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EFFECT OF NITROGEN AND MAGNESIUM FERTILIZATION ON THE DEVELOPMENT AND YIELDS OF POT MARIGOLD (*Calendula officinalis* L.)

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Abstract. Poland occupies a prominent place in the cultivation of herbal plants. One of the main species is the marigold, which is widely used in pharmaceutical, cosmetic and food industry. In 2007–2009, a pot experiment was carried out in a greenhouse on cv. Radio pot marigold (*Calendula officinalis* L.). The experiment included two factors: nitrogen fertilization ($g \cdot pot^{-1}$): A – 0 (control), B – 0.3, C – 0.6 (0.6 + 0), D – 0.9 (0.6 + 0.3), E – 1.2 (0.6 + 0.6) and magnesium fertilization ($g \cdot pot^{-1}$): a – 0 (control), b – 0.5. The experiment demonstrated a significant effect of nitrogen fertilization on the number of pot marigold inflorescences. A significant increase in yields (versus the control) appeared after a dose of 0.6 g $N \cdot pot^{-1}$ was applied. In contrast, magnesium fertilization had a negative effect on all the analyzed traits.

Key words: Radio cultivar, inflorescences yield, pot experiment

INTRODUCTION

Poland is a leading producer of herbal plants and an important exporter of herbs to the European Union countries and the USA. In the EU, the biggest herb producers are France and Spain, which broadly promote cultivation of herbal plants. Jambor [2007] reports that in Poland herbal plants are grown over a total area of 30,000 ha. The average annual production of medicinal plants from field plantations is about 26,000 tons and further 3,000 to 5,000 tons are obtained from natural habitats.

Most of herbal plants are produced to supply the pharmaceutical industry but herbs are gaining in importance in the cosmetics, food and fodder industries. Oborska et al. [2001] mention that the therapeutic effects are an unquestionable value of herbal plants, including calendula (*Calendula officinalis* L.), also known as pot marigold.

Biesiada et al. [2007] mention that the pot marigold cultivars characterized by deep orange colour of flowers and full inflorescences are more valuable as herbal material

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compared to yellow flowers contain smaller amounts of active substances. Dedio and Kozłowski [1998] report that the volume and quality of herbal produce are considerably shaped under the influence of environmental conditions and applied agrotechnical treatments, such as the date and density of seeding, mineral fertilization, complex disease, pest and weed control measures, harvest date, drying and storage conditions. In the present study, three plants per pot was assumed to be the optimum plant density. Taiz and Zeiger [2004] mention that excessively dense seeding may restrict the growth and development of plants, thus depressing their yields.

Mrugasiewicz et al. [1979], Dedio and Kozłowski [1998], Oborska et al. [2001] all emphasize that owing to its rich chemical composition as herbal raw material, calendula finds a broad scope of applications in medicine and pharmacy. Volak and Stodoła [1992] point to the fact that owing to its broad spectrum of therapeutic applications, pot marigold is grown on large plantations in Asia, America and Europe and in some countries of the Near East. Calendula has a wide range of constituents, e.g. essential oil, triperene sapnonins (calendulosides), flavonoids (up to 3%), carotenoids, saponins, polyacetylenes, sterols, carbohydrates, bitter glycosides, vitamin C, mucilages, mineral compounds (especially manganese).

The purpose of this study has been to evaluate the effect of nitrogen and magnesium fertilization on the growth and development of calendula plants and their yields.

MATERIAL AND METHODS

In 2007–2009, a pot experiment involving pot marigold plants (*Calendula officinalis* L.) was carried out in a greenhouse at the University of Warmia and Mazury in Olsztyn. The experiment was designed and performed by researchers from the Chair of Agrotechnology and Crop Production Management of the UWM in Olsztyn. Seeds of cv. Radio pot marigold were used in the trials. The experimental part of the research was designed according to the independent series method and set up in 4 replicates, 4 pots in one replicate, in modified Kick-Brauckmann pots. In each pot were sowing 3 marigold plants. Two factors were tested. The first order factor was nitrogen fertilization (in $g \cdot pot^{-1}$): A – 0 (control), B – 0.3, C – 0.6 (0.6 + 0), D – 0.9 (0.6 + 0.3), E – 1.2 (0.6 + 0.6). Magnesium fertilization constituted the second factor (in $g \cdot pot^{-1}$): a – 0 (control), b – 0.5.

Pots were filled with light soil (10 kg), classified as good rye complex soil, developed from heavy loamy sand. The soil was highly abundant in phosphorus, potassium and medium magnesium (139 mg P, 124 mg K, 59.0 mg $Mg \cdot kg^{-1}$) and had neutral reaction (pH in 1 M KCl – 6.5). Fertilization with phosphorus ($Ca(H_2PO_4) \times H_2O$), dosed as 0.11 g $P \cdot pot^{-1}$, and potassium (KCL), in a dose of 0.3 g $K \cdot pot^{-1}$, were constant for all the variants. The first rate of nitrogen (NH_4NO_3) (treatments B, C) and magnesium ($MgSO_4 \times 7H_2O$) (treatment b) were applied according to the methodological assumptions made for the experimental factors. The fertilizers were applied as solutions while pots were being filled with soil. Soil in pots was incubated for 10 days before seeding calendula seeds. The second rate of nitrogen (treatments D, E) was applied during the full plant emergence phase (concentration of the solution was 0.13%). Three seeds of calendula were sowed in each pot, in last decade of April. Soil moisture was maintained at around 70% of water capacity.

Pot marigold inflorescences were harvested in the full bloom phase, every 5 days (5 to 7 times during a growing season, depending on the year of the experiment). Before the harvest, biometric measurements of the plants were taken, including plant height and number of branches. Fresh mass of the harvested inflorescences was determined, after which the flowers were dried in a thermal drying chamber (at 30–35°C) and their air-dry mass was weighed. The results underwent statistical processing with a two-factorial analysis of variance. For the assessment of differences between the treatments, t-Student test was applied at the LSD level p = 0.05.

RESULTS AND DISCUSSION

An essential agrotechnical treatment for the cultivation of pot marigold to be successful, as it ensures high yields and affects their chemical composition and quality. Great number of researchers recommend moderate quantities of mineral fertilizers, especially nitrogen, which should be dosed according to the quality of produce harvested previously. However, it should be added that pot marigold requires additional magnesium fertilization for better development of flowers [Dębowski 1968, Czuba 1972, Golcz et al. 1975, Biesiada et al. 2007].

The authors' own experiment has demonstrated that nitrogen nutrition had some effect on the height of pot marigold plants (tab. 1). Significantly higher plants were observed when nitrogen was added to soil in the dose of 0.6 g N per pot compared to the control. Higher nitrogen fertilization rates likewise had significant influence on the height of pot marigold plants. The highest plants grew on soil fertilized with 1.2 g N per pot. The biggest difference in the plants' height (over 20%) appeared between the treatment to which 0.9 g N per pot was added and the one fertilized with 1.2 g N per pot. Magnesium fertilization had little effect (not proven statistically) on the height of plants, although higher plants tended to grow on soil not fertilized with this element.

Table 1. Plants hight of pot marigold, cm
Tabela 1. Wysokość roślin nagietka lekarskiego, cm

Magnesium fertilization, g Mg per pot Nawożenie magnezem, g $Mg \cdot wazon^{-1}$	Nitrogen fertilization, g N per pot Nawożenie azotem, g $N \cdot wazon^{-1}$					Mean Średnio
	0	0.3	0.6	0.9	1.2	
0	24.3	26.9	29.5	36.3	44.5	32.3
0.5	25.1	27.5	31.6	33.1	39.4	31.3
Mean – Średnio	24.7	27.2	30.5	34.7	41.9	-

$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
nitrogen fertilization – nawożenie azotem – 4.2
magnesium fertilization – nawożenie magnezem – n.s.* – r.n
interaction – interakcja – n.s.* – r.n.

* n.s. – r.n. – non signifacant differences – różnica nieistotna

Both nitrogen and magnesium fertilization significantly differentiated the number of inflorescences on pot marigold plants (tab. 2). Significantly more flowers – versus the control – were harvested from pots fertilized with the rate of 0.6 g N per pot. Raising the rate of nitrogen by an additional 0.3 g N per pot caused a significant increase in the number of flowers per plant. However, higher rates of nitrogen (1.2 g N) did not have any significant effect on this trait. Significantly fewer flowers (*ca* 23%) were harvested from the pots fertilized with magnesium. In the authors' own studies, completed in a greenhouse, a relatively small number of flowers per pot was obtained (12 flowers on average). Rumińska [1983] reports that a pot marigold plant can produce as many as 50 flowers. Martin and Deo [2000], who examined pot marigold growing in New Zealand, noticed around 20 flowers per plant. In turn, Khalid and Zaghloul [2006], who

Table 2. Flower number of pot marigold, no per plant
Tabela 2. Liczba kwiatostanów nagietka lekarskiego, szt. na rośl.

Magnesium fertilization, g Mg per pot Nawożenie magnezem, g Mg·wazon^{-1}	Nitrogen fertilization, g N per pot Nawożenie azotem, g N·wazon^{-1}					Mean Średnio
	0	0.3	0.6	0.9	1.2	
0	6.3	9.2	12.3	19.6	20.0	13.5
0.5	4.7	7.4	9.0	15.7	18.2	11.0
Mean – Średnio	5.5	8.3	10.6	17.6	19.1	-

$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
nitrogen fertilization – nawożenie azotem – 5.1
magnesium fertilization – nawożenie magnezem – 1.2
interaction – interakcja – n.s. – r.n.

grew pot marigold in India, reported between 70 to 140 inflorescences per plant. Our studies suggest that nitrogen fertilization has a positive effect on this trait. Similar conclusions are formulated by Hoffmann and Komosa [1974], who observed that both the number of flowers and yield of green mass significantly rose when higher NPK rates had been applied. Dedio et al. [1986] as well as Biesiada et al. [2006] state that pot marigold does not demand high nitrogen fertilization, suggesting that an optimum rate of this fertilizer is 30–50 kg·ha^{-1}. However, Mili and Sable [2003] noticed a higher number of flowers produced when pot marigold was fertilized with rates of nitrogen equal 100 kg·ha^{-1}. According to Gantait and Chattopadhyay [2004], pot marigold produced most flowers when fertilized with as much as 200 kg N·ha^{-1}, which resembles the results reported by Król [2011], who obtained the highest number of marigold flowers per plant as a result of the application of the highest tested rate of nitrogen (160 kg N·ha^{-1}).

Depending on its intended use, herbal raw material could be composed of whole inflorescences or petals of ligulate flowers. Florets can be pinched from the bases on field or after harvest [Rumińska 1983]. The fresh mass of inflorescences increased at higher rates of nitrogen (tab. 3). Significantly higher fresh mass of inflorescences was recorded in the treatments fertilized with the rate of 0.6 g N per pot, compared to the control. A further increase of the nitrogen rate by 0.3 g N per pot did not cause a significant increase in the fresh mass of inflorescences. It was not until the rate of 1.2 g of nitrogen per pot was applied that the mass of flowers was significantly affected compared to the variant fertilized with 0.6 g of nitrogen per pot. Although magnesium fertilization did not have any significant influence on this trait, a decreasing tendency in fresh mass of flowers was observed.

Table 3. Fresh inflorescences weight of pot marigold, g per plant
Tabela 3. Świeża masa kwiatostanów nagietka lekarskiego, g na rośl.

Magnesium fertilization, g Mg per pot Nawożenie magnezem, g Mg·wazon^{-1})	Nitrogen fertilization, g N per pot Nawożenie azotem, g N·wazon^{-1}					Mean Średnio
	0	0.3	0.6	0.9	1.2	
0	10.35	13.34	21.85	30.16	33.82	21.90
0.5	9.51	12.67	17.58	24.63	32.01	19.28
Mean – Średnio	9.93	13.00	19.71	27.39	32.91	-

$LSD_{0,05}$ for – $NIR_{0,05}$ dla:
nitrogen fertilization – nawożenie azotem – 9.20
magnesium fertilization – nawożenie magnezem – n.s. – r.n
interaction – interakcja – n.s. – r.n.

Table 4. Fresh weight of ligulate flowers, g per plant
Tabela 4. Świeża masa kwiatów języczkowych, g na rośl.

Magnesium fertilization, g Mg per pot Nawożenie magnezem, g Mg·wazon^{-1}	Nitrogen fertilization, g N per pot Nawożenie azotem, g N·wazon^{-1}					Mean Średnio
	0	0.3	0.6	0.9	1.2	
0	5.09	7.43	11.68	13.65	14.21	10.41
0.5	3.81	5.91	7.07	11.46	13.57	8.36
Mean – Średnio	4.45	6.67	9.37	12.55	13.89	-

$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
nitrogen fertilization – nawożenie azotem – 4.29
magnesium fertilization – nawożenie magnezem – n.s. – r.n
interaction – interakcja – n.s. –r.n.

The response of the fresh mass of ligulate flowers to nitrogen fertilization was analogous to that of the fresh mass of inflorescences (tab. 4). A significant increase occurred under the influence of the rate of 0.6 g nitrogen per pot, compared to the control. However, any further increase in the nitrogen dose applied to soil had no significant effect on this yield trait, up to the rate of 1.2 g N per pot. Magnesium fertilization caused a decrease in the fresh mass of pot marigold petals, which fell by as much as 24%.

In our studies, the yield of fresh mass of pot marigold inflorescences varied over a wide range. This trait strongly depends on the site and conditions of cultivation and on the plant's cultivar. Big differences in flower yields have also been recorded by Dedio et al. [1986], Hojden et al. [1990], Piccaglia et al. [1997], Martin i Deo [2000], Berti et al.[2003], Gantait and Chattopadhyay [2004], Biesiada et al. [2006].

The present experiment has also revealed that the share of ligulate flowers in the total mass of inflorescences of pot marigold decreased under the influence of increasing rates of nitrogen fertilization. Significant difference, relative to the control, was observed in the treatments receiving 0.9 g N per pot. Further increase in nitrogen rates caused a decline in the percentage of the fresh mass of ligulate flowers although the difference was not statistically significant. Despite the lack of significant differences, a tendency towards a lower share of ligulate flowers in the total fresh mass of flowers harvested from the pots fertilized with magnesium was noticed.

Table 5. Share of fresh weight of ligulate flowers in inflorescences, %
Tabela 5. Udział świeżej masy kwiatów języczkowych w kwiatostanach, %

Magnesium fertilization, g Mg per pot Nawożenie magnezem, g Mg·wazon^{-1}	Nitrogen fertilization, g N per pot Nawożenie azotem, g N·wazon^{-1}					Mean Średnio
	0	0.3	0.6	0.9	1.2	
0	47.9	46.7	47.1	42.3	40.6	44.9
0.5	45.1	45.9	43.3	42.3	39.4	43.2
Mean – Średnio	46.5	46.3	45.2	42.3	40.0	-

$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
nitrogen fertilization – nawożenie azotem – 2.7
magnesium fertilization – nawożenie magnezem – n.s. – r.n,
interaction – interakcja – n.s. – r.n.

Table 6. Air-dry weight of ligulate flowers, g per plant
Tabela 6. Sucha masa kwiatów języczkowych, g na rośl.

Magnesium fertilization, g Mg per pot Nawożenie magnezem, g Mg·wazon^{-1}	Nitrogen fertilization, g N per pot Nawożenie azotem, g N·wazon^{-1}					Mean Średnio
	0	0.3	0.6	0.9	1.2	
0	1.29	1.83	2.59	3.72	4.10	2.71
0.5	0.98	1.86	2.14	2.91	3.65	2.31
Mean – Średnio	1.14	1.85	2.37	3.32	3.88	-

$LSD_{0.05}$ for – $NIR_{0,05}$ dla:
nitrogen fertilization – nawożenie azotem – 1.06
magnesium fertilization – nawożenie magnezem – n.s. – r.n,
interaction – interakcja – n.s. – r.n.

Statistical analysis has demonstrated significant effect of nitrogen on the dry mass of ligulate flowers of pot marigold (tab. 6). Dry mass of ligulate flowers increased at each level of nitrogen fertilization, but the effect proved to be significant (compared to the control) when 0.6 g N per pot was applied. Further increase in the rate of nitrogen (0.9 g N per pot) did not have any significant influence on the analyzed trait. In turn, the rate of 1.2 g per pot significantly raised the dry mass of ligulate flowers compared to the dose of 0.6 g N per pot (by 1.5 g). Magnesium fertilization depressed the dry mass of petals by 0.4 g versus the pots not fertilized with this element. A similar response to magnesium in terms of the dry mass of ligulate flowers was noticed by Król [2011].

CONCLUSIONS

1. Nitrogen fertilization had a significant increase on the height of plants, number of inflorescences and volume of fresh and dry mass of capitula as well as ligulate flowers. The differences were observed in dose of 0.6 g N per pot.
2. The share of ligulate flowers in a single inflorescence significantly decreased as the rate of nitrogen fertilization increased.
3. Magnesium fertilization had a negative effect on all the analyzed traits of pot marigold.

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WPŁYW NAWOŻENIA AZOTEM I MAGNEZEM NA ROZWÓJ I PLONOWANIE NAGIETKA LEKARSKIEGO (*Calendula officinalis* L.)

Streszczenie. Polska zajmuje czołowe miejsce w uprawie roślin zielarskich. Jednym z głównych gatunków jest nagietek lekarski, mający szerokie zastosowanie w przemyśle farmaceutycznym, kosmetycznym i spożywczym. Doświadczenie wazonowe z nagietkiem lekarskim odmiany Radio prowadzono w latach 2007–2009 w hali wegetacyjnej. W badaniach uwzględniono dwa czynniki: nawożenie azotem ($g \cdot wazon^{-1}$): A – 0 (próba kontrolna), B – 0,3, C – 0,6 (0,6 + 0), D – 0,9 (0,6 + 0,3), E – 1,2 (0,6 + 0,6) i nawożenie magnezem ($g \cdot wazon^{-1}$): a – 0 (próba kontrolna), b – 0,5. W badaniach odnotowano istotny wpływ nawożenia azotem na liczbę kwiatostanów nagietka. Stwierdzono istotny wzrost plonów (w porównaniu z obiektem kontrolnym) po zastosowaniu dawki 0,6 g $N \cdot wazon^{-1}$. Natomiast nawożenie magnezem negatywnie oddziaływało na wszystkie badane cechy.

Słowa kluczowe: odmiana Radio, plon kwiatostanów, doświadczenie wazonowe

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