Intensification methods effect on carbon stock of spring rape plant matter

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Abstract. The authors study influence of foliar liquid top dressing and growth stimulants on carbon stocks formation of spring rape plant matter. A significant increase in carbon stocks of phytomass and rapeseed roots with the simultaneous use of Reggy preparations (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha) was shown, the increase in relation to the control was 63.2%. Methods of intensification did not significantly affect the carbon stocks of underground mortar mass.

1. Introduction
Modern agricultural production intensification means make it possible to have high-quality and stable crops even in adverse edaphoclimatic conditions. This is especially important for oilseed cabbage crops, such as spring rape (*Brassica napus oleifera annua, Metzd.*), which is quite demanding on the level of soil fertility, clean crops and weather conditions [1]. In this regard, it is proposed to use a number of nonroot liquid fertilizers, herbicides, fungicides and growth stimulators to cultivate spring rape, which increase the number of productive shoots and seed quality, prevent crops lodging, and increase resistance to diseases and pests [2,3,4]. Along with the growth of crop productivity, the stock of plant residues in soils increases. The replenishment of agricultural soils with plant matter makes a significant contribution to the formation of effective fertility, since the mortar mass is the closest source of easily mineralizable organic matter [5]. The purpose of our research is to establish the effect of foliar top dressing and growth regulators on the formation of carbon stocks of spring rape plant matter.

2. Research conditions and targets
The research was conducted in 2019 at the experimental production farm “Solyanskoye, LLC” on the territory of the Kansk forest-steppe. This territory is characterized by a sharply continental climate with 360-450 mm of rainfall annually, the average annual air temperature ranges from -0.3 °C to -1.7 °C, the soil freezes to a depth of 1.5-3.0 m, and duration of biological activity period varies between 84-115 days. The sum of active temperatures is 1561-1818 °С [6]. The hydrothermal conditions of vegetation at the experimental production farm “Solyanskoye, LLC” in the year of the experiment were favorable for spring rape. The conditions of the growing season in 2019 were characterized as warm and humid. At the beginning of the growing season in May, there was a deficit of precipitation (52.2% of the norm) during warm weather (hydrothermal index = 0.5), however, by the appearance of rape seedlings, the
amount of precipitation increased sharply, overall the hydrothermal index of the summer months amounted to 1.1-1.2.

Soils: a complex of typical clayey-illuvial agrochernozems and clay-illuvial podzolized agrochernozems of medium and powerful types of medium- and heavy-loamy varieties, which were characterized by a high humus content (6-9%), a high amount of exchange bases (51-64 mmol·100 g⁻¹), neutral and slightly alkaline reaction of the medium (pH 6.5-7.3), low availability of nitrate nitrogen (6-8 mg·kg⁻¹), very high – mobile phosphorus (307 mg·kg⁻¹), medium – exchangeable potassium (59-66 mg·kg⁻¹) [7].

Experimental crop: a hybrid of spring rape Contra KL, the precursor is a pea-oat mixture. The plot area is 5 hectares, the accounting area is 10 m² with fourfold repetition. The main tillage for spring rape cultivation was autumn plowing with a PSKU-8 plow, early spring harrowing, and pre-sowing cultivation. Rapeseed was sown in the second decade of May. When rapeseed was cultivated on oilseeds during the budding stage (late June – early July) against plant protection products (herbicides: Hacker + Miura and insecticides: Beyk + Tabu Neo), growth stimulants and liquid top dressing were used according to the following experimental scheme: 1. Control; 2. Ultramag Combi (2l/ha) + Reggy (1.2 l/ha); 3. Ultramag Combi (2 l/ha); 4. Beres-8 (0.2 l/ha) + Ultramag Combi (2l/ha); 5. Beres-8 (0.2 l/ha); 6. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha); 7. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha); 8. Reggy (1.2 l/ha).

3. Research methods
The aboveground and underground plant matter was taken into account after foliar treatment with growth stimulants and top dressing in the following growth and development phases of spring rape: flowering – fructification (July 18, 2019), ripening of fruits and seeds (August 29, 2019), after harvesting (October 2, 2019). Accounting for aboveground plant matter was performed by the method of mowing. The aboveground biomass was fractionated into crop phytomass, weed phytomass, and aboveground mortmass. The underground plant matter was taken into account simultaneously with the aboveground method of monoliths to a depth of 0-20 and 20-40 cm. The monoliths were washed from the soil in running water on a sieve with a mesh diameter of 0.25 mm. The underground plant matter was disassembled into fractions of roots, coarse mortmass > 0.5 mm and shallow mortmass < 0.5 mm. The carbon content in the plant matter was determined by the Anstet method, the nitrogen content in the plant matter was determined according to Kjeldahl on a UDK-159 analyzer [8].

4. Findings
By July and August, carbon reserves concentrated in the crop phytomass prevailed in the structure of the aboveground plant matter (figure 1). Two-way analysis of variance of the data showed a significant effect (p-value <0.05) on the formation of phytomass of spring rape during the growing season and the experimental variant, the strength of influence indicator of the factor was 88.7% and 9.3%, respectively. In July, we observed a marked increase in carbon stocks of phytomass in the experimental versions: 4. Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha); 6. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha); 8. Reggy (1.2 l/ha). By the time of ripening of fruits and seeds, a significant increase in phytomass reserves was found in the versions 4. Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha); 7. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha); 8. Reggy (1.2 l/ha). Thus, the combined use of Beres-8 and Ultramag Combi, as well as Reggy, leads to significant and stable over time increase in carbon stocks of spring rape phytomass by an average of 14.8% of control.
Figure 1. The dynamics of carbon stocks of aboveground plant matter, tC·ha⁻¹.

The weed phytomass stocks had no significant differences either in terms of vegetation or in the experiment options and averaged 0.07 to 0.64 tC·ha⁻¹. Some of the phytomass stocks are alienated from the seed crop, but most of it is crushed and remains on the surface, after which significant stocks of mortmass remain in the aboveground part of the agrocenosis. The carbon reserves concentrated in the aboveground mortmass in July and August were insignificant and ranged from 0.04 to 0.12 tC·ha⁻¹, however, after harvesting, the carbon reserves of the aboveground mortmass significantly increased in all experiment variants. The highest carbon stock of aboveground mortmass after harvesting rapeseed was formed where there were maximum phytomass reserves in options 4. Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha) and 8. Reggy (1.2 l/ha).

Underground plant matter is represented by roots, large (> 0.5 mm) and small (<0.5 mm) mortmass (figure 2). Separation of mortmass into fractions makes it possible to isolate the reserves of labile organic matter, which is represented by small, partially humified plant residues and microbial biomass.

Since rapeseed roots penetrate to a sufficiently large depth and at the same time develop a network of lateral and shallow roots, the reserves of underground plant matter were studied in layers 0-20 and 20-40 cm. As well as the reserves of aboveground phytomass and roots gradually increase as the crop grows. The maximum reserves of carbon concentrated in the roots of rapeseed were formed by August and ranged from 0.5 to 2.3 tC·ha⁻¹ in the layer of 0-20 cm and from 0.24 to 1.51 tC·ha⁻¹ in the layer of 20-40 cm. At this time, 65.2% of the root carbon reserves were concentrated in a soil layer of 0-20 cm. The ratio of aboveground phytomass to roots in the 0-40 cm layer was 2.9 in August. After harvesting, the roots reserves in the 0–20 cm layer decreased insignificantly and ranged from 0.55 to 1.44 tC·ha⁻¹, and in the 20–40 cm layer there was a noticeable reduction in the carbon stock of roots on average to 0.08 tC·ha⁻¹. Thus, the proportion of roots in the 0-20 cm layer of the harvesting field was 91.4%. In all the accounting periods, the largest part of the roots is concentrated in the layer of 0-20 cm, which becomes especially noticeable after rape harvesting.
Figure 2. The dynamics of carbon stocks of underground plant matter, tC·ha⁻¹.
Analysis of the data by variance showed that the vegetation period (strength of influence indicator = 50.2%) and the depth of the soil layer (strength of influence indicator = 72.1%) have a significant effect on the carbon stocks of the roots. The intensification mean effect on the carbon stocks of the roots was proved (p-value = 0.02), but weaker, the strength of influence indicator of the factor “experiment option” was 8.6%. In August, in the 0-20 cm layer, a significant predominance of the root carbon stocks was found in the version 3. Ultramag Combi (2 l/ha) and in the version 6. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha); in the 20-40 cm layer, the root carbon stocks were significantly higher only in the version 6. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha). At the end of the growing season after harvesting, the maximum carbon reserves of the roots in the 0-20 cm layer were in the version 3. Ultramag Combi (2 l/ha) and 4. Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha); in the 20-40 cm layer, no significant differences in the roots carbon stocks were found for the experimental versions. Thus, the use of Ultramag Combi at a dose of 2 l/ha and with the combination of Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha) led to an increase in carbon roots reserves in the 0-20 cm layer at 1.65 and 0.94 tC∙ha⁻¹ with respect to the control, where the carbon reserves were 0.65 tC∙ha⁻¹.

In general, if we consider the total carbon stocks of living biomass during the seed ripening period in August, we received the largest increase with respect to the control in the version 3. Ultramag Combi at a dose of 2 l/ha by 47.4%, mainly due to the roots’ growths and in the version 6. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha) by 63.2% due to both phytomass and roots’ growth. The carbon stocks of large and small mortmass did not have significant differences in the experimental versions, however, the growing season and depth had a significant effect. Thus, the stocks of large mortmass in the 0–40 cm layer in July and August averaged 2.83 and 2.32 tC∙ha⁻¹, respectively, and after harvesting they decreased to 0.15 tC∙ha⁻¹. The carbon stocks of small mortmass (labile organic matter) in July and August averaged 0.93 and 0.78 tC∙ha⁻¹, after harvesting 0.05 tC∙ha⁻¹, respectively. Thus, the strength of influence indicator of the factor “vegetation period” was at the level of 75.4-82.6%. In July and August, 1.89 tC∙ha⁻¹ of large plant residues and 0.53 tC∙ha⁻¹ of small mortmass are concentrated in the soil layer of 0-20 cm, and 0.68 tC∙ha⁻¹ and 0.33 tC∙ha⁻¹ in the layer of 20-40 cm, respectively. The strength of influence indicator of the factor “soil layer depth” was 81.9-76.0%. No influence of the experimental versions on the underground mortmass stocks is explained by the fact that the dead aboveground organs of rape and its roots have not yet had time to transfer to its composition. The pool of underground mortmass in July and August was formed by the predecessor – pea-oat mixture and by October this stock was almost completely used up in decomposition processes. It is possible that the used intensification methods did not significantly affect the biological activity of soils, and the processes of plant residues transformation were quite active and without regard to the use of foliar top dressing and plant growth regulators. It is known that the chemical composition, namely, the C/N ratio, has a significant effect on the processes of plant matter transformation [9]. As our studies showed (table 1), the narrowest ratio was in the large and small mortmass and averaged 15.8-24.5.

| Statistic parameter | Rape phytomass | Weed phytomass | Aboveground mortmass | Roots | Large mortmass | Small mortmass |
|---------------------|----------------|---------------|----------------------|-------|----------------|----------------|
| July                |                |               |                      |       |                |                |
| X±Sx               | 24.8±2.7       | 16.9±1.8      | 23.8±9.0             | 93.3±19.6 | 22.0±7.9       | 21.8±12.6       |
| Cv, %              | 10.8           | 10.4          | 27.5                 | 21.8   | 36.0           | 57.7           |
| August              |                |               |                      |       |                |                |
| X±Sx               | 30.6±2.6       | 21.3±2.7      | 36.4±7.2             | 101.3±20.3 | 17.7±3.6       | 15.8±1.8       |
| Cv, %              | 8.6            | 12.9          | 19.8                 | 25.2   | 20.2           | 11.6           |
| October             |                |               |                      |       |                |                |
| X±Sx               | -              | -             | 67.2±12.5            | 98.5±21.0 | 24.5±6.1       | 17.7±2.9       |
| Cv, %              | -              | -             | 18.6                | 21.4   | 24.7           | 16.3           |

* X – avg, Sx – error of avg, Cv, % – variation index.
A wider C/N ratio was in the above ground mortmass formed by rape residues and in rape phytomass, it varied from 23.8 to 67.2 and increased with the crop growth due to the carbon assimilation. The widest C/N ratio was in the race roots – 93.3-101.3. Thus, the underground mortmass formed by the previous crop residues (pea-oat mix) had a narrow C/N ratio and almost completely decomposed during the growing season, the rape residues had a much wider C/N ratio and accumulated after harvesting in the form of above ground mortmass and roots.

5. Conclusion
The foliar liquid top dressing and plant growth regulators had a significant impact on formation of carbon stocks of phytomass and spring rape roots. By the time of harvesting, an increase in carbon stocks concentrated in the phytomass was found in the following versions: 4. Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha); 7. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha); 8. Reggy (1.2 l/ha), the increase in relation to control was an average of 14.8%. In the same versions, the carbon reserves of the aboveground mortmass were also maximum. The increase in carbon stocks concentrated in the roots occurred in the following versions: 3. Ultramag Combi (2 l/ha) and 6. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha), the increase in relation to control was 253.8 and 58.4%, respectively. In general, the largest stocks of both phytomass and roots were in the version 6. Reggy (1.2 l/ha) + Beres-8 (0.2 l/ha) + Ultramag Combi (2 l/ha), where the increase in relation to control amounted to 63.2%. The intensification methods did not have a significant effect on the carbon stocks of underground mortmass; the dynamics of these fractions depended on the growing season, the depth of the soil layer, and the C/N ratio in the plant matter.

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