Pol. J. Environ. Stud. Vol. 23, No. 1 (2014), 211-214

Original Research

Content of Mineral Nitrogen in Soil at the Beginning of Sorghum Development after Application of Polyolefin-Coated Urea

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Received: 17 February 2013
Accepted: 10 December 2013

Abstract

In 2010-12 a field experiment aimed at assessing the content of mineral nitrogen (N-NO_3, N-NH_4) in the tilled layer (0-30 cm) and subsoil (30-60 cm), and the level of nutrition of sucrosorgo were conducted in research in Pawłowice at Wroclaw University of Environmental and Life Sciences. The influence of: urea and polyolefin-coated urea (Meister®), in comparison to the control without fertilizing were studied. The fertilizer was applied before sorghum sowing in doses of 60 and 120 kg N·ha^{-1}.

Meister® in comparison to urea, positively influenced the decreasing of N-NO_3 accumulation in both soil layers, with higher N-NH_4 concentrations in the tilled layer.

Keywords: ammonium, nitrate, soil, sweet sorghum, nitrogen fertilization, polyolefin-coated urea

Introduction

Nitrogen is the main factor influencing soil fertility as well as yield quantity and quality. In the soil organic nitrogen form dominates but for plant nutrition and soil dynamic changes most important is mineral nitrogen [1]. Mineralization of organic matter, fertilization, and rainfall replenish content of mineral nitrogen in the soil, and simultaneously the content of nitrogen in the soil decreases due to plant and microorganism uptake, leaching to the ground water, and gas emissions [1, 2]. Applying slow-release nitrogen fertilizer decreased nitrogen losses and environmental pollution. Polyolefin coated urea (PCU, trade name Meister® produced by Chissoasahi), belongs to this group of fertilizers. Meister® is a combination of coated fertilizer with nitrification inhibitor. Urea fertilizer is coated with dicyandiamide, and then with polyolefin for controlling the release of N on linear or a sigmoidal release pattern. The longevity of fertilizer release is 40-140 days for the linear type, and 60 days for the sigmoidal form [3].

Sucrosorgo – grass species – is characterized by high effectiveness of photosynthesis and better water and nitrogen utilization in comparison to the other cultivated plants [4]. High yielding sucrosorgo has nutrient requirements similar to maize and depends on soil conditions needing high nitrogen doses ranging from 45 to 224 kg N·ha^{-1} [4, 5]. Those high doses of nitrogen cause a rise of fertilization cost and may cause environmental pollution [6, 7].

The main purpose of this investigation was assessment of the content of mineral nitrogen (N-NO_3 and N-NH_4) in the tilled layer (0-30 cm) and subsoil (30-60 cm), after application of two forms of urea, and nitrogen content in sucrosorgo leaves in the beginning of development of sweet sorghum.

Materials and Methods

Our paper presents results of the field experiment conducted in 2010-12 in the experimental fields in Pawłowice

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Table 1. Average air temperature and total rainfall from sowing to soil sampling.

Year	Months/decade								Average/ Sum
	V			VI			VII		
	1	2	3	1	2	3	1	2	
Temperature (ºC)									
2010	14.4	11.0	14.6	18.6	16.6	18.5	20.9	23.7	17.3
2011	10.2	16.0	17.9	20.5	18.7	18.2	18.1	20.3	17.5
2012	16.1	13.1	18.0	14.4	18.5	18.9	22.4	17.4	17.4
1981-2010	13.2	14.7	15.3	16.7	16.6	17.9	18.7	19.2	16.5
Rainfall (mm)									
2010	32.1	75.6	33.0	12.2	20.7	0	2.8	24.3	200.7
2011	20.3	17.4	11.7	33.4	3.1	59.2	54.7	34.7	234.5
2012	49.2	6.5	8.0	25.7	59.5	0.5	42.8	38.5	230.7
1981-2010	15.2	18.8	18.6	18.2	20.3	24.2	27.8	26.9	132.3

belonging to the Department of Crop Production of Wrocław University of Environmental and Life Sciences obtained using the method of random sub-blocks with four replications.

The following factors were studied: the type of urea (urea vs. polyolefin coated urea – Meister®) and the dose of nitrogen (60 kg N·ha^{-1},120 kg N·ha^{-1}). The variants with fertilizer were compared to the control without fertilizing.

The experiment was established on the sandy loam soil of V Polish bonitation class defined as Arenosol. The particle size structure of soil: sand (fraction 2.0-0.05 mm) 62% at soil layer 0-27 cm and 49-60% (27-75 cm), silt (fraction 0.5-0.002 mm) 34% at soil layer 0-27 cm) and 35-38% (27-75 cm), clay (< 0.002 mm) 4% at soil layer 0-27 cm and 5-13% (27-75 cm) [8]. Soil pH 7.5 (soil layer 0-27 cm), 7.4-7.6 (soil layer 27-75 cm), organic carbon 23 g·kg^{-1} (layer 0-27 cm) and 10.8-18.7 (27-75 cm), Ntotal 1.44 g·kg^{-1} (layer 0-27 cm) and 0.98 (27-75 cm) [8]. The size of the plots was 14.7 m^2 (7 m in length and 2.1 m wide). Mineral fertilizers were applied before sowing in the following doses: 30.5 kg P·ha^{-1}, in the form of triple superphospate and 99.6 K·ha^{-1} in the form of potassium salt. Nitrogen was applied according to the scheme of the experiment. After application the fertilizer was mixed with soil using spring tooth harrow. The seeds of the Sucrosorgo 304 hybrid were sown in the second decade of May by Wintersteiger plot seed drill.

Before sowing and at the beginning of the sorghum shoot formation (~70 days after sowings – DAS), the contents of N-NO_3 and N-NH_4 in the tilled layer of the soil (0-30 cm) and in the subsoil (30-60 cm) were evaluated. Soil samples were taken using a gouge auger set made by Eijkelkamp Company. Directly after collection soil samples were stored at -20ºC until mineral nitrogen analysis. The nitrogen forms were indicated calorimetrically: N-NO_3 using phenol-disulphonic acid, N-NH_4 using potassium-sodium tartrate, and Nessler reagent. Kjeldahl nitrogen methods determine total nitrogen content in sorghum leaves at the date of soil sampling, i.e. at the beginning of the shoot formation from the youngest sorghum leaves taken from the top of plants.

The results were analyzed using Statistica software 10.0 ANOVA/MANOWA procedure and presented in the "box-whiskers" diagram.

Results and Discussion

Weather conditions from sowing to soil sampling were warmer and wetter than multi-year averages for the same period. Temperature was higher by 0.8-1.0ºC, and amount of rainfall was higher by 68.4-102.2 mm (Table 1). Climate change and more humid weather conditions can increase leaching of nitrogen to the ground water. Slow release fertilizer is recommended on light soils where mineral nitrogen fertilizers are easily leached, or in rainy zones where heavy rainfall accelerates nutrient leaching [3].

Higher content of N-NH_4 was observed in the tilled layer of the soil (0-30 cm), except for the plots fertilized by urea in the amount of 60 kg·ha^{-1} (Figs. 1 and 2). After the application of Meister® at the dose of 60 kg·ha^{-1}, the amount of ammonium in the tilled layer was around four times higher than in the control. After application of the same dose of urea, the amount of N-NH_4 was similar to the values in the control object.

Higher nitrogen fertilizing, at the amount of 120 kg·ha^{-1}, did not cause accumulation of ammonium in the subsoil (Fig. 2). After urea fertilizing the amount of ammonium form of nitrogen was higher by 1.3 kg·ha^{-1}, and when fertilizing with Meister® it was higher by 2.8 kg·ha^{-1} than without fertilizing (control).

Higher amounts of N-NO_3 in both layers of the soil profile was observed after application of urea (Figs. 3-4).

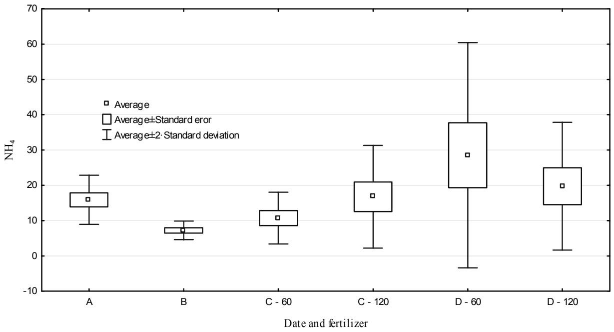

Fig. 1. Amount of NH_4 (kg N·ha^{-1}) in soil layer 0-30 cm.
A – before sowing
B – 70 DAS (control)
C-60 – 70 DAS urea 60 kg·ha^{-1}
C-120 – 70 DAS urea 120 kg·ha^{-1}
D-60 – 70 DAS slow realize urea (Meister®) 60 kg·ha^{-1}
D-120 – 70 DAS slow realize urea (Meister®) 120 kg·ha^{-1}

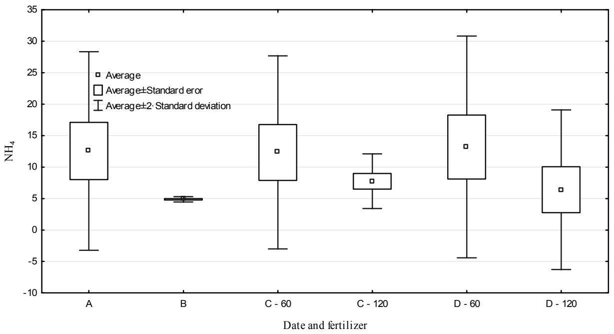

Fig. 2. Amount of NH_4 (kg N·ha^{-1}) in soil layer 30-60 cm.

The amount of nitrates was higher by 90.7% and 124.4% (respectively, after fertilizing with 60 and 120 kg N·ha^{-1} compare to control object) in the tilled layer. While after the application of Meister® the increase was respectively lower by 17.8 and 85.9%. Similar tendencies were observed in the subsoil.

In the presented result, the content of the ammonium form of nitrogen was higher after the application of Meister® than after the application of urea, and it was decreasing together with the depth of the soil profile. Similar results were obtained by Chen et al. [9] after application of Meister® and urea in cotton cultivation. Lehmann et al. [10], after fertilizing sorghum in the blooming phase with a dose of 100 kg N·ha^{-1}, observed the most N-NH_4 in the 15-30 cm layer (30 kg·ha^{-1}) with the falling tendency in the deeper layers. It is also confirmed by the studies of Adu-Gyamfi et al. [11], who on the 40th day after sowing and after fertilizing 50 kg N·ha^{-1} observed 16 mg·kg^{-1} N-NO_3 in the 0-15 cm layer and 7 mg·kg^{-1} in the 45-60 cm layer. Lehmann et al. [10] observed a decrease of N-NO_3 content down to the 30-60 cm soil layer; in the deeper layer (60-90 cm) the accumulation of ammonium ions took place.

After fertilization, the total amount of mineral nitrogen ~70 days after sowing, at the soil layer 0-60 cm, was higher compared to control by 97.4, 125.3, 67.7, 72.5%, respectively for urea (60 and 120 kg N per ha) and Meister® (60 and 120 kg N per ha) (Fig. 5). Nitrate form dominates independently from the soil layer (Fig. 6). After the application of Meister® (60 kg per ha), ammonium form content was higher and represented 42.7% of total mineral nitrogen.

The content of total nitrogen in the youngest leaves in the phase of shoot formation was not very diversified and ranged from 25.9 g·kg of dry matter (leaves of non-fertilized plants) to 29.2-29.3 g·kg of dry matter after fertilizing with 60 kg of Meister® and 120 kg urea per ha (Fig. 7). Similar results were observed by Traore and Maranville [12] in the phase of forming sorghum shoots. After fertilizing with nitrogen in the amount of 100 kg·ha^{-1} they observed 23.3 g of nitrogen·kg^{-1} dry matter and without fertilizing it was little bit lower 22.2 g·kg^{-1}. Those results were less than in our own studies, both for 120 and for 60 kg N·ha^{-1}. Also, the difference in comparison to the control variant was higher. Zhao et al. [5], after 30 days from sowing observed that sorghum fertilized with maximum dose had the highest N content in leaves (48 g·kg^{-1}), while

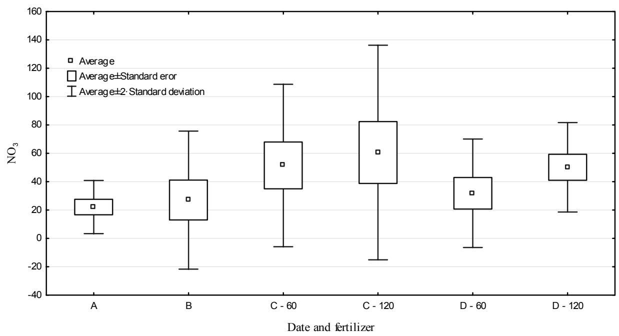

Fig. 3. Amount of NO_3 (kg N·ha^{-1}) in soil layer 0-30 cm.

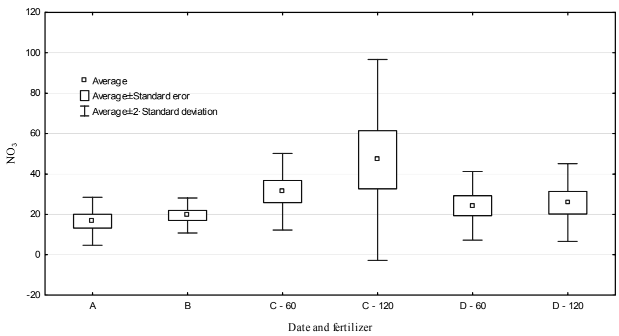

Fig. 4. Amount of NO_3 (kg N·ha^{-1}) in soil layer 30-60 cm.

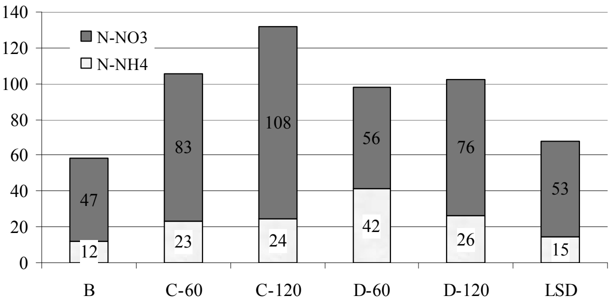

Fig. 5. Amount of mineral nitrogen (kg N·ha^{-1}) in soil layer 0-60 cm.

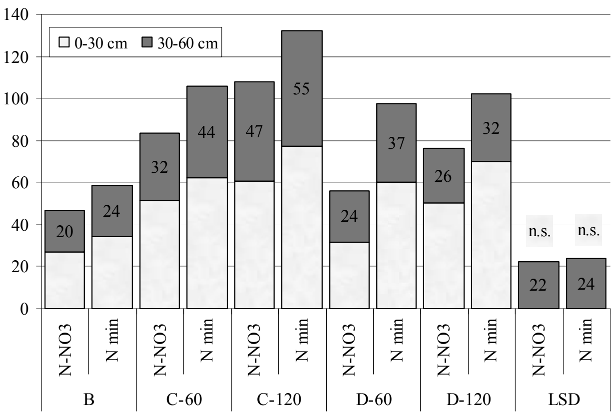

Fig. 6. Amount of NO_3 and mineral nitrogen (kg N·ha^{-1}) in soil layer 0-60 cm.
n.s.– not significant

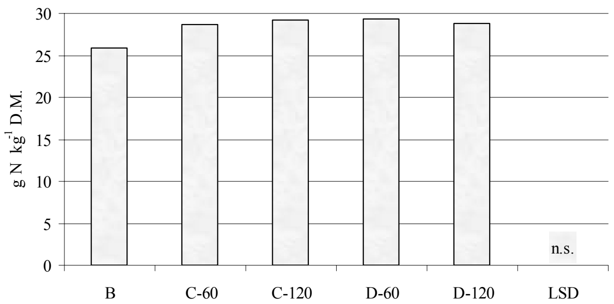

Fig. 7. Content of total nitrogen – 70 DAS – at sorghum leaves g N·kg^{-1} D.M.
n.s.– not significant

sorghum fertilized with doses reduced to 20% of maximum had the least N. After 40 days from fertilizing the content of N in the leaves of the non-fertilized plants decreased to 20 g·kg^{-1} dry matter.

Conclusions

1. Fertilizing with Meister®, in comparison to fertilizing with urea, positively influenced the limitation of nitrate accumulation in both layers of the soil, with higher accumulation in the tilled layer of the less changeable and better absorptive soil ammonium form.
2. In the initial stage of vegetation, the reserve of mineral nitrogen in the soil satisfies the demand of sorghum, and the content of total nitrogen in the leaves was slightly differentiated by both the form and the dose of fertilizer.
3. Polyolefin-coated urea Meister® is offering the advantages of nitrogen fertilizer with nitrification inhibitors and reducing adverse environmental effects of nitrogen fertilization.

References

1. FOTYMA E., FOTYMA M., PIETRUCH C., BERLE H. The sources of mineral nitrogen and its utilization in Polish agriculture. **1.10**, 30, **2002** [In Polish].
2. SAPEK A., SAPEK B. Changes of the mineral nitrogen content in meadow soil on the background of differentiated nitrogen fertilization. Rocz. Gleb. **LVIII.1**, 99, **2007** [In Polish].
3. TRENKEL M.E. Slow- and controlled-release and stabilized fertilizers: an option for enhancing nutrient use efficiency in agriculture. International Fertilizer Industry Association (IFA) pp. 163, **2010**.
4. ZHAO D., REDDY K., KAKANI V., REDDY V. Nitrogen deficiency effects on plant growth, Lear photosynthesis, and hyperspectral reflectance properties of sorgum. Eur. J. Agron. **22**, 391, **2005**.
5. SOWIŃSKI J. Maize and sucrosorgo field comparison at different nitrogen fertilization dosen. Pam. Puł. **151** II, 649, **2009** [In Polish].
6. MARSALIS M.A., ANGADI S.V., CONTRERAS-GOVEA F.E., Dry matter yield and nutritive value of corn, forage sorghum, and BMR forage sorghum at different plant populations and nitrogen rates. Field Crop. Res. **116**, 52, **2010**.
7. SAINJU U., WHITEHEAD W., SINGH B., WANG S. Tillage, cover crops, and nitrogen fertilization effects on soil nitrogen and cotton and sorghum yields. Eur. J. Agron. **25**, 372, **2006**.
8. KABAŁA C., GAŁKA B., JEZIERSKI P., BOGACZ A. Transformation of fluvisols caused by river regulation and long-term farming . A case study from the Dobra river valley in the Silesian lowland. Rocz. Gleb. **LXII**, 141, **2011** [In Polish].
9. CHEN D., FRENEY J.R., ROCHESTER I., CONSTABLE G.A., MOSIER A. R., CHALK P.M. Evaluation of a polyolefin coated urea (Meister) as a fertilizer for irrigated cotton. Nutr. Cycl. Agroecosys. **81**, (3), 245, **2008**.
10. LEHMANN J., FEINER T., GEBAUER G., ZECH W. Nitrogen uptake of sorghum (*Sorghum bicolor* L.) from tree mulch and mineral fertilizer under high leaching conditions estimated by nitrogen-15 enrichment. Biol. Fert. Soils. **30**, 90, **1999**.
11. ADU-GYAMFI J., ITO O., YONEYAMA T., DEVI G., KATAYAMA K. Timing of N fertilization on N_2 fixation, N recovery and soil profile nitrate dynamics on sorhum/pigeonpea on Alfisols on the semi-arid tropics. Nutr. Cycl. Agroecosys. **48**, 197, **1997**.
12. TRAORE A., MARANVILLE J. Nitrate reductase activity of diverse sorghum genotypes and its relationship to nitrogen efficiency. Agron. J. **91**, 863, **1999**.