INFLUENCE OF TRACTOR BALANCE AT FERTILIZER SPREADING ON WINTER WHEAT YIELD

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Abstract. The rigorous implementation of the European Green Deal, which calls for suitable fertilizer usage, requires attention to technical solutions and accordance. This study was aimed to improve the efficient usage of fertilizers depending on machinery adjustment using the front ballast with a possibility to change its forward distance. The mass of the suspended spreader varies from maximum when it is full of fertilizers to a minimum when it is empty. Variable spreader load unavoidably changes deformations of front and rear tires, which affects the front and rear axis height and tilt angle, and brings trouble, especially during crop fertilizing. Such repetitive uneven crop fertilization arises influence on the crop vegetation and yield. The results of two-year research showed how much winter wheat responds to the unevenly position of the tractor and suspended spreader. The data of biomass and grain yield were collected from 27 variants: when the spreader was full, half full and empty; when the front ballast of the tractor was maximal, middle, and minimal. The biomass of winter wheat was measured three times during vegetation, and cereal fields were harvested on 8 August 2020, and 26 July 2021. Results reveal that the average aboveground biomass of the winter wheat per square meter was lower in the edge plots. The inner and middle plots had 3.8 and 9.1% higher biomass than at edges, at full spreader and lowest ballast. The average underground mass of the winter wheat at the inner and middle plots was 2.5 and 4.2% higher than in the edge plots, where was the greatest fertility inequality. Grain yield was greater in plots where more fertilizer fell, at the inner and middle plots the yield higher by 3.2 and 7.5%, respectively, compared with the edge plots when the spreader was full, and the ballast was lowest. But there were no significant differences between the yield options, when the spreader was half empty and empty at maximal ballast mass.

Keywords: fertilizer spreading, yield uniformity, variable load, ballast mass.

Introduction

The suitable fertilizer usage requires attention to economic and environmental consequences [1]. Centrifugal spreaders with double rotating discs are usually used to keep the correct fertilizer rates [2]. When the quantity of nitrogen fertilizer is too much than the plants can take, some amount of the nitrogen can penetrate to the deeper soil layers and cause water contamination, and when the quantity of fertilizer is too little, it has an undesirable effect on the plant productivity [3]. Most uneven spreading of fertilizer application is obtained on longitudinal soil slopes [4]. When the ballast mass of the tractor is too low compared to the load, it causes mass disbalance [5]. There is a lot of research on the problem of accurate fertilization [6,7]. The mass of the suspended sprayer changes from maximum when it is full of fertilizers to minimum when it is empty. Variable load of tractor brings unavoidably changing deformations of front and rear tires, which affects the front and rear axis height and tilt angle and brings harmful over-fertilization effect [8]. Every time as we come to the field with a full spreader to fertilize, and especially at the beginning of the field, such inequalities in the color and size of the plants become apparent. Repetitive uneven crop fertilization influences the crop productivity and yield. To avoid uneven crop fertilization the front ballast weight should be changed if the suspended rear load is changed [9]. The special front ballast positioning system was made and investigated for solving such mass transfer.

This study was aimed to improve the usage of fertilizers depending on machinery adjustment using the front ballast with a possibility to change its forward distance. The task of the research was to evaluate the crop biomass yield and crop grain yield using the ballast positioning system.

Materials and methods

Field experiments were conducted at the Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2020 and 2021. According to FAO classification, the soil of the experimental site is Endocalcari Endohypogleyic Cambisol (CMg-n-w-can). Topsoil (0-25 cm) texture – clay loam. The results of two-year research showed how much the winter wheat yield responds to the unevenly tilt angle of the tractor and suspended spreader. Weed control, diseases and pest management were carried out in accordance with the crop development as required impact not assessed.

The investigative tractor "Ford 8340" and fertilizer spreader "Bogballe EX Trend" were used in this research (Figure 1). The main data of the experimental tractor are given in Table 1. The tire inflation pressure value was 23 psi according to the tire load and tire data sheet chart. The changing load of the suspended spreader makes significant weight transfer (ΔL_W) of the tractor. Weight transfer changes the height of the tractor axles R_f and R_r because of tire deformations Δ_{front} Δ_{rear}; the load of the suspended spreader tilts the tractor at some angle, thus spreading of fertilizers becomes inappropriate [10]. The ballast positioning system was made to compensate the tractor tilting (Figure 2).

Fig. 1. **Equipment at field test**

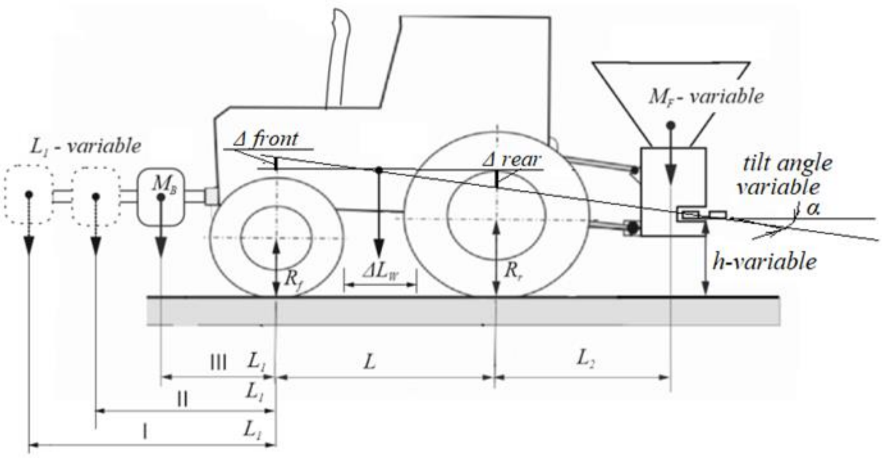

Fig 2. **Principal scheme of ballast positioning system**

The dependence of the forward distance of the ballast (L_1) on the spreader weight (M_F), when there is no weight transfer:

$$L_1 = \frac{M_B \cdot L_2}{M_F}, \quad (1)$$

where M_B – ballast mass;
L_2 – distance of the spreader mass point;
M_F – mass of the spreader.

Table 1

Tractor and spreader parameters

Parameter	Value
Mass of the tractor	5566.7 kg
Front tires	Petlas 440/65 R24
Rear tires	Alliance 18.6 R38
Wheelbase	2.6 m
Hitch point from the rear axle	1.7 m
Mass of spreader "Bogballe"	361.3 kg

Fertilization of ammonium nitrate (N) was performed three times during vegetation every year: 200 kg·ha^{-1}, 150 kg·ha^{-1}; 100 kg·ha^{-1}, it was the whole amount of N153. The marked tramline places were fertilized with a full, half full and empty spreader; when the front ballast of the tractor was maximal, middle, and minimal distance. To achieve the desired level of fertilizer in the spreader, it was spread elsewhere in the field. After fertilizing the marked test variant, the ballast was moved in each pass. Grain yield was harvested with a special combine harvester Sampo 500. The two-year data of crop biomass yield and grain yield was collected from each variant (Figure 3).

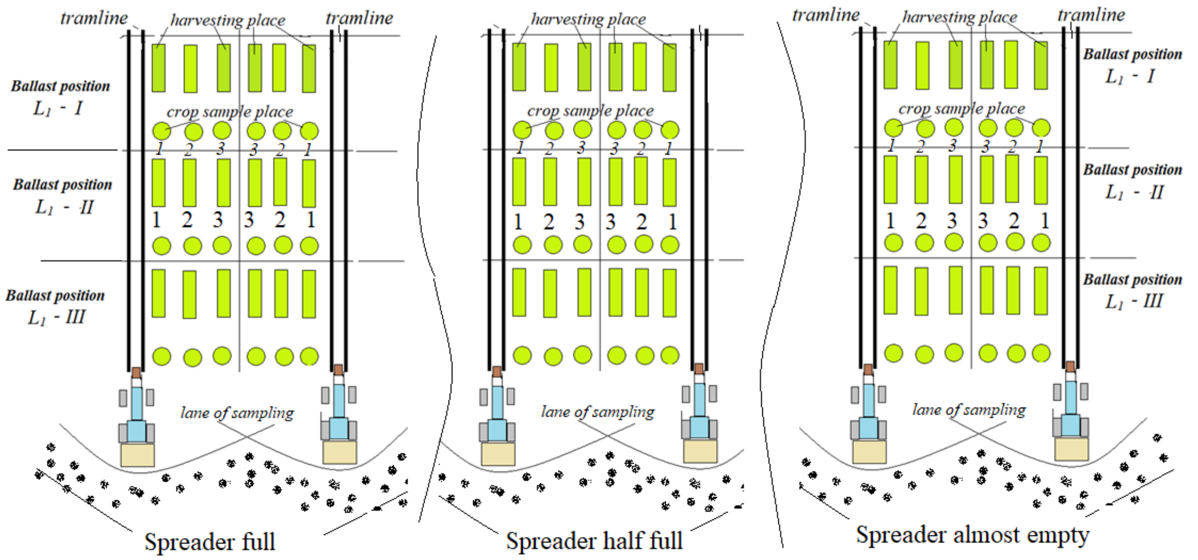

Fig 3. **Field scheme of crop sampling and harvesting place**

Fig. 4. **Crop samples at different growth stages**

The biomass of winter wheat was divided into aboveground and underground because at later growth stages it is difficult to dig all of plant roots – only aboveground biomass was collected and compared. The underground biomass was compared to each other only in early growth stages. The aboveground and underground mass was determined from three wheat rows of 50 cm length from each variant plot with three replications for measurement accuracy. The biomass of winter wheat was measured three times during vegetation, in middle (M3), inner (M2) and edge (M1) plots of crop samples (Figure 4). The biomass of winter wheat was different each time and is not provided here. More fertilized plants grew more biomass, compared to low-fertilized plants, regardless of the plant growth period, the plant biomass ratios were similar at each measurement. The biomass yield divergence between plants was calculated as a ratio of biomass in the middle to edge plots, and inner to edge plots of tramline. The ratios were marked as M3/M1, M2/M1. Crops were harvested on 8 August 2020, and 26 July 2021, the grain yield was expressed at 14% moisture content (Figure 5).

Fig. 5. **Crop grain yield harvesting places and weighting**

Results and discussion

The crop highest productivity reliance is due to favourable moisture conditions during the whole growing period and resulted from the nitrogen (N) fertilization level. In the study of Pecio (2010), it was found that thw grain yield increased with increasing N rates up to N90-N120 [11]. The yield enlargement effect of N was found in the studies of many authors [12,13]. Mut et al. (2005) concluded that N rates should be between N120-N180 [14].

The data of the research showed that the plant biomass and grain yield of winter wheat responds to the uneven position of the tractor and suspended spreader. The results reveal that the biomass of winter wheat per square meter was lower in the edge plots than in the inner plots. The inner and middle sample plots had 3.8 and 9.1% higher aboveground biomass than at the edge, at a full spreader and the lowest ballast distance (Table 2).

Table 2

Biomass ratio of winter wheat at various ballast positions

Ballast position L_1	Winter wheat	Mass ratio when spreader almost empty		Mass ratio when spreader half full		Mass ratio when spreader full	
		M2/M1	M3/M1	M2/M1	M3/M1	M2/M1	M3/M1
I	aboveground	0.980	0.970	1.002	1.015	1.024	1.061
	underground	0.990	0.980	1.003	1.004	1.016	1.027
II	aboveground	0.987	0.985	1.009	1.031	1.031	1.076
	underground	0.994	0.988	1.008	1.011	1.021	1.034
III	aboveground	0.995	1.000	1.016	1.046	1.038	1.091
	underground	0.999	0.996	1.012	1.019	1.025	1.042

Note: M1, M2, M3 –biomass of winter wheat

The underground mass of the winter wheat at the inner and middle plots was 2.5 and 4.2% higher than in the edge plots, at a full spreader and the lowest ballast distance.

Grain yield was greater in the plots where more fertilizer fell, at the inner and middle plots the yield was higher by 3.2 and 7.5%, respectively, compared with the edge plots when the spreader was full, and the ballast was at the lowest distance (Table 3).

Table 3

Grain yield ratio of winter wheat at various ballast positions

Ballast position L_1	**Grain yield ratio when spreader almost empty**		**Grain yield ratio when spreader half full**		**Grain yield ratio when spreader full**	
	G2/G1	G3/G1	G2/G1	G3/G1	G2/G1	G3/G1
I	0.995	0.987	1.009	1.020	1.023	1.053
II	1.000	0.998	1.014	1.031	1.027	1.064
III	1.004	1.009	1.018	1.042	1.032	1.075

Note: G1, G2, G3 – grain yield mass.

The results show that there are no significant grain yield mass differences between the options when the spreader was half full and empty, differing the ballast distance. The research determined that the front ballast positioning system can adjust the yield uniformity.

Conclusions

1. The results reveal that uneven fertilization of winter wheat going repeatedly increases the influence on the crop biomass and the grain yield. The inner and middle plots had 3.8 and 9.1% higher aboveground mass than at the edge plots, fertilizing with the lowest ballast distance or without the tractor balance system. The maximum inequality of underground mass at the inner and middle plots was 2.5 and 4.2% higher than in the edge plots. From the results it is concluded that the tractor balance system can increase the biomass yield uniformity by 3%.
2. The obtained results suggest that the tractor balance system increases the grain yield uniformity by 2,3% compared with the edge plots when the spreader was full and the ballast distance was lowest. The tractor balance system is most effective when the spreader is full.
3. For further research, in case when the tire deformation changes their rolling radius and fertilization travel speed, it is advisable to test according to tire deformation to evaluate the speed decrease. The best way to uniform the yield is to use trailed spreaders or belted tractors.

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Author contributions

Conceptualization, V.D.; methodology, V.D. and A.J.; investigation, V.D.; writing—review and editing, A.J. and V.D. All authors have read and agreed to the published version of the manuscript.

References

[1] Connor D. J., InésMínguez M. Evolution not revolution of farming systems will best feed and green the world. Global Food Security 1(2), 2012, pp. 106-113
[2] Kweon G., Grift T. E. Feed gate adaptation of a spinner spreader for uniformity control. Biosystems Engineering. 95(1) 2006, pp.19-34.
[3] Martínez-Dalmau, J.; Berbel, J.; Ordóñez-Fernández, R. Nitrogen Fertilization. A Review of the Risks Associated with the Inefficiency of Its Use and Policy Responses. Sustainability 2021, 13, 5625.

[4] Abbou-Ou-Cherifa E-M., Pirona E., Chateauneuf A., Micleta D., Villette S. On-the-field simulation of fertilizer spreading: Part 3 – Control of disk inclination for uniform application on undulating fields. Computers and Electronics in Agriculture 158, 2019, pp. 150-158.
[5] Zoz F. M., Grisso R. D. Traction and Tractor Performance. Transactions of the ASAE, Lecture Nr 27, 2003, pp. 1-44.
[6] Søgaard H. T., Kierkegaard P. Yield reduction resulting from uneven fertilizer distribution. Transactions of the ASAE. 37(6), 1994, pp. 1749-1752. (DOI: 10.13031/2013.28262)
[7] Khudher A. Y., Himoud M.S., Almaliki S. A. Modulating a centrifuge spreader disc and evaluating performance under some different operating factors. International Journal of Agricultural and Statistical Sciences. 2020, https://connectjournals.com/03899.2020.16.1799
[8] Damanauskas V. Influence of adjustable front ballast on tractor axles balance. Engineering for rural development. Jelgava, 2020, pp. 672-678
[9] Varani M., Mattetti M., Maraldi M., Molari G. Mechanical Devices for Mass Distribution Adjustment: Are They Really Convenient? Agronomy 2020, 10, 1820. DOI: 10.3390/agronomy10111820
[10] ASAE S341.2. Procedure for measuring distribution uniform and calibrating granular broadcast spreaders.
[11] Pecio A.. Productivity of triticale affected by nitrogen fertilization and weather conditions. Fertilizer and Fertilization, 40, 2010, pp. 101-116
[12] Sekeroglu N., Yilmaz N. Effects on increasing nitrogen doses on yield and yield components in some triticale lines under dry conditions in Eastern Anatolia. Pakistan Journal of Biological Sciences, 4 (6), 2001, pp. 672-673. DOI: 10.3923/pjbs.2001.672.673
[13] Gibson L. R., Nance C. D., Karlen D. L. Winter triticale response to nitrogen fertilization when grown after corn or soybean. Agronomy Journal, 99, 2007, pp. 49-58 DOI: 10.2134/agronj2006.0195
[14] Mut Z., Sezer I., Gülümser A. Effect of different sowing rates and nitrogen levels on grain yield, yield components and some quality traits of triticale. Asian Journal of Plant Sciences, 4 (5), 2005, pp. 533-539 DOI: 10.3923/ajps.2005.533.539