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Nutrient Uptake by Weeds in a Long-term Maize Field Experiment

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The yield of maize – grown on more than one million hectares in Hungary – is influenced either by ecological or other factors. It is known to be a nutrient demanding crop with an effective nutrient utilization. It was concluded from the study on the relationship between weed infestation and maize yield that with a 1% rise in the total weed cover values the yield decreased by 68 kg·hectare^{-1} (BERZSENYI, 1979). The average 10.41% value of total weed cover reduced the yield by 708 kg·hectare^{-1}

Several research and practical field observations proved that weed infestation during the emergence period of maize resulted in yield loss (SZÉLL & MAJOR, 1993; LEHOCZKY & REISINGER, 2003; LEHOCZKY et al., 2004).

In a long-term maize field experiment significant differences were found among the yields of the different crop years, but the effect of the different crop years (dry or humid) was not always synonymous (TÓTH & KISMÁNYOKY, 2003, 2004). The reason for this was presumably the differing level of weed infestation in correlation with the efficiency of the weed control that was also influenced by the varying amount and distribution of precipitation in the various crop years.

The weed flora of a particular field is influenced by several factors (previous crop, soil tillage, pest management, weather etc.). The ecological factors (amount and distribution of precipitation, clay and humus content, as well as pH of soil) play an important role (REISINGER, 1992, 1995).

From a field experiment studying the effect of the sowing date (RADICS et al., 1982) it was concluded that the date of sowing influenced the development of *Amaranthus retroflexus*, but plant density was of greater importance. The unfavourable effect of low plant density on yield was reported by several authors (UJVÁROSI, 1973; GYŐRFFY, 1976; BERZSENYI, 1980) as a consequence of greater weed infestation.

Inappropriate manuring may enlarge weediness, if crop covering is not achieved early enough. Powerful species from the wide weed diversity, which are better adapted to the extreme nutrition situation, start to grow rather and better than the crops. Sufficient manuring produces powerful crop plant cover and less weediness (KÁDÁR et al., 1999).

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The previous crop's effect on weed infestation was already published in the book of WAGNER (1908). Both maize and wheat monoculture has been considered to be unfavourable as a cause of greater weed infestation (UJVÁROSI, 1951). During continuous maize cropping mainly the monocotyledon weeds become dominant as a consequence of uniform herbicide application (REISINGER, 1981, 1997). The large-scale propagation and infestation of *Sorghum halepense* and *Panicum miliaceum* was promoted by the general use of chloramino-triazin herbicides and continuous maize cropping (CZIMBER et al., 1978; CZIMBER, 1998).

Materials and Methods

The study was conducted in a continuous maize cropping long-term field experiment set up in 1969 on the research field of the Department of Soil Management and Land Use at the University of Veszprém in Keszthely (Hungary).

The sandy loam soil (Eutric Cambisol), containing 41% sand, 32% silt and 27% clay has a low available phosphorus (AL-P_2O_5: 60–80 mg·kg^{-1}), moderate potassium (AL-K_2O: 140–160 mg·kg^{-1}) and fairly low humus content (1.6–1.7%), with a pH(KCl) value of 7.3.

The area of the main ("a") plots is 18.0 m×14.3 m = 266.4 m² and the sub ("b") plots is 14.8 m×6.0 m = 88.8 m². The bifactorial long-term field experiment has a split plot design with four replications involving four fertilizer treatments (a_1–a_4). In addition to the fertilizer rates the effect of timing of N application can also be studied ("b_1": once in spring, "b_2": once in autumn, "b_3": twice in spring).

The fertilizers applied in the experiments are: lime ammonium nitrate (28% N), superphosphate (18% P_2O_5), and potassium chloride (60% K_2O). The total amount of P and K was incorporated into the soil in the autumn by deep mouldboard ploughing. In the text the a_1, a_2, a_3 and a_4 treatments (0; 312.9; 625.8; 938.4 kg·ha^{-1} NPK active ingredients) are referred to as NPK_0, NPK_{300} (104.3–104.3–104.3 N–P_2O_5–K_2O) NPK_{600} (208.6–208.6–208.6 N–P_2O_5–K_2O) and NPK_{900} (312.8–312.8–312.8 N–P_2O_5–K_2O).

The soil tillage was conventional deep mouldboard ploughing in autumn, then secondary tillage and seedbed preparation in spring. The Dekalb 471 hybrid was sown on 24 April, 2003, with a density of 71 thousand germs. The pre-emergence Erunit Profi (4 L·ha^{-1}) herbicide was applied on 30 April.

The crop year 2003 was very dry and hot. The monthly precipitation data (from January to December) were as follows: 51.0, 17.4, 9.6, 35.1, 50.9, 16.8, 57.0, 46.3, 51.9, 108.0, 41.1 and 31.2 mm. The average monthly temperatures (from January to December) were: -2.4, -3.9, 5.6, 10.3, 18.8, 23.0, 22.1, 23.8, 15.5, 8.4, 7.0 and 0.9 ºC.

The weed and maize plant samples were taken on 1 June, 2003. The entire canopy of the different weed species was removed separately from each 1 m² area of each plot of the four replications. Fresh and dry weights of the canopies were measured as well. In the case of maize 7 plants were collected from each plot in accordance with plant density. The length, fresh and dry weights of the canopy were measured and the number of the leaves was recorded. In the laboratory the N, P, K and Ca contents of the samples were quantified.

The statistical significance of the treatments was analysed by Anova-SPSS 9.0 statistical software.

Results

Maize samples were taken and the records were registered at 6–8 leaf stage.

Nine weed species were found in all experimental plots, of which – in the order of frequency – the perennial *Cynodon dactylon* (L.) Pers. was the dominant and the annual warm demanding *Chenopodium album* L. and *Abutilon theophrasti* Medicus, as well as the perennial *Convolvulus arvensis* L. were the most frequently registered ones. These were followed by *Panicum miliaceum* L., *Amaranthus chlorostachys* L., *Elymus repens* (L.) Gould., *Ambrosia artemisiifolia* L. and *Lathyrus tuberosus* L., respectively.

Weed infestation was serious on the studied plots. This was due to the effect of monoculture, as well as to the dry and warm season in 2003, when pre-emergence herbicide application could not result in an effective weed control.

Biomass production

As an effect of the different fertilizer application rates the canopy biomass weights of the plants differed from each other (Fig. 1).

The smallest dry canopy weight (26 $g \cdot m^{-2}$) was measured for the unfertilized control plots in the case of weeds. This value was twice as high in the NPK_{900} plots, while the highest values were recorded for the NPK_{300} and NPK_{600} plots. The highest weight values measured for the NPK_{300} and NPK_{600} treatments were quite similar, so a double increase in the applied quantity of fertilizers had no further weight increasing effect.

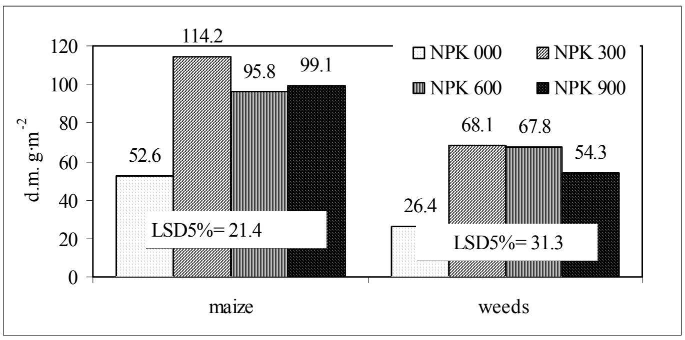

Fig. 1

Dry matter weight ($g \cdot m^{-2}$) of the maize and weed canopies as a function of different fertilizer application rates of a long-term maize field experiment (Keszthely, 2003)

The total (maize+weeds) dry biomass weight recorded for the control plots was 79 g·m^{-2}. This value became more than twice as high as a function of the NPK_{300} treatment (182 g·m^{-2}). A further double (NPK_{600}) and triple (NPK_{900}) increase in applied fertilizer rates did not cause a further significant total biomass weight increase, even a decline was measured (164 and 153 g·m^{-2}).

In case of weeds the NPK_{300} and NPK_{600} treatments resulted in a 2.6-times greater dry weed canopy weight production as compared to the control plots. Such tendency was not observed at the highest fertilizer rate, even a decline occurred.

In the case of maize, as a consequence of increasing applied fertilizer rates the dry canopy production became diversified. A significant (2.1-fold) increase was registered in the dry canopy weight for the NPK_{300} treatments, while an 8.5–12.5% decrease occurred with the further increase in fertilizer rates. The surplus (NPK_{900}) fertilizer application disadvantageously affected both maize and weed canopy production.

The dry weight values of weeds originating from the control plots were 60% smaller than those from fertilized plots, when averaged over the fertilizer rates, while in the case of maize this value was 43%. From this it can be concluded that the relative increase in dry canopy weight as a function of fertilizer application was greater in the case of weeds, presumably due to the weed flora composed of different weed species having various nutrient demands.

Weeds took advantage of favourable fertilizer application in weight production intensity over maize. In comparison to the control plots, in the NPK_{300} treatment the dry canopy weight increase of weeds was more intense (more than 2.7-fold) than that of maize (1.9-fold). Similar tendencies were observed for the NPK_{600} treatments, resulting in similar total (maize+weeds) dry canopy weight production, in which the proportion of the weeds grew by 4%.

In the NPK_{900} treatment the dry canopy weight production of both maize and weeds decreased due to the depressing effect of surplus fertilizer application.

Nutrient uptake

The nitrogen uptake of maize and weeds in the NPK_{300} treatment was three times higher than that of the control plots. In the case of maize the further increase in fertilizer rates (NPK_{600}) caused a 17% decrease in nitrogen uptake in comparison to the NPK_{300} treatment, which was greater than the decrease found for dry canopy weight. A similar tendency was observed for weeds, with a smaller decline (10%) in nitrogen uptake. The decrease in the total (maize+weeds) nitrogen uptake was smaller than the decrease in biomass weight. In the case of weeds the surplus fertilizer rate (NPK_{900}) resulted in a further 18% decrease in nitrogen uptake (similarly to the biomass data) as compared to the NPK_{300} treatment. There was a slight (but not significant) increase in the nitrogen uptake of maize in this treatment, similarly to the changes in biomass (Fig. 2).

The phosphorus uptake of maize increased with the rise in fertilizer rates, as compared to the control plots. This increase, however, was smaller than the biomass and other nutrient (N and K) uptake data (Fig. 3).

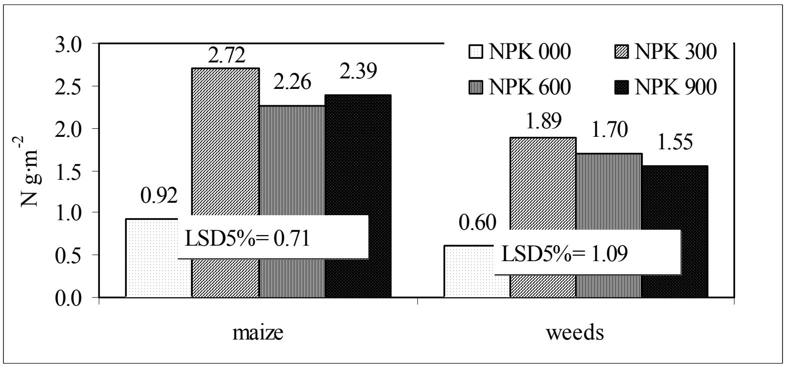

Fig. 2
Nitrogen uptake by maize and weeds as a function of NPK fertilization application rates in a long-term maize field experiment (Keszthely, 2003)

In the control plots the phosphorus uptake of maize was higher than that of weeds, as the phosphorus demand of maize is high in the 6–8 leaf development stage. This is also proven by the fact that the decline in phosphorus uptake with the further rise in fertilizer rates (NPK_{600} and NPK_{900}) – as compared to the N_{300} treatment – was slighter than the decrease in dry matter production in the same treatments (Fig. 1).

Fertilizer application caused a greater increase in the phosphorus uptake of weeds than that of maize, as weeds utilized fertilizer phosphorus more efficiently than maize.

Among the applied nutrients potassium was taken up in the largest quantities by both maize and weeds in all treatments (Fig. 4). As a function of the NPK_{300} treatment a 4-fold increase was registered in the potassium uptake of weeds, while maize only achieved a 2.9-fold increase, as compared to the control. With a further

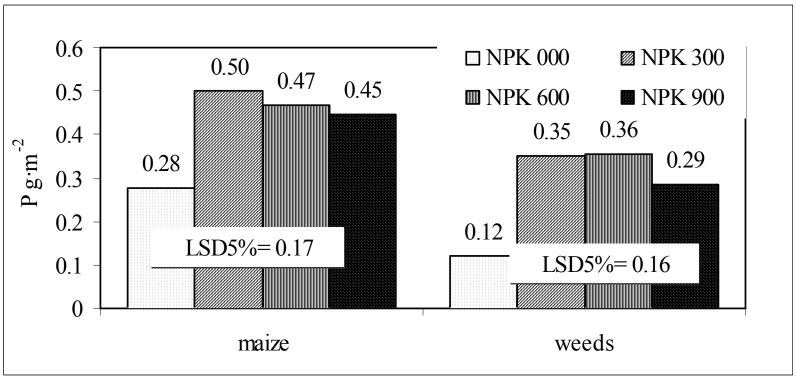

Fig. 3
Phosphorus uptake by maize and weeds as a function of NPK fertilization application rates in a long-term maize field experiment (Keszthely, 2003)

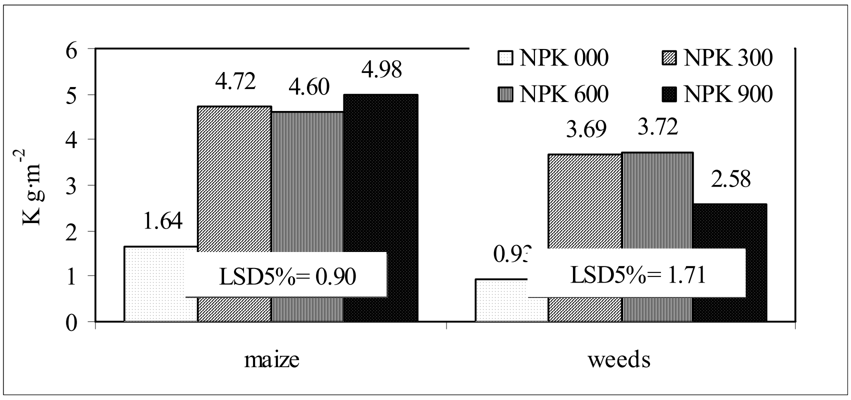

Fig. 4
Phosphorus uptake by maize and weeds as a function of NPK fertilization application rates in a long-term maize field experiment (Keszthely, 2003)

rise in fertilizer rates (NPK_{600} and NPK_{900}) – unlike the tendencies for other nutrients – the potassium uptake of maize changed only moderately.

Up to the 38^{th} day after sowing the total nutrient uptake of maize and weeds was 15–46 kg N, 4–8.5 kg P_2O_5 and 26–84 kg K_2O per hectare. In this early development stage the nutrient uptake of maize is quite intensive; nevertheless there was a strong competition between the weeds and maize.

Conclusions

Weed infestation was serious in the studied plots, due to the effect of monoculture as well as the dry and warm season in 2003, when pre-emergence herbicide application could not achieve an effective weed control.

Among the weed species the perennial *Cynodon dactylon* was dominant. In addition, *Cynodon dactylon, Chenopodium album*, *Abutilon theophrasti* and *Convolvulus arvensis* were the most frequently registered species. The high infestation rate of the perennial weeds – especially of *Cynodon dactylon* – was mainly due to the maize monoculture.

Dry canopy weight measurement data show that weed infestation was the lowest in the control plots. As compared to fertilized plots, in the control plots the dry weight of weeds was 60% smaller, when averaged over the fertilizer rates, while this value was 43% for maize. This fact leads to the conclusion that the relative increase in dry canopy weight as a function of fertilizer application was greater in the case of weeds, presumably due to the weed flora composed of different weed species, having various nutrient demands and utilization.

As an effect of favourable fertilizer application weeds took advantage over maize in weight production intensity.

Up to the 38th day after sowing the total nutrient uptake of weeds growing on the maize plots was 15 kg N, 2.8 kg P_2O_5 and 27 kg K_2O per hectare, producing an average weight of 541 kg·ha^{-1} biomass.

There was a strong competition between weeds and maize for all three nutrients. In the control plots maize was relatively less efficient in the uptake of nitrogen and potassium as well, while weeds were less efficient in the uptake of phosphorus.

As a function of fertilizer application the increase in dry canopy weight production of maize was greater than that in its nutrient uptake, while in controversy to maize the nutrient uptake of weeds was more efficient with a rise in fertilizer rates.

Summary

The effect of four NPK fertilizer rates (NPK[1:1:1]: 0, 300, 600, 900 kg active ingredients·ha^{-1}) was studied on the growth of maize and on weed infestation – biomass production and nutrient uptake of weeds – in four replications in a 35-year old long-term maize continuous cropping field experiment (Keszthely, Hungary). The weed flora was recorded on 1 June, 2003 in the 6–8-leaf development stage of maize.

The effect of the increasing rates of fertilizers was analyzed and evaluated from the results of biomass production as well as the nutrient uptake of weeds and maize, respectively.

On the experimental plots 9 weed species were registered at the date of sampling, from which 4 species were perennial and 5 species were annual ones. All the weeds were collected from 1 m² areas of each plot and the different weed species were separated from each other. The fresh and dry weights of the canopy of maize and the different weed species were measured.

The nutrient (NPK) contents of maize and weed samples were measured in the laboratory. Total and species scale nutrient concentration, as well as per-unit nutrient uptake of maize and weeds were compared. The increasing rates of mineral fertilizers had a significant effect on the biomass production and on the nutrient uptake of weeds. Significant differences were also found between the biomass production and nutrient uptake of the different weed species.

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Key words: maize, weeds, nutrients, competition, monoculture

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