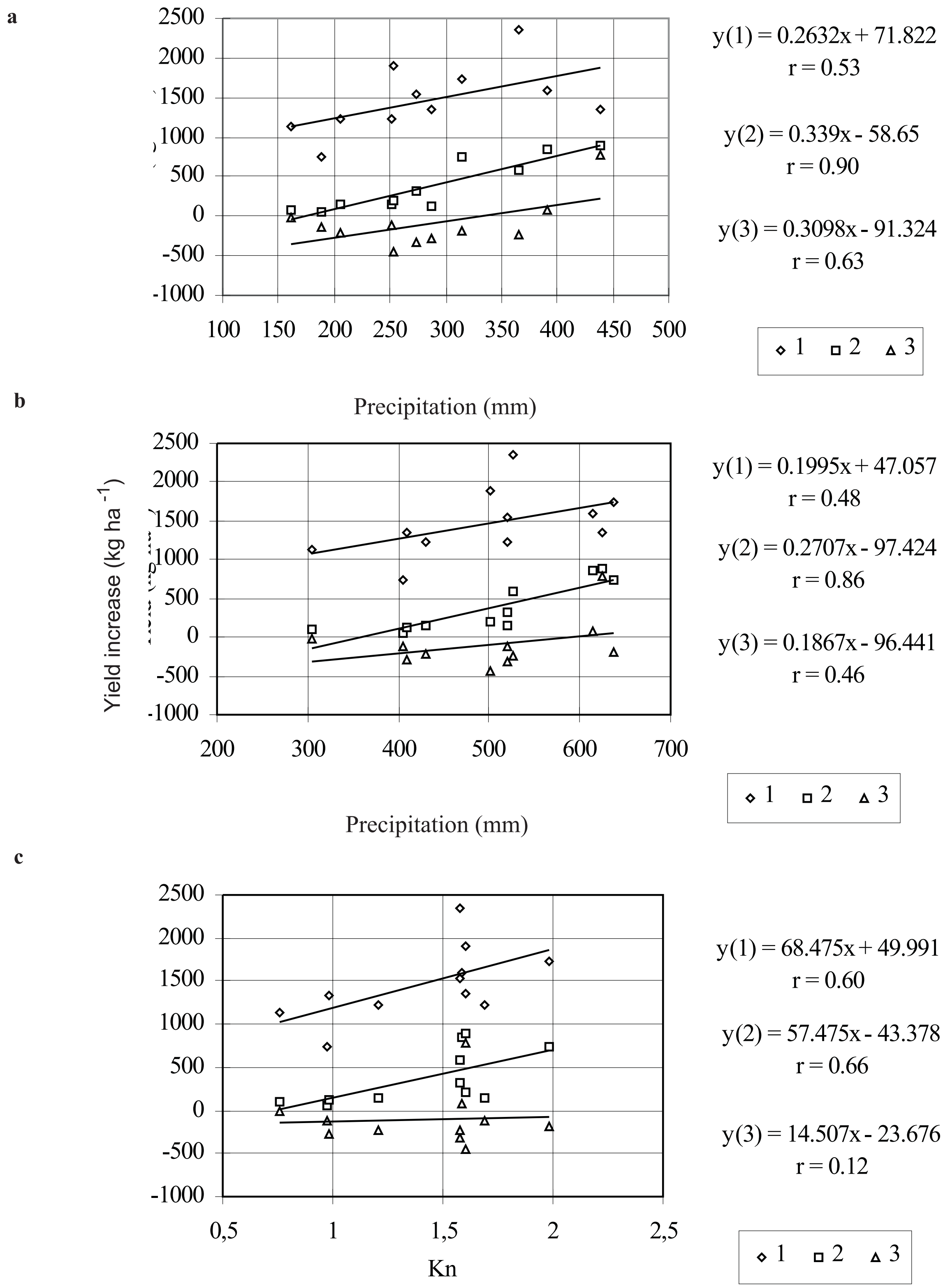

Fig. 2. Yield increase (kg ha^{-1}) as it depends on: a) autumn-winter precipitation (X-III) - (mm); b) precipitation during vegetation (X-VI) - (mm); c) moisture index (K) by: 1) $N_{60}P_{40}K_{120}$ kg ha^{-1} comparable with $N_0P_0K_0$ kg ha^{-1}; 2) $N_{120}P_{80}K_{120}$ kg ha^{-1} comparable with $N_{60}P_{40}K_{120}$ kg ha^{-1}; 3) $N_{180}P_{120}K_{120}$ kg ha^{-1} comparable with $N_{120}P_{80}K_{120}$ kg ha^{-1}.

and 615-624 mm during vegetation period), and with the absence of plant infection by powder mildew. It is necessary to mention that the application of high nitrogen rates is a precondition for faster development of wheat plant diseases, as compared with lower optimum nitrogen rates, which had a negative impact on the yields.

Comparing the yields received from the variants with higher nitrogen treatments, it is visible that in most of the cases the differences were negative. Despite that, the correlation between the increases of the yields depending on autumn-winter precipitation amounts was good – r = 0.63.

The weak dependence between the precipitation during the vegetation period, moisture index and the yields was reflected by the low values of r = 0.46 and 0.13.

CONCLUSIONS

1. The established correlation between the fertilizer utilization and the meteorological conditions gives an opportunity to correctly derive the optimum nitrogen fertilizer rates.

2. Especially important are the amounts of autumn-winter (October-March) precipitation, because the end of this period coincides with the early spring dressing with nitrogen. This is the basis for precise determination of the optimum nitrogen rates.

3. The application of nitrogen at 120 kg ha^{-1} in wheat grown on dark-grey forest soil after late predecessor and autumn-winter precipitation below 250 mm is economically unprofitable. Yields increases in such years are not more than 200 kg ha^{-1} grains.

4. Significantly more effective is the utilization of the same nitrogen rates during years with autumn-winter precipitation which ranges between 280-300 mm and especially above 300 mm. Yields increases during such years vary from 700 to 900 kg ha^{-1} in comparison with the variants where nitrogen was applied at the rate of 60 kg ha^{-1}.

5. Application of nitrogen at 180 kg ha^{-1} should be done very carefully. Such nitrogen rates can be used only in cases where the average autumn-winter precipitation amounts are above 300 mm, because in most of the cases it was observed that the increases of yields obtained in nitrogen 120 kg ha^{-1} treatments were negative or negligible.

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