Kasetsart J. (Nat. Sci.) 44 : 783 - 788 (2010)

Comparison of the Effectiveness of Local and Broadcast Application of NP-Fertilizer on Maize (*Zea mays* L.) Growing for Silage

Tomáš Lošák[1], Karel Prokeš[2], Jaroslav Hlušek[1], Rostislav Richter[1] and Samuel Antwi Darkwah[1]

ABSTRACT

In field experiments over three years (2002–2004), the effect was compared of local and broadcast application of the mineral NP fertilizer Amofos (ammonium phosphate with 12% N and 52% P_2O_5) on the N and P content in plants in the stage of the 4th leaf (DC 22) and on yields of silage matter of the maize hybrid Romario. The experimental site was situated in the Bohemian-Moravian Highlands in the Czech Republic, at an altitude of 520 m above sea level. The soil type was a cambisol, with good (P, Ca, Mg) or satisfactory (K) fertility status and slightly acid (Mehlich III). The fertilizer was applied to soil with a good supply of phosphorus at rates of 70 and 140 kg ha^{-1}. Locally, the fertilizer granules were placed at a soil depth of 70-80 mm and 50-60 mm beside the seeds. Each variant included 60 plants. In the early growth stages, local applications of both doses of fertilizers had a highly positive effect on N and P concentration in the plants, when compared to the broadcast application. There were no significant differences in the contents of N and P in the biomass between the doses of 70 and 140 kg ha-^{1} of fertilizer applied locally. The yields of total above-ground dry biomass were dependent on the weather (namely on the amount and distribution of temperature and precipitation) and fluctuated in September 2002, August 2003 and September 2004 with ranges of 18.56-20, 14.85-15.97 and 14.06-15.27 t ha^{-1}, respectively. Neither the dose of fertilizer nor the method of application had a significant effect on the silage yield of maize, except in 2002, when broadcasting 140 kg ha^{-1} fertilizer gave a significantly lower yield than the others.

Keywords: maize, nitrogen, phosphorus, local and broadcast fertilization, plants, chemical composition, silage yield

INTRODUCTION

On a global scale, maize is the third most important crop after wheat and rice and its use is very broad. A balance of soil nutrients, with macro- and micro-elements, is an essential component of successful cropping, which results in high yields of good quality. Along with nitrogen and potassium, phosphorus is the most frequently discussed macro element in plant nutrition. It is actively absorbed by the plants in the form of the anions H_2PO_4 or HPO4^{2-} and its intake is considerably influenced by the temperature and pH value (Marschner, 1995). In terms of the balance of the sorption processes, the best pH value is approximately 6.2-6.5 (Balík *et al.*, 2008).

[1] Mendel University of Agriculture and Forestry in Brno, Zemědělská 1, 613 00 Brno, Czech Republic.
[2] KWS OSIVA s.r.o., Pod Hradbami 2004/5, 594 01 Velké Meziříčí, Czech Republic.

Received date : 05/06/09 Accepted date : 13/07/09

Phosphorus can exist in plants as both inorganic phosphate anions and organophosphate compounds. It is active as an energy transporter and is an important structural component. Phosphate is relatively unavailable to plant roots (Mengel and Kirkby, 2001). Many publications on this subject cite the proven positive effects of applying phosphorus fertilizer to a localized area, usually near the plant roots, as opposed to a general soil broadcast application (Prummel, 1957; Lucas and Vittum, 1976; Randall and Hoeft, 1988; Lošák *et al.*, 2006; Prokeš, 2008). It is generally presumed that a localized application reduces fertilizer contact with the soil thereby resulting in less phosphorus sorption and precipitation reactions and, thus, enhanced availability to crops. However, for soils with a high phosphorus-fixing capacity, where phosphorus is relatively immobile, placement of the fertilizer where root contact is enhanced may be an equally or more important mechanism than restricting fixation (Anghinoni and Barber, 1980a, 1980b; Sleight *et al.*, 1984).

The fertilizer is usually applied at about 40-50 mm below the sown seeds and 40–50 mm to the side to ensure the effectiveness of the fertilizer. Granulated superphosphate and fertilizers of the Amofos type are usually applied to widely spaced crops, such as maize, potatoes or sugarbeet (Balík *et al.,* 2003).

The effectiveness of this measure is mainly dependent on how well it is carried out, that is, keeping the specified distance from the sown seeds. If spacing is narrow, the $NH4^+$ ion released from Amofos may have a negative effect on the germinating plants and inhibit emergence considerably (Gerendás, 1992).

The objectives of the current study were to compare the effects of local and broadcast applications of two doses of NP-fertilizers on the N and P contents in plants during the 4th leaf stage of growth and also to assess the yield of silage dry matter of the plants over the period 2002-2004.

MATERIALS AND METHODS

The experiments were conducted from 2002-2004 in the form of pilot field trials on farmland belonging to the Agro Z·blatÌ company in the Bohemian-Moravian Highlands. The experimental site was at an altitude of 520 m above sea level. Table 1 gives the agrochemical characteristics of the soil prior to beginning the experiment.

Soil samples from the site were analyzed for available nutrient content using the Mehlich III method (CH_3COOH, NH_4NO_3, NH_4F, HNO_3 and EDTA). The amount of available P in the sample was analyzed colorimetrically and the amount of available K, Mg and Ca by means of AAS. The ion-selective electrode (ISE) method was used to determine the pH value (Table 1).

The experiments began on 23 April 2002, 24 April 2003 and 29 April 2004 with the hybrid Romario (FAO 250) for silage. This hybrid is suitable for silage, with a cob including between 520-550 corns and the thousand seed weight is approximately 300 g. The experiment involved five fertilization variants and four replications of each variant. The size of the plots was 400 m^2, spacing was 0.15 × 0.75 m and the seeding rate was 88,800 seeds ha^{-1}. Table 2 provides some details of the variants used in the experiment.

Table 1 Agrochemical characteristics of the experimental site (2002).

Soil reaction	Soil nutrient content (mg kg^{-1})			
(pH/KCl)	P	K	Ca	Mg
6.24	85.6	166.8	2,507	188.7
Slightly acid	Good	Satisfactory	Good	Good

Table 2 Plan of the field experiment.

Variants	Method of application of the Amofos fertilizer	Dose of the Amofos fertilizer (kg ha^{-1})	Dose of N (kg ha^{-1})	Dose of P (kg ha^{-1})
1	Not fertilised	0	0	0
2	Local	70	8.4	16
3	Broadcast	70	8.4	16
4	Local	140	16.8	32
5	Broadcast	140	16.8	32

Each year in spring, in all the variants, nitrogen was applied in the form of urea (46% N) at a dose of 161 kg N ha^{-1} and potassium in the form of KCl at a dose of 80 kg K_2O ha^{-1}. The mineral fertilizers were applied in single doses and incorporated into the soil with a rotary harrow prior to sowing. Variants 1-5 were fertilized with the same basic doses of N and K. Table 2 shows only the N and P doses applied in the Amofos fertilizer to the respective variants. The Amofos fertilizer (12% N, 52% P_2O_5) was always applied at sowing. In the case of local fertilization, the seeding machine (Amazone) placed the fertilizers at a depth of 70-80 mm and 50-60 mm beside the row of maize seeds. Broadcasting was done manually immediately before sowing. After broadcasting, the fertilizer was immediately incorporated at ≠70 mm into the soil profile with a rotary harrow.

During the vegetative period, the maize plants were sampled for chemical analyses at the DC 22 (4^{th} leaf) stage. After wet mineralization (H_2SO_4 and H_2O_2), the level of N was assessed according to Kjeldahl, the P colorimetrically, the K by flame photometry and the Ca and Mg using the AAS method.

Maize was harvested manually, that is 60 plants of maize for silage in the stage of milk ripeness = DC 75 (on 5 September 2002, 25 August 2003 and 24 September 2004). Multifactorial variance analysis (ANOVA) was used for statistical evaluation and was followed by Tukey's tests at $P < 0.05$.

RESULTS AND DISCUSSION

The dates of sampling in the stage of the 4^{th} leaf (DC 22) were different in the individual years (Table 3). The sum of effective temperatures had a major effect on the dates of sampling, especially in 2004, when the weather at the beginning of the vegetative period was much cooler than in 2002 and 2003.

In all three years, the mode of application of the Amofos fertilizer had a marked effect on the content of N and P in the plant dry matter in the stage of the 4^{th} leaf (Table 3). Both doses of the fertilizers applied locally (variants 2 and 4) increased the N and P contents, compared with the other variants (1, 3 and 5) in all years. The N content of the control variant not fertilized with

Table 3 Chemical analyses of plants in the stage of the 4^{th} leaf - DC 22 (% dry matter).

Variant	Dose of Amofos fertilizer (kg ha^{-1})	Method of application	21 May 2002		20 May 2003		08 June 2004	
			% N	% P	% N	% P	% N	% P
1	0	Not fertilized	4.88	0.39	5.13	0.33	4.85	0.40
2	70	Local	5.34	0.69	5.50	0.62	5.11	0.51
3	70	Broadcast	5.01	0.41	4.86	0.36	4.85	0.42
4	140	Local	5.29	0.66	5.06	0.64	5.15	0.60
5	140	Broadcast	4.90	0.41	4.80	0.38	4.97	0.45

Amofos (variant 1) fluctuated in all three years between 4.85 and 5.13%, while a local application of 70 kg ha^{-1} fertilizer increased it to 5.11-5.50% N. Even more marked were the differences in the P content. The P content in the variant not fertilized with Amofos (variant 1) ranged between 0.33 and 0.40%, while with a lower dose of fertilizer applied locally, the P content increased markedly to 0.51-0.69% P (Table 3). There were no significant differences in the contents of N and P between the two doses of local application. Locally applied fertilizers (variants 2 and 4) resulted in a higher content of both elements compared to broadcast application (variants 3 and 5).

From the above results, it is evident that from the very beginning, roots of the locally fertilized variant had better access to N and P from the dissolving granules. The results correspond with data of Kovaevic *et al*. (2004), who stated that the P content in maize leaves increased by 25% after the application of P. The results were even higher depending on the weather. Bukvic *et al*. (2003) also reached the conclusion that an application of 61 and 183 kg ha^{-1} P increased the P content in the leaves.

In variants where the fertilizers were broadcast (variants 3 and 5), the content of N and P increased only minimally, compared to variant 1, which was not fertilized with Amofos. Similar results were reported by Richter and Hlušek (1994) and Amberger (1996), who concluded that the mobility of phosphorus in the soil was very low.

In 2002, 2003 and 2004, the yields of the total above ground dry biomass (silage) fluctuated in the range 18.56-20.64, 14.85-15.97 and 14.06-15.27 t ha^{-1}, respectively. The yearly effect (namely the amount and distribution of temperature and the sum of precipitation) was relevant, as the yields were markedly affected by a lack of rainfall, particularly in 2003.

With the exception of one variant in 2002, there were no statistically significant differences among the variants in all the years in the yield of total above ground biomass (Table 4). During the vegetative period, the plants also took up N and P from the broadcast fertilizer. On top of that, the level of the soil content of P before establishing the experiment was good. That is why higher doses of fertilizer compared with lower doses did not show any effect, regardless of the mode of application (Table 4).

The results achieved confirmed the findings of Mallarino *et al*. (1999) that a presowing application of P at a depth of 13-18 cm or locally at 5 cm next to and below the seeds will result in more rapid early growth of the plants and higher absorption of nutrients, but will not always enhance yields. Likewise Kucharovic and Kováč (2003) proved that yields of individual crops were dependent on the content of available phosphorus in the soil. Munoz and Arscott (1991) reached the opposite conclusion from the results of an application of 0, 112 and 224 kg ha^{-1} P in their pot trials. They discovered that increasing doses of phosphorus significantly increased the yield of

Table 4 Yields of total above ground dry matter from 2002 to 2004 ($P < 0.05$).

Variants	Fertilizer dose(kg ha^{-1}) and method of application	2002		2003		2004	
		t ha^{-1}	rel. %	t ha^{-1}	rel. %	t ha^{-1}	rel. %
1	Not fertilized	19.91 b	100.0	15.85 a	100.0	14.06 a	100.0
2	70 kg locally	20.64 b	103.6	14.85 a	93.7	14.82 a	105.4
3	70 kg broadcast	20.17 b	101.3	15.97 a	100.8	15.08 a	107.2
4	140 kg locally	18.97 b	95.3	15.63 a	98.6	15.27 a	108.6
5	140 kg broadcast	18.56 a	93.2	15.63 a	98.6	14.88 a	105.9

Values within columns with the same letter have non-significant differences ($P<0.05$).

green matter and dry matter of the plants.

CONCLUSION

Local application of the Amofos fertilizer at the rate of 70 and 140 kg ha^{-1} fertilizer in the early growth stages of maize had a positive effect on the concentration of N and P in the plants, compared to a broadcast application. The yield of the total aboveground dry matter was affected by the weather conditions of the year, particularly by the amount and distribution of temperatures and precipitation. Neither the doses of the fertilizer nor the mode of application affected yields, but contributed to an increased content of N and P in the soil. It can be concluded that a local application of 70 kg ha^{-1} fertilizer is sufficient for soils with a good supply of phosphorus.

ACKNOWLEDGEMENT

This study was supported by Research Plan No. MSM6215648905 'Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change', which was funded by the Ministry of Education, Youth and Sports of the Czech Republic.

LITURATURE CITED

Amberger, A. 1996. **Pflanzenernährung.** 4. Auflage. Verlag Eugen Ulmer. Stuttgart. 319 pp.

Anghinoni, I. and S.A. Barber. 1980a. Phosphorus influx and growth characteristics of corn roots as influenced by phosphorus supply. **J. Agron.** 72: 685-688.

Anghinoni, I. and S.A. Barber. 1980b. Predicting the most efficient phosphorus placement for corn. **Soil Sci. Soc. Am. J.** 44: 1016-1020.

Balík, J., D. Pavlíková, M. Kulhánek and K. Sýkora. 2003. Utilization of local phosphorus fertilizers application in agricultural practice. **Agrochemistry** 43: 11-13.

Balík, J., M. Kulhánek, D. Pavlíková, P. Tlustoš and B.W. Kielian. 2008. Phosphorus in soil, pp. 23-30. *In* **Proceedings of 14th International Conference** "**Reasonable use of fertilizers**". Czech University of Life Science Prague. Prague. 27.11.2008. Prague.

Bukvic, G., M. Antunovic, S. Popovic and M. Rastija. 2003. Effect of P and Zn fertilization on biomass yield and its uptake by maize lines (*Zea mays* L.). **Plant Soil Environ.** 49: 505-510.

Gerendás, J. 1992. **Einfluss von Form und Konzentration des Stickstoffangebotes auf Wachstum und Physiologie junger Maispflanzen (*Zea mays* L.)**. Dissertation. Institut für Pflanzenernährung und Bodenkunde der Christian-Albrechts-Universität. Kiel.

Kovaevic, V., D. Banaj, I. Brkic, M. Antunovic and D. Petosic. 2004. Fertilization impacts on the yield and nutritional status of maize (*Zea mays* L.). **Cereal Res. Commun.** 32: 403-410.

Kucharovic, A. and K. Kováč. 2003. Systems of fertilization in terms of phosphorus balance and soil fertility, pp. 68-71. *In* **Proceedings of international conference** "**Plant Nutrition in Sustainable Agriculture**". Mendel University of Agriculture and Forestry in Brno. Brno.

Lošák, T., K. Prokeš and J. Hlušek. 2006. The effect of local applications of the amofos fertilizer when growing maize (*Zea mays* L.). **Agrochemistry** 46: 20-23.

Lucas, R.E. and M.T. Vittum. 1976. Fertilizer placement for vegetables, pp. 39-68. *In* G.E. Richards (ed.). **Phosphorus Fertilization-Principles and Practices of Band Application**. Olin. Corp. St Louis.

Mallarino, A.P., J.M. Bordoli and R. Borges. 1999. Phosphorus and potassium placement effects on early growth and nutrient uptake of no-till corn and relationships with grain yield. **Agron. J.** 91: 37-45.

Marschner, H. 1995. **Mineral Nutrition of Higher Plants**. 2nd ed. Academic Press Limited. London. 889 pp.

Mengel, K. and E.A. Kirkby. 2001. **Principles of Plant Nutrition**. 5th ed. Kluwer Academic Publishers. Dordrecht / Boston / London. 849 pp.

Munoz, M.A. and T.G. Arscott. 1991. On phosphorus uptake and growth of corn (*Zea mays* L). **J. Agric. of the University of Puerto Rico** 75: 153-162.

Prokeš, K. 2008. **The Nutrition of Maize in a Potato-Growing Region.** Dissertation thesis. Mendel University of Agriculture and Forestry in Brno. Brno.

Prummel, J. 1957. Fertilizer placement experiments. **Plant Soil** 8: 231-253.

Richter, R. and J. Hlušek.1994. **Výživa a hnojení rostlin. VŠZ Brno. Brno.** 171 pp.

Randall, G.W. and R.G. Hoeft. 1988. Placement methods for improved efficiency of P and K fertilizers: a review. **J. Prod. Agri.** 1: 70-78.

Sleight, D.M., D.H. Sander and G.A. Peterson. 1984. Effect of fertilizer phosphorus placement on the availability of phosphorus. **Soil Sci. Soc. Am. J.** 48: 336-340.