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ORIGINAL PAPER

THE EFFECT OF MEAT AND BONE MEAL APPLIED WITHOUT OR WITH MINERAL NITROGEN ON MACRONUTRIENT CONTENT AND UPTAKE BY WINTER OILSEED RAPE*

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Abstract

Meat and bone meal (MBM) can be a viable alternative to natural, organic and mineral fertilizers because it is rich in nitrogen (N), phosphorus (P), calcium (Ca), micronutrients and organic matter that can be recycled back into agricultural land. The aim of this study was to determine the optimal dose of MBM for winter oilseed rape (*Brassica napus* L.). Meat and bone meal was applied at three doses (1.0, 1.5 and 2.0 Mg ha^{-1}) with the addition of mineral nitrogen at 79 and 40 kg N ha^{-1}, and without the addition of mineral nitrogen (0 kg N ha^{-1}), respectively. The effects exerted by MBM were compared with those exerted by mineral NPK fertilization (control treatment). Since MBM had low K content, K rate was 145 kg ha^{-1} in all treatments, and it was applied with mineral fertilizers. The macronutrient (N, P, K, Ca and Mg) content of winter oilseed rape seeds and straw, and macronutrient uptake by aboveground biomass were evaluated. A small-scale field experiment was conducted in northeastern Poland. The experiment had a randomized block design, and it was established on Dystric Cambisol developed from loamy sand. Changes in the uptake of the analyzed macronutrients and their concentrations in winter oilseed rape seeds and straw were affected by fertilization and weather conditions. Supplemental mineral N was applied before sowing to widen the narrow N/P ratio in MBM, which had a beneficial influence on the mineral composition and macronutrient uptake by the aboveground biomass of winter oilseed rape. Macronutrient (N, P, Ca and Mg) uptake by plants was highest in the treatment with the lowest MBM dose (1.0 Mg MBM ha^{-1}) supplemented with 79 kg mineral N (50% N from mineral fertilizer and 50% N from MBM). The results of this study indicate that MBM applied at the dose of 1.0 t ha^{-1} meets the P and N requirements of winter oilseed rape in 100% and 50%, respectively. Therefore, the recommended mineral N fertilizer rate for winter oilseed rape can be reduced by 50%.

Keywords: rapeseeds, straw, nitrogen, phosphorus, potassium, calcium, magnesium, animal meal.

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INTRODUCTION

Winter oilseed rape (*Brassica napus* L.) is the most important oilseed crop in Poland. The world's leading producers of oilseed rape are the European Union (EU) countries, Canada, China and India. On the EU market, Poland is the third largest producer after France and Germany. Rapeseed is used for the production of vegetable oil and energy, whereas fat-free seed residues are a source of protein for animal feed. Oilseed rape also delivers environmental benefits (post-harvest residues, intercropping). Winter oilseed rape has high nutrient requirements, which largely depend on the nutrient content of seeds and straw, nutrient ratios and yield. The mineral composition of oilseed rape seeds is evaluated based on the content of N, P, K, Ca and Mg, and macronutrient concentrations vary across varieties and in response to weather conditions and agronomic factors (Bell et al. 1999, Jankowski et al. 2016, Jankowski, Sokólski 2018). Fertilization is one of the most determinants of the yield and quality of oilseed rape seeds (Rathke et al. 2006). Oilseed rape responds well to manure which supplies not only macronutrients and micronutrients but also organic matter, thus improving soil structure and stimulating microbial activity. However, manure is rarely used as an organic fertilizer for oilseed rape, for various practical reasons. Meat and bone meal (MBM) can be a viable alternative to manure and mineral N-P fertilizers, because it is rich in N (approx. 8%), P (approx. 5%) and Ca (approx. 10%) as well as micronutrients and organic matter (approx. 70%) (Jeng et al. 2006, Brod et al. 2016). In MBM, N is present in the form of protein compounds, therefore it is steadily released into the soil through mineralization and becomes available to plants already in the first year after application (Jeng et al. 2004). Phosphorus is present in organic form (meat fraction), which is readily available to plants, and in the form of hydroxyapatite (bone fraction). Available P is released from apatite in an acidic soil environment (Jeng et al. 2006, Brod et al. 2016). Phosphorus is a major mineral fertilizer component required by crop plants, and nowadays its supply poses a challenge and can even become a political issue due to phosphate shortage. Therefore, new and renewable sources of phosphorus compounds must be continuously searched for. One of the solutions can be the recycling of P from by-products and waste materials from the meat processing industry (Saeid et al. 2013). Previous field experiments (Nogalska, Zalewska 2013, Nogalska et al. 2013, 2014, Nogalska 2016) have shown that only high doses of MBM (approx. 2.5 Mg ha^{-1}) supplied N in similar amounts to mineral fertilizers. However, high doses of MBM lead to the accumulation of P in the soil because 2.5 Mg MBM is equivalent to 110 kg P ha^{-1}, which considerably exceeds the P requirements of crop plants (Nogalska et al. 2012, Nogalska et al. 2017). Lower doses of MBM, supplemented with mineral N to widen the narrow N/P ratio in MBM, are safer for the soil environment.

In view of the above, the aim of this study was to determine the optimal dose of MBM for winter oilseed rape (*Brassica napus* L.) without or with supplemental mineral N. The macronutrient (N, P, K, Ca and Mg) content of winter oilseed rape seeds and straw, and macronutrient uptake by aboveground biomass were also evaluated.

MATERIALS AND METHODS

A small-scale field experiment was conducted at the Agricultural Experiment Station in Tomaszkowo, owned by the University of Warmia and Mazury in Olsztyn, in two growing seasons of 2015/16 and 2016/17. The experiment had a randomized block design with four replications, and it was established on brown soil developed from loamy sand, Dystric Cambisol according to the WRB (2015). The soil was slightly acidic (pH_{KCl} = 5.61), moderately abundant in available P, abundant in K and highly abundant in Mg (65 mg P kg^{-1}, 163 mg K kg^{-1} and 96 mg Mg kg^{-1} soil).

The experimental treatments were as follows: 1) 0 – no fertilization; 2) control treatment with mineral NPK fertilization; 3) 1.0 Mg ha^{-1} MBM + K (145 kg K) + N (79 kg of mineral N); 4) 1.5 Mg ha^{-1} MBM + K (145 kg K) + N (40 kg of mineral N); 5) 2.0 Mg ha^{-1} MBM + K (145 kg K) (without mineral N) – Table 1. In the control treatment, the following mineral fertilizers were applied: N – 158, P – 45 and K – 145 kg ha^{-1}. In this treatment, N was applied presowing at 30 kg N ha^{-1} in the form of urea (46% N), P was applied presowing at 45 kg P ha^{-1} in the form of granular triple superphosphate (20.1% P), and K was applied presowing at a total rate of 145 kg K ha^{-1} in the form of two fertilizers, as potassium chloride (49.8% K) and potassium sulfate (41.5% K and 17% S), at 72 and 73 kg K ha^{-1}, respectively. 30 kg S ha^{-1} was applied with potassium sulfate. Nitrogen as ammonium

Table 1

Rates of nitrogen (N), phosphorus (P) and potassium (K) applied with meat and bone meal (MBM) and mineral fertilizers (kg ha^{-1}) to winter rape in 2015-2017

Treatment	2015/2016			2016/2017		
	N	P	K	N	P	K
0 (no fertilization)	0	0	0	0	0	0
Control NPK*	158	45	145	158	45	145
1.0 Mg MBM+K+N_{79}**	$158_{(79+79)}$	45	145	$158_{(79+79)}$	45	145
1.5 Mg MBM+K+N_{40}***	$158_{(118+40)}$	68	145	$158_{(118+40)}$	68	145
2.0 Mg MBM+K****	158	90	145	158	90	145

* NPK – mineral fertilization; ** MBM+K+N_{79} – meat and bone meal with mineral potassium (145 kg K ha^{-1}) and nitrogen (79 kg N ha^{-1}) fertilizers; *** MBM+K+N_{40} – meat and bone meal with mineral potassium (145 kg K ha^{-1}) and nitrogen (40 kg N ha^{-1}) fertilizers; **** MBM+K – meat and bone meal with mineral potassium (145 kg K ha^{-1}) fertilizer.

nitrate (34% N) was top-dressed twice, at 80 kg N ha^{-1} at the beginning of the growing season and at 48 kg N ha^{-1} at the beginning of the bud formation stage. In all treatments, MBM was applied presowing. One megagram of MBM contained 79 kg N and 45 kg P. In treatments No. 3 and 4, apart from MBM, 79 and 40 kg of mineral N (ammonium nitrate 34% N) was applied, which accounted for 50% and 25% of the total N rate (158 kg N ha^{-1}), respectively. In the above treatments, ammonium nitrate was applied at the neginning of the growing season. In all treatments, P was applied presowing solely with MBM (1.0, 1.5 and 2.0 Mg ha^{-1}) at 45, 68 and 90 kg P ha^{-1}. Since MBM had low K content (3.3 kg K per 1.0 Mg), K rate was 145 kg ha^{-1} in all treatments, and it was applied presowing with mineral fertilizers, as in the control treatment.

The MBM used in the experiment contained on average 96.3% dry matter (DM), 710 g organic matter, 280 g crude ash, 137 g crude fat, 78.7 g N, 45.3 g P, 3.32 g K, 100.1 g Ca, 6.8 g Na, and 2.0 g Mg kg^{-1}. The pH in distilled H_2O was 6.3. It was low-risk (category 3) material, purchased from the Animal By-Products Disposal Plant SARIA Poland in Długi Borek near Szczytno.

Winter oilseed rape of the hybrid cultivar SY SAVEO was grown on 20 plots. Plot size was 20 m^2 (4×5 m). The preceding crop was winter wheat. All cultivation and crop protection measures were applied at the optimum time, in accordance with the generally observed standards for winter oilseed rape. Once-over harvest was carried out at the full ripe stage, with a combine harvester. Plant samples (seeds and straw), which had been dried to absolutely dry mass at 105^{o}C, weighted and ground, were then wet mineralized in concentrated sulfuric (VI) acid with hydrogen peroxide (H_2O_2) as the oxidizing agent. Mineralized plant samples were analyzed for the content of total nitrogen – with the sodium hypochlorite reagent (UV-1201 V spectrophotometer, Shimadzu Corporation Kyoto, Japan), phosphorus – by the vanadium-molybdenum method (UV-1201 V spectrophotometer, Shimadzu Corporation Kyoto, Japan), magnesium – by atomic absorption spectrometry, AAS (AAS1, Carl Zeiss Jena, Germany), calcium and potassium – by atomic emission spectroscopy, AES (BWB Technologies UK Ltd.). Nutrient (N, P, K, Ca and Mg) uptake by the aboveground biomass of winter oilseed rape was calculated based on the yield of seeds and straw, and their mineral composition.

Statistical analysis

The experimental data were processed statistically by repeated measures analysis of variance (ANOVA) using Statistica 12 software, where MBM dose was the fixed grouping factor (5 fertilization treatments), and year of the study was the repeated measurement factor (two years). The significance of differences between mean values was estimated by Tukey's test at a significance level of $P < 0.05$.

Table 2

Weather conditions in the growing seasons of 2015-2017 and in the 1981-2010 reference period according to the Agricultural Experiment Station in Tomaszkowo

Month	Average air temperatures (°C)			Total rainfall (mm)		
	2015/2016	2016/2017	1981-2010	2015/2016	2016/2017	1981-2010
August	19.8	17.1	17.9	14.3	70.4	59.4
September	13.5	13.6	12.8	63.8	21.1	56.9
October	6.1	6.1	8.0	19.4	104.3	42.6
November	4.8	2.4	2.9	84.5	84.8	44.8
December	3.4	0.8	-0.9	56.6	41.1	38.2
January	-4.0	-3.4	-2.4	24.7	20.2	36.4
February	2.3	-1.4	-1.7	57.1	47.6	24.2
March	3.0	4.0	1.8	21.6	45.3	32.9
April	7.4	5.7	7.7	28.8	59.1	33.3
May	13.7	12.1	13.5	56.9	25.1	58.5
June	17.1	15.7	16.1	69.3	74.5	80.4
July	18.1	16.8	18.7	130.4	107.6	74.2
Mean/Sum	8.7	7.5	7.9	627.4	700.6	581.8

Weather conditions

The experiment was conducted under adverse weather conditions (Table 2), particularly in the year 2016 when many rapeseed plantations in Poland were closed due to freeze damage. The total area under winter oilseed rape in Poland was 786,000 ha in 2016 and 879,100 ha in 2017 (increase by over 90,000 ha) (Statistics Poland 2016, 2017). In the first growing season (2015/16), winter oilseed rape was sown at the optimum date (26 August 2015). In August and September, mean air temp. was 0.9°C and 0.7°C higher than the long-term average (1981-2010). Precipitation was uneven and differed considerably from the long-term average. Drought persisted in August, which adversely affected seed germination. Precipitation was two-fold lower than the long-term average also in October. November and December were warmer and wetter than the long-term average. The period of winter dormancy in 2015/2016 differed from the long-term pattern, the plants did not go through cold hardening, and January was frosty, with no snow cover. In February and March, air temperatures were substantially higher (mostly above zero), and precipitation in February was over two-fold higher than the long-term average. Under adverse weather conditions, ground frost in spring causes considerable plant losses because the return of a warmer spell increases tissue hydration and leads to dehardening followed by frost damage. Similar observations were made in the present study: mean air temp. in March was 1.2°C higher than the long-term average, but ground frost occurred between 10 and 20 March. In the following months (until harvest), air temperatures were optimal whereas abundant rainfall in July (which exceeded the long-term average 1.8-fold) hindered harvest operations (18 July 2016).

In the second growing season (2016/2017), mean air temperatures were similar to the long-term average, whereas total precipitation levels were considerably higher (by 118.8 mm) than the long-term average of 1981-2010, and unevenly distributed (Table 2). Winter oilseed rape was sown on 25 August 2016. In autumn, a dry spell was noted only in September when precipitation was 2.7-fold lower than the long-term average. In October and November, rainfall substantially exceeded the water needs of plants. In spring, rainfall deficiency (precipitation was 2.3-fold lower than the long-term average) was observed in May, i.e. during flowering and pod setting. Similarly to the first growing season, abundant precipitation in July (rainfall was 1.5-fold higher than the long-term average), hindered harvest which was carried out on 20 July 2017.

RESULTS AND DISCUSSION

The field experiment revealed that changes in the uptake of macronutrients (N, P, K, Ca and Mg) and their concentrations in winter oilseed rape seeds and straw were affected by fertilization and weather conditions (Tables 3, 4 and 5). Over the two-year study, the average N content of oilseed rape seeds ranged from 28.33 g kg^{-1} DM in the unfertilized treatment to 31.61 g kg^{-1} DM in the NPK (control) treatment, which corresponded to 177.1 and 197.6 g kg^{-1} DM total protein, respectively. Similar values were reported by other authors (Krasucki et al. 2001, Jankowski, Sokólski 2018). A statistical analysis of results confirmed that fertilization had a significant

Table 3

Macronutrient content of winter oilseed rape seeds (g kg^{-1} DM)

Mean for treatment		N	P	K	Ca	Mg
0 (no fertilization)		28.33^{a}	8.28^{a}	4.55	1.05	2.78
Control NPK*		31.61^{b}	8.65^{b}	5.06	1.04	2.76
1.0 Mg MBM+ K+N_{79}**		30.25^{ab}	8.68^{b}	4.77	1.01	2.81
1.5 Mg MBM+ K+N_{40}***		28.46^{a}	8.73^{b}	4.71	0.96	2.76
2.0 Mg MBM+K****		29.77^{ab}	8.82^{b}	4.93	0.99	2.83
Annual mean	2016	30.17^{B}	8.79^{B}	4.27^{A}	1.10	3.31^{B}
	2017	29.20^{A}	8.47^{A}	5.33^{B}	0.92	2.27^{A}
Interaction (d×y)		ns	ns	ns	ns	ns

Explanations as in Table 1;
a,*b* – significant differences between means for fertilization (in columns), *A*,*B* – significant differences between means for the years 2016 and 2017 (in columns), according to Tukey's test (P<0.05), Interaction between MBM dose and year (d×y), ns – not significant.

Table 4

Macronutrient content of winter oilseed rape straw (g kg^{-1} DM)

Mean for treatment		N	P	K	Ca	Mg
0 (no fertilization)		4.81^{a}	2.24	4.28	8.00^{a}	1.62
Control NPK*		6.48^{b}	2.23	4.43	9.69^{b}	1.60
1.0 Mg MBM+K+N_{79}**		5.87^{ab}	2.47	4.23	9.74^{b}	1.67
1.5 Mg MBM+K+N_{40}***		5.15^{a}	2.41	4.67	8.08^{a}	1.74
2.0 Mg MBM+K****		6.42^{b}	2.52	4.20	10.58^{b}	1.71
Annual mean	2016	5.47^{A}	2.67^{B}	4.39	10.02^{B}	1.85^{B}
	2017	6.02^{B}	2.08^{A}	4.33	8.41^{A}	1.49^{A}
Interaction (d×y)		s	ns	ns	ns	ns

Explanations as in Table 1 and Table 3; s – significant

Table 5

Macronutrient uptake by winter oilseed rape plants: seeds + straw (kg ha^{-1})

Mean for treatment		N	P	K	Ca	Mg
0 (no fertilization)		56.13^{a}	18.18^{a}	16.31^{a}	18.30^{a}	7.89^{a}
Control NPK*		129.52^{c}	37.06^{b}	34.05^{c}	41.68^{b}	15.38^{c}
1.0 Mg MBM+K+N_{79}**		112.27^{bc}	35.40^{b}	30.97^{c}	41.94^{b}	14.99^{c}
1.5 Mg MBM+K+N_{40}***		102.05^{b}	34.50^{b}	31.33^{c}	33.38^{b}	14.61^{bc}
2.0 Mg MBM+K****		95.70^{b}	30.22^{b}	25.01^{b}	33.76^{b}	12.41^{b}
Annual mean	2016	99.88	32.62^{B}	26.26^{A}	36.80^{B}	15.10^{B}
	2017	98.39	29.73^{A}	28.80^{B}	30.83^{A}	11.02^{A}
Interaction (d×y)		s	ns	ns	ns	s

Explanations as in Table 1 and Table 3; s – significant

effect on the average N content of winter oilseed rape seeds and straw (Tables 3 and 4). In comparison with the NPK treatment, a significant decrease (over 10%) in the N content of seeds was noted in the treatment with 1.5 Mg MBM ha^{-1} + 40 kg of mineral N (25% N from mineral fertilizers and 75% N from MBM) and in the unfertilized treatment (Table 3). The concentration of N in oilseed rape seeds in the remaining two treatments, i.e. 1.0 MBM + 79 kg N ha^{-1} (50% N from mineral fertilizers and 50% N from MBM) and 2.0 MBM ha^{-1} without mineral N, was comparable with that in the control plants. Similar changes in the content of N and Ca were observed in straw (Table 4), which implies that N from MBM is relatively efficiently utilized by winter oilseed rape. According to Jeng et al. (2004), N supplied by MBM meets the N requirements of cereals in 80%, and the remaining 20% should be provided by mineral fertilizers. The present study demonstrated that replacing mineral nitrogen with 50% MBM supplied N to rapeseed in similar amounts to the NPK (control) treatment (Tables 3 and 4). On the other hand, the highest MBM dose (2.0 Mg ha^{-1}) applied without supplemental mineral N resulted in the N content of seeds and straw comparable with that noted in the control treatment. It should be stressed that N rate was 158 kg ha^{-1} in all treatments, and supplemental mineral N accounted for part of the total N rate. Our previous research has shown that lower doses of MBM (below 1.5 Mg ha^{-1}) do not fully meet the N requirements of maize, winter oilseed rape, winter wheat, winter triticale and spring barley (Nogalska et al. 2012, Nogalska, Zalewska 2013, Nogalska et al. 2013, 2014, Nogalska 2016, Nogalska et al. 2017). Stępień and Wojtkowiak (2015) also demonstrated that the concentration of protein in winter oilseed rape seeds and wheat grains increased steadily with increasing doses of MBM. When MBM is applied as a source of N for crop plants, the availability of P to successive crops in the rotation should be monitored (Jeng et al. 2006).

The average P content of winter oilseed rape seeds was high, ranging from 8.28 g kg^{-1} DM in the unfertilized treatment to 8.82 g kg^{-1} DM in the treatment with the highest MBM dose (Table 3). Somewhat higher values were reported by Jankowski and Sokólski (2018) and Szczepaniak et al. (2017), whereas considerably lower P concentrations were noted in other studies (Nogalska, Zalewska 2013). In the present study, winter oilseed rape seeds harvested in fertilized treatments had significantly higher P content than those harvested in the unfertilized treatment. No differences in the P content of seeds were found between mineral fertilization at 45 kg P ha^{-1} and increasing doses of MBM which supplied 45, 68 and 90 kg P ha^{-1}. The P content of oilseed rape seeds increased with increasing P rates and similar results were reported for white mustard (Nogalska et al. 2018). A two-fold increase in P rate (from 45 to 90 kg) had no significant effect on the P content of seeds, which increased by only 1.6%. High rates of P supplied with MBM contribute to its excessive accumulation in the soil (Jeng, Vagstadt 2009). In the current study, the concentrations of the remaining macronutrients (K, Ca and Mg) in winter oilseed rape seeds were not affected by increasing doses of MBM, regardless of supplemental fertilization with mineral N (Table 3).

Weather conditions during the growing season of winter oilseed rape had a significant effect on the macronutrient content of seeds and straw (Tables 2, 3 and 4). In the first year of the study, when mean air temperatures were higher (by 0.7°C) than the long-term average (1981-2010), winter oilseed rape seeds were more abundant in N, P and Mg, and straw was more abundant in P, Ca and Mg than in the second year (statistically significant differences). In the second year of the experiment, characterized by high precipitation levels (118.8 mm higher than the long-term average), seeds had significantly higher K content and straw had significantly higher N content than in the first year. There was a significant fertilization and season interaction for the N content of straw. In the treatments with mineral fertilization and 1.0 Mg MBM + 79 kg N ha^{-1}, the N content of straw was lower in the second year of the study than in the first year, whereas opposite results were noted in the remaining three treatments. A similar interaction was observed for N uptake by the aboveground biomass of winter oilseed rape.

Nutrient uptake by crop plants is one of the key criteria for fertilizer evaluation, and it is estimated based on the produced biomass and the content of the analyzed nutrients in biomass. In the present experiment, the uptake of all nutrients was approximately two-fold higher in fertilized treatments than in the unfertilized treatment (Table 5). The significantly highest N uptake by the aboveground biomass of winter oilseed rape was noted in the control treatment (129 kg N ha^{-1}) and in the treatment with 1.0 Mg MBM + 79 kg N (112 kg N ha^{-1}). The uptake of N, K and Mg was lowest in the treatment with the highest MBM dose (2.0 Mg ha^{-1}) applied without supplemental mineral N. The noted differences were statistically significant relative to the control treatment. No significant differences were found in the uptake of N, P and Ca between MBM treatments, regardless of supplemental fertilization with mineral N. Significantly lower P uptake by winter oilseed rape in MBM treatments, compared with mineral fertilization treatments, was also reported by Nogalska and Zalewska (2013). In contrast, Brod et al. (2012) found no significant differences in P uptake by grasses in treatments with MBM and mineral fertilizers. In a study by Jeng et al. (2004), an increase in the rate of N supplied by MBM, from 60 to 180 kg, increased N uptake by spring barley 3.8-fold. However, the noted increase was significantly lower than that induced by similar rates of mineral N. Nogalska et al. (2013) demonstrated that cereal crops intensively fertilized with MBM accumulated significantly more N relative to the treatment fertilized with mineral N.

Significant differences in nutrient uptake were observed between the growing seasons of winter oilseed rape (Table 5). In the first year of the study, the uptake of P, Ca and Mg was significantly higher due to higher yields. In the second year, higher K uptake resulted from the higher K content of seeds (Table 3). There was also a significant interaction between fertilization and season for the uptake of N and Mg by the aboveground biomass of winter oilseed rape (Table 5). In an earlier study by Nogalska (2016), the uptake of N and P by spring barley varied significantly across years. In the second year of the experiment, N uptake by spring barley was significantly higher due to higher yields and greater N abundance in plants, whereas increased P uptake resulted from greater biomass.

CONCLUSIONS

1. The field experiment revealed that changes in the uptake of macronutrients (N, P, K, Ca and Mg) and their concentrations in winter oilseed rape seeds and straw were affected by fertilization and weather conditions.

2. Macronutrient (N, P, Ca and Mg) uptake by plants was highest in the treatment with the lowest MBM dose (1.0 Mg MBM ha^{-1}) supplemented with 79 kg mineral N (50% N from mineral fertilizer and 50% N from MBM). Meat and bone meal applied at 1.0 Mg ha^{-1} meets the P and N requirements of winter oilseed rape in 100% and 50%, respectively. Therefore, the recommended mineral N fertilizer rate for winter oilseed rape can be reduced by 50%.

3. Meat and bone meal doses should be adjusted to the nutrient requirements of crop species. Supplemental mineral N should also be applied to widen the narrow N/P ratio in MBM.

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