

Response of winter oilseed rape to differentiated foliar fertilisation

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This article presents results of a three-year field experiment laid out on medium textured soil, in north-eastern Poland. Winter oilseed rape was sprayed with foliar fertilisers Agravita®Active 48 (AA48) - NPK 8:8.7:16.6 and Agravita®Active70 (AA70) - NPK 10:22.7:6.6 at different phases of the crop's vegetative growth (BBCH 14, BBCH 35). The impact of the fertilisers on yield of seeds, straw, total protein, crude fat and on the content of macro- and micronutrients in aerial parts (BBCH 20 and 89) and roots (BBCH 20) of oilseed rape was evaluated. Foliar nutrition of oilseed rape plants with AA48 and AA70 significantly increased the seed yield of oilseed rape. The best yield-stimulating effect was achieved after the application of AA48 in autumn. Fertilisation of oilseed rape in that season of the year caused an increase in seed yield by 430 kg ha⁻¹. Each fertiliser contributed to a rise in the yield of protein and yield of crude fat, but had no effect on the content of magnesium, copper and zinc in seeds.

Key words: mineral nutrients, yield seed, protein, crude fat, winter oilseed rape

Introduction

Winter oilseed rape belongs to the crops of high economic importance. The constantly growing demand for oilseed rape seeds in Europe and globally mainly follows from its use for animal and human consumption and for production of biofuels (Rondanini et al. 2012, Budzyński et al. 2015, Kowalska et al. 2020). Winter oilseed rape is a crop that requires very careful, energy-demanding cultivation, in addition to which it is a very sensitive plant to unfavourable moisture and thermal conditions (Jankowski et al. 2014). These characteristics of the plant substantiate the search for reducing the risks during its cultivation as well as the costs it incurs. In modern farming, possible savings are seen, for example, in the technology of soil preparation for sowing (Velykis et al. 2014). Research is also carried out to improve the wintering of winter oilseed rape varieties (Paulauskas et al. 2013). New technologies are being implemented to allow plants to use nutrients more effectively (Schulte auf'm Erley et al. 2011). Considering the very high demand of oilseed rape for nutrients, this crop can be fertilised with some waste substances, rich in macro- and micronutrients, such as sewage sludge or animal meal (Nogalska et al. 2014). Scientific reports suggest the need to optimise technologies designed for soil tillage, fertilisation and chemical protection of oilseed rape (Triboi and Triboi-Blondel 2002, Orzech and Załuski 2020). Despite considerable progress in plant breeding, the pressure exerted by plant diseases remains strong, forcing the farmers to carry out many chemical treatments. Due to environmental requirements and expected cost reduction, it is becoming more and more common to combine several chemical treatments (Blandino and Reyneri 2009, Jankowski et al. 2016b, Jankowski et al. 2019b). For plants to develop an adequate root system so as to absorb sufficient amounts of nutrients from the soil, many authors recommend strengthening the plants by applying foliar fertilisers that provide both nutrients and biostimulants (Szczepanek et al. 2015, Wierzbowska et al. 2015, Kováčik et al. 2016). This is especially advisable in the case of young or weak plants exposed to unfavourable environmental factors in the different developmental stages (Colnenne et al. 2002, Szczepaniak et al. 2015).

The aim of this study was to evaluate the influence of foliar fertilisation with Agravita®Active 48 (AA48) - NPK 8:8.7:16.6 and Agravita®Active 70 (AA70) - NPK 10:22.7:6.6 on yields and quality of yields produced by winter oilseed rape, and on the content of selected macro- and micronutrients at two development phases.

Material and methods

The field experiment was established in the village Skajboty (53°47'N 20°41'E Poland) and set up in a random block design with three replications (each plot 200 m² in area). The trials were carried out in the years 2011–2013. The experimental factor was composed of two foliar fertilisers (0.5 kg ha⁻¹) Agravita®Active 48 (AA48) - NPK 8:8.7:16.6

and Agravita® Active 70 (AA70) - NPK 10:22.7:6.6, applied during different development stages of winter oilseed rape. Treatment: A - control; B - autumn (BBCH 14) AA48; C - autumn/spring (BBCH 14/35) AA48 and AA70; D – spring (BBCH 35) AA70. According to the manufacturer's recommendation and due to the very low content of available potassium in the soil, AA48 with a higher potassium content was selected for autumn use. AA70 was used in spring because of the higher content of nitrogen and phosphorus, which are responsible for the generative development of plants. The chemical composition of the fertilisers was as follows: AA48 (N-80, P-87, K-166 g kg⁻¹); AA70 (N-100, P-227, K-66 g kg⁻¹), and both fertilisers had the same amount of micronutrients (in mg kg⁻¹): B-200, Cu-500, Fe-1000, Mn-500, Zn-500.

The NPK fertilisation plan was based on the average uptake for the yield of 3 t ha⁻¹ of winter rape seeds. Furthermore, the straw left annually after harvesting winter triticale (6 t ha⁻¹) was included in the calculations. Before sowing the crop, fertilisation was applied to soil, providing the following quantities of nutrients: 30 kg N ha⁻¹ in the form of ammonium nitrate, phosphorus - 30 kg P ha⁻¹ as single superphosphate, and potassium - 100 kg K ha⁻¹ as potassium salt (Table 1). In spring, the first dose of fertiliser consisting of ammonium nitrate (100 kg N ha⁻¹) was applied at the BBCH 30 stage. The second dose of nitrogen 80 kg N ha⁻¹ together with 40 kg S ha⁻¹ (at BBCH 35) was applied in the form of Saletrosan®26 (26% N and 13% S). In each year, the crop preceding oilseed rape was winter triticale variety Leontino.

Table 1. Mineral fertilisation regime

| Treatment* | Type of fertiliser | Dose of fertiliser (dose of nutrients) kg ha ⁻¹ | Application form | Development stage of winter oilseed rape |
|------------|-------------------------------------------------------------|------------------------------------------------------------------|---------------------|---------------------------------------------|
| A, B, C, D | Ammonium nitrate Single superphosphate Potassium salt | 90 (30 N) 360 (30 P) 200 (100 K) | broadcasting | - |
| A, B, C, D | Ammonium nitrate Saletrosan®26 | 295 (100 N) 310 (80 N+40 S) | top dressing | BBCH 30 BBCH 35 |
| B, C | Agravita® Active 48 (AA48) | 0.5 (**) | foliar | BBCH 14 |
| C, D | Agravita® Active 70 (AA70) | 0.5 (***) | | BBCH 35 |

* A = Control; B = AA48 - (autumn); C = AA48+AA70 - (autumn+spring); D = AA70 - (spring); ** N-40 g ha⁻¹, P-43.5 g ha⁻¹, K-83 g ha⁻¹, B-100 mg ha⁻¹, Cu-250 mg ha⁻¹, Fe-500 mg ha⁻¹, Mn-250 mg ha⁻¹, Zn-250 mg ha⁻¹; *** N-50 g ha⁻¹, P-113.5 g ha⁻¹, K-33 g ha⁻¹, B-100 mg ha⁻¹, Cu-250 mg ha⁻¹, Fe-500 mg ha⁻¹, Mn-250 mg ha⁻¹, Zn-250 mg ha⁻¹

The crop chosen for the experiment was a population variety of winter oilseed rape called Monolit, recommended for cultivation on poorer soils and in harsher climatic conditions of north-eastern Poland. All agronomic treatments were performed every year according to the same pattern. Full plant protection against weed infestation, fungal diseases and plant pests was applied. The experiment was set up on a *Haplic cambisol* (IUSS Working Group WRB 2015). Soil properties before setting up the field experiment were as follows (0–30 cm soil layer; in mg kg⁻¹ of soil): C_{org.} 9500–12030; N_{total} 1080–1240; N-NH₄ 3.42–3.70; N-NO₃ 4.63–4.87, available forms of: P 43.1–49.8; K 39.9–51.8; Mg 36.2–41.5; Cu 1.49–2.87; Zn 1.03–1.81; Mn 163.7–295.2 and pH in 1 mol dm⁻³ KCl 5.5–5.6.

Plant material for analyses was collected from every plot in autumn (at BBCH 20 stage) and in summer, directly before harvest at the full maturity phase of oilseed rape (at BBCH 89 stage). The plant material sampled in autumn was separated into roots and aerial mass, while that collected before seed harvest was divided into seeds and straw. To determine the content of macronutrients, the plant material was digested in concentrated H₂SO₄ with H₂O₂ added as an oxidising reagent. The content of total nitrogen was determined with the Kjeldahl method on a BÜCHI Kjelflex K360 device, phosphorus by colorimetry with the vanadium-molybdate method (a Shimadzu UV1201V spectrophotometer), potassium and calcium by atomic emission spectrometry (AES) using a flame photometer made by BWB Technologies, and magnesium by atomic absorption spectrometry (AAS) on a Shimadzu AA-6800 spectrometer. For determination of the content of Cu, Zn, Mn and Fe, the plant material was digested in a BÜCHI Speed Digester K-439 in a mixture of acids HNO₃, HClO₄ in a 3:1 ratio (Ostrowska et al. 1991). Afterwards, the content of micronutrients was determined with atomic absorption spectrometry (Shimadzu AA-6800). The content of crude fat was determined with the Soxhlet method (Soxtec System 2043 Extraction Unit). The content of crude protein was calculated from the formula: Cr.P-cont. = N-cont. x 6.25, where: Cr.P-cont. – crude protein content (g kg⁻¹ d.m.); N-cont. – N-total content (g kg⁻¹ d.m.); 6.25 – factor (because 100 g of protein contains 16 g N). Harvest index (HI) was calculated according to the following formula: Harvest index = seed yield / yield of biomass of aerial parts of a crop.

Soil for analysis was collected every year after triticale harvest, from the 0–30 cm depth. The soil material underwent the following determinations: pH in 1 mol dm⁻³ KCl by potentiometry using an electrode with temperature compensation within a 20 °C range; total organic carbon measured on a Vario Max Cube CN Elementar analyser; available forms of phosphorus and potassium extracted from soil with buffered calcium lactate of pH 3.55 (in line with the Egner-Riehm method); P by colorimetry with the molybdate method using tin(II) chloride as a reducing reagent; K with the ESA method on a flame photometer made by BWB Technologies. Finally, available magnesium was extracted with 0.0125 mol dm⁻³ CaCl₂ and its content was determined by AAS, while the concentrations of Zn, Cu, Mn and Fe were determined by AAS (on a Shimadzu AA-6800 apparatus) after extracting the metals from the soil with 1 mol dm⁻³ HCl solution (Ostrowska et al. 1991).

The temperatures and sums of precipitation during the experiment diverged from the long-term means (Table 2). Much lower temperatures than the multi-year average ones were recorded in February 2011 and 2012 and in March 2013. Low temperatures at that time of the year may have had a negative effect on the condition of plants. The distribution of precipitations during the experiment was far from being even. In 2011 and 2013, rainfalls in March and April were distinctly lower than the ones determined over many years, which could also have had a negative impact on the growth and development of winter oilseed rape. After the onset of the crop's vegetative growth, there were no periods of persistent drought. During the blooming of oilseed rape, the amount of precipitation in every year of the trials was very close to the multi-annual average.

Table 2. Meteorological conditions

| Year | Month | | | | | | | | | | | | Mean |
|---------------------|-------|------|------|------|------|-------|-------|------|-------|------|------|------|-------|
| | J | F | M | A | M | J | J | A | S | O | N | D | |
| Temperature (°C) | | | | | | | | | | | | | |
| 2011 | -1.5 | -5.8 | 1.6 | 9.1 | 13.1 | 17.1 | 17.9 | 17.6 | 14.1 | 8.3 | 3.1 | 2.3 | 8.2 |
| 2012 | -1.7 | -7.5 | 3.0 | 7.8 | 13.4 | 15.0 | 19.0 | 17.7 | 13.5 | 7.4 | 4.9 | -3.5 | 6.9 |
| 2013 | -4.6 | -1.1 | -3.5 | 5.9 | 14.8 | 17.5 | 18.0 | 17.4 | 11.3 | 8.9 | 5.0 | 2.3 | 7.7 |
| 1961–2010 | -2.9 | -2.3 | 1.2 | 7.0 | 12.7 | 15.9 | 18.0 | 17.3 | 12.6 | 7.7 | 2.8 | -1.2 | 7.4 |
| Precipitations (mm) | | | | | | | | | | | | | |
| 2011 | 34.8 | 36.9 | 16.3 | 22.5 | 51.1 | 81.7 | 202.8 | 82.1 | 67.5 | 29.5 | 14.1 | 25.8 | 665.1 |
| 2012 | 61.8 | 27.7 | 24.7 | 73.1 | 51.7 | 103.2 | 121.0 | 45.1 | 45.7 | 68.5 | 45.2 | 11.8 | 679.5 |
| 2013 | 44.1 | 22.6 | 18.1 | 28.5 | 54.5 | 61.2 | 121.9 | 37.6 | 101.1 | 16.0 | 18.0 | 27.7 | 551.3 |
| 1961–2010 | 31.2 | 21.9 | 28.5 | 34.2 | 54.6 | 79.0 | 75.4 | 68.7 | 57.1 | 46.0 | 47.9 | 36.6 | 581.1 |

The analytical results were processed statistically in a Statistica 10[®] software package. The results underwent one-way ANOVA (analysis of variance), and the significance of differences between means was determined by the Tukey's test at the level of significance $\alpha=0.05$.

Results and discussion

The meteorological conditions during the experiment were not quite suitable for the cultivation of winter oilseed rape, which most probably was one of the reasons why the yield potential of the grown variety was not fully achieved (Table 2). Only foliar fertilisation with AA48 or AA70 significantly modified the yield of seeds, straw, total protein and crude fat of winter oilseed rape, regardless of research years (Table 3). The yield of protein and fat was largely dependent on the yield of seeds. Based on the experimental results, it can be concluded that the application of AA48+AA70 in autumn and in spring (tr. C) caused an increase in the yield of seeds, protein and fat. The best yield-stimulating effects were achieved after the application of AA48 in autumn. Fertilisation of the plants in this season of the year improved the seed yield and fat yield by nearly 13% in comparison with the control treatment. The best effects on yield of total protein, which rose by over 19%, were achieved following the exclusive application of AA48 in autumn.

This study showed that AA48 and AA70 had positive influence on yields of winter oilseed rape. These fertilisers had a weaker effect when applied in spring than in autumn, rising the seed yield of winter oilseed rape by 220 kg ha⁻¹ (after the application during the BBCH 14 and 35 stages) and by 290 kg ha⁻¹ (when only AA70 was applied at BBCH 35).

Table 3. Yields of winter oilseed rape

| Time of application | Year | Seed yield (t ha ⁻¹) | Straw yield (t ha ⁻¹) | HI* | Yield of total protein (t ha ⁻¹) | Yield of crude fat (t ha ⁻¹) |
|----------------------------------------------------------------|------|-------------------------------------|--------------------------------------|--------------------|----------------------------------------------------|------------------------------------------------|
| Control | 2011 | 3.26 ^a | 6.13 ^d | 0.35 ^a | 0.74 ^d | 1.58 ^f |
| | 2012 | 3.11 ^d | 5.91 ^d | 0.35 ^a | 0.70 ^d | 1.52 ^d |
| | 2013 | 3.14 ^d | 5.47 ^b | 0.36 ^d | 0.70 ^d | 1.53 ^d |
| | Mean | 3.17 ^c | 5.84 ^A | 0.35 ^A | 0.71 ^C | 1.54 ^C |
| Agravita®Active** | 2011 | 3.81 ^f | 8.12 ^h | 0.32 ^c | 0.89 ^c | 1.84 ^c |
| | 2012 | 3.55 ^c | 7.23 ^f | 0.33 ^c | 0.83 ^b | 1.72 ^c |
| | 2013 | 3.45 ^{bce} | 7.16 ^{ef} | 0.33 ^c | 0.81 ^{ab} | 1.67 ^{ab} |
| | Mean | 3.60 ^b | 7.50 ^C | 0.32 ^B | 0.85 ^B | 1.74 ^A |
| Agravita®Active 48 + Agravita®Active 70 autumn+spring*** | 2011 | 3.53 ^{ce} | 6.72 ^{bc} | 0.34 ^{ab} | 0.82 ^b | 1.70 ^b |
| | 2012 | 3.29 ^a | 6.24 ^a | 0.35 ^a | 0.77 ^a | 1.61 ^a |
| | 2013 | 3.36 ^{ab} | 6.31 ^a | 0.35 ^a | 0.79 ^a | 1.62 ^a |
| | Mean | 3.39 ^A | 6.42 ^B | 0.35 ^A | 0.78 ^A | 1.64 ^B |
| Agravita®Active 70 spring**** | 2011 | 3.58 ^c | 6.83 ^{cef} | 0.34 ^{ab} | 0.84 ^{cb} | 1.74 ^b |
| | 2012 | 3.39 ^{ab} | 6.39 ^{ab} | 0.35 ^a | 0.79 ^a | 1.64 ^a |
| | 2013 | 3.41 ^{ab} | 6.55 ^a | 0.34 ^{ab} | 0.80 ^a | 1.65 ^a |
| | Mean | 3.46 ^{AB} | 6.59 ^B | 0.34 ^A | 0.81 ^{AB} | 1.68 ^{AB} |
| Mean for years | | | | | | |
| | 2011 | 3.47 ^A | 6.81 ^A | 0.34 ^A | 0.81 ^A | 1.68 ^A |
| | 2012 | 3.27 ^A | 6.31 ^A | 0.34 ^A | 0.76 ^A | 1.58 ^A |
| | 2013 | 3.27 ^A | 6.25 ^A | 0.34 ^A | 0.75 ^A | 1.58 ^A |

*HI = harvest index – an index expressing the seed yield ratio to the yield of biomass of aerial parts of a crop; **N-40 g ha⁻¹, P-43.5 g ha⁻¹, K-83 g ha⁻¹, B-100 mg ha⁻¹, Cu-250 mg ha⁻¹, Fe-500 mg ha⁻¹, Mn-250 mg ha⁻¹, Zn-250 mg ha⁻¹; *** N-90 g ha⁻¹, P-157 g ha⁻¹, K-116 g ha⁻¹, B-200 mg ha⁻¹, Cu-500 mg ha⁻¹, Fe-1000 mg ha⁻¹, Mn-500 mg ha⁻¹, Zn-500 mg ha⁻¹; **** N-50 g ha⁻¹, P-113.5 g ha⁻¹, K-33 g ha⁻¹, B-100 mg ha⁻¹, Cu-250 mg ha⁻¹, Fe-500 mg ha⁻¹, Mn-250 mg ha⁻¹, Zn-250 mg ha⁻¹; A, B, C = significant differences at $p \leq 0.05$ between years of experiment; a, b, c (...) = significant differences at $p \leq 0.05$ between time of application of Agravita

The research results obtained from our trials confirm the ones reported by other researchers, who suggest that oilseed rape needs a good supply of nutrients from its early stages of development. According to Jankowski et al. (2016a), the best yield-stimulating effects are achieved by foliar fertilisation of oilseed rape with boron in the autumn season. This treatment increased the seed yield by 300 kg ha⁻¹. Supplying oilseed rape crops with micronutrients does not always lead to a rise in seed yield. Yang et al. (2009) claim that there could be interactions between micronutrients, which may have negative influence on seed yield. On the other hand, oilseed rape is a plant with high nutritional demand and, according to Jankowski et al. (2016b), it typically responds to a higher supply of nutrients by producing a higher yield of seeds. Gharechaei et al. (2019) underline that despite its long period of vegetative growth and development, apparently ensuring enough time to make up for possible losses, oilseed rape is exposed to several stress factors. Periodic deficits of nutrients, e.g. due to a drought, can be set off by foliar fertilisation (Fageria et al. 2009).

In such circumstances, foliar fertilisation can be the only alternative way to feed plants. However, supplying nutrients through leaves is often an intervention measure, even though it may have a considerable effect on the growth and development of plants. Many authors emphasise that under stress conditions it is recommended to use a foliar supply of elements, especially copper and boron. Foliar fertilisation with these elements can increase the seed yield by as much as over 10% (Jankowski et al. 2019a).

Oilseed rape straw is not an important commodity, but can provide valuable biomass for the enrichment of soil with organic matter and nutrients and therefore should be left on a field and ploughed in. As reported by Trinsoutrot et al. (2000), after half-year mineralisation of rape plant residue in soil, there is release of nitrogen, which can be effectively used by consecutive crops. Our experiment proved that, in comparison with the control

treatment, fertilisation contributed to a higher yield of oilseed rape straw. The highest straw yields (over 7.5 t ha⁻¹) were obtained after the application of AA48 in autumn.

According to Szczepaniak et al. (2015), the nutritional status of winter oilseed rape in autumn (BBCH 30) is the most reliable tool to foresee seed yields of this crop. Fertilisation with AA48 in autumn caused significant changes in the mineral composition of winter oilseed rape at BBCH 20 stage (Table 4). At the same time, bigger changes in the mineral composition of winter oilseed rape at BBCH 20 stage were noted in roots than in aerial parts of the plants. The spraying of plants with AA48 in autumn led to a decrease in the content of phosphorus, potassium, calcium and zinc in aerial parts of the analysed plants. However, no significant effect of AA48 on the nitrogen content in aerial mass of the plants was detected. This finding can be explained by the good supply of oilseed rape with nitrogen in autumn. Typically, soil is found to contain large amounts of N in autumn, and the nitrogen uptake by oilseed rape at this stage of plant development is moderate (Šidlauskas and Tarakanovas 2004). AA48 applied in autumn in this study did not cause a significant effect on the accumulation of copper, manganese and iron in aerial parts of oilseed rape plants (BBCH 20 stage). The spraying of this plant with AA48 carried out in autumn led to a decrease in the root content of nitrogen, potassium, calcium, copper and zinc. The chemical analysis of roots demonstrated that the application of AA48 in autumn resulted in a high increase in the concentrations of manganese and iron in oilseed rape roots. A similar response of winter oilseed rape was observed by Jankowski et al. (2019b). In their experiment, the cited authors noted a considerable increase in the content of zinc, manganese and iron in roots of oilseed rape at BBCH 30 stage after sowing winter oilseed rape seeds together with a fertiliser in the form of microgranules containing macro- and micronutrients (Physiostart®).

Table 4. Macro- and micronutrient content in winter oilseed rape (BBCH 20)

| Mineral components | Units | Aerial parts | | Roots | |
|--------------------|---------------------|---------------------|------------------------------|---------------------|------------------------------|
| | | Control | Agravita®Active 48 (autumn)* | Control | Agravita®Active 48 (autumn)* |
| N | | 39.41 ^a | 38.06 ^a | 30.72 ^b | 26.09 ^a |
| P | | 4.44 ^b | 4.21 ^a | 3.76 ^a | 3.67 ^a |
| K | g kg ⁻¹ | 66.37 ^b | 63.78 ^a | 47.31 ^b | 41.18 ^a |
| Ca | | 19.94 ^a | 19.56 ^b | 7.02 ^b | 4.94 ^a |
| Mg | | 1.52 ^a | 1.60 ^b | 2.17 ^a | 2.04 ^a |
| Cu | | 5.15 ^a | 4.74 ^a | 5.46 ^b | 5.04 ^a |
| Zn | mg kg ⁻¹ | 46.37 ^b | 42.32 ^a | 53.20 ^b | 47.92 ^a |
| Mn | | 53.45 ^a | 50.13 ^a | 52.95 ^a | 64.82 ^b |
| Fe | | 239.37 ^a | 261.81 ^a | 733.32 ^a | 1286.36 ^b |

*N-40 g ha⁻¹, P-43.5 g ha⁻¹, K-83 g ha⁻¹; B-100 mg ha⁻¹, Cu-250 mg ha⁻¹, Fe-500 mg ha⁻¹, Mn-250 mg ha⁻¹, Zn-250 mg ha⁻¹

AA48 and AA70 contributed to an increase in the macroelement content in oilseed rape seeds (Table 5). In our trials, the application of Agravita®Active caused a rise in the content of magnesium in winter oilseed rape seeds. According to Jankowski et al. (2019b), macro- and micronutrients supplied in autumn as microgranules in the direct proximity of the seeds can lead to a higher content of Cu, Zn and Fe in mature seeds (BBCH 89 stage). In our experiment, no effect of the applied fertilisers on the content of Cu, Zn and Mn in seed was determined.

Our analysis of the selected elements in oilseed rape straw revealed significant differences in their concentrations determined in the straw due to foliar fertilisation, but they varied in character, hence the response of the crop to foliar spray fertilisation can be deemed as inconsistent.

Fertilisation with AA48 had an effect on the harvest index. This index, which corresponds to the ratio of seed yield to biomass yield, ranged within an interval from 0.32 to 0.36 (Table 3). The HI results substantiate the conclusion that autumn is the most effective time for the application of Agravita®Active.

Table 5. Macro- and micronutrient content in winter oilseed rape (BBCH 89)

| Mineral components | Seeds | | | | Straw | | | |
|--------------------|---------------------|---------------------|--------------------|--------------------|----------------------|----------------------|--------------------|---------------------|
| | A | B | C | D | A | B | C | D |
| | g kg ⁻¹ | | | | | | | |
| N | 36.25 ^b | 37.53 ^a | 37.38 ^a | 37.44 ^a | 8.51 ^{ab} | 10.28 ^{bc} | 8.35 ^a | 10.61 ^c |
| P | 8.21 ^b | 8.44 ^{ab} | 8.76 ^a | 8.68 ^a | 2.09 ^a | 2.42 ^b | 2.17 ^{ab} | 2.33 ^{ab} |
| K | 9.28 ^b | 10.24 ^a | 10.58 ^c | 10.21 ^a | 29.66 ^a | 30.48 ^a | 28.31 ^a | 27.71 ^a |
| Ca | 5.46 ^b | 5.66 ^c | 6.02 ^a | 5.98 ^a | 16.47 ^a | 17.59 ^a | 17.05 ^a | 19.74 ^b |
| Mg | 3.00 ^b | 3.28 ^a | 3.42 ^a | 3.31 ^a | 0.87 ^a | 1.09 ^b | 0.87 ^a | 1.03 ^{ab} |
| | mg kg ⁻¹ | | | | | | | |
| Cu | 3.20 ^a | 3.12 ^a | 3.06 ^a | 3.29 ^a | 2.89 ^a | 3.47 ^b | 2.92 ^a | 3.08 ^a |
| Zn | 44.52 ^a | 44.66 ^a | 45.21 ^a | 45.92 ^a | 15.40 ^a | 18.45 ^b | 14.26 ^a | 16.21 ^{ab} |
| Mn | 47.35 ^a | 46.05 ^a | 47.88 ^a | 48.18 ^a | 46.66 ^{ab} | 54.41 ^{bc} | 44.77 ^a | 58.57 ^c |
| Fe | 106.95 ^b | 89.33 ^{ab} | 84.95 ^a | 88.60 ^a | 110.65 ^{ab} | 100.36 ^{ab} | 89.44 ^a | 129.10 ^b |

A = Control; B = Agravita[®]Active 48 – autumn; C = Agravita[®]Active 48 + Agravita[®]Active70 - autumn + spring; D = Agravita[®]Active 70 - spring

Conclusions

The two tested fertilisers (AA48 and AA70) significantly increased the seed yield of winter oilseed rape, and better effects were achieved when AA48 was applied in autumn. These fertilisers also improved the yield of protein and yield of crude fat. AA48 applied in autumn led to a decrease in the content of phosphorus, potassium, calcium and zinc in aerial parts of winter oilseed rape at BBCH 20 phase, but did not have a significant effect on the accumulation of copper, manganese and iron in these organs, although it induced an increase in the concentrations of manganese and iron in roots. Both Agravita fertilisers contributed to an elevation in the content of N-total and magnesium in seeds of winter oilseed rape. Based on the results of this study, it can be concluded that AA48 and AA70 are useful fertilisers in cultivation of winter oilseed rape.

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