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The Effect of Rising Doses of NPK Fertilizers on Weeds of Proso Millet (*Panicum miliaceum*) on a Calcareous Loamy Chernozem Soil

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ABSTRACT

The effect of different NPK levels (poor, satisfactory, excessive and toxic) and their combinations on the soil cover percentage of the natural weed flora of proso millet (*Panicum miliaceum*) was studied on a loamy chernozem soil with lime deposit. The N levels were 0 (poor), 100 (satisfactory), 200 (excessive) and 300 (toxic) kg ha^{-1} $year^{-1}$; P and K fertilizing was done with 0 (poor), 500 (satisfactory), 1000 (excessive), 1500 (toxic) kg ha^{-1} P_2O_5 and K_2O refilling doses. Later, only the sustaining of PK levels was targeted, refilling was repeated every 5-10 years. The P and K fertilizers and half of the N fertilizer was spread in autumn before ploughing the plots, the other half of N was spread in spring in the form of 25-28% calcium ammonium nitrate, 18% superphosphate and 40-60% potassium chloride. The series of mineral fertilization experiments was established in the autumn of 1973. Different crops were produced on these plots every year. Proso millet was sown in 1996. This long-term series of experiments consisted of 4N × 4P × 4K = 64 treatments, or nutritional levels, in two replications, giving a total of 128 plots. The plot size was 6 × 6 = 36 m^2 in mixed factorial design. Weed surveys were done in 4 m^2 quadrats in two replications and contained not only weed flora but crop cover too. The number of weed species, the soil cover of weeds and the crop were highly dependent upon the doses and ratio of different fertilizers.

Keywords: combination of fertilisers, millet cover, nutritional level, weed cover
Abbreviations: K, potassium; **P**, phosphorus; **N**, nitrogen

INTRODUCTION

Proso millet (*Panicum miliaceum* L.) is a short-season grain crop in semi-arid regions of North and South America and Asia.

The objective of a Turkish study was to evaluate the effect of nitrogen (N) fertilization on proso millet seed yield, and biomass yield under irrigated and dryland conditions in a Mediterranean-type transition climate near Bursa, Turkey. Seed and protein yield increased with increasing N doses, although biomass did not significantly increase (Turgut *et al.* 2006).

As not only the crop was examined in our experiment but weeds too, the nutrient uptake of weeds in general and that of particular species is very important. The nutrient uptake ability of weeds is significant. This is proved by a Hungarian experiment where the nutrient content of weeds in maize was examined. Although the biomass of weeds was only 30% of that of maize, their NPK content was still 42%, 59% and 95.5% respectively (Lehoczky *et al*. 2006, 2009).

A small dose of N fertilizer increased the diversity of herbaceous plants in an arid environment in India (Singh and Shukla 2011) while a 100-150 kg ha^{-1} $year^{-1}$ dose decreased it in a wet environment in China (Lu *et al.* 2010).

In a wetland in Somerset, when higher rates (75 kg ha^{-1} $year^{-1}$) of phosphorus were included, biomass increased very significantly, but species diversity was severely reduced (Kirkham *et al.* 1996).

Phosphorus fertilizers are a major input in crop production as many soils lack sufficient P to maximize crop yield (Grant *et al.* 2001).

Crop fertility recommendations rarely consider that added nutrients might enhance weed growth as well as crop growth, and that the resulting competitive crop–weed interactions can be influenced by fertilizers (Blackshaw and Brandt 2009).

In the present experiment the effects of four different NPK levels and their combinations (64 altogether) on the soil cover percentage of natural weed flora of proso millet (*Panicum miliaceaum*) were studied on a loamy chernozem soil with lime deposit. This experiment was performed in 1996 but the data set has not yet been published in detail, not even in Hungarian, because it was the yield and chemical composition of the crop that was mainly in focus and not the ground cover of the crop and weeds.

MATERIALS AND METHODS

The present experiment was conducted in 1996, as part of a long-term series of experiments established in 1973 at Mezőföld at the experimental station of the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences in Nagyhörcsök. Proso millet was produced only once, in the 23rd year of the long-term experiment, in 1996. The soil of the production site was calcareous loamy chernozem soil and contained 3% humus, 5% $CaCO_3$ and 20% clay in the ploughed layer. pH(KCl) was 7.3, AL-P_2O_5 60-80 mg kg^{-1}, AL-K_2O 140-160 mg kg^{-1}, KCl-Mg 150-180 mg kg^{-1}, EDTA-Mn 80-150 mg kg^{-1}, EDTA-Cu 2-3 mg kg^{-1}, and EDTA-Zn 1-2 mg kg^{-1}. These data show that the soil was supplied poorly with P and Zn, moderately well with N and K, well with Mg and Cu and very well with Mn. The groundwater was at a depth of 13-15 m and the area was susceptible to drought.

The P and K fertilizers and half of the N fertilizer were spread in autumn before ploughing the plots, the other half of N was spread in spring in the form of 25-28% calcium ammonium nitrate,

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Original Research Paper

Table 1 Agronomic measures and surveys done in proso millet experiment in 1996. (calcareous loamy chernozem soil, Nagyhörcsök, Mezőföld) 12 cm row distance, 2cm sowing depth, with 85-100 seeds/running m.

Agronomic measures, surveys	Day, month, year	Comment
1. NPK fertilizer spreading	14. 11. 1995	by hand, plot by plot
2. Ploughing	14. 11. 1995	MTZ-80 + Lajta plough
3. Finishing	10. 04. 1996	MTZ-50 + harrow
4. N-fertilizer spreading	17. 05. 1996	by hand, plot by plot
5. Incorporation of fertilizer	17. 05. 1996	MTZ-50 + combinator
6. Sowing (cv. 'Alföld-1') + rolling	20. 05. 1996	MTZ-50 + sowing machine + roller
7. Alignment of plots	22. 05. 1996	by hand
8. Weed and crop survey	16. 06. 1996	plot by plot
9. Harvesting	28. 08. 1996	Combine, plot by plot

18% superphosphate and 40-60% potassium chloride. The N levels were 0, 100, 200 and 300 kg ha^{-1} per year and P and K fertilizing was done with 0, 500, 1000, 1500 kg ha^{-1} P_2O_5 and K_2O refilling doses (Kádár and Elek 1999). Later only the sustaining of PK levels was targeted. Refilling was repeated every 5-10 years with slow-acting P and K fertilizers. In Hungary, this refilling is usually done with a reserve fertilizing method every 5-10 years. In 1973, the experiment consisted of 4N × 4P × 4K= 64 treatments, or nutritional levels, in two replications, giving a total of 128 plots. The plot size was 6 × 6 = 36 m^2 in mixed factorial design.

In the 23rd year of the experiment the proso millet cv. 'Maxi' was produced. Sowing was done on 20th May 1996, with 12 cm row distance, at 2 cm depth and with 85-100 seeds/ m. During the growing season, a survey of the state of the crop and the weeds was carried out on the 16th of June.

Agronomic measures and surveys in the experiment are shown in **Table 1** in chronological order.

Weed surveys were done in 4 m^2 quadrats in two replications and contained not only weed flora but crop cover too, according to the evaluation method described in Reisinger (2000).

As far as precipitation is concerned, after harvesting the forecrop - rye - in 1995 between the end of July and the end of December, 191 mm precipitation was detected in the experimental area. In 1996, until the sowing of millet in May, 33 mm more precipitation arrived. During the growing season the following amounts had fallen: 63 mm in May, 41 mm in June, 15 mm in July, 25 mm in August. That makes it 144 mm in total. Theoretically, plants had 223 + 144 = 367 mm water, provided that the soil stored precipitation suitably in the root zone.

Statistics

The collected data were analysed according to Sváb (1981) by IBM SPSS Inc. PASW Statistics 18 software.

Means were compared by one-way ANOVA. Weed cover data from the survey were compared with one-way comparison of independent samples in which the software calculated with means and decided whether weed cover data were homogeneous or different. Standard deviations are indicated on the graphs.

For multivariate analysis correspondence analysis (CA) was used. CA or reciprocal averaging finds a set of synthetic variables that summarise the original set. The underlying model assumes chi-squared dissimilarities among records (cases).

RESULTS AND DISCUSSION

Weed species

Weed species of the experiment were prostrate amaranth (*Amaranthus blitoides*) with a 2.99% average ground cover, redroot pigweed (*Amaranthus retroflexus*) with 0.52%, white goosefoot (*Chenopodium album*) with 0.11%, maple-leaved goosefoot (*Chenopodium hybridum*) with 0.09%, field bindweed (*Convolvulus arvensis*) with 0.05%, jimson weed (*Datura stramonium*) with 0.01%, European turnsole (*Heliotropium europaeum*) with 0.01%, flower-of-an-hour (*Hibiscus trionum*) with 0.05%, wild mignonette (*Reseda lutea*) with 0.05%, sharp-fringed sow thistle (*Sonchus asper*) with 0.01%, and annual woundwort (*Stachys annua*) with 0.01%.

The dominant weed species was prostrate amaranth (*Amaranthus blitoides*) with its 2.99% average soil cover. The one with the second highest (0.52%) average cover was redroot pigweed (*Amaranthus retroflexus*). All other species covered less than 0.5% of the soil at the time of the weed survey. Average cover of proso millet in the experiment was 60.4% at the time of the weed survey.

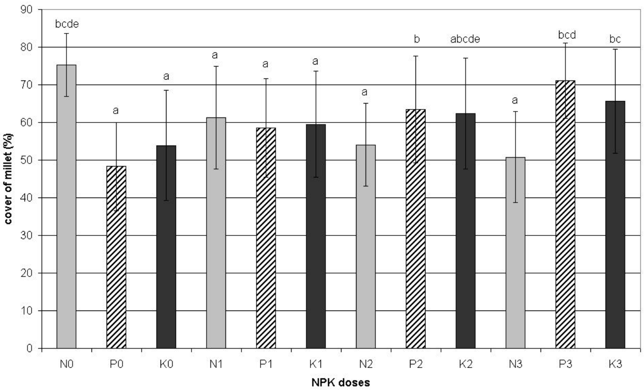

Fig. 1 Average soil cover (%) of proso millet according to different NPK fertilizer doses. (N0) 0 N kg ha^{-1} per year, (N1) 100 N kg ha^{-1} per year, (N2) 200 kg ha^{-1} per year, (N3) 300 kg ha^{-1} per year, (P0) 0 P kg ha^{-1}, (P1) 500 P kg ha^{-1}, (P2) 1000 P kg ha^{-1}, (P3) 1500 P kg ha^{-1}; (K0) 0 K kg ha^{-1}, (K1) 500 K kg ha^{-1}, (K2) 1000 K kg ha^{-1}, (K3) 1500 K kg ha^{-1}. Standard deviations are indicated on the graphs with error bars. Significant differences at level of $p \leq 0,05\%$ are indicated with different lower case letters above the bars.

Ground cover of proso millet

Average cover of the crop (**Fig. 1**) decreased significantly as a consequence of increasing the dose of N fertilizer. Compared to the highest cover at zero dose of N, all three higher doses showed significantly lower crop cover. N fertilizer decreased millet grain production in an experiment (Anderson *et al.* 1986) on the Central Great Plains of the USA. The moderate nutrient demand of proso millet is also confirmed by Reisinger *et al.* (2005).

Ascendant doses of P increased the cover of millet. The two higher doses showed significantly higher millet cover than the lowest and zero doses.

K also increased the cover of the crop. The highest dose showed significantly higher crop cover than the lowest and zero doses.

The average number of weed species

The average number of weed species (**Fig. 2**) decreased with increasing N doses but these increases were not significant. This can be confirmed by the results of several experiments (Bobbink 1991; Lu *et al.* 2010; Singh and Shukla 2011).

In the case of the two highest P doses the number of weed species was significantly higher than in the case of zero P dose. According to Contrarily Kirkham *et al.* (1996) higher rates (75 kg ha^{-1} year^{-1}) of phosphorus reduced species diversity.

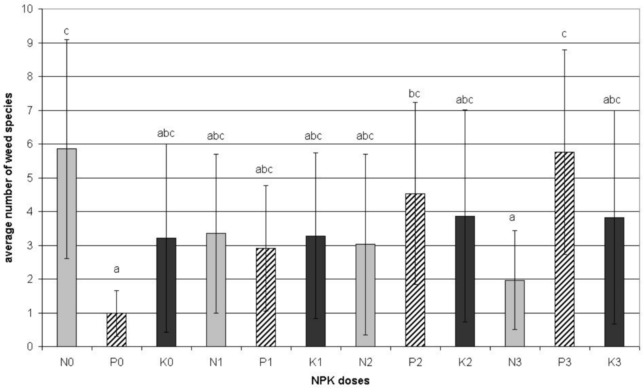

Fig. 2 Average number of weed species according to different NPK fertilizer doses. (N0) 0 N kg ha^{-1} per year, (N1) 100 N kg ha^{-1} per year, (N2) 200 kg ha^{-1} per year, (N3) 300 kg ha^{-1} per year, (P0) 0 P kg ha^{-1}, (P1) 500 P kg ha^{-1}, (P2) 1000 P kg ha^{-1}, (P3) 1500 P kg ha^{-1}; (K0) 0 K kg ha^{-1}, (K1) 500 K kg ha^{-1}, (K2) 1000 K kg ha^{-1}, (K3) 1500 K kg ha^{-1}. Standard deviations are indicated on the graphs with error bars. Significant differences at level of p≤0,05% are indicated with different lower case letters above the bars.

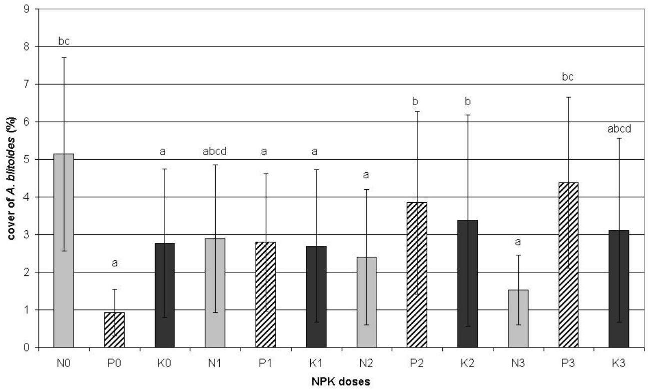

Fig. 4 Average soil cover (%) of *Amaranthus blitoides* according to different NPK fertilizer doses. (N0) 0 N kg ha^{-1} per year, (N1) 100 N kg ha^{-1} per year, (N2) 200 kg ha^{-1} per year, (N3) 300 kg ha^{-1} per year, (P0) 0 P kg ha^{-1}, (P1) 500 P kg ha^{-1}, (P2) 1000 P kg ha^{-1}, (P3) 1500 P kg ha^{-1}; (K0) 0 K kg ha^{-1}, (K1) 500 K kg ha^{-1}, (K2) 1000 K kg ha^{-1}, (K3) 1500 K kg ha^{-1}. Standard deviations are indicated on the graphs with error bars. Significant differences at level of p≤0,05% are indicated with different lower case letters above the bars.

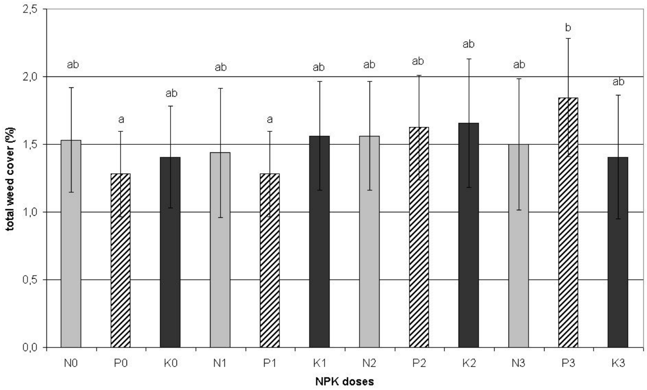

Fig. 3 Average total weed cover (%) according to different NPK fertilizer doses. (N0) 0 N kg ha^{-1} per year, (N1) 100 N kg ha^{-1} per year, (N2) 200 kg ha^{-1} per year, (N3) 300 kg ha^{-1} per year, (P0) 0 P kg ha^{-1}, (P1) 500 P kg ha^{-1}, (P2) 1000 P kg ha^{-1}, (P3) 1500 P kg ha^{-1}; (K0) 0 K kg ha^{-1}, (K1) 500 K kg ha^{-1}, (K2) 1000 K kg ha^{-1}, (K3) 1500 K kg ha^{-1}. Standard deviations are indicated on the graphs with error bars. Significant differences at level of p≤0,05% are indicated with different lower case letters above the bars.

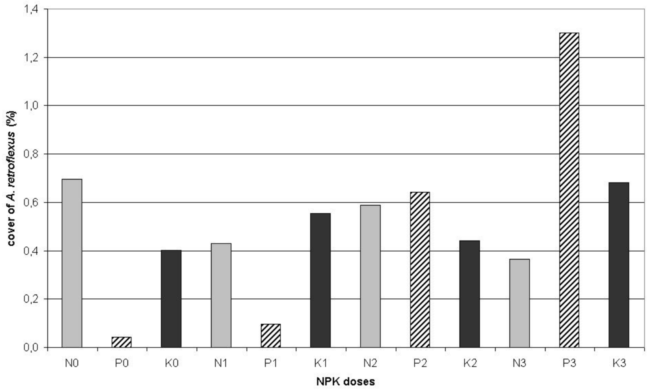

Fig. 5 Average soil cover (%) of *Amaranthus retroflexus* according to different NPK fertilizer doses. (N0) 0 N kg ha^{-1} per year, (N1) 100 N kg ha^{-1} per year, (N2) 200 kg ha^{-1} per year, (N3) 300 kg ha^{-1} per year, (P0) 0 P kg ha^{-1}, (P1) 500 P kg ha^{-1}, (P2) 1000 P kg ha^{-1}, (P3) 1500 P kg ha^{-1}; (K0) 0 K kg ha^{-1}, (K1) 500 K kg ha^{-1}, (K2) 1000 K kg ha^{-1}, (K3) 1500 K kg ha^{-1}.

K-fertilizing had no detectable effect (Pywell *et al.* 2007) on the number of weed species.

Total weed cover and the average ground cover of main weed species

Average total weed cover was very low (**Fig. 3**). Only ascendant doses of P increased the total cover of weeds. The two higher doses showed significantly higher weed cover than the lowest and zero doses (Blackshaw and Brandt 2009).

N and K fertilizing had no detectable effect on the total weed cover.

Ascendant doses of N decreased the cover of prostrate amaranth (**Fig. 4**). The two highest doses showed significantly lower cover of *A. blitoides* than zero dose.

The two higher P doses showed significantly higher prostrate amaranth cover than the lowest and zero doses.

The second highest K dose (K2: 1000 K kg ha^{-1}) gave significantly higher prostrate amaranth cover than the lowest and zero doses.

Significant differences were not found in the case of any other weed species but some tendencies are observable. The weed species with the second highest soil cover, redroot pigweed (*Amaranthus retroflexus*), clearly but not significantly followed the ascending doses of P (Vengris *et al.* 1955) with its soil cover (**Fig. 5**). The other two macroelements did not show such clear tendency. However, Lehoczky (2000) mentioned redroot pigweed as a N-preferring weed species.

Combinations of different NPK doses

Correspondence analysis (**Fig. 6**) shows the places of the crop, the weed species and the total weed cover in the areas defined by different combinations of fertilisers. This method places the different factors in a frame of reference (map), like the cover of the crop (MILLET), the weed species (AMABL) and total weed cover (WEED) and related combinations of fertilizer doses.

Those treatments (combinations of doses) that are in the same half of the map – vertically or horizontally – constitute a group, while those in different halves of the map differ significantly from one another. The distance between a factor and a combination of fertilizer doses indicates the strength of connection between the given combination of doses and the factor. The closer the point to the factor the more typical it is of it. Combinations of doses on the edge of the map or close to the edge are the most characteristic ones and they are distinctive characteristics of the factor closest to them. The further a combination of doses is from the edge of the map, the closest it is to the zero point, the less it can be regarded as characteristic – these are the gene-

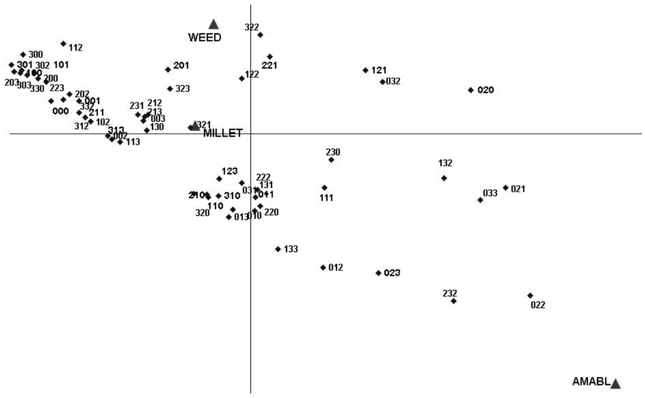

Fig. 6 Correspondence analysis of the crop (MILLET), prostrate amaranth (AMABL) and total weed cover (WEED) and related combinations of fertilizer doses. First digit of the triple-digit code is for N dose, second is for P dose and third is for K dose. 0=no treatment, 1=100 kg ha^{-1} N, 500 kg ha^{-1} P_2O_5 or K_2O; 2= 200 kg ha^{-1} N, 1000 kg ha^{-1} P_2O_5, or K_2O; 3= 300 kg ha^{-1} N, 1500 kg ha^{-1} P_2O_5, or K_2O.

ral characteristics of the examined category. Those points that are between the zero point and the factor could also be connected with the factor, but they are not distinctive characteristics of the factor because they are shared with other factors.

Cover of the crop (MILLET) is close to the zero point (**Fig. 6**) so all the combinations that are between the edge of the map and the MILLET point could be called distinctive characteristic of this plant.

Total weed cover (WEED) and prostrate amaranth (AMABL) are on the edge of the map. It means that weeds in general and this particular weed species accommodate well to any circumstances and utilize nutrients well (Hunyadi 1988). None of the combinations show a strong correlation with total weed cover and cover of this species. Those points that are between the zero point and the factors could also be connected with the factor but they are not distinctive characteristics of the factor because they are shared with other factors.

A greater understanding of these relationships may allow the development of strategic fertilizer management depending on the weed species existing in an agricultural crop.

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