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# VEGETATIVE AND REPRODUCTIVE POTENTIAL OF BLACKBERRY CULTIVARS "HULL THORNLESS" GROWN IN DIFFERENT REGIONS OF BULGARIA

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***Abstract***

*The vegetative and reproductive traits of the blackberry cultivar Hull Thornless, grown in different agro-ecological conditions of Bulgaria, was monitored. The study was conducted during the period 2022-2024 in a collection plantation of the Research Institute of Mountain Stockbreeding and Agriculture, Troyan and the Experimental Field at the Faculty of Agriculture of Trakia University - Stara Zagora. The indicators of average number, average height (m) and thickness of shoots (mm) of two linear meters of the inter-row area were monitored. The results show that the studied parameters were influenced by environmental factors during the study. Regarding vegetative indicators, the number of shoots (17 ± 6.34), the thickness of the shoots (14.85 mm ± 2.36) and the height of the shoots (3.49 m ± 0.32) are greater in the blackberry grown in the conditions of Troyan. During the tested period, the highest average yield (1666.33 g/2m) and average fruit weight (5.63 g) was recorded by the plants in the plantation of Stara Zagora.*

***Key words**: berry fruits, fruit weight, vegetative indicators, yield.*

## INTRODUCTION

The blackberry belongs to the genus *Rubus, subgenus Eubatus,* family *Rosaceae.* The genus *Rubus* includes 13 subgenera distributed worldwide (GRIN datebase, USDA, 2006), of which five are of greatest breeding importance - *Idaeobatus* - raspberry, *Eubatu*s - blackberry, *Anoplobatus* - decorative raspberry, *Cyclactis* - northern grassy raspberry and *Chamaemorus* - wild raspberry (Hollman et al, 1996; Bravo et al., 1998; Sellappan et al., 2002; Wang et al., 2000; Wada et al., 2002). The blackberry cultivars developed so far are derived from 10 American and 3 European species. Today, many high-quality and high-yielding cultivars are used in blackberry production (Lykins et al., 2021), yet the industry needs new cultivars that adapt to changing climatic conditions and provide higher yields to meet modern requirements. Blackberries (*Rubus fruticosus* L.) are widespread throughout the world, but areas with mild winters and prolonged temperate summers are more suitable for their cultivation. The main production areas are North America, South America, Central America, Europe, Asia, and Africa.

In recent years, Europe has become one of the world leaders in blackberry production.

The largest areas of this crop have been recorded in Serbia and Hungary (Cuevas-Rodríguez et al., 2010; Paczkowska-Walendowska et al., 2021; Skrovankova et al., 2015; Zhao, 2007; Zia-Ul-Haq et al., 2014). In Serbia, after raspberries, blackberries are the most widespread small-fruited species and occupy an area of 4 000 ha, with production mainly concentrated in the central, northwestern and southern regions. The dominant cultivars are Čačanska Bestrna and Thorn Free, which represent for 95% of blackberry production in the country (Nikolić & Milivojević, 2010).

Due to increasing awareness of the valuable qualities of the fruit, global consumption of berry and berry-based products has increased significantly (Nile & Park, 2014; Padmanabhan et al., 2016). Fruits of the genus *Rubus* are among the rich in bioactive compounds. Their nutritional profile indicates that they contain dietary fiber, vitamins, minerals and carbohydrates (Cuevas-Rodríguez et al., 2010; Kiple et al., 2000; Vega et al., 2021).

Blackberries are present on the market for fresh consumption, but are more often processed into juices, jams, purees, concentrates and sweets. They are notable for their health benefits due to their high dietary content of fiber, vitamin C, vitamin K, folic acid and the essential mineral manganese (Sariburun et al., 2010). The productivity of small fruit crops (raspberry, blackberry) is determined by the number of shoots per meter, their development (height and thickness) and the number and weight of fruits per bush.

Fruit weight is an important qualitative reproductive trait influenced by genetic background (Kaldmäe et al.,2013; Kikas et al., 2017) and yield. Yield is one of the main indicators in fruit crops, determining to a significant extent the application of the cultivar in practice (Georgiev, 2009). In their studies, a number of authors found that environmental and cultivar factors have variable effects on vegetative and reproductive characteristics of small-fruited plants.

Strik (2012) indicated that fruit bud differentiation in raspberries and blackberries depends exclusively on the light regime, temperature conditions and the cultivation system applied.

There are relatively few blackberry plants in our country. The main reasons for the poor cultivation of this fruit species are its insufficient knowledge and the lack of cold-resistant cultivars with stalk upright and without thorns.

According to world and national literature, suitable growing areas for blackberry are high mountain areas with the necessary air and soil humidity. For locations where there is insufficient rainfall, an irrigation system is necessary.

The aim of the present study is to follow the behaviour of the introduced blackberry cultivar “Hull Thornless” grown under the mountain conditions of the Troyan region and the plain conditions of the town of Stara Zagora.

## MATERIALS AND METHODS

The research work was carried out in the period 2022-2024 in the experimental field of Trakia University - Stara Zagora and the collection plantation of RIMSA - Troyan. The object of the research is the blackberry cultivar “Hull Thornless”, introduced in the USA, which has not yet been sufficiently tested for our climatic conditions.

The blackberry plants were planted at 3.00 m row spacing and 1.50 m row spacing in two variants:

I var. - Plants planted in the collection plantation of RIMSA - Troyan;

II var. - Plants planted in the experimental field of Trakia University- Stara Zagora.

The trial was set in three replicates, each two linear metres of in-line area. A support structure was constructed. The soil in the area of Troyan is light grey forest, gleyey, medium to heavy sandy loam, moderately eroded, with low humus content (Mihailova at al., 2008), and in Stara Zagora the soil is meadow-clay, medium sandy loam, with a slightly alkaline reaction.

The following indicators are monitored:

- Number of shoots per two linear meters - the number of shoots in each replicate was listed;
- Shoot height measured in (cm) - all shoots from each replicate were measured;
- Shoot thickness (mm) - measured at 10 cm from the soil surface;
- Average fruit weight (g) - samples of 30 fruits were taken at one of the first and two of the mass harvests;
- Average yield (g/2m).

The methodology for studying plant resources in fruit plants (Nedev et al., 1979) was used to report the indicators. The data were processed by variance-statistical univariate, bivariate analysis of variance and correlation analysis (Lidanski, 1988), MS Excel - 2010 software was used.

## RESULTS AND DISCUSSIONS

The shoot-forming ability is an important factor characterizing the potential of the cultivar as well as determining to a large extent the cultivation technology. The results of the first trial showed a large difference between the cultivar variants in the index, which ranged from 4.33 pcs (variant II) to 17.00 pcs (variant I) (Table 1). The average shoot height of the blackberry plants of variant I (275.92 cm) was found to be higher. For the average shoot thickness parameter, the differences in values for both cultivation treatments were less and ranged from 8.21 mm (treatment II) to 12.92 mm (treatment I). In 2016, Karaklajić-Stajić, Ž et al. reported an average number of shoots ranging from 3.41 to 5.19 pcs, results lower than our study. The same authors reported twice as high a value for the average shoot length (353.60 and 530.22 cm) and diameter between 13.89 and 18.09 mm. Regarding the reproductive index, the average fruit weight in both locations did not show significant differences, 4.54 g (variant I) and 5.08 g (variant II). In the first experimental year, the yield obtained in the second variant of the tested cultivar was higher and was 2018.40 g /2m.

Table 1. Vegetative and reproductive indicators in "Hull Thornless" cultivar for the period of 2022-2024

| Indicators \ Cultivar | I variant | II variant |
|---|---|---|
| **2022** | | |
| Average number of shoots/m | 17.00 | 4.33 |
| Average height of shoots (cm) | 275.92 | 180.36 |
| Average shoots thickness (mm) | 12.92 | 8.21 |
| Average fruit weight (g) | 4.54 | 5.08 |
| Average yield (g/2m) | 918.08 | 2018.40 |
| **2023** | | |
| Average number of shoots/m | 17.00 | 5.33 |
| Average height of shoots (cm) | 266.19 | 331.04 |
| Average shoots thickness (mm) | 12.73 | 8.29 |
| Average fruit weight (g) | 4.59 | 6.84 |
| Average yield (g/2m) | 781.88 | 1469 |
| **2024** | | |
| Average number of shoots/m | 12.33 | 7.33 |
| Average height of shoots (cm) | 348.92 | 284.33 |
| Average shoots thickness (mm) | 14.85 | 6.61 |
| Average fruit weight (g) | 4.16 | 4.97 |
| Average yield (g/2m) | 2298.65 | 1511.62 |

In the second year of the trial, the average number of shoots in the first variant of the cultivar was the same compared to the previous year (17 pcs) (Table 1). In the second variant a higher number of shoots was recorded compared to the beginning of the trial (5.33 pcs). The average height of shoots ranged from 266.19 cm (variant I) to 331.04 cm (variant II). The average shoot thickness of the blackberry cultivar grown in Troyan was greater at 12.73 mm. The average fruit weight in the second year in variant I was very similar to the previous year (4.59 g), while in variant II it was higher at 6.84 g. In 2023, a lower average yield was recorded for both variants compared to the previous year - 781.88 g/2m (variant I), 1469 g/2m (variant II). In the third year, the number of shoots of the first variant of the tested cultivar decreased significantly to 12.33, but an opposite trend was observed in terms of average height and thickness of shoots. In the second variant, the number of shoots increased and reached 7.33 counts (Table 1). but a significant decrease in shoot height and thickness was found. In 2024 trial year, significantly higher average yield was recorded in first variant of the tested cultivar 2298.65 g/2m which was also found to be the highest during the trials period. A yield of 1511.62 g/2m was recorded for the second variant. There were no significant differences in the average fruit weight in both locations of cultivation, but the advantage, although minimal, was in the second variant. In their study on the vegetative traits of the blackberry cultivar "Čačanska Bestrna" (Karaklajić-Stajić et al., 2016), found that the indicators, number of stems (4.48 ± 0.21) and stem height (467.91 ± 16.26 cm), were greater in blackberry grown with a rain protection system, while stem diameter (15.68 ± 0.45 mm) was greater when grown outdoors.

In the first year of the trial, a very strong positive correlation between shoot number and shoot height and a strong correlation between yield, shoot number and average shoot height was observed in the cultivar in the first variant (r=0.99, r=0.77 and r=0.81, respectively)

(Table 2). Significant negative correlation was recorded between yield and shoot thickness (r= -0.70). Other correlations for the remaining parameters were observed in the second variant, with a strong negative correlation reported between number, shoot thickness and yield (r= -0.73, r= -0.84), a strong positive correlation between yield, average shoot height (r=0.82) and a very strong correlation between average shoot thickness and height, and between yield and shoot thickness (r=0.91 and r=0.98).

Table 2. Correlation dependences between vegetative and reproductive indicators of "Hull Thornless" in 2022

| Indicators | Average number of shoots /m | Average height of shoots (cm) | Average shoots thickness (mm) | Average yield (g/2m) |
|---|---|---|---|---|
| **I variant** | | | | |
| Average number of shoots/m | 1 | | | |
| Average height of shoots (cm) | 0.99 | 1 | | |
| Average shoots thickness (mm) | -0.08 | -0.14 | 1 | |
| Average yield (g/2m) | 0.77 | 0.81 | -0.70 | 1 |
| **II variant** | | | | |
| Average number of shoots/m | 1 | | | |
| Average height of shoots (cm) | -0.38 | 1 | | |
| Average shoots thickness (mm) | -0.73 | 0.91 | 1 | |
| Average yield (g/2m) | -0.84 | 0.82 | 0.98 | 1 |

The statistical correlation between the indicators of the cultivar "Hull Thornless" in 2023 from the trial at planting variant I showed a very strong positive correlation between the number of height and shoot thickness and between the average height and shoot thickness, with a correlation coefficient of (r=0.99), respectively (Table 3). No correlation was observed among the other parameters. In blackberry cultivation variant II, a very strong negative correlation was observed only between the indicators height and shoot thickness (r=0.99) and a high positive correlation between shoot thickness and yield (r=0.77). For all other parameters, a weak to significant correlation was observed (r<0.7).
In the third trial year, the first cultivar variant showed a very strong correlation between shoot thickness and height with a correlation coefficient of (r=0.99) and a high but negative correlation between average height, average thickness and yield with a correlation coefficient of (r=-0.92, r=-0.91) (Table 4).

Table 3. Correlation dependences between vegetative and reproductive indicators of "Hull Thornless" in 2023

| Indicators | Average number of shoots /m | Average height of shoots (cm) | Average shoots thickness (mm) | Average yield (g/2m) |
|---|---|---|---|---|
| **I variant** | | | | |
| Average number of shoots/m | 1 | | | |
| Average height of shoots (cm) | 0.99 | 1 | | |
| Average shoots thickness (mm) | 0.99 | 0.99 | 1 | |
| Average yield (g/2m) | 0.09 | -0.02 | 0.02 | 1 |
| **II variant** | | | | |
| Average number of shoots /m | 1 | | | |
| Average height of shoots (cm) | 0.57 | 1 | | |
| Average shoots thickness (mm) | -0.52 | -0.99 | 1 | |
| Average yield (g/2m) | 0.22 | -0.67 | 0.71 | 1 |

For all other parameters, weak to moderate correlation was observed (r<0.5). In variant II of plant growth, a very high correlation was found only between the number of shoots and their height (r=0.99). A high correlation was observed between the parameters number, height and thickness of shoots, respectively (r=0.89, r=0.85). A weak to moderate correlation was observed for all other indicators (r<0.5).

Table 4. Correlation dependences between vegetative and reproductive indicators of "Hull Thornless" in 2024

| Indicators | Average number of shoots /m | Average height of shoots (cm) | Average shoots thickness (mm) | Average yield (g/2m) |
|---|---|---|---|---|
| **I variant** | | | | |
| Average number of shoots/m | 1 | | | |
| Average height of shoots (cm) | 0.43 | 1 | | |
| Average shoots thickness (mm) | 0.46 | 0.99 | 1 | |
| Average yield (g/2m) | -0.05 | -0.92 | -0.91 | 1 |
| **II variant** | | | | |
| Average number of shoots /m | 1 | | | |
| Average height of shoots (cm) | 0.99 | 1 | | |
| Average shoots thickness (mm) | 0.89 | 0.85 | 1 | |
| Average yield (g/2m) | -0.03 | 0.07 | -0.47 | 1 |

The averaged values of vegetative and reproductive indicators of the studied blackberry cultivar over the three-year period reported higher shoot number (15.44), and shoot thickness (13.65 mm) scores of I variant and shoot height (414.91 cm), average yield (1666.33 g) and average fruit weight (5.63 g) of II variant (Table 5). In the analysis of variance, it was observed that on the parameter of average number of shoots, the factors of variance (67.67%) and random factors (20.53%) were the most influential and the interaction between years (0.16%) was the least. In terms of average height of shoots, the years during the test period (22.44%) and random factors (73.17%) were the most influential.

Table 5. Average values of vegetative and reproductive indicators by variants in "Hull Thornless" for the period (2022-2024)

| Cultivar / Indicators | I variant Troyan | II variant Stara Zagora | Level of significance (%)/ Degree of influence of factors (%) |
|---|---|---|---|
| Average number of shoots/m | 15.44 | 5.42 | (P<0.05) |
| | | | A=0.16 |
| | | | B=67.67 |
| | | | C=11.63 |
| | | | D=20.53 |
| Average height (cm) | 296.61 | 414.91 | (P<0.05) |
| | | | A=22.44 |
| | | | B=4.14 |
| | | | C=0.25 |
| | | | D=73.17 |
| Average shoots thickness (mm) | 13.50 | 6.45 | (P<.05) |
| | | | A=0.02 |
| | | | B=85.04 |
| | | | C=7.01 |
| | | | D=7.93 |
| Average yield (g/2m) | 1332.87 | 1666.33 | (P<0.05) |
| | | | A=10.67 |
| | | | B=0.75 |
| | | | C=8.39 |
| | | | D=80.18 |
| Average fruit weight (g) | 4.43 | 5.63 | (P<0.05) |
| | | | A=3.30 |
| | | | B=34.96 |
| | | | C=0.12 |
| | | | D=61.62 |
| Legend: A - degree of impact of years (%); B - degree of impact of the variants (%); C - degree of interaction impact of the variants and years (%); D - Degree of impact of random factors (%) | | | |

The influence of location was low (4.14%). Average shoot thickness was most strongly influenced by variants (85.04%) and significantly lower by variants and fits (7.01%), random factors (7.93%), and years (0.02%). Among the reproductive indicators, average yield was significantly influenced by years (10.67%) and random factors (80.18%). Mathematically, the differences were not proved at significance level ($P<0.05$). In the analysis of variance, it was reported that the parameter average fruit weight with the greatest influence were the variants (34.96%) and random factors (61.62%).

Linear regression was applied to quantify the relationships between vegetative indicators (number of shoots, shoot height and shoot thickness) and the reproductive indicator (yield). In 2022, the linear regression analysis performed on the test cultivar showed high correlation between vegetative traits shoot number and shoot height in variant I (R2=0. 99) and between shoot height, shoot thickness and shoot yield and shoot thickness in variant II (R2=0.82; (R2=0. 99) (Figures 1, 2, 3).

The regression analysis for the cultivar Hull Thornless in 2023 showed a high positive correlation between the number, height and thickness of shoots and between the height and thickness of shoots in the first cultivation variant. and between the height and thickness of shoots in the second cultivation variant.

The coefficient of determination R2 was high with values ranging from 0.98 to 0.99 (Figures 4, 5, 6, 7). The linear regression analysis done in 2024 between vegetative and reproductive indicators of blackberry cultivar showed high correlation between shoot height and shoot thickness in variant I (R2=0.99), and between shoot number and height and shoot number and thickness in variant II (R2=0.99; R2=0.80) (Figures 8, 9, 10).

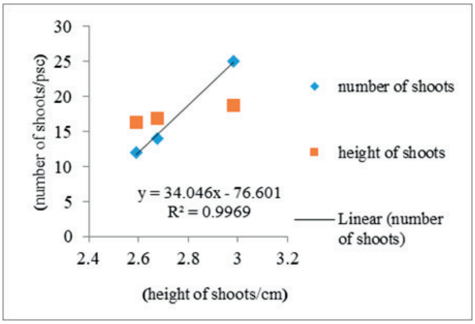


Figure 1. Regression analysis between vegetative indicators of "Hull Thornless", I variant in 2022

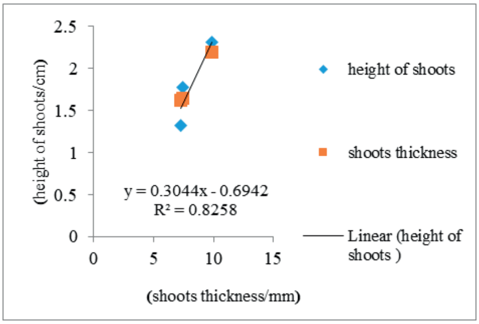


Figure 2. Regression analysis between vegetative indicators of "Hull Thornless", II variant in 2022

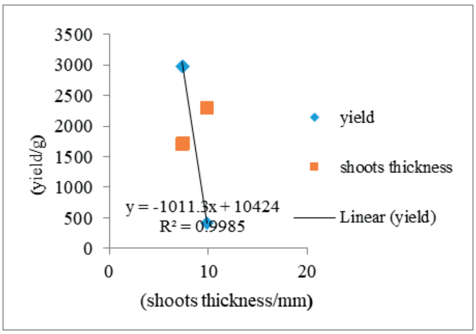


Figure 3. Regression analysis between vegetative and reproductive indicators of "Hull Thornless", II variant in 2022

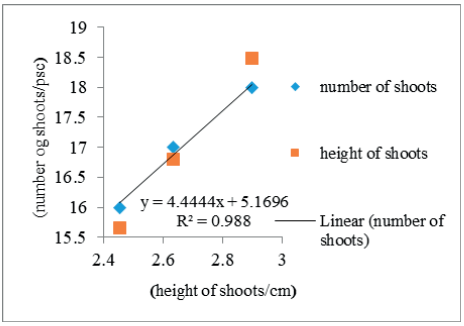


Figure 4. Regression analysis between vegetative of "Hull Thornless", I variant in 2023

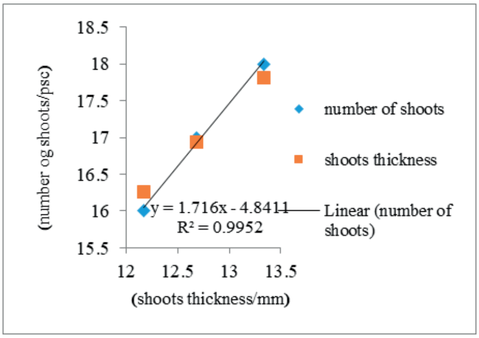


Figure 5. Regression analysis between vegetative indicators of “Hull Thornless”, I variant in 2023

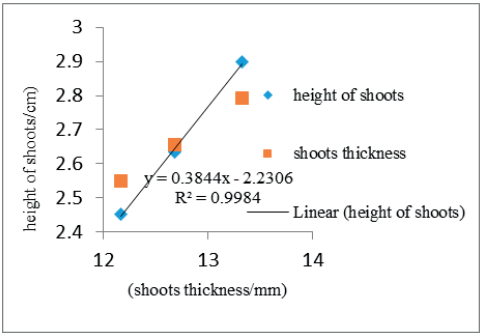


Figure 6. Regression analysis between vegetative indicators of “Hull Thornless”, I variant in 2023

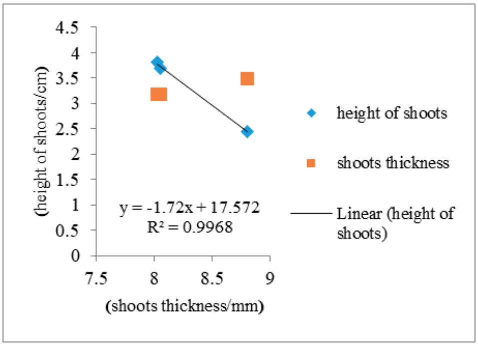


Figure 7. Regression analysis between vegetative indicators of “Hull Thornless”, II variant in 2023

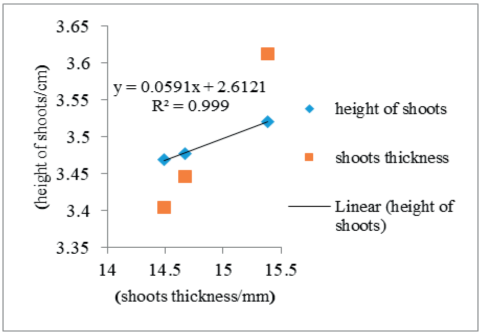


Figure 8. Regression analysis between vegetative indicators of “Hull Thornless”, I variant in 2024

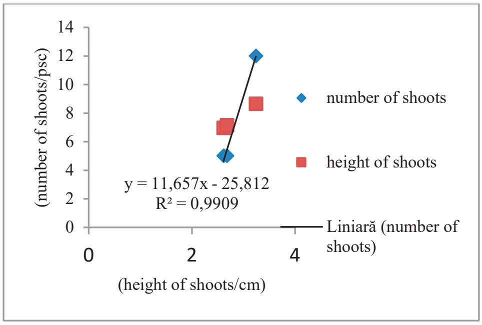


Figure 9. Regression analysis between vegetative indicators of “Hull Thornless”, II variant in 2024

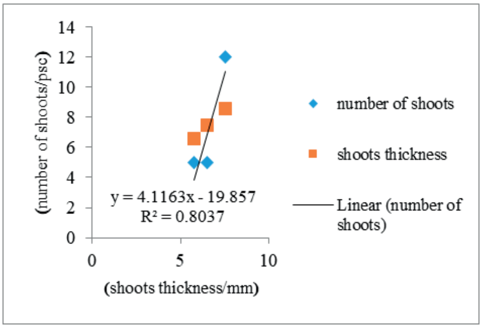


Figure 10. Regression analysis between vegetative “Hull Thornless”, II variant in 2024

## CONCLUSIONS

The averaged values of vegetative and reproductive indicators of the studied blackberry cultivar for the three-year period reported the higher shoot number (15.44) and shoot thickness (13.650 mm) of I variant and shoot height (414.91 cm), average yield (1666.33 g/2m) and average fruit weight (5.63 g) of II variant.

From the results of correlation relations of vegetative and reproductive traits in variant I of cv. “Hull Thornless”, a very strong positive correlation was observed between average number and height of shoots in 2022 and 2023, a very strong correlation relation between number, height and thickness of shoots in 2024. In the II cultivation variant, a strong to very strong correlation was found between the studied parameters (2022), a very strong correlation between shoot height and shoot thickness (2023) and a strong correlation between shoot number and shoot thickness to a very strong correlation between shoot number and shoot height (2024). From the results on the regression dependences of vegetative and reproductive plant traits we can summarise:

- in variant I, a very strong correlation was reported between number and height; height and shoot thickness for 2022; number and height and shoot thickness for 2023 and between height and shoot thickness for 2024.
- option II shows a strong correlation between shoot height and thickness and yield for 2022, between height and thickness for 2023 and 2024 and between number, height and thickness of shoots for 2024.

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