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THE USE OF SPECIALIZED EQUIPMENT FOR GRASSING THE INTER–ROW IN FRUIT ORCHARDS

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Abstract: The grassing of the inter–row can be accomplished through direct seeding or by preserving spontaneous vegetation, with careful management of mowing to prevent excessive competition with the trees. Regular pruning of the vegetation is essential to maintain a balance between the benefits provided and the requirements of the fruit trees. For the direct seeding of grass mixtures, specialised seeding equipment can be employed, ensuring uniform seed distribution and promoting optimal germination. This approach streamlines the process, facilitating rapid and uniform establishment of the vegetation while minimising any adverse effects on soil health. The maintenance of the grass cover will be carried out using specialised mowing equipment designed specifically for orchards, allowing for optimal vegetation management without damaging tree roots or soil structure. This equipment has been developed using a specialised CAD–CAE analysis program, which enabled the optimisation of its design and efficiency. As a result, mowing is performed uniformly with minimal energy consumption, contributing to the preservation of soil health and the orchard ecosystem. The adoption of grassing the inter–row in fruit orchards represents a sustainable horticultural technology that benefits both the environment and farmers' economies. By implementing this method, it is possible to achieve healthy and sustainable production with a reduced impact on the agricultural ecosystem. In an era where sustainability is becoming increasingly important, grassing serves as a crucial step towards responsible and efficient agriculture.
Keywords: grass establishment/grass planting, Direct seeding, Fruit trees

1. INTRODUCTION

For the establishment of grass cover(înierbare?) in the inter–row spaces of orchard plantations, according to the PD–06 scheme under the Strategic Plan 2023–2027, farmers whose holdings include at least 1 hectare of permanent crops, with a minimum agricultural parcel size of 0.1 hectares, are eligible to access funding in the form of direct payments [1]. The payments are granted to farmers in accordance with the Romanian Strategic Plan 2023–2027 and the environmental and climate compensatory measures of the National Rural Development Programme (NRDP) 2014–2020. In order to receive these payments, farmers must comply with conditionality requirements, including those applicable under the PD–06 scheme — Grass Cover Establishment in the Inter–Row Spaces of Orchards, Vineyards, Nurseries, and Hop Fields [2].

A major agronomic challenge within modern orchard operations is maintaining an optimal balance between productivity, soil resource conservation, and the reduction of environmental impact through the natural control of arthropod pests, weed suppression, and as an alternative to nitrogen–based fertilizers [3], [4]. Controlled grassing of the inter–row spaces in fruit tree orchards represents one of the increasingly adopted agroecological practices aimed at achieving these objectives, significantly contributing to the enhancement of orchard sustainability [5], [6].

The establishment of grass cover in the inter–row spaces of fruit–growing plantations involves the deliberate installation of a herbaceous vegetative layer, composed of either perennial or temporary species, functioning as a biological soil cover. For example, when fruit trees are planted at a spacing of 1 meter within the row and 3.5 meters between rows, a vegetative ground cover can be established, centrally positioned within the inter–row space, with a width of 2 meters. This cover may consist of species such as *Lolium perenne*. It can be mown to a height of 5 cm at intervals of 7 to 10 days during the March to August growing season, with the mown biomass retained on the soil surface. This management practice has been shown to improve soil fertility and stimulate biological activity within the soil profile [7]. Establishing ground cover in the inter–row spaces of fruit orchards plays a key role in reducing water and wind erosion, enhancing soil water infiltration capacity, increasing soil biological activity, and minimizing compaction caused by machinery traffic. Additionally, ground cover helps suppress weed competition [8], contributes to carbon sequestration, and supports the long–term improvement of the soil's natural fertility [9]. However, the effective implementation of ground cover systems requires equipment capable of performing both precise and efficient seedbed preparation, as well as uniform seed distribution [10].

In conventional orchard management, the establishment of ground cover in the inter–row space involves several sequential operations: shredding of plant residues with a mulcher, incorporation and mixing with the soil with a weeder, seedbed preparation with a combinator, sowing using a seed drill suitable for small and very small seeds, followed by rolling with a smooth roller. In order to improve the efficiency of this process, the present study analyzes the use of a specialized direct seeding implement for establishing ground cover in the inter–row spaces of fruit orchards. The equipment consists of a horizontal – axis rotary tiller with blades, a pneumatic seeder with electrically driven metering units, flexible distribution hoses, spreading discs [11], and a roller designed to compact and press the soil particles above the seeds.

The management of vegetated inter–row strips in fruit orchards is largely dependent on the adoption of a strategy that maintains soil cover using either spontaneous flora or carefully selected live plant species. This living cover functions as an in situ mulch, contributing to effective weed suppression and promoting ecological sustainability within the orchard system [12].

The management of vegetated inter–row areas in fruit orchards can be performed using various types of grass–cutting equipment, each suited to specific orchard conditions and maintenance objectives [13]:

- Grass trimmers equipped with a horizontal rotary drum fitted with multiple small blades, suitable for uniform cutting across inter–row surfaces.
- Rotary mowers featuring a single rotating blade, commonly used for managing low to moderate vegetation in orchard alleys.

This approach requires a significant input of time and resources, including fuel consumption, labour, and mechanical wear, and it also poses a risk of soil compaction due to multiple passes of the aforementioned machinery. The objective of this study is to present, in detail, the development of an innovative technology for establishing vegetative ground cover in the inter–row spaces of fruit orchards. This technology is designed to improve soil structure, reduce erosion, enhance biodiversity, and support more efficient orchard maintenance.

The proposed technology involves direct seeding of a mixture of herbaceous species using specialised direct seeding equipment without prior soil preparation. The recommended mixture includes species such as smooth brome (Bromus inermis), sainfoin (Onobrychis viciifolia), perennial ryegrass (Lolium perenne), meadow fescue (Festuca pratensis), Kentucky bluegrass (Poa pratensis) and various clovers (Trifolium spp.). These species were selected on the basis of their adaptability, resistance to agro–technical traffic and capacity for biological nitrogen fixation. The established vegetation is allowed to develop naturally, with maintenance carried out through periodic mowing using mechanized grass–cutting equipment. The equipment employed (both for seeding and mowing operations) is mounted on a three–point hitch system, Category 1, in accordance with the SR ISO 730:2012 standard [14], and is compatible with low–power horticultural tractors [15].

2. MATERIALS AND METHODS

In the context of research carried out at the National Institute for Research and Development of Machinery and Installations for Agriculture and the Food Industry – INMA Bucharest, an integrated grassing technology for inter–row spaces has been developed. This technology employs a specialized piece of equipment capable of performing, in a single pass, the following operations: soil preparation, transverse distribution of grass seeds across the entire working width, uniform spreading of seeds close to the soil surface, incorporation of seeds into the soil, compaction and rolling of the topsoil layer to ensure optimal seed–to–soil contact during germination. Additionally, the system includes equipment designed for mowing the grassed strips within the inter–row spaces of orchard plantations, carried out in two successive passes [16].

In the first stage, an analysis was conducted on the existing solutions for pneumatic and mechanical seeders for grass seeds, as well as disc mowers or shredders, with the aim of identifying their strengths and technical limitations. The next stage involved defining the design objectives by establishing the technical and technological requirements to be met by the seeding and mowing equipment, incorporating innovative, energy–efficient mechanized solutions adapted to the real conditions of medium–sized orchard operations.

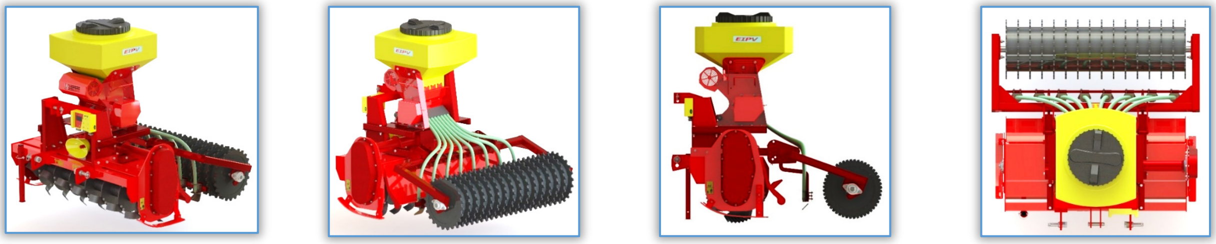
The subsequent phase involved the CAD–CAE modelling of 3D designs for the seeding and mowing equipment, utilizing modules for assembly, kinematic simulation, and strength analysis (FEM regarding the stability of the assembly, mass distribution, and centre of gravity).

The following materials were used:

— A 22H2 workstation with an Intel® Xeon® W–2123 CPU @ 3.60GHz for running design software;
— The SOLIDWORKS® Premium 2018 S.P. 0.1 parametric design software for CAD modelling;
— The SOLIDWORKS SIMULATION® software for CAE analysis [17];
— Databases containing catalogues, brochures, and design manuals;
— Standards defining the safety requirements and verification methods for agricultural machinery [18], [19], [20].

3. RESULTS

As part of the technology, for the direct seeding of a mix of herbaceous species between fruit tree rows, a direct seeding equipment (Figure 1) has been designed. This equipment performs soil preparation, transverse distribution of seeds across the entire working width, uniform spreading of seeds close to the soil surface, incorporation of seeds into the soil, compaction, and rolling of the topsoil particles above the seeds to ensure better seed–to–soil contact during germination. The aim is to improve the quality of the inter–row grassing operation in orchards.



Front–side view | Rear–side view | Side view | Top view

Figure 1. Direct seeding equipment for a mix of herbaceous species between fruit tree rows

Figure 2 illustrates the operations performed by the direct seeding equipment for a mix of herbaceous species between fruit tree rows.

The movement of the equipment in the field is initiated by the tractor to which the soil tillage implement is attached. This action sets the power take–off in motion, which in turn drives the horizontal rotor with knives through the cardan shaft, bevel gearbox and chain transmission. The rotor blades are designed to slice through the soil, propelling slices of soil in a rotational motion into the metal casing. This process breaks down the soil into finer particles, thereby loosening and levelling the soil. The constant speed of the rotor ensures uniform soil fragmentation, thereby preventing excessive breakdown that could deplete the soil's humus content. The distribution of grass seeds across the working width is facilitated by an airflow generated by a fan, which directs the seeds through flexible tubes. The cylindrical seed metering device is powered electrically by a 12 V DC motor, controlled by a dedicated device.

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The seeds are uniformly spread in an airstream close to the soil surface, across the entire working width, by a set of deflectors which are inclined forward in the direction of travel. Once on the soil surface, the seeds are guided and incorporated into the soil by a device consisting of a frame equipped with a rotating cylindrical drum, mounted on bearings. A series of discs are fixed transversely onto the drum at equal intervals.

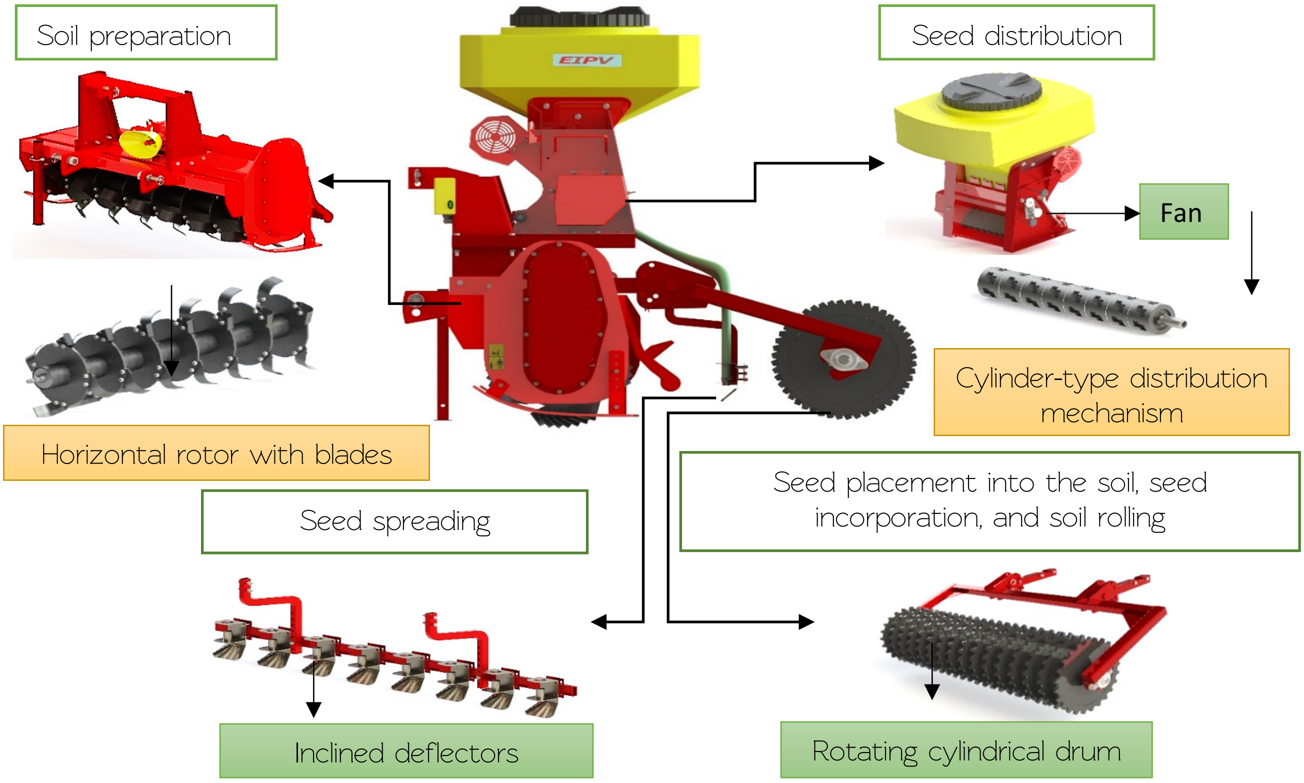
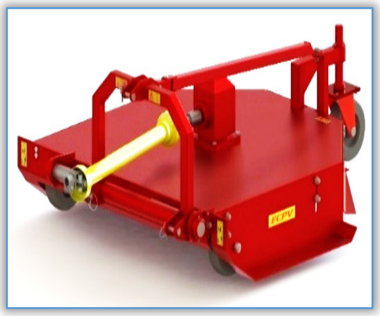
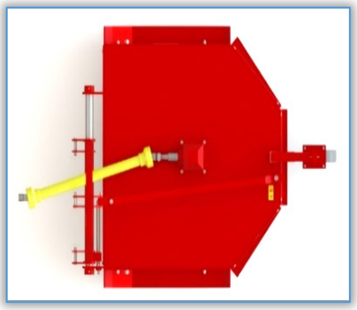


Figure 2. Operations performed by the direct seeding equipment for a mix of herbaceous species

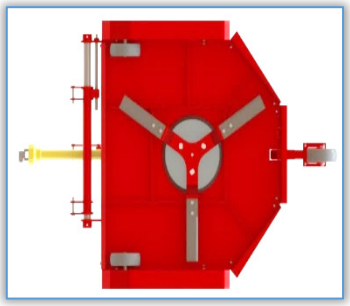
The maintenance of the grass strip is undertaken using a grass mower (Figure 3), which executes two successive passes, leaving the resulting plant debris on the ground. This approach serves to assist in the maintenance of moisture and the enhancement of the organic matter present in the topsoil. Figure 4 shows the operations performed by the grass mowing equipment.



Front side view

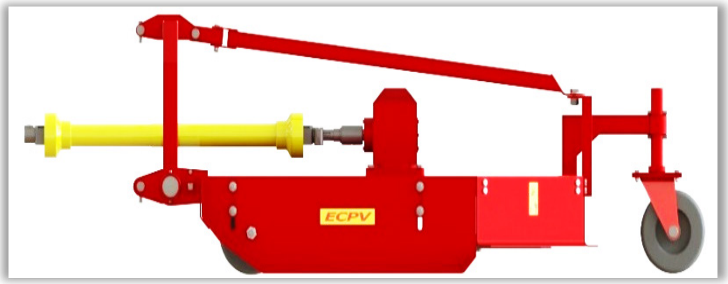


Top view



Bottom view

Rear side view

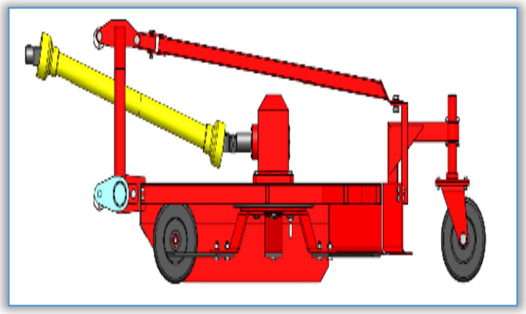


Side view

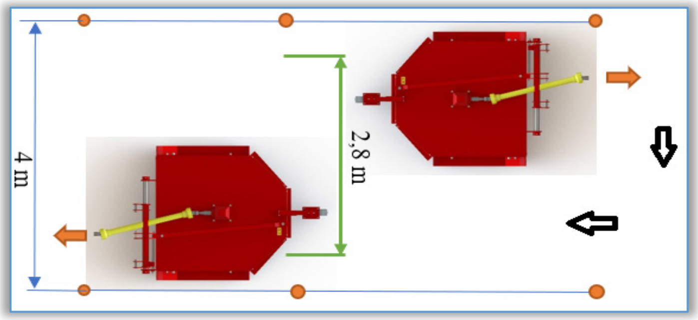
Figure 3. Grass mowing equipment

The grass–mowing equipment, equipped with a rotor comprising three radially arranged blades at equidistant intervals, achieves a uniform cutting of the grass, thereby ensuring a uniform regeneration of the entire plot. The apparatus is equipped with a robust drivetrain comprising a gearbox, thereby ensuring optimal performance during mowing operations, particularly in scenarios involving taller grass. The apparatus's innovative design, incorporating a low, bevelled frame, front guide wheels, and a standard swivel castor, ensures optimal manoeuvrability.

Orchard plantations



Mowing at a cutting height of 30 to 80 mm



Mowing the inter–row space in fruit tree orchards

Figure 4. Operations performed by the grass mowing equipment

The virtual testing of a subassembly subjected to high loads, in terms of resistance to static loading, was performed using the SOLIDWORKS SIMULATION® structural analysis application, based on Finite Element Analysis (FEA). The process involved importing the geometry of the model created in the computer–aided engineering (CAE) software, assigning material properties to each component, defining appropriate boundary conditions and mesh settings, conducting the analysis to determine stresses, displacements under applied loads, the safety factor, and visualising the results.

For example, virtual testing was performed on the "Support Plate" component, which is part of the direct seeding equipment for a mix of grass species. The process began with the creation of the 3D geometric model of the subassembly, with each component being drawn individually. These components were then assembled using the Assemblies module in SOLIDWORKS.

For each component, a supplementary information field was completed, which included the material used, the component name, the person who created the drawing, as well as any relevant remarks. After completing the 3D geometric model, the structural analysis phase was carried out using the SOLIDWORKS SIMULATION® application. This phase involved importing the geometry of the model, defining the materials, setting the appropriate constraints, meshing the model, and running the simulation. The analysis focused on calculating the Von Mises stresses, displacements, relative elongation, determining the safety factor, as well as visualising the results in the form of relevant diagrams. The SOLIDWORKS SIMULATION® structural analysis application provided the ability to generate a detailed report, which presents the results of the analysis, including the distribution of Von Mises stress intensity, the displacement field, specific deformation, and the safety factor. These results are integrated into the work in the form of tables (Table 1) and illustrative graphs (Figures 5–8), facilitating the interpretation of the structural behaviour of the analysed subassembly.

Tabel 1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	$1.601e^{+01}$ N/m^2 Node: 64089	$1.591e^{+08}$ N/m^2 Node: 61504
Displacement1	URES: Resultant Displacement	$0.000e^{+00}$ m Node: 63300	$1.208e^{-03}$ m Node: 28028
Strain1	ESTRN: Equivalent Strain	$7.495e^{-11}$ Element: 36022	$5.036e^{-04}$ Element: 5779
Factor of Safety1	Automatic	$2.992e^{+00}$ Node: 400	$4.049e^{+03}$ Node: 44760

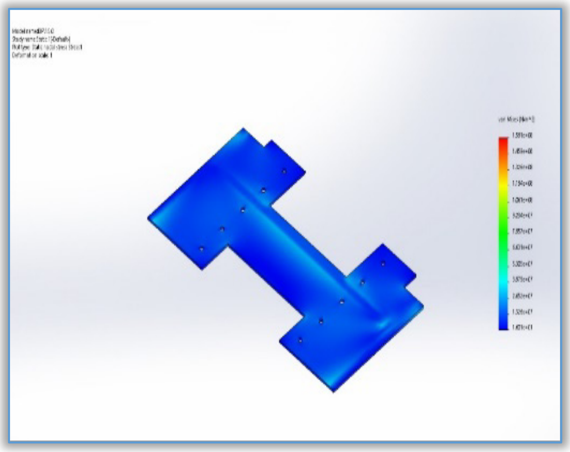


Figure 5. Distribution of Von Mises stress intensity

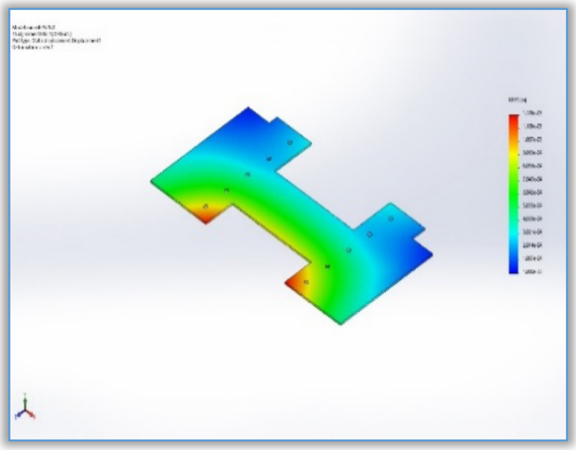


Figure 6. Distribution of relative displacement intensity

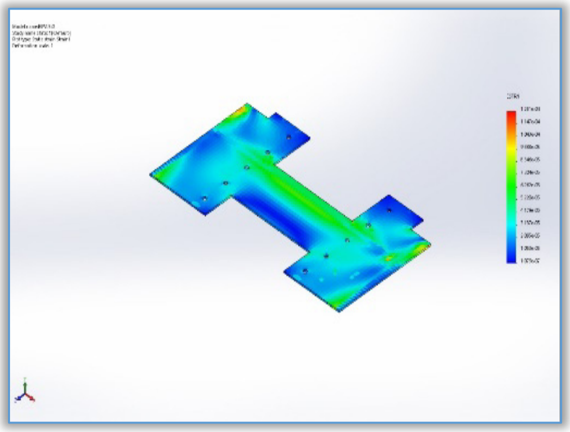


Figure 7. Distribution of specific deformation intensity

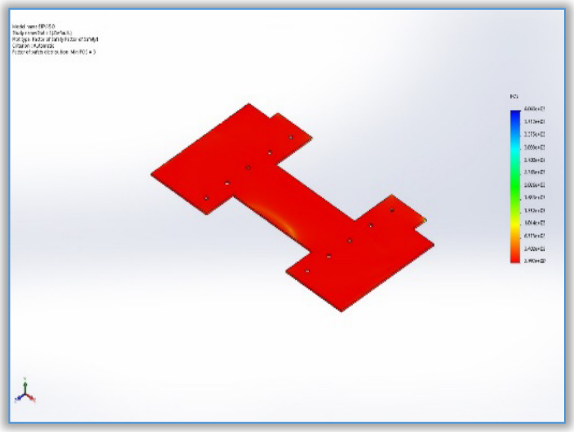


Figure 8. Distribution of Power Factor Intensity

Similarly, the 'Frame' subassembly of the grass mowing equipment underwent the same virtual analysis procedure. The process involved 3D geometric modelling, definition of operating conditions and material specifications (carbon steel rectangular profiles), followed by structural simulation.

The results obtained highlighted the behaviour of the frame under the specific loading conditions associated with the mowing process, indicating the distribution of mechanical stresses and potential failure points. These are presented in Table 2 and Figures 9–12.

The calculated safety factor for the 'Frame' subassembly of the grass mowing equipment was 2.017, which further confirms that the structure is safe and sufficiently robust for operational use.

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Tabel 2

Name	Type	Min	Max
Stress1	VON: von Mises Stress	$5.813e^{-09}$ N/m^2 Node: 52479	$1.363e^{+07}$ N/m^2 Node: 37192
Displacement1	URES: Resultant Displacement	0.000e+00 m Node: 38075	$6.770e^{-07}$ m Node: 34971
Strain1	ESTRN: Equivalent Strain	$2.988e^{-20}$ Element: 21905	$4.626e^{-05}$ Element: 16828
Factor of Safety1	Automatic	$2.017e^{+01}$ Node: 37192	$1.000e^{+16}$ Node: 38208

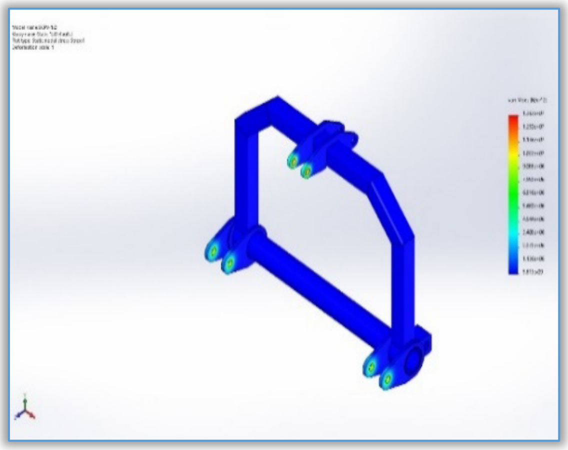

Figure 9. Distribution of Von Mises stress intensity

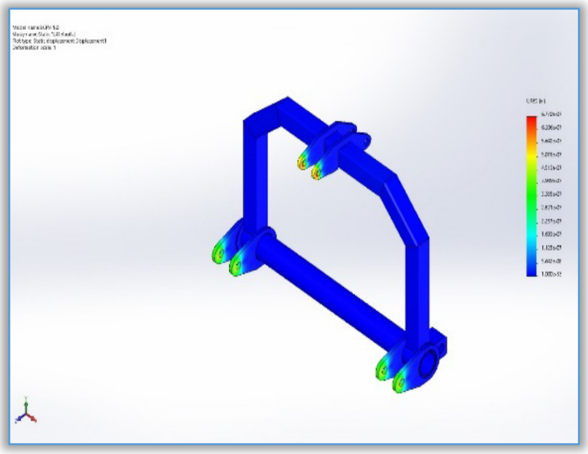

Figure 10. Distribution of relative displacement intensity

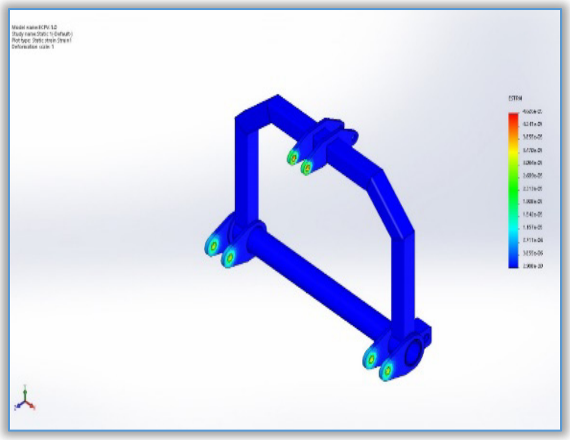

Figure 11. Distribution of specific deformation intensity

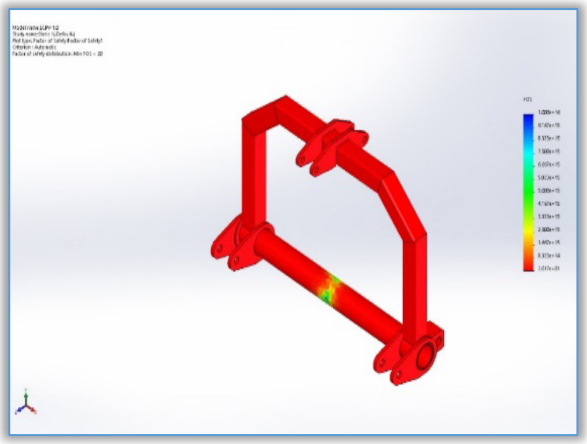

Figure 12. Distribution of the safety factor intensity

4. DISCUSSION

Following the structural analysis carried out on the 'Support Plate' of the direct seeding equipment for a mixture of herbaceous species, a Von Mises stress of 1.591 × 10^8 N/m² was obtained, which is below the yield strength of the material (approximately 2.5 × 10^8 N/m² for S275JR steel). The obtained Von Mises stress value is significantly lower than the material's yield limit, suggesting that the component will operate safely within the seeding equipment, providing an adequate structural margin under normal operating conditions.

For the 'Frame' subassembly of the innovative grass mowing equipment, the obtained Von Mises stress value was 1.363 × 10^7 N/m². This indicated that the subassembly is structurally robust and capable of operating safely under the anticipated working conditions, without risk of damage. Considering that the material used for the 'Frame' is S275JR steel, with a yield strength of approximately 250 MPa (2.5 × 10^8 N/m²), the obtained Von Mises stress value lies significantly below the yield limit. This confirms that the structure possesses an adequate safety margin and is capable

of withstanding mechanical loads without experiencing permanent deformation or structural damage.
The safety factor values for two key components of the developed equipment are as follows:
— For the 'Support Plate' component of the direct seeding equipment for a mixture of herbaceous species, the obtained safety factor value was 2.992, indicating superior structural capacity and providing a higher level of safety margin. This value can be justified by the lower stresses experienced by the component or by the need for greater rigidity in the fixation or contact area.
— For the 'Frame' subassembly of the innovative grass mowing equipment, the safety factor value was 2.017, indicating a structure capable of supporting more than twice the nominal loads applied. This value falls within the accepted limits for such applications, confirming a good balance between structural strength and material economy.

Both values fall within the optimal range (2 – 3.5) recommended for agricultural equipment subjected to moderate dynamic loads.
The structural analysis conducted using SOLIDWORKS SIMULATION® led to the validation and optimisation of the critical components of the designed agricultural equipment.
By evaluating the mechanical behaviour under real operating conditions of the components and subassemblies, the following was achieved:
— Identification of areas with potential risk of stress concentration, prior to the transition to the physical manufacturing phase;
— Optimisation of the shape and material distribution within the structure, leading to an optimal balance between mechanical strength and mass;
— Determination of safety factors, essential for ensuring reliability and durability during use;
— Technological design for manufacturing with reduced costs.

5. CONCLUSIONS
— The establishment of grass cover through direct seeding, when properly managed, represents a sustainable practice that supports the healthy development of fruit tree orchards.
— The use of specialized equipment for direct seeding of grass guarantees uniform seed distribution and rapid germination, thus streamlining the grass establishment process
— The equipment specifically designed for mowing in fruit tree orchards enables efficient management of herbaceous vegetation without affecting the tree roots or the soil structure.
— The adoption of grass establishment in fruit tree orchards promotes sustainable agriculture with a reduced environmental impact
— The use of CAD–CAE design methodology for the direct seeding equipment of herbaceous species mixtures and for vegetation mowing in orchard plantations led to:
  ≡ Optimisation of the geometry of key components (those subjected to high stresses during operation), by creating detailed 3D models and functional assemblies in the virtual environment;
  ≡ Identification and correction of potential structural deficiencies, reducing construction risks;
  ≡ Determination of the distribution of stresses, deformations, and safety factors, ensuring appropriate mechanical behaviour under real operating conditions;
  ≡ Reduction of manufacturing costs without the need for multiple physical tests;
  ≡ Scientific grounding of the design through the integration of testing and validation stages.

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