DE GRUYTER
OPEN

herba polonica
Vol. 59 No. 2 2013
DOI: 10.2478/hepo-2013-0007

EXPERIMENTAL PAPER

Effect of fertilization on the development and yields of pot marigold (*Calendula officinalis* L.)

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Summary

In 2007–2009, a pot experiment was carried out in a greenhouse at the University of Warmia and Mazury in Olsztyn on cv. Promyk pot marigold (*Calendula officinalis* L.). The aim of the study was to assess the impact of nitrogen and magnesium in plant growth and development and yield of marigold. 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 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.
The experiment demonstrated a significant effect of nitrogen fertilization on the plants hight, number of pot marigold inflorescences, fresh inflorescences weight, fresh and air-dry ligulate weight. Magnesium fertilization had a positive effect on all the analyzed traits. No statistical correlation was proven between the nitrogen and magnesium fertilization.

Key words: *Calendula officinalis, Promyk cv., N and Mg fertilization, biometric, yield*

INTRODUCTION

Calendula (*Calendula officinalis* L.) is one of the major medicinal plants grown on field plantations. Its cultivation is stimulated not just by the pharmaceutical industry but also by the dynamically developing manufacturing of cosmetics.

The pharmaceutical industry uses either ligulate florets (*Flos Calendulae*) or complete composite flowers of calendula *(Flores Calandulae cum Calycibus)* which are deep orange in colour and have a specific smell and bitter taste. With its rich

chemical composition, the calendula plant material contains a whole range of active substances, including essential oil, triterpene saponins (calendulosides), flavonoids, carotenoids, saponins, polyacetylenes, sterols, carbohydrates, vitamin C, mucilages and minerals, e.g. manganese, which makes the plant an important source of preparations with therapeutic effects used in pharmacy and medicine [1].

The objective of this study was to evaluate the effect of nitrogen and manganese fertilization on the growth and development and yields of calendula plants.

MATERIAL AND METHODS

The pot experiment involving pot marigold plants (*Calendula officinalis* L.) was carried out in 2007–2009 at the University of Warmia and Mazury in Olsztyn, Poland. Seeds of Promyk cv. 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 and two factors were tested were sown. 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 a neutral reaction (pH in 1 M KCl – 6.5). The content of phosphorus was determined according to the PN-R-04023:1996 norm, potassium according to the PN-R-04022:1996 norm. The content of mineral nitrogen ($N\text{-}NH_4$–2.29 $mg \cdot kg^{-1}$, $N\text{-}NO_3$–1.70 $mg \cdot kg^{-1}$) was determined by the method of flow colorimetry. 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 The analysis was performed using the Statistica® 9. For the assessment of differences between the treatments, t-Student test was applied at the LSD level $p=0.05$.

RESULTS AND DISCUSSION

In our experiments, it was demonstrated that nitrogen fertilization had an effect on the height of calendula plants (tab. 1). Significantly taller plants were recorded when nitrogen had been applied in a dose of 0.6 g per pot. Likewise, the subsequently higher rates of nitrogen affected significantly the height of plants. Studies reported by Hussein *et al.* [2], as well as Kumar and Singh [3] also indicate that nitrogen has a strong effect on the height of calendula plants. However, Ganjali *et al.* [4] obtained contrary results and claimed that differences in the height of calendula plants fertilized with 50 and 100 kg N·ha^{-1} were not significant. Magnesium fertilization did not have significant effect on the plants' height. However, taller plants tended to grow in pots which had been enriched with magnesium.

Table 1.

Plants height of pot marigold [cm]

Magnesium fertilization [g Mg per pot]	Nitrogen fertilization [g N per pot]					Mean
	0	0.3	0.6	0.9	1.2	
0	15.5	18.2	24.5	26.8	31.8	23.4
0.5	20.8	20.7	26.0	29.5	37.0	26.8
Mean	18.1	19.5	25.3	28.1	34.4	–
$LSD_{0.05}$ for: nitrogen fertilization – 6.0, magnesium fertilization – NS, interaction – NS						

Both nitrogen and magnesium fertilization treatments significantly differentiated the number of inflorescences on calendula plants (tab. 2). Significantly higher amount of flowers was harvested from the pots fertilized with 0.3 g N per pot than from the control treatments. By raising the nitrogen fertilization to 0.6 g per pot, a significant increase in the number of flowers gathered from a single plant was achieved. The subsequently higher doses of nitrogen also produced a significant effect on the number of flowers. A significantly higher number of flowers (24% more than in the control) were collected from magnesium-nourished pots. However, in another study by Szwejkowska and Bielski [5], Radio cv. responded to magnesium fertilization by significantly decreasing the number of flowers. In general, the number of flowers harvested from a single plant in the present experiment was small. In the treatments fertilized with the highest dose of nitrogen and magnesium, 21.5 inflorescences per plant on average were harvested. A similar number of flowers was obtained by Martin and Deo [6] in a study conduced in New Zealand. More flowers from calendula plants (28 flowers) were collected by Berimavandi *et al.* [7]. As many as 50 flowers per plant were obtained in a study by Rumińska [8]. Similar results were demonstrated by Król [9, 10] who gathered on average 60 and 45.6 flowers per plant in the respective years. Under the climatic conditions of in India, considerably more flowers were obtained by Khalid *et al.* [11], who harvested from 70 to 140 flowers per plant. The present results seem to confirm the positive

effect of nitrogen fertilization on this trait. Similar conclusions were drawn from the authors' previous experiment [5]. Hoffmann and Komosa [12] concluded likewise when discussing their experiment, in which higher NPK fertilization rates significantly increased the number of flowers and weight of herbal yield. Dedio *et al.* [1], as well as Biesiada *et al.* [13] conclude that calendula does not require intensive nitrogen nutrition and set the optimum dose at 30-50 kg·ha^{-1}. Mili and Sable [14] claim otherwise, and report the highest number of flowers after the soil enrichment with 100 kg N·ha^{-1}. Gantait and Chattopadhyay [15] produced a record number of calendula flowers having applied 200 kg N·ha^{-1}. By analogy, Król [9] reported the highest number of flowers under the effect of the highest dose of nitrogen (160 kg·ha^{-1}).

Table 2.

Number of flowers per pot marigold (no per plant)

Magnesium fertilization [g Mg per pot]	Nitrogen fertilization [g N per pot]					Mean
	0 .	0.3	0.6	0.9	1.2	
0	2.3	6.3	6.7	15.0	17.5	9.6
0.5	1.8	10.3	14.0	16.0	21.5	12.7
Mean	2.1	8.3	10.3	15.5	19.5	-
$LSD_{0.05}$ for: nitrogen fertilization –3.3, magnesium fertilization –2.1, interaction – NS						

The factors tested in our experiment did not have any significant effect on the diameter (n.i.) of calendula flowers (tab. 3). However, some tendency was observed towards a larger diameter of flowers on plants fertilized with nitrogen and magnesium. Similar results with respect to nitrogen fertilization were obtained by Król [9, 10] and Ganjali *et al.* [4]. In turn, Hussein *et al.* [2] demonstrated a significant difference in the flower diameter between the control and the treatments fertilized with nitrogen in doses of 1.5 and 3.0 g per pot.

Table 3.

Diameter of flower heads in pot marigold [mm]

Magnesium fertilization [g Mg per pot]	Nitrogen fertilization [g N per pot]					Mean
	0	0.3	0.6	0.9	1.2	
0	76.6	79.1	79.4	80.7	81.3	79.4
0.5	76.9	79.3	79.7	80.3	81.5	79.5
Mean	76.75	79.20	79.55	80.50	81.40	-
$LSD_{0.05}$ for: nitrogen fertilization – NS, magnesium fertilization – NS, interaction – NS						

In the present experiment, flowers were harvested manually every fife days (5–7 times during a growing season, depending on the year). Under the influence of increasing nitrogen doses, the fresh mass of flowers increased (tab. 4). Significantly larger fresh mass than in the control treatment was achieved from

the pots fertilized with 0.6 g N per pot. When the nitrogen doses were gradually raised by additional 0.3 g per pot, the fresh mass of inflorescences also increased significantly. However, the highest nitrogen dose, compared to 0.9 g N, did not cause a significant change in the fresh mass of flowers. A significant increase in the fresh mass of flowers (especially at an early sowing date and high seeding density) was reported by Ganjali *et al.* [4], but when sowing was delayed and the seed density was lower, a higher fresh weight of flowers was obtained under the nitrogen fertilization rate of 50 kg N·ha^{-1} rather than 100 kg. Positive impact of nitrogen fertilization on this trait has also been noticed by Kumar and Singh [3], as well as Szwejkowska and Bielski [5]. The response of this trait to magnesium fertilization was also significant. The weight of fresh flowers was 29% higher than in pots not fertilized with magnesium. In another trial conducted by Szwejkowska and Bielski [5], however, the fresh mass of flowers tended to decrease under the influence of magnesium fertilization.

Table 4.

Weight of fresh inflorescences in pot marigold [g per plant]

Magnesium fertilization [g Mg per pot]	Nitrogen fertilization [g N per pot]					Mean
	0	0.3	0.6	0.9	1.2	
0	2.88	5.92	10.22	21.41	24.53	12.99
0.5	3.77	7.77	15.39	27.08	29.91	16.78
Mean	3.33	6.85	12.81	24.25	27.22	-
$LSD_{0.05}$ for: nitrogen fertilization –5.88, magnesium fertilization – 3.72, interaction – NS						

The response of the yield of fresh mass of ligulate florets to nitrogen fertilization was analogous as that of the fresh mass of inflorescences (tab. 5). A significant increase was observed to appear under the effect of a nitrogen dose as low as 0.6 g per pot. Higher rates of nitrogen also led to a significantly higher fresh mass of ligulate florets up to the dose of 1.2 g N per pot. Magnesium fertilization, too, had a positive impact on the yield of fresh mass of calendula petals, but the difference was not significant.

Table 5.

Weight of fresh ligulate flowers [g per plant]

Magnesium fertilization [g Mg per pot]	Nitrogen fertilization [g N per pot]					Mean
	0	0.3	0.6	0.9	1.2	
0	1.43	1.91	4.17	7.81	9.86	5.04
0.5	1.45	2.40	7.10	8.13	11.06	6.03
Mean	1.44	2.15	5.64	7.97	10.46	-
$LSD_{0.05}$ for: nitrogen fertilization – 2.19, magnesium fertilization – NS, interaction – NS						

In the authors' own study, the yield of fresh mass of calendula flowers varied over a broad range. The actual yield seems to depend on a location and conditions of cultivation as well as on a calendula variety. Considerable differences in yield of inflorescences have also been recorded by Dedio *et al.* [1], Hojden *et al.* [16], Piccaglia *et al.* [17], Martin and Deo [6], Berti *et al.* [18], Gantait and Chattopadhyay [15].

In the present study, it has been demonstrated that the share of ligulate florets in composite flowers of calendula decreased significantly under the influence of increasing nitrogen doses (tab. 6). A big difference, versus the control, was observed in pots nourished with a dose of 0.6 g N per pot. Further increase in nitrogen fertilization rates caused a decrease in the percent share of fresh weight of flower petals, but the differences were not significant. Was not observed statistically significant differences for a higher contribution of ligulate florets in the flowers of calendula plants fertilized with magnesium.

Table 6.

Share of weight of fresh ligulate flowers in inflorescences (%)

Magnesium fertilization [g Mg per pot]	Nitrogen fertilization [g N per pot]					Mean
	0	0.3	0.6	0.9	1.2	
0	46.1	44.7	41.3	38.4	35.6	41.2
0.5	47.6	45.1	42.8	39.1	36.4	42.2
Mean	46.9	44.9	42.1	38.8	36.0	-
$LSD_{0.05}$ for: nitrogen fertilization – 3.1, magnesium fertilization – NS, interaction – NS						

The statistical analysis has demonstrated a significant effect of nitrogen on the dry matter of calendula ligulate florets (tab. 7). The dry matter of flower petals increased under each growing rate of nitrogen. However, a significant effect versus the control was noticeable from the rate of 0.6 g N per pot. Each subsequently higher dose of nitrogen (up to the rate of 1.2 g N per pot) also produced a significant effect on this trait. Magnesium fertilization had a positive influence on the yield of dry mass of flower petals. The difference was 5% versus the pots not fertilized with this element. A similar response to nitrogen fertilization in respect to dry matter of ligulate florets was observed by Król [10].

Table 7.

Weight of air-dried ligulate flowers [g per plant]

Magnesium fertilization [g Mg per pot]	Nitrogen fertilization [g N per pot]					Mean
	0	0.3	0.6	0.9	1.2	
0	0.28	0.45	1.04	1.79	2.19	1.15
0.5	0.31	0.59	1.15	1.65	2.34	1.21
Mean	0.29	0.52	1.09	1.72	2.26	-
$LSD_{0.05}$ for: nitrogen fertilization – 0.44, magnesium fertilization – NS, interaction – NS						

CONCLUSIONS

1. Nitrogen fertilization had a significant effect on the height of calendula plants, number of inflorescences per plant as well as the volume of yields of fresh and dry mass of composite flowers and ligulate florets. No significant differences, however, were observed in the diameter of composite flowers under the analyzed fertilization regimes.
2. The share of ligulate florets in the composite flower decreased significantly under increasing doses of nitrogen fertilization.
3. Magnesium fertilization had a positive effect on most cases the analyzed traits of calendula plants. Significant variation was noticed in the number and fresh mass of calendula flowers.

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WPŁYW NAWOŻENIA NA ROZWÓJ I PLONOWANIE NAGIETKA LEKARSKIEGO (*CALENDULA OFFICINALIS* L.)

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S t r e s z c z e n i e

Doświadczenie wazonowe z nagietkiem lekarskim odmiany Promyk prowadzono w latach 2007–2009 w hali wegetacyjnej Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. W badaniach uwzględniono dwa czynniki: nawożenie azotem (g·wazon^{-1}): A–0 (próba kontrolna), B–0,6 (0,6+0), C–0,9 (0,6+0,3), D–1,2 (0,6+0,6) i nawożenie magnezem (g·wazon^{-1}): a–0 (próba kontrolna), b–0,5. Część eksperymentalną założono metodą serii niezależnych, w 4 powtórzeniach, w wazonach zmodyfikowanego systemu Kick-Brauckmanna. Wykazano istotny wpływ nawożenia azotem na wysokość roślin, liczbę kwiatostanów nagietka, świeżą masę kwiatostanów, świeżą i suchą masę kwiatów języczkowych. Nawożenie magnezem miało pozytywny wpływ na wszystkie badane cechy – nie udowodniono statystycznie. Nie odnotowano istotnych statystycznie interakcji nawożenia azotem i magnezem na badane cechy nagietka lekarskiego.

Słowa kluczowe: *nagietek lekarski, odm. Promyk, nawożenie N i Mg, pomiary biometryczne, plon*