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ASPECTS REGARDING THE USAGE OF GROUND AUGERS FOR DRILLING HOLES SAPLINGS IN FORESTRY SECTOR

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Abstract

This paper presents the results of our research regarding the usage of ground augers in the forestry sector for drilling holes in order to plant saplings. In order to carry out the research, we settled in two forest divisions in the plains of the West of Romania so that we could have four different types of soils which are representative for that specific area.
The objectives of the research were to make a comparative determination, on different types of soil, of the qualitative parameters, among which the most important ones are: timing of drilling holes, fuel consumption for the drilling of the hole, evacuate ratio, degree of evacuation of the soil from the hole, medium range scattering, settlement angle, resistance to penetration, resistance to shearing, degree of scattering of the soil taken out from the hole, degree of loosening of the soil taken and left in the hole, using the Stihl BT 121 auger in order to establish its technical efficiency.
In order to observe the influence which, the drilling of holes has on its walls, we measured the resistance to penetration and resistance to shearing every 10 cm at a 30 cm depth, the proper depth for planting small-sized saplings, on two opposing sides, so that we could get the most probable values of these physical-mechanical properties of the soil. We started by measuring the particle size distribution and the main physical properties of the soil (moisture, bulk density and total porosity) and then, we determined the duration of drilling holes, split times (duration of movement from one hole to the other) and the fuel consumption when using a Stihl BT 121 auger equipped with a 150/200 mm diameter drill.
The average values for the duration of digging and the fuel consumption for each type of soil was as follows: 1st type of soil - timing 11.7 ± 3.09 sec. and average consumption 4.31 ± 1.14 ml; 2nd type of soil - timing 12.0 ± 3.76 sec. and average consumption 5.75 ± 1.80 ml; 3rd type of soil - timing 12.06 ± 1.99 sec. and average consumption 4.76 ± 0.79 ml; 4th type of soil - timing 9.83 ± 2.52 sec. and average consumption 3.49 ± 0.89 ml (mean ± SD).
The usefulness of the present paper stays in the research data collected, processed, analyzed and valorized in order to offer a pertinent study material, which could indeed be used by specialists in designing the process for obtaining, through a mechanized means, the holes for planting small-sized saplings on a horizontal ground, using the Stihl BT 121 auger.

Key words: *ground auger, physical properties, timing of drilling holles.*

INTRODUCTION

The need to afforest greater and greater surfaces in Romania as a result of widely known causes, together with the development of forestry nurseries that are able to produce a certain quantity of saplings to cover the production needs, imply an enormous work volume in the afforestation sector which is difficult to carry out only by manual means.
In the future, the afforestation activity will become compulsory in even greater surfaces. For this reason, we consider that the optimal solution in this case is the mechanization of hole digging for planting saplings by using ground augers.
From this point of view, there is a wide range of ground augers able to mechanically dig holes for saplings, which are available on the market. In order to comparatively observe the performance rate, we used a Stihl ground auger. From the very many types of machinery available in Romania, we have chosen for the study regarding the auger performance in terms of fuel consumption: the Stihl BT 121 auger (Popescu, 1984; Popescu et al., 2013).
The research was carried out to observe the auger efficiency and to make measurements regarding the quantity and auger performance in a shift (8 hours) (Popescu, 2006; Popescu et al., 2006; Boja et al., 2011).

In order to encompass the ground diversity in forests, we chose to make our research on four different types of soil (1st soil, 2nd soil, 3rd soil, 4th soil).
The present research is carried out only on plains, and fuel consumption are linked to the nature of the ground in terms of particle size analysis.
The soil is the environment of the growth and development of the saplings, because in it and through it there are the nutritive elements and the activity of the micro-organisms in the context of a normal thermo-aero-hydro regime. It can be penetrated by the roots of the plants, it is stirred, it contains water, air and living matter (flora and fauna) and it represents the necessary support for the growth and development of the saplings (Boja et al., 2012).
The characteristic of the soil as a growth and development environment for the plans is given by a series of properties (texture, structure, porosity, compaction, reaction, humus content and nutritive elements), expressed globally through the notion of fertility (Boja et al., 2011; Boja et al., 2010; Onet et al., 2016).
In order to obtain pertinent results, the research was done according to a complex methodology, with a novelty character in this domain, which gave the possibility to study different technical aspects of usage of the motto-borer.
Because of the compaction, while digging holes for planting saplings, there are several phenomena of friction occurring which increase the resistance to penetration through the walls of the hole. For the same reason, the soil offers resistance to some mechanical, exterior forces, presenting resistance to compression, shearing and penetration (Popescu, 2006).
Machineries that realize digging holes to plant seedlings are part of the large group of ground working machines whose active components have a moving rotation generated by a power source. The specific of these machineries is the fact that the soil is prepared by chipping, action from which the soil mobilization and aeration is carried out with or without putting out the soil from the hole.
The principle of this action is not exclusively reserved to machineries digging holes for seedlings. This principle exists in other machineries whose destination is to prepare the soil to be a germinating bed, to maintain crops along rows gap, a.s.o. The same principle has applicability on a large scale in the wood and metal industries (Popescu et al., 2006; Boja et al., 2011).

MATERIALS AND METHODS

The experimental research was conducted in two forest divisions in the plains (Figure 1). For this purpose, we chose the soils which are most frequently spread in those areas. In this respect, we made measurements in order to determine the moisture, the bulk density, the total porosity and the particle size analysis of the soils. The particle size analysis of the soils was carried out in a specialized laboratory.

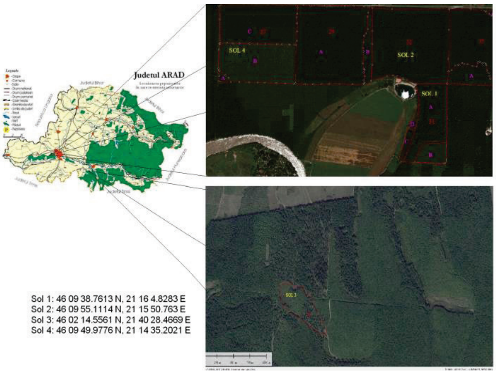

Figure 1. Experimental field map

We determined the fuel consumption and digging duration for each hole, but also the split times (duration of movement from one hole to the other).
The digging duration and the split times were determined by using a timer; for determining the fuel consumption, we placed inside the tank a precise quantity of fuel and after depleting it, we related it to the digging duration and we multiplied it with the digging time allotted for each hole, according to the relation (1):

$$Q_n = \frac{Q}{\sum T} \cdot t_n \tag{1}$$

where: Q_n is the fuel quantity needed for each hole;

Q -total quantity of fuel placed in the tank;

$\sum T$-total sum of digging duration of the holes;

t_n-duration of digging of a hole.

The technical characteristics of the ground auger used in our research are given in Table 1, and its photography appears in Figure 2.

Figure 2. Ground auger Stihl BT 121 (www.stihl.ro)

The technical characteristics of the ground auger Stihl BT 121 are given in Table 1.

Table 1. Technical data of the ground auger Stihl BT 121 (www.stihl.ro)

Cylindrical capacity	30.8 cm³
Weight	9.4 kg
Power	1.3/1.8 kW/CP
Level of vibrations left/right	2.2/2.5 m/s²
Speed of rotation	190 1/min.
Level of acoustic pressure	103.0 dB (A)
Level of acoustic pressure	109.0 dB (A)

In this paper, we presented the results gathered after digging the holes for planting saplings in the previously unprepared ground, taking into account: the durations implied by digging holes according to the physical-mechanical properties of the soil and the fuel consumption needed for digging a hole.

The physical properties were determined by using the method of the cylinders with a constant volume of 100 cm^3, carrying out five repetitions at different depth, from 10 to 10 cm until the depth of 30 cm. The methods of analysis and interpretation of the results as well as the work procedure for the determination of the physical – mechanical properties are those indicated in the specialized literature (Boja et al., 2012; Boja et al., 2013; Boja et al., 2013).

In order to reach our objectives, we have dug n holes for each type of soil chosen for the experiment, placed on a previously unprepared horizontal ground, using the Stihl BT 121 auger with a 150/200 mm drill, until exhausting the whole quantity of fuel placed in the tank (500 ml) (Boja et al., 2012; Boja et al., 2012; Boja et al., 2012).

In order to observe the influences which the digging of holes have on their walls, we measured the resistance to penetration and the resistance to shearing on the holes' walls from 10 to 10 cm until the depth of 30 cm, on two opposing sides, so as to get the most probable values for these physical-mechanical properties of the soil, depth sufficient enough for the planting of small-sized saplings. The placement of samples for the resistance to penetration and shearing on the walls of the holes is given in Figure 3.

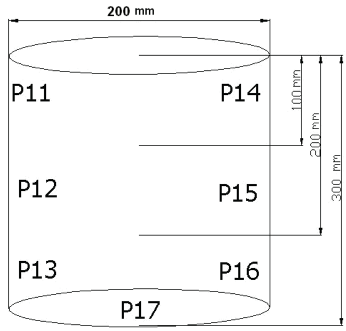

Figure 3. Placement of samples for the resistance to penetration and shearing on the walls of the holes

The degree of scattering of the evacuated soil from the hole was expressed by the ratio of the maximum diameter of scattering or of the diameter at which is deposited most of the quantity of soil, at the diameter of the hole. The degree of evacuation of the soil from the hole was expressed by the ratio between the volume of the soil evacuated from the hole and the volume of the soil left in the hole at a 30 cm - depth. The elements measured for the determination of these qualitative indexes are given in Figure 4.

In order to accomplish the objectives we have for each type of soil chosen for the experiment, placed on a horizontal ground, previously unprepared, using the Stihl BT 121 motto-borer with a 150/200 mm drill.

Statistical analysis. Data was subjected to two-way analysis of variance (ANOVA) ($P = 0.05$), and in order to determine the samples means statistical differences the Tukey test of pairwise comparisons was done (Minitab software, Minitab, Inc. Quality Plaz, 1829 Pine Hall Road, State College, PA 16801 USA). Multivariate analysis was done following the sequence: principal component analysis (PCA), and (P = 0.05), in order to determine the possible variables grouping and samples clustering (Hammer et al., 2001).

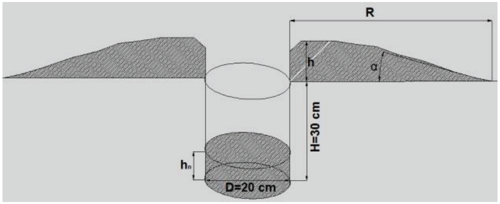

Figure 4. Determination of the degree of scattering and degree of evacuation of the soil in the hole: *H - depth of digging, hn - height of the un-evacuated soil, h - height of the soil bed evacuated, D - diameter of the hole,* α *- angle of setting of the evacuated soil, R - radius of scattering of the evacuated soil (mean R)*

RESULTS AND DISCUSSIONS

a. Physical properties

The state of aeration of the processed soil in the natural setting can be expressed through specific issues such as: bulk density and total porosity (Maior et al., 2016; Boja et al., 2016).

The types of soil on which the research was carried out are: gleysoil the muddy subtype (soil 1), alluvial soil the vertical-gleyed subtype (soil 2), brown typically luvic soil (soil 3) and a alluvial soil-typical (soil 4). The physical properties determined during the digging of the holes and the particle size distribution of the soil are presented with average values in Tables 2 and 3.

We could notice the fact that the holes were dug when the values of soil moisture were ranging from 20.75 to 24.11% for the 0-10 cm depth, 19.46-22.73% for 10-20 cm depth and 8.74-20.09% for the 20-30 cm depth.

In order to show the influence of the soil type (particle size distribution) and of the physical properties of the soils included in the experiment on the digging duration and fuel consumption, all the holes were dug on a previously unprepared ground, which can be noticeable in the values of total porosity that vary as follows: for 0-10 cm between 35.54-37.89%; for 10-20 cm between 33.28-37.43% and for 20-30 cm between 31.25-36.45%.

Table 2. The values of physical properties of the soils analyzed (mean ± SD)

Type of soil	Physical properties	Depth 0-10 cm	10-20 cm	20-30 cm
SOIL 1 gleysoil	Soil moisture, %	24.11 ± 1.2	22.73 ± 1.0	20.09 ± 0.8
	Bulk density, g/cm^3	1.62 ± 0.23	1.69 ± 0.19	1.72 ± 0.06
	Total porosity, %	37.89 ± 2.51	37.43 ± 2.24	36.45 ± 1.15
SOIL 2 alluvial soil – vertical gleyed	Soil moisture, %	20.75 ± 0.9	19.46 ± 0.7	17.38 ± 0.5
	Bulk density, g/cm^3	1.70 ± 0.02	1.75 ± 0.01	1.73 ± 0.00
	Total porosity, %	36.97 ± 1.32	35.73 ± 1.11	35.19 ± 0.92
SOIL 3 brown typically luvic	Soil moisture, %	22.43 ± 0.8	21.10 ± 0.5	8.74 ± 0.3
	Bulk density, g/cm^3	1.69 ± 0.05	1.71 ± 0.03	1.73 ± 0.01
	Total porosity, %	37.43 ± 1.05	36.31 ± 0.96	36.09 ± 0.53
SOIL 4 alluvial soil – typical	Soil moisture, %	23.35 ± 0.5	21.68 ± 0.3	19.54 ± 0.1
	Bulk density, g/cm^3	1.64 ± 0.01	1.58 ± 0.01	1.51 ± 0.00
	Total porosity, %	35.54 ± 2.52	33.28 ± 2.01	31.25 ± 1.85

Table 3. Average values of the granulometric analysis at different depths of prelevation

Type of soil	Depth of prelevation	Values of the granulometric analysis: Sand (Coarse + Fine)	Dust (I + II)	Clay
SOIL 1 gleysoil	0-10	36.78	33.88	29.54
	10-20	47.78	25.08	27.34
	20-30	41.18	30.38	28.64
SOIL 2 alluvial soil – vertical gleyed	0-10	40.78	38.78	20.64
	10-20	39.38	37.18	23.84
	20-30	41.98	33.08	25.24
SOIL 3 brown typically luvic	0-10	38.78	36.33	25.09
	10-20	43.58	31.13	25.59
	20-30	41.58	31.73	26.94
SOIL 4 alluvialsoil – typical	0-10	40.36	38.36	21.28
	10-20	40.63	36.08	23.29
	20-30	41.2	33.95	24.85

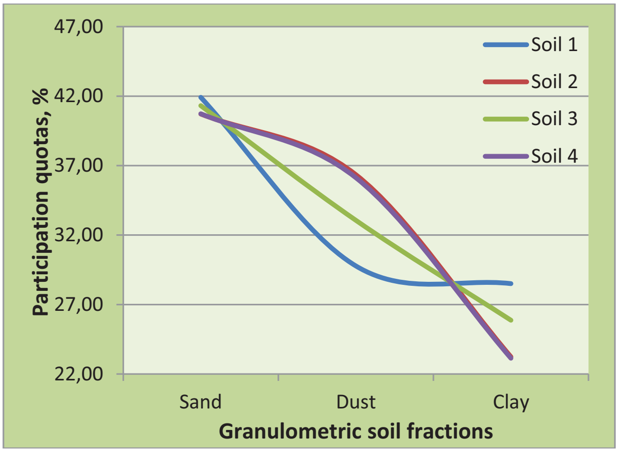

Figure 5. Granulometric curves analysis of the soils

When analysing the granulometric curves presented in Figure 5, one can notice the fact that there was a sandy-dusty-clay-like texture in all the soils encompassed in the experiment at a participation quota that scarcely varies, with the exception of the 1st soil where the particle size distribution is slightly different: sandy-clay-like-dusty texture.

b. Qualitative parameters

Significant differences between the borer type and between the four types of soils studied in relation to the physical and mechanical properties of the soil were assessed using two-way ANOVA (Figures 6-13), principal component analysis (PCA) (Table 4, Figure 14). The highest value for the duration of digging was registered for the 2nd type of soil (17.708 s), while the lowest value appeared in the case of the 1st type of soil (8.553 s). Taking into account the diameter of the drill and the type of soil, the maximum digging duration was noted with the 15-cm diameter drill on the 2nd type of soil (D15*Soil02 = 23.420 s), while the minimum one was found with the 15-cm diameter drill on the 1st type of soil (D15*Soil01 = 5.407 s).

Analysed only from the perspective of the type of soil, the fuel consumption reached maximum values on the 2nd type of soil (5.649 ml) and minimum ones on the 1st type of soil (4.513 ml). Analysed both from the perspective of the type of soil and the type of drill, the fuel consumption reached maximum values with the 15-cm diameter drill on the 4th type of soil (D15*Soil04 = 6.863 s) and minimum ones with the 20-cm diameter drill on the 4th type of soil (D20*Soil01 = 3.486 s). In the present case, the amplitude of variance of fuel consumption can reach values of ± 3.377 ml in the same pedological conditions.

The volume of the earth removed reached maximum values in case of the 4th type of soil (0.180 m^3) and minimum ones with the 1st type of soil (0.005 m^3).

The same values also apply when we take into account both the type of soil and drill: a maximum value was acquired in the case of the 15-cm diameter drill on the 4th type of soil (D15*Soil04 = 0.352 m^3) and a minimum one with the 15-cm diameter drill on the 1st type of soil (D15*Soil01 = 0.003 m^3).

The removal ratio acquires maximum values for the holes dug in the 3rd type of soil and minimum ones for the 2nd type. However, when we analyse both the type of soil and drill, maximum values appear with the 20-cm diameter drill on the 4th type of soil (D20*Soil04 = 6.012) and minimum ones with 15-cm diameter drill on the 4th type of soil (D15*Soil04 = 2.903).

The average radius of scattering of the earth removed had maximum values in the case of the 4th type of soil (34.355 cm), and miminum ones with the 2nd type of soil (13.495 cm). The same situation occurs when we analyse both the type of soil and drill: a maximum value is reached with the 15-cm diameter drill on the 4th type of soil (D15*Soil04 = 36.125 cm) and a minimum one with the 20-cm diameter drill on the 2nd type of soil (D20*Soil02 = 12.899 cm).

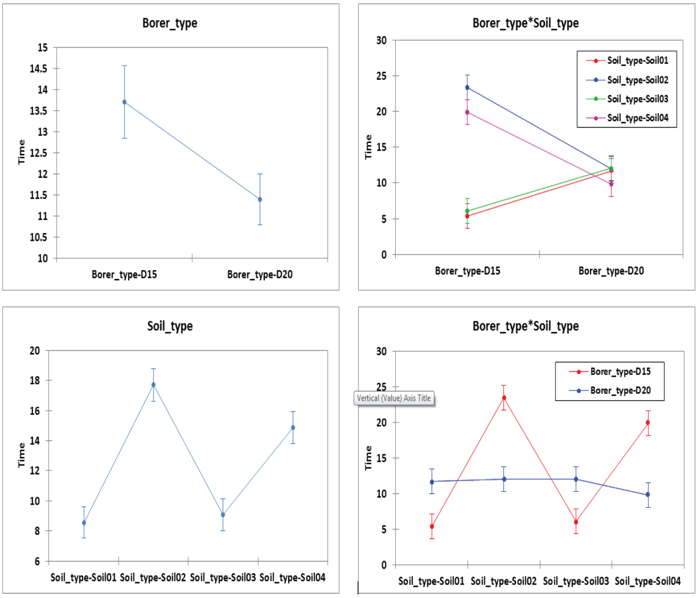

Figure 6. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated timing of drilling holes (Time)

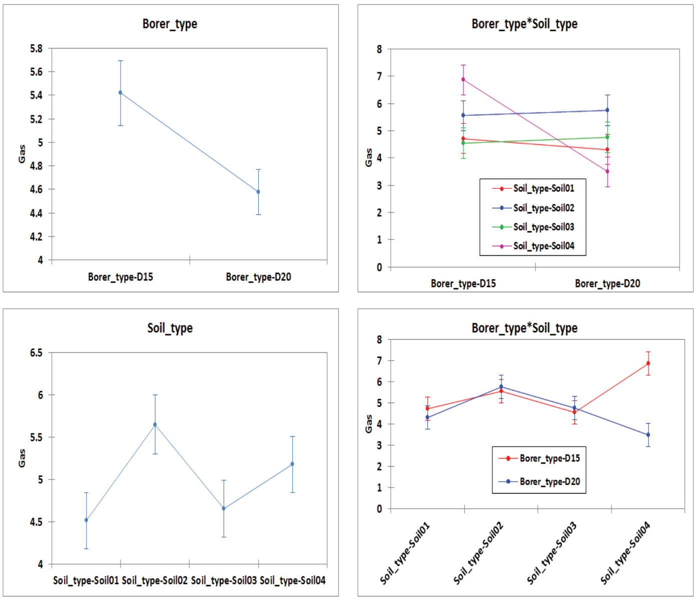

Figure 7. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated fuel consumption (Gas)

The angle of placement of the earth removed reaches maximum values in the case of the 3rd type of soil (22.578°), and minimum ones in the 1st type of soil (11.213°).
By analysing this qualitative index both from the point of view of the type of soil and drill, a maximum value is reached with the 20 cm diameter drill on the 2nd type of soil (D20*Soil02 = 32.399° and a minimum one with the 15 cm diameter drill on the 1st type of soil (D15*Soil01 = 9.597°).

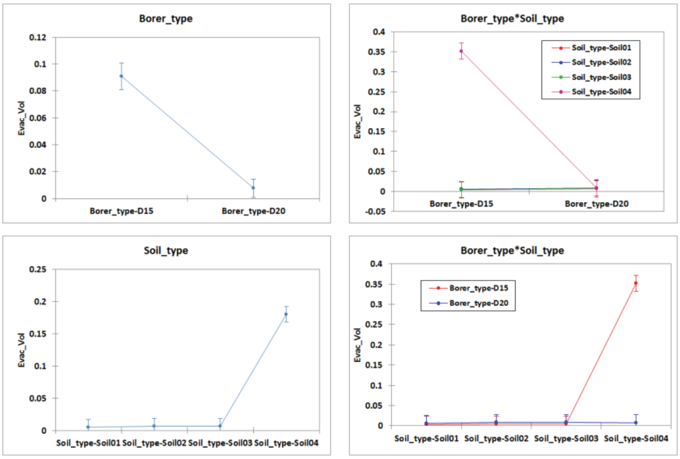

Figure 8. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated degree of evacuation (Evac_Vol)

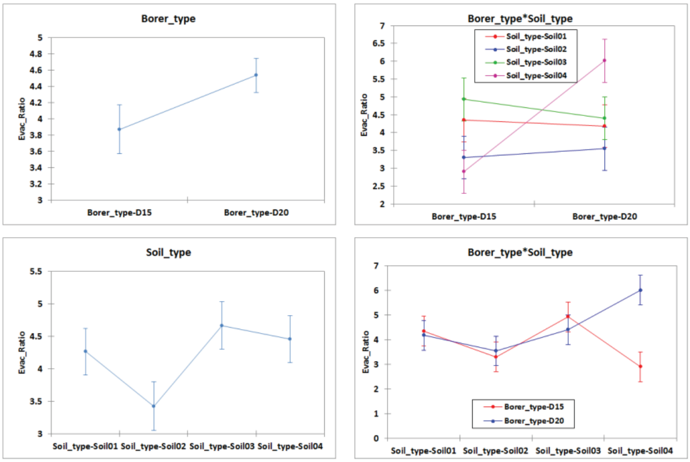

Figure 9. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated evacuate ratio (Evac_Ratio)

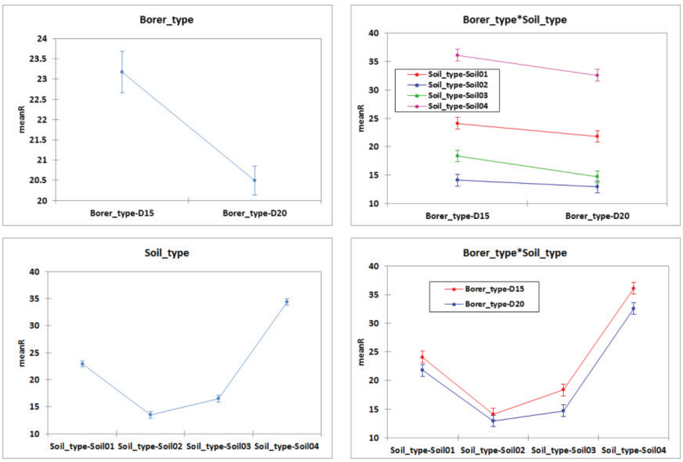

Figure 10. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated medium range scattering (mean R)

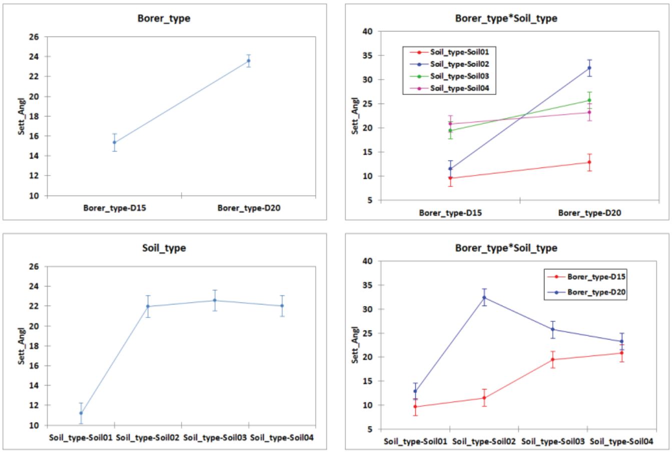

Figure 11. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated settlement angle (Sett_Angl)

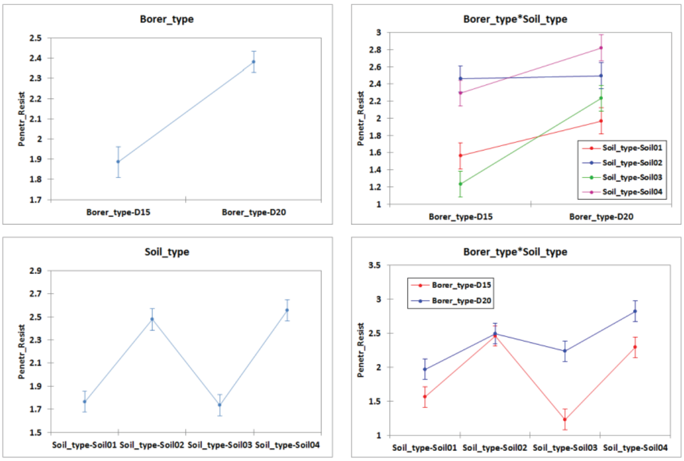

Figure 12. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated resistance to penetration (Penetr_Resist)

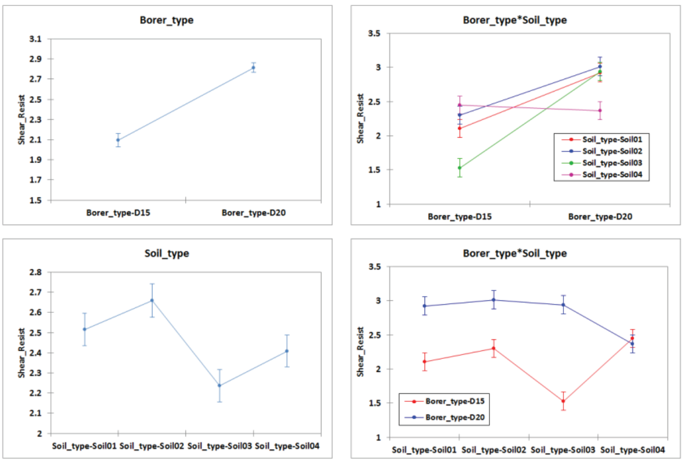

Figure 13. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated resistance to shearing (Shear_Resist)

By analysing the values of the penetration resistance, only from the point of view of the soil, the highest value is met in the case if the 4th type of soil (2.557 daN/cm^2) and the lowest one in the 3rd type (1.734 daN/cm^2). Thus, there is a very low risk that saplings could experience a physiological unbalance due to the fact that their roots cannot penetrate the sides of the holes (as a result of the fact that they were pressed during execution). The same situation also occurs in the case of the analysis based on both the type of soil and drill, as we run a very low risk of pressing the sides of the holes: a maximum value appears with a 20 cm diameter drill on the 4th type of soil (D20*Soil04 = 2.822 daN/cm^2) and a minimum one with the15-cm diameter drill on the 3rd type of soil (D15*Soil03 = 1.232 daN/cm^2).

A similar situation also occurred in the case of the shear resistance measured in the holes: the highest value was acquired in the 2nd type of soil (2.658 daN/cm^2) and a minimum one in the 3rd type (2.236 daN/cm^2). The quotas are maintained for the values involving both the type of soil and drill, as the maximum value was reached with a 20-cm diameter drill on the 2nd type of soil (D20*Soil02 = 3.016 daN/cm^2 and a minimum one with the 15 cm diameter drill on the 3rd type of soil (D15*Soil03 = 1.530 daN/cm^2).

PCA analysis was calculated using the correlation matrix of the variables and the between group algorithm. First two principal components explain 65.24% from the total variance of the data. The first three principal components explain 81.89% from the total variance of the data (Table 3 and Figure 14).

Table 3. Principal components statistical results

Principal component	Eigen value	Variance (%)
1	2.84974	40.711
2	1.71729	24.533
3	1.16566	16.652
4	0.736855	10.527
5	0.456835	6.5262
6	0.0718962	1.0271
7	0.0017237	0.024624

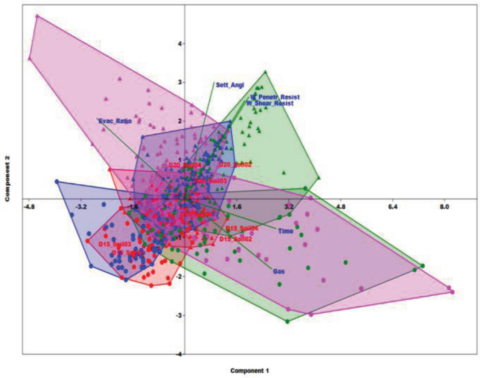

Figure 14. Principal component analysis (PCA) biplot

To alleviate the samples groups overlapping in PCA biplot, there was used the linear discriminant analysis (LDA) which uses canonical projections similar with the PCA method but aims to increase the linear distance between the samples groups (i.e. to get a better discrimination).

CONCLUSIONS

From all of the above, we can infer the following conclusions regarding the behaviour of the Stihl BT 121 auger with a 150/200 mm drill in the forestry sector and on a previously unprepared horizontal ground:

The holes were dug when the values of soil moisture were ranging from 20.75 to 24.11% for the 0-10 cm depth, 19.46-22.73% for 10-20 cm depth and 8.74-20.09 % for the 20-30 cm depth.

The values of total porosity that vary as follows: for 0-10 cm between 35.54-37.89%; for 10-20 cm between 33.28-37.43% and for 20-30 cm between 31.25-36.45%.

The average values of duration needed to dig holes (starting from the moment when the drill penetrated the soil, bored until reaching the 30 cm depth and was pulled out of the hole) vary between 9.83 ± 2.52 and 12.06 ± 1.99 seconds (mean ± SD).

The amplitude of average variation (the mean between the difference of maximum and minimum values) for the duration of digging holes is 13.36 sec., which is a high value. However, in terms of particle size distribution, the soil texture is similar. These differences occur as a result of physical properties of the different soils while digging.

The average value of split times derived from hole digging (time lapse of the auger put on, from one hole to the other, according to the planting layout: 1, 2, 3 or 4 metres), is at a 1 m distance, 2.71 ± 1.41 sec.; at 2 m, 5.42 ± 2.83sec.; at 3 m, 8.14 ± 4.24 sec. and at 4 m, 10.85 ± 5.66 sec. (mean ± SD).

The average values of fuel consumption for the four types of soil are: 3.49 ± 0.89 for the 4th type of soil, 4.31 ± 1.14 ml for the 1st type of soil, 4.76 ± 0.79 ml for the 3rd type of soil and 5.75 ± 1.80 ml for the 2nd type of soil (mean ± SD).

The average quantity of fuel needed for digging a hole up to 30 cm: 4.31 ml for the 1st type of soil, 5.75 ml for the 2nd type of soil, 4.76 ml for the 3rd type of soil and 3.49 for the 4th type of soil.

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