ACTA Acta Sci. Pol., Agricultura 10(3) 2011, 111-118

EFFECT OF NITROGEN AND BORON FERTILIZATION ON THE MORPHOMETRIC FEATURES AND YIELD OF CORIANDER (*Coriandrum sativum* L.)

Justyna Nowak, Władysław Szempliński
University of Warmia and Mazury in Olsztyn

Abstract. Pot experiments were conducted in 2006-2008 to evaluate the effect of nitrogen and boron fertilization on the morphometric features and yield of coriander. The research showed significant positive effect of increasing nitrogen fertilization on stem length, number of I line side branchings, inflorescences and fruit number per plant and negative effect on I side branching height. With increasing nitrogen fertilization fruit number and fruit yield per coriander plant were higher, and the maximum yield was obtained at the highest nitrogen rate. Coriander reacted to increasing nitrogen rates with an increase of fruit yield per plant, however at the same time decrease of the weight of 1000 fruits was observed, mainly as a result of formation of a greater number of them. In the research, boron fertilization did not differentiate morphometric features or the fruit yield of coriander.

Key words: coriander fruit, coriander morphology, *Coriandri fructus*, medicinal herbs

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is an annual medicinal and spice plant, adapted to cultivation in a dry and warm climate, though able to adapt quite well to the temperate zone. With regard to the short growing period, its cultivation is widespread in a lot of countries all over the world. Coriander fruit (*Fructus Coriandri*) constitutes a usable raw material, which is applied in therapeutics as a stimulant for digestion, hence in the powdered version it is used as an additive to herbal mixtures improving flavor of many dishes. The main biologically active compound of coriander fruit is an essential oil (*Oleum Coriandri*), being a mixture of many terpene compounds, from which the greatest significance have linalool and geraniol, valuable raw materials in the perfume industry [Rumińska 1981]. On the home market periodically there is a deficiency of this raw material, as the disadvantage of this plant is a relatively low yield level, hence there is a national demand which is satisfied with fruit import, mainly from countries with a warmer climate.

Corresponding author – Adres do korespondencji: dr hab. Władysław Szempliński, prof. UWM, Department of Agrotechnology and Crop Management of University of Warmia and Mazury in Olsztyn, M. Oczapowskiego 8/114, 10-719 Olsztyn, e-mail: wladyslaw.szemplinski@uwm.edu.pl

A lot of factors, among others climatic conditions [Rumińska 1981, Suchorska and Rumińska 1981, Rzekanowski et al. 2007] and agricultural technique factors [Rumińska 1981, Suchorska and Rumińska 1981, Oliveira et al. 2003, Rzekanowski et al. 2007, Kucharski and Mordalski 2008] have an effect on coriander yield, as well as on the content of the essential oil in fruits. From agricultural technique factors, level of coriander yield significantly determines mineral fertilization, especially nitrogen fertilization [Rumińska 1979, 1981, Oliveira et al. 2003]. In agricultural recommendations concerning coriander cultivation, attention is paid to the need of fertilizing it with boron [Filoda et al. 1996]. Boron fulfils an important physiological role in the control of basic metabolic processes. The greatest plant demand for this microelement, especially in plants whose agricultural yield are seeds, occurs at the stage of budding and flowering, which indicates its participation in the yield-forming processes [Szukalski 1979, Wróbel and Sienkiewicz-Cholewa 2003]. Nitrogen and boron are elements which to a large degree condition the proper course of plant ontogenesis, favorably affecting both the vegetative and generative development. With regard to this, plants positively react to fertilization with these elements [Szukalski and Sikora 1985, Krauze et al. 1991, Bowszys 1996, Bobrzecka et al. 1998, Oliveira et al. 2003, Wróbel and Sienkiewicz-Cholewa 2003, Rzekanowski et al. 2007]. Their deficiency leads to inhibition of plant growth, decline in resistance to negative influence of the environment, and also to yield decrease and deterioration of its quality. Coriander is classified as a plant characterized by high sensitivity to stress factors [Kucharski and Mordalski 2008], among others to the deficiency of nutrients in the soil.

The aim of the research was the determination of the effect of nitrogen and boron fertilization on morphometric features and yield, as it was assumed that both these elements fulfill an important role in the process of ontogenesis of this plant.

MATERIAL AND METHODS

Research results come from pot experiments with coriander conducted in the years 2006-2008 in a greenhouse in three one-year cycles by the Department of Agrotechnology and Crop Management of the University of Warmia and Mazury in Olsztyn. Polish cultivar Ursynowska was used in the research [Rumińska 1976]. The experiment was set up with independent series method in 4 replications, in pots of modified Kick-Brauckmann system.

The experiment included two variables. Nitrogen fertilization was the primary factor: A – 0, B – 0.4 (0.4 + 0), C – 0.8 (0.4 + 0.4), D – 1.2 (0.8 + 0.4), E – 1.6 (1.2 + 0.4) g N per pot. Secondary factor was boron fertilization: a – 0 and b – 3 mg B per pot.

Pots were filled with 10 kg of soil from the arable layer of the field, formed from the silty heavy loamy sand of the following granulometric composition: sand – 44%, silt – 37%, silt and clay fraction – 19%. With regard to agricultural suitability, it was included in the good rye complex. In all years of research the soil was characterized by high abundance in available phosphorus, potassium and magnesium (71-151 mg P, 133-142 mg K and 51-63 mg $Mg \cdot kg^{-2}$ of soil) and its reaction was from slightly acid to neutral (pH in 1 mole KCl 6.2-6.7). Soil moisture in pots was maintained on the level optimum for the growth and development of coriander, that is 65-75 %.

Phosphorus fertilization [$Ca(H_2PO_4) \times H_2O$] at a rate of 0.22 g P per pot and potassium fertilization (KCl) at a rate of 0.83 g K per pot was constant for all the combinations. The first nitrogen rate (NH_4NO_3 – combinations B, C, D, E) and boron fertilization ($Na_2B_4O_7 \times 10H_20$ – combination b) were applied directly to the soil in the form of a solution before setting up the experiment. Soil incubation in pots before sowing lasted 10 days. Coriander in all years of research was sown in the second half of April. Fertilization with the second nitrogen rate (NH_4NO_3 – combinations C, D, E) was applied directly to the soil in the form of a solution at the 4-5 leaf stage and planting in the pot of 10 coriander plants.

Before harvest, biometric measurements of plants were taken, including their height, the height of the I side branching, number of I line side branchings, and the number of inflorescences. Moreover, the number of fruits from the plant was determined, as well as the fruit yield from the plant and weight of 1000 fruits. Obtained results were processes statistically with the analysis of variance for two-factorial experiments, and the significance of differences was evaluated with Tukey test at the significance level P = 0.05. Test results were presented in tables as means from a 3-year period.

RESULTS

Among studied factors, nitrogen fertilization had a definite effect on the differentiation of morphometric features of plants included in the evaluation, as well as of the yield-forming abilities of coriander. Under the effect of nitrogen fertilization, the stem length significantly increased to the rate of 1.2 g N per pot (Table 1). However, longest stems were formed by coriander at a rate of 1.6 g N per pot and they were 1.8 times higher compared to the plants not fertilized with this element. Boron fertilization did not differentiate stem length of coriander.

Table 1. Height of coriander plants, cm
Tabela 1. Wysokość roślin kolendry siewnej, cm

Boron fertilization mg B per pot Nawożenie borem mg B na wazon	Nitrogen fertilization, g N per pot Nawożenie azotem, g N na wazon					
	0	0.4	0.8	1.2	1.6	mean – średnia
0	56.2	87.1	94.1	102.1	103.7	88.7
3	55.5	86.9	95.3	102.1	102.2	88.4
Mean – Średnia	55.9	87.0	94.7	102.1	103.0	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:						
nitrogen fertilization – nawożenia azotem			3.4			
boron fertilization – nawożenia borem			ns – ni			
interaction – interakcji			ns – ni			

ns – ni – non-significant differences – różnice nieistotne

Highest I side branchings were formed by plants fertilized with nitrogen at a rate of 0.4 g N per pot. Although increase of nitrogen fertilization caused stem elongation, it visibly reduced the height of I side branching, and mostly at the highest nitrogen rate (Table 2). Application of boron fertilization did not have a significant effect on the height of I side branching of coriander.

Nitrogen fertilization significantly affected the number of I line side branchings formed by the plant (Table 3). The fewest branchings were formed by coriander not fertilized with nitrogen. Even the lowest of the applied nitrogen rates (0.4 g N per pot) resulted in a significant increase of the number of branchings, by app. 80% compared to the test plants (not fertilized with nitrogen). The most intensive branching was characteristic of coriander fertilized with nitrogen at a rate of 1.6 g N per pot. 2.5 times more branchings were formed on the plant then, compared to plants growing without nitrogen. Boron did not have a significant effect on the number of formed I line side branchings.

Table 2. I side branching height of coriander, cm
Tabela 2. Wysokość osadzenia I rozgałęzienia bocznego kolendry siewnej, cm

Boron fertilization mg B per pot Nawożenie borem mg B na wazon	Nitrogen fertilization, g N per pot Nawożenie azotem, g N na wazon					
	0	0.4	0.8	1.2	1.6	mean – średnia
0	39.9	43.6	35.8	34.9	32.5	37.3
3	39.6	45.0	34.9	34.4	31.2	37.0
Mean – Średnia	39.7	44.3	35.4	34.6	31.8	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:						
nitrogen fertilization – nawożenia azotem			2.2			
boron fertilization – nawożenia borem			ns – ni			
interaction – interakcji			ns – ni			

ns – ni – non-significant differences – różnice nieistotne

Table 3. I line side branching number of coriander
Tabela 3. Liczba rozgałęzień bocznych I rzędu kolendry siewnej

Boron fertilization mg B per pot Nawożenie borem mg B na wazon	Nitrogen fertilization, g N per pot Nawożenie azotem, g N na wazon					
	0	0.4	0.8	1.2	1.6	mean – średnia
0	3.6	6.5	7.8	8.4	9.1	7.1
3	3.5	6.3	7.5	7.9	9.3	6.9
Mean – Średnia	3.6	6.4	7.6	8.2	9.2	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:						
nitrogen fertilization – nawożenia azotem			0.3			
boron fertilization – nawożenia borem			ns – ni			
interaction – interakcji			ns – ni			

ns – ni – non-significant differences – różnice nieistotne

Analogical dependences were found concerning the number of inflorescences formed by the plant. Increase of applied nitrogen rate every time caused significant increase of the number of inflorescences formed on the plant, whereas at a rate of 1.6 g N per pot, almost 10-fold increase of the number of inflorescences was noted compared to plants not fertilized with nitrogen (Table 4). Also in the case of this feature, boron fertilization proved to be statistically insignificant and only to a lesser degree caused the increase (by 3.4%) of the number of inflorescences formed by the plant.

Among factors included in the experiment, nitrogen fertilization had a definitely greater effect on the yield-forming properties of coriander than boron fertilization. Nitrogen fertilization significantly increased the number of fruits per plant, and statistically their greatest amount was obtained at a rate of 1.6 g N per pot (Table 5). The number of fruits produced at this level of fertilization was almost 13-fold greater than when nitrogen fertilization was not applied. Boron fertilization caused slight, though statistically not proved, decrease of the number of fruits per plant.

Table 4. Number of inflorescences per coriander plant
Tabela 4. Liczba kwiatostanów na roślinie kolendry siewnej

Boron fertilization mg B per pot Nawożenie borem mg B na wazon	Nitrogen fertilization, g N per pot Nawożenie azotem, g N na wazon					
	0	0.4	0.8	1.2	1.6	mean – średnia
0	3.1	8.8	16.9	18.4	27.0	14.8
3	2.7	8.7	15.9	21.0	28.1	15.3
Mean – Średnia	2.9	8.8	16.4	19.7	27.5	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:						
nitrogen fertilization – nawożenia azotem			1.3			
boron fertilization – nawożenia borem			ns – ni			
interaction – interakcji			ns – ni			

ns – ni – non-significant differences – różnice nieistotne

Table 5. Number of fruits per coriander plant
Tabela 5. Liczba owoców z rośliny kolendry siewnej

Boron fertilization mg B per pot Nawożenie borem mg B na wazon	Nitrogen fertilization, g N per pot Nawożenie azotem, g N na wazon					
	0	0.4	0.8	1.2	1.6	mean – średnia
0	33.0	130.2	250.0	294.2	352.4	211.9
3	24.1	115.8	227.1	286.5	371.9	205.1
Mean – Średnia	28.5	123.0	238.5	290.4	362.2	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:						
nitrogen fertilization – nawożenia azotem			18.9			
boron fertilization – nawożenia borem			ns – ni			
interaction – interakcji			ns – ni			

ns – ni – non-significant differences – różnice nieistotne

Increasing rates of nitrogen fertilization while increasing the number of fruits per plant, significantly affected quantity of obtained fruit yield from the plant (Table 6). The lowest fruit yield (0.28 g per plant) was obtained when no nitrogen fertilization was applied. Even the lowest nitrogen rate caused 4-fold increase of fruit yield, while the highest yield was found after application of 1.6 g N per pot. This yield was over 12-fold greater than the one from the test pots (without fertilization). Boron fertilization applied in the experiment did not significantly affect quantity of fruit yield from the plant.

The greatest weight of 1000 fruits (10.7 g) was obtained from coriander fertilized with nitrogen at a rate of 0.4 g N per pot. Further increase of fertilization with this element resulted in a small and statistically insignificant decrease of the value of this feature (Table 7). Boron, similarly to nitrogen, did not cause statistically significant differences in the weight of 1000 coriander fruits.

Table 6. Yield of fruits per coriander plant, g
Tabela 6. Plon owoców z rośliny kolendry siewnej, g

Boron fertilization mg B per pot Nawożenie borem mg B na wazon	Nitrogen fertilization, g N per pot Nawożenie azotem, g N na wazon					
	0	0.4	0.8	1.2	1.6	mean – średnia
0	0.33	1.28	2.28	2.83	3.28	2.00
3	0.23	1.12	2.27	2.91	3.73	2.05
Mean – Średnia	0.28	1.20	2.28	2.87	3.50	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:						
nitrogen fertilization – nawożenia azotem			0.16			
boron fertilization – nawożenia borem			ns – ni			
interaction – interakcji			ns – ni			

ns – ni – non-significant differences – różnice nieistotne

Table 7. Weight of 1000 coriander fruits, g
Tabela 7. Masa 1000 owoców kolendry siewnej, g

Boron fertilization mg B per pot Nawożenie borem mg B na wazon	Nitrogen fertilization, g N per pot Nawożenie azotem, g N na wazon					
	0	0.4	0.8	1.2	1.6	mean – średnia
0	10.0	11.1	10.3	10.3	9.7	10.3
3	9.3	10.3	10.7	10.8	10.6	10.4
Mean – Średnia	9.7	10.7	10.5	10.5	10.2	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:						
nitrogen fertilization – nawożenia azotem			ns – ni			
boron fertilization – nawożenia borem			ns – ni			
interaction – interakcji			ns – ni			

ns – ni – non-significant differences – różnice nieistotne

DISCUSSION

Coriander reacted to nitrogen fertilization with a significant stem elongation, obtaining maximum stem length at the highest of the applied nitrogen rates. This dependence is confirmed by research results obtained by Oliveira et al. [2003], in which coriander‘s height increased linearly, in a directly proportional manner to increasing nitrogen rates. Apart from the plant height, this element also significantly increased the number of formed branchings as well as the number of inflorescences. Coriander reacted to nitrogen fertilization with a significant reduction of the height of I side branching, which was most visible after application of its highest rate. In research by Suchorska and Rumińska [1981] optimum moisture and fertilization conditions favorably affected the number of formed buds, and thus the fruit yield.

Increase of nitrogen fertilization caused formation of a much greater number of fruits per plant, which manifested itself in the significant yield increase compared to plants not fertilized with nitrogen. Positive effect of nitrogen fertilization with regard to the quantity of coriander fruit yield, apart from pot experiments [Suchorska and Rumińska 1981], is also confirmed by field experiments [Rumińska 1981, Rzekanowski et al. 2007].

Weight of 1000 fruits of the studied coriander cultivar equals approximately 7 g [Rumińska 1979]. In the discussed experiment even fruits obtained from plants not fertilized were riper, whereas the mean weight of 1000 fruits was 10.3 g. However, the highest value of this feature (10.7 g) was obtained by coriander at the lowest nitrogen rate. Higher rates of nitrogen caused a small decrease of the weight of 1000 fruits, however these differences were not statistically confirmed. Although increase of nitrogen fertilization caused formation of less ripe fruits, the number of fruits per plant increased significantly, which compensated for the decrease of ripeness. However, the obtained yield significantly increased.

In field experiments conducted by Rzekanowski et al. [2007], nitrogen fertilization significantly increased the fruit yield of coriander, and the optimum rate was 50 kg $N \cdot ha^{-1}$. Productivity of 1 kg N applied at this rate was 5.6 $kg \cdot ha^{-1}$. Also, Oliveira et al. [2003] in Brazilian conditions proved that nitrogen is a factor which significantly differentiates the fruit yield, which increased linearly in a directly proportional manner to the rates of nitrogen fertilization increasing up to 80 g $N \cdot ha^{-1}$. Thus, one should agree with Rumińska [1981] that in coriander cultivation nitrogen is the main mineral component affecting its yield.

In discussed studies, boron fertilization proved to be the factor which does not significantly differentiate analyzed morphometric features of plants or the fruit yield and weight of 1000 coriander fruits. In literature, no research results were found concerning coriander's reaction to boron fertilization, although in agricultural recommendations [Filoda et al. 1996] the need for fertilizing it with this microelement is emphasised. From research on other crop plants, whose agricultural and usable raw material are seeds, it follows that there is a positive effect of fertilization with this component on their yield. From research of Szukalski and Sikora [1985], Krauze et al. [1991], Bowszys et al. [1996] conducted on rape and from the research of Bobrzecka et al. [1998] conducted on amaranth it follows that in these plants there is a close dependence between boron fertilization and yield and fat content in the seeds.

CONCLUSIONS

1. Increasing nitrogen fertilization significantly increased stem length, number of I line side branchings, number of inflorescences per plant as well as the number of fruits per plant, while it decreased the height of the I side branching.
2. Coriander's reaction to increasing rates of nitrogen fertilization was the increase of fruit yield per plant, however at the same time decrease of the weight of 1000 fruits was observed, mainly as a result of formation of a greater number of fruits per plant.
3. Boron fertilization did not differentiate morphometric features of plants or the fruit yield from coriander evaluated in the research.

REFERENCES

Bobrzecka D., Bowszys T., Procyk Z., 1998. Wpływ technologii nawożenia azotem i borem na plon i jakość nasion szarłatu (*Amaranthus aruentus* L.) [Effect of technology of nitrogen and boron fertilization on the yield and quality of amaranth seeds (*Amaranthus aruentus* L.)]. Rośl. Oleiste 19, 141-149 [in Polish].

Bowszys T., 1996. Reakcja rzepaku ozimego „0" na dolistne nawożenie borem [Reaction of winter rape '0' to foliar boron fertilization]. Zesz. Prob. Post. Nauk Rol. 434, 71-76 [in Polish].

Filoda G., Kordana S., Kucharski W. A., Załęcki R., 1996. Instrukcja uprawy. Kolendra siewna (*Coriandrum sativum* L.) [Cultivation instruction. Coriander (*Coriandrum sativum* L.)]. Wyd. IRiPZ Poznań [in Polish].
Krauze A., Bowszys T., Bobrzecka D., Ratkiewicz K., 1991. Effect of foliar boron fertilization on the yield and quality of winter rape. GRIRC Congres, Saskatoon, Canada, 547-553.
Kucharski W.A., Mordalski R., 2008. Porównanie efektywności uprawy kolendry siewnej (*Coriandrum sativum* L.) w systemach ekologicznym i konwencjonalnym [Comparison of effectiveness of coriander (*Coriandrum sativum* L.) cultivation in an ecological and conventional system]. J. Res. Appl. Agric. Eng. 53(3), 152-155 [in Polish].
Oliveira A.P., Paiva Sobrinho S., Barbosa J.K.A., Ramalho C.J., Oliveira A.L.P., 2003. Rendimento de coentro cultivado com doses crescentes de N. Hortic. Bras. 21(1), 81-83.
Rumińska A., 1979. Nowa odmiana kolendry „Ursynowska" [New coriander cultivar, 'Ursynowska']. Wiad. Ziel. 21(4), 1 [in Polish].
Rumińska A., 1981. Rośliny lecznicze. Podstawy biologii i agrotechniki [Medicinal plants. Basics of biology and agricultural techniques]. PWN Warszawa [in Polish].
Rzekanowski C., Marynowska K., Rolbiecki S., Rolbiecki R., 2007. Effect of nitrogen fertilization on the yield of coriander (*Coriandrum sativum* L.). Herba Pol. 53(3), 164-170.
Suchorska K., Rumińska A., 1981. Badania nad rozwojem kolendry siewnej (*Coriandrum sativum* L.) na tle zróżnicowanej wilgotności gleby i nawożenia NPK [Research on coriander (*Coriandrum sativum* L.) development on the background of diversified soil moisture and NPK fertilization]. Herba Pol. 27(2), 111-118 [in Polish].
Szukalski H., 1979. Mikroelementy w produkcji roślinnej [Microelements in plant production]. PWRiL Warszawa [in Polish].
Szukalski H., Sikora H., 1985. Wpływ doglebowego i dolistnego stosowania boru na jego zawartość w roślinach i na plon rzepaku ozimego [Effect of foliar and soil application of boron on its content in plants and on the winter rape yield]. Biul. IHAR 157, 87-93 [in Polish].
Wróbel S., Sienkiewicz-Cholewa U., 2003. Potrzeby nawożenia borem roślin uprawnych w Polsce [Boron fertilization needs of crop plants in Poland]. Post. Nauk Rol. 301(1), 103-118 [in Polish].

WPŁYW NAWOŻENIA AZOTEM I BOREM NA CECHY MORFOMETRYCZNE I PLONOWANIE KOLENDRY SIEWNEJ (*Coriandrum sativum* L.)

Streszczenie. W doświadczeniach wazonowych prowadzonych w latach 2006-2008 określano wpływ nawożenia azotem i borem na cechy morfometryczne i plonowanie kolendry siewnej. Badania wykazały, że wzrastające nawożenie azotem istotnie zwiększało długość łodygi, liczbę rozgałęzień bocznych pierwszego rzędu, liczbę kwiatostanów na roślinie oraz liczbę owoców z rośliny, obniżało natomiast wysokość osadzenia pierwszego rozgałęzienia bocznego. Na zwiększające się dawki nawożenia azotem kolendra reagowała zwiększeniem plonu owoców z rośliny, jednakże obserwowano jednocześnie zmniejszenie się masy 1000 owoców, głównie na skutek wykształcenia się na roślinie większej ich liczby. Nawożenie borem nie różnicowało ocenianych w badaniach cech morfometrycznych roślin oraz plonu owoców z rośliny kolendry siewnej.

Słowa kluczowe: *Coriandri fructus*, morfologia kolendry, rośliny lecznicze, owoce kolendry

Accepted for print – Zaakceptowano do druku: 26.04.2011