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EXPERIMENTAL RESEARCH FOR THE PROMOTION OF TECHNICAL EQUIPMENT FOR CLEARING MOUNDS AND FERTILIZING SOILS OCCUPIED BY GRASSLANDS

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Abstract

Depending on pedoclimatic and operational conditions, different situations may arise regarding the coverage of soils occupied by grasslands with mounds, stones, low-value vegetation, manure, etc. Based on the degree of coverage with mounds, low-value herbaceous and woody vegetation, manure, etc. and the size of these elements, different technological variants are selected for mechanizing the operations of clearing mounds, removing manure, leveling micro-relief, aerating, and fertilizing the soils occupied by grasslands. This paper presents the results of experimental research conducted under operational conditions of technical equipment designed for clearing mounds and fertilizing grassland soils. The experimental results obtained in this study are used to optimize the working process, aiming to surpass the performance of existing equipment in the same category. The goal is to provide farmers with access to technical equipment that meets the requirements for adapting techniques and technologies for the rational utilization of grasslands in the context of global and regional climate change.

Key words: *clearing weeds, fertilizing soils, grasslands.*

INTRODUCTION

Grasslands represent one of Earth's dominant biomes, covering approximately 30-40% of the terrestrial surface. They are essential for global ecological balance as they are characterized by the predominant presence of grasses, other herbaceous plants, various assemblages of other plant life forms, and diverse animal communities that contribute to biodiversity (Petermann & Buzhdygan, 2021).

Due to inefficient management, whether through overgrazing, intensive agriculture, or abandonment, grassland ecosystems are under enormous pressure, threatening biodiversity (Prangel et al., 2023).

Being among the most vulnerable ecosystems to climate change and human interventions, grasslands pose substantial political challenges in maintaining ecological balance at a global level (Zhang et al., 2024).

In Europe, natural grasslands, which cover limited areas and are increasingly fragmented, face unique conservation challenges due to agricultural development, urbanization, and anthropogenic climate change (Shipley et al., 2024).

The differentiated application of improvement measures for permanent grasslands requires a detailed understanding of vegetation characteristics, site conditions (soil, climate, relief factors), and land use practices (grazing, mowing, etc.), enabling sustainable management that increases productivity without compromising biodiversity (Liu & Li, 2023).

For example, fertilization increases the abundance of plant species with high average productivity indicator values and raises the average values of moisture indicators (Boch et al., 2021).

Additionally, through the application of mineral and organic fertilization, subalpine grasslands dominated by *Nardus stricta* can be improved, while the evaluation of green fodder mass production and pastoral value can be conducted based on floristic surveys, followed by the application of the forage-to-milk conversion coefficient (Marușca, 2024).

An essential role, regardless of the practice used for improving permanent grasslands, is played

by grazing, which can have numerous positive effects on biodiversity if carried out properly and sustainably. It contributes to maintaining and even enhancing species diversity among plants and animals, positively influencing grassland ecosystems (Janišová et al., 2023).
Another crucial factor in increasing productivity and improving the efficiency of grasslands is the type of fertilization equipment used.
The application of fertilizers (organic or mineral) through uniform distribution - avoiding over-fertilization in certain areas and under-fertilization in others - using modern equipment stimulates biomass growth and improves forage quality (Mocanu et al., 2021).
The growing need to produce more food for an increasing population has led to the intensive use of grasslands, negatively affecting soil quality, biodiversity, and long-term productivity.
The solution does not lie in excessive exploitation, but rather in sustainable management through modern technologies to maintain a balance between production and ecosystem conservation (Wang et al., 2023).
The Research - Development Institute for Grasslands Brașov (ICDP Brașov), which coordinates the project "*ADER 15.3.2 - Research on the development and promotion of mechanization technologies for the reconstruction, maintenance of permanent grasslands, environmental protection, and biodiversity conservation using new specialized equipment*", has carried out, within the stage "*Identifying solutions to reduce or eliminate degradation factors in locations with a high degree of zonal extrapolation*", an experimental field test in collaboration with the National Institute of Research - Development for Machines and Installations for Agriculture and Food Industry (INMA Bucharest).
This test involved a prototype grassland planer in aggregate with fertilization equipment (during the autumn season), aiming to optimize the work process and surpass the performance of existing technologies.

MATERIALS AND METHODS

At ICDP Brașov, a grassland maintenance technology has been developed, consisting of operations such as clearing mounds and low-value vegetation, fertilization during the years of exploitation, and cleaning residual plant debris left after grazing (Mocanu et al., 2024).
During experiments aimed at determining energy efficiency indices under operational conditions, a New Holland TL 100A tractor - an existing piece of equipment at ICDP Brașov - was used, coupled with the grassland planer experimental model in aggregate with the fertilization equipment for field testing (Figure 1).

Figure 1. Grassland planer experimental model in aggregate with the fertilization equipment

The experimental model is a modular agricultural implement consisting of a fertilization unit mounted directly onto a grassland clearing planer.
The fertilization equipment comprises the following main components: assembled frame, fertilizer boxes, mechanism for transmitting movement to the dosing devices and agitator drive shaft.
The grassland clearing planer consists of the following main subassemblies: frame with a three-point hitch for tractor attachment and working units composed of two U-profile skid rails, connected by two transverse profiles, two rows of adjustable vertical chisel-type knives for varying cutting depth and two rows of inclined horizontal knives, mounted behind the chisel knives, positioned in two different planes with opposing inclinations.
During the operation of the aggregate, consisting of the fertilization equipment mounted on the grassland planer, the pivoting drive wheel, which is kept in contact with the ground by an adjustable spring, transmits rotational motion through a chain transmission, two equal bevel gear transmissions, and a coupling bushing to the Norton-type gearbox. This gearbox allows for multiple speed selections of the main shaft through a stepped gear set, enabling the adjustment of the desired

fertilizer application rate and transmitting motion to the distributors, ensuring precise dosing and uniform spreading of the fertilizers across the field surface.
Subsequently, the grassland planer begins its operation, with the vertical chisel-type knives fragmenting mounds, uneven surfaces, and manure in a vertical-longitudinal plane, while the inclined horizontal knives cut and evenly spread the fragments over the soil. This process creates optimal conditions for their assimilation by plant roots.
The pivoting drive wheel allows for motion transmission even when the implement is moving along a curve, with a steering angle (tilt) of up to 35° to the left or right. This angle exceeds the turning limit of the tractor's steering wheels, enabling the use of the equipment even during turning maneuvers or on narrow paths, a situation frequently encountered in grassland maintenance operations.
Table 1 presents the main technical character-ristics of the grassland planer experimental model coupled with the fertilization equipment.

Table 1 Main technical characteristics of the equipment used in the experiment

Characteristic	UM	Value
Working width	m	3.75
Number of fertilizer boxes	pcs	3
Distance between distribution boxes	mm	125
Fertilizer box volume	dm^3	325
Total weight	kg	1290

The tests were conducted on the experimental fields of ICDP Brașov, following a specific testing procedure.
The average climatic data recorded at the experimental research location were as follows: in August 2024 the average daily temperature was 13°C, with an average precipitation of 74 mm; in September 2024 the average daily temperature was 9°C, with an average precipitation of 56 mm.
The additional equipment used to determine the soil characteristics of the experimental field included: FIELDSCOUT SC 900 digital electronic penetrometer with cone and Extech MO750 portable soil moisture meter.
For weighing to determine the front axle load (to verify the longitudinal stability condition of the experimental model coupled with the wheeled agricultural tractor), a Dini Argeo WWSRF portable platform scale was used. This is a mobile scale with platforms connected via a radio signal (Figure 2).

Figure 2. Aspects of the weighing process for the grassland planer experimental model coupled with the fertilization equipment

The percentage value of the front axle load relative to the total mass of the tractor (Mateescu et al., 2015) TL 100A New Holland type, when coupled with the experimental model, is given by equation (1):

$$\frac{M_{Tpf}}{M_{Tpt}} \cdot 100,\ [\%] \qquad (1)$$

where: M_{Tpf} is the mass of the tractor on the front axle (kg) and M_{Tpt} is the total mass of the tractor (kg).
According to internal vehicle circulation regulations, the mass on the front axle must not be less than 20% of the tractor's own weight.
The traction force was determined using the tensometric method with a computer running the nSOFT software package. The following materials and equipment were used:
- 120 Ω strain gauges, type KFG-6-120-C1-11 N15C2, mounted on the tractor's tie rods (Figure 3a);
- 220V AC power supply (Figure 3b);
- Laptop with QuantumX 1615 data acquisition system, featuring 2 modules and 32 measurement channels (Figure 3c).

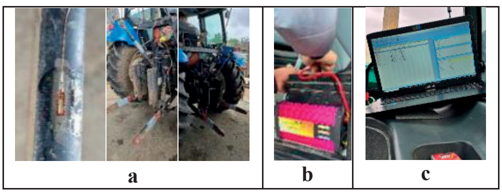

Figure 3. Materials and equipment used for determining traction resistance force

The traction power P_{tr} was calculated based on the travel speed v_l and the traction force F_{tr} determined earlier, using the following equation (2):

$$P_{tr} = \frac{F_{tr} \times v_l}{270}, \text{HP} \qquad (2)$$

where F_{tr} is measured in N and v_l in km/h (Marin et al., 2012).

RESULTS AND DISCUSSIONS

The experimental plot belonging to ICDP Brașov can be visualized as a raster-type map from the Google Earth archive (Figure 4).

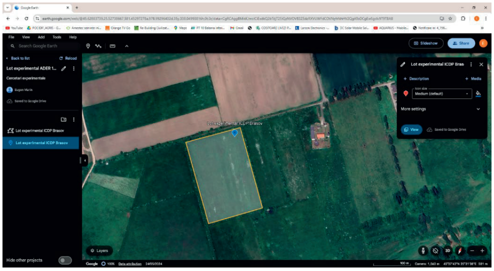

Figure 4. View of the experimental plot on a raster map – Google Earth

On-site measurements conducted on the experimental field plots at ICDP Brașov included the determination of the following physical soil properties: soil penetration resistance and soil moisture content.

Soil penetration resistance is a significant indicator for characterizing the physical-mechanical properties of the soil and its consistency. It correlates with soil plowing resistance (Jiang et al., 2020). The measurement of soil penetration resistance was carried out using the FieldScout SC 900 digital cone penetrometer, where the penetration force was manually applied by the operator. The measurement process included the following steps:

- selection of the cone type: 1 cm² and 60° tip angle;
- attachment of the rod to the cone by screwing them together and mounting them to the "data logger";
- saving the data into the "data logger" by pressing the ON button.

The penetration resistance measurements were carried out at various depths and multiple points (Table 2) to ensure an accurate evaluation. High penetration resistance values (>2000 kPa) indicated strong compaction, which may lead to reduced soil permeability and hinder root development.

Table 2. Average values of soil penetration resistance

No.	Soil depth (cm)	R1	R2	R3	Average soil penetration resistance (kPa)
1	2.5	170	171	179	173
2	5	1370	1362	1376	1369
3	7.5	2705	2701	2705	2704
4	10	3890	3897	3904	3897
5	12.5	3685	3682	3692	3686
6	15	4215	4215	4211	4214

The water content expressed as a percentage of soil volume was measured directly using the Extech MO750 portable soil moisture meter (Hilal et al., 2022).

Moisture values were measured at an average soil temperature of 24°C.

The results obtained from the experimental field measurements for average soil moisture values are presented in Table 3.

Table 3 Average values of soil moisture content

No	Soil depth (cm)	R1	R2	R3	Average soil moisture (%)
1	0-10	8.8	13.1	8.2	**10.03**
2	10-20	8.6	12.8	8	**9.80**
3	20-30	9	13.8	9.1	**10.63**

Figure 5 presents field aspects during the measurement of soil penetration resistance using the FieldScout SC 900 digital cone penetrometer, as well as the determination of soil moisture content expressed as a percentage of soil volume using the Extech MO750 portable soil moisture meter.

Figure 5. Field measurements of the main physical soil properties: penetration resistance and soil moisture content

Analyzing the data from Table 3, it can be observed that the average soil moisture content falls within the optimal range for the application of solid mineral fertilizers.

The traction power was calculated based on the working speed (v_l) of the implement and the traction force (F_{tr}) for two gear levels (V_1 and V_2) of the tractor in the aggregate, both ascending and descending a slope. The results are presented in Table 4.

Table 4. Measured working speed, traction force, and calculated traction power for the experimental model

	Average working speed		Average traction force	Average traction power	
	ascending the slope		ascending the slope	ascending the slope	
	[m/s]	[km/h]	[daN]	[CP]	[kW]
V_1	1.8	6.48	811.7	19.48	14.32
V_2	1.89	6.82	871.3	22.01	16.18
	descending the slope		descending the slope	descending the slope	
V_1	1.82	6.55	801.2	19.44	14.29
V_2	1.94	6.98	852.8	22.05	16.21

Figure 6 presents a graphical representation of the variation of the determined indices at two speed levels for the experimental model coupled with the TL 100A New Holland tractor while ascending the slope.

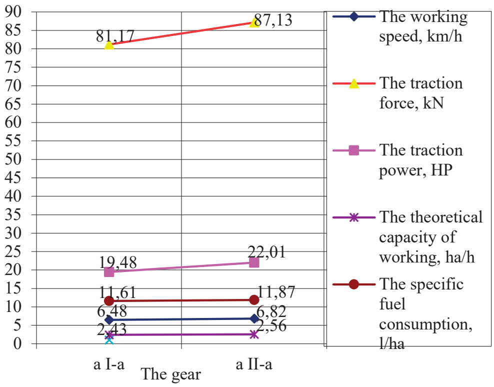

Figure 6. Graphical representation of the variation of determined indices at ascending the slope

Figure 7 presents a graphical representation of the variation of the determined indices at two speed levels for the experimental model coupled with the TL 100A New Holland tractor while descending the slope.

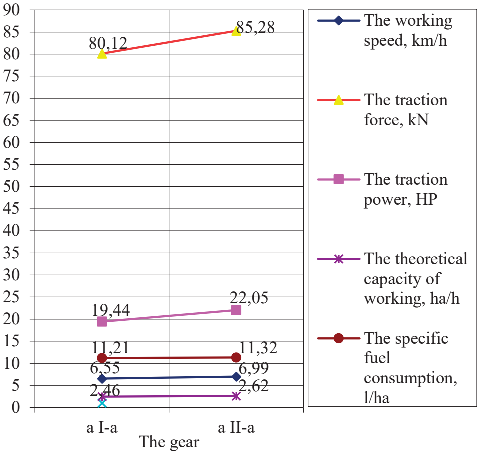

Figure 7. Graphical representation of the variation of determined indices at descending the slope

Table 5 presents the results of technological parameters during operation in aggregate with the TL 100A New Holland tractor on the ICDP Brașov experimental plot, for grassland fertilization over an area of 2 ha, in stubble land.

Table 5. Technological parameters during working in aggregate with the TL 100A New Holland tractor

Specification	UM	Values
Fertilizer type	-	NPK
Average displacement speed	km/h	2.56
Surface	ha	1
Real working time, T_1	min	24.7
Working hourly capacity at real time, W_{ef}	ha/h	2.43
Capacity of working per hour at shift time W_{07}	ha/h	1.80
Technological safety coefficient, K_{41}	-	0.98
Technological safety coefficient, K_{42}	-	1.0
Reliability coefficient, K_4	-	0.98
Shift time utilization coefficient, K_{07}	-	0.83
Fuel consumption per ha	l/ha	10.82

During the operational experiments conducted over an area of 1 ha, the grassland planer experimental model coupled with the fertilization equipment performed efficiently throughout the entire period. Under these conditions, it achieved: an operational safety coefficient of 0.98, a performance working capacity of 1.80 ha/h and a fuel consumption rate of 10.82 l/ha.

Figure 8 presents an aspect from the operational experiments conducted on the experimental plot near ICDP Brașov.

Figure 8. Aspect from the operational experiments

CONCLUSIONS

From an operational perspective, the technical equipment achieved technological parameters that comply with agrotechnical requirements for the application of solid chemical fertilizers.

During the tests, the experimental model coupled with the TL 100A New Holland tractor demonstrated good performance, achieving an average working capacity of 2.43 ha/h and an average fuel consumption of 10.82 l/ha.

The experimental research enabled the validation of the technical and technological solutions implemented in the design of the experimental model.

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