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Within-field variability of plant and canopy traits of sugar beet and their relation to individual root mass during harvest

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Abstract: The present study reports on research results obtained in the years 2014–2015 on two sugar beet production plantations in Central Poland. The purpose of any production is to obtain homogeneous canopy with the plants of demanded morphological and qualitative traits. The aim of the research was the assessment of the range and scale of plant variability in sugar beet canopy and impact of investigated plant and canopy traits (number of days from sowing to emergence, development stage of plants in the juvenile period, the plant living area, the location centrality index) to the final root mass at harvest time. Variability of investigated plant and canopy traits was evaluated using the variation coefficient, while the impact of these traits on the final root mass was assessed using the analysis of multiple linear regression. The obtained results show that sugar beet canopy reveals large, within-field variability in the investigated traits. The established relationship between final root mass during harvest and the canopy traits indicates that to obtain a large final root mass of individual plants during harvest, the most important is fast and even plant emergence, as well as the rapid development of plants in the juvenile period. At both production plantations, the impact of the living area of individual plants on the final mass of their roots was significant. However, no significant effect of the location centrality index on plant living area and the final root mass was found.

Keywords: *Beta vulgaris* L.; weather condition; plant density; yield; competition

Plants, usually of the same species, grown in a given production field form the so-called plant canopy. The canopies (production fields) of individual plant species are very similar to each other due to their characteristic morphological structure (Norman and Campbell 1989). Factors like the diversity of soil and weather conditions or applied cultivation technology, cause specific changes in the spatial structure of canopy of a given species (Freckleton et al. 1999, Pidgeon et al. 2001, Jones et al. 2003, Kenter et al. 2006, Malnou et al. 2006, 2008, Richter et al. 2006, Hoffmann 2019). The sugar beet field consists of plants sown in rows with a specified distance between the rows and between plants in a row. With row spacing of 45 cm and assuming around 100 000 plants per 1 ha as the optimal density, the distance between sugar beet plants in a row should be 20–25 cm. This arrangement of plants in sugar beet canopy in a production field should be considered correct and optimal (Cakmakci and Oral 2002, Sögüt and Aroglu 2004, Honsová 2008, Jaggard et al. 2011).

The spatial structure of sugar beet canopy is related to the yield components of this species, i.e. the canopy characteristics, whose product corresponds to the root yield harvested per unit area. In sugar beet cultivation, root yield components are the number of plants per unit area and the average root mass. Optimisation of these canopy characteristics guarantees a large root yield from a given field (Wyszyński 2006, Jaggard et al. 2011, Mahmood and Murdoch 2017). Plant density is shaped during sowing by determining the appropriate distance between the seeds in a row. Good seedbed preparation, high quality of seed and precise sowing guarantee high field emergence and

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Table 1. Monthly rainfall (mm) in the growing season 2014 and 2015 and water requirements, according to Dzieżyc et al. (1987)

Year	Month							Sum for IV–X
	IV	V	VI	VII	VIII	IX	X	
2014	32.3	44.5	74.7	28.7	87.9	22.9	20.6	311.6
2015	28.6	34.4	41.6	60.5	21.6	29.8	35.8	252.3
Rainfall requirements	18.0	65.0	74.0	85.0	78.0	54.0	34.0	408.0

allow obtaining the assumed plant density (Boiffin et al. 1992, Durr and Boiffin 1995, Stibbe and Märländer 2002, Gallardo-Carrera et al. 2007). The root mass of individual plants is generated throughout the growing season and is characterised by much greater variability on production plantations than plant density. The planter's goal is to obtain plants with uniform growth during the growing season and a large, even final mass of their roots during harvest (Tsialtas and Maslaris 2010, Hoffmann 2017, 2018).

High variability of sugar beet plants in the canopy in terms of the final root mass found in the present study and other authors' research is an important problem in cultivation of this species (Michalska-Klimczak and Wyszyński 2010). Identifying and eliminating the causes of this variation is challenging. Usually, plants that emerge later in comparison with those germinating earlier differ in size and stage of development until the end of the growing season. Under equal conditions of growth and development of sugar beet plants, the largest roots are obtained from plants that emerged first (Boiffin et al. 1992, Durr and Boiffin 1995).

The aim of this study was to assess the variability of sugar beet plant and canopy traits in two production plantations and their effect on the final root mass of individual plants.

MATERIAL AND METHODS

Experimental conditions. The study was carried out at two sugar beet production plantations (fields) located in Central Poland, one of which was cultivated in 2014 in the Mazovian voivodship and the other in 2015 in the Łódź voivodship. According to the World Reference Base for Soil Resources (WRB), the soils have been classified as Podzols at plantation A, and Cambisols at plantation B. Soil reaction (pH) in the arable layer at the investigated plantations was neutral, for plantation A it was 7.2, and for plantation B it was 6.7 in a suspension of 1 mol/L KCl. At plantation A the soil was characterised by a high concentration of 71.1 mg P/kg, 191.0 mg K/kg and 47.0 mg Mg/kg. At plantation B, the concentration of P and K was high (P = 66.3 and K = 178.0 mg/kg) and that of Mg moderate (36.8 mg/kg).

Site conditions are summarised in Tables 1 and 2. Relatively high total rainfall and more favourable rainfall distribution were reported in 2014 at plantation cultivated in the Mazovian voivodship. Rainfall at this plantation in June and August corresponded to the needs of sugar beet according to Dzieżyc et al. (1987), while in 2015 rainfall during these months at the plantation in the Łódź voivodeship was characterised by a large shortage. Higher average air temperature in April and May 2014 had a positive effect on the rate of emergence and development of plants at the plantation cultivated in that year compared to the plantation from 2015.

Experimental management and measurements. The basic cultivation data of the studied production plantations are presented in Table 3. Farmers decided about the levels of cultivation factors in sugar beet production plantations (fields). The previous crop for sugar beet at both study plantations was winter wheat. After harvest, the field was cultivated and stubble breaking with harrowing was performed. Cattle manure at a rate of 35 t/ha as well as phosphorus

Table 2. Average monthly air temperatures (°C) in the growing season 2014 and 2015

Year	Month							Average IV–X
	IV	V	VI	VII	VIII	IX	X	
2014	9.8	13.6	15.2	21.2	17.4	14.4	9.1	14.4
2015	8.1	13.0	16.5	19.7	22.3	14.9	7.5	14.6

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Table 3. Basic cultivation data of the studied sugar beet production plantations (A, B)

Specification	Production plantation – A	Production plantation – B
Localisation	20°28'E, 52°42'N Sochocin community Mazovian voivodeship	19°34'E, 52°16'N Oporów community Łódz voivodeship
Plantation area (ha)	3	2
Soil quality	arable soil of medium quality	good arable soil
Soil type	Podzols	Cambisols
Forecrop	winter wheat	winter wheat
Sowing date	13/04/2014	11/04/2015
Distance between seeds in a row (cm)	15.8	18.0
Cultivar	Monza (Syngenta Breeding Company)	Telimena (WHBC Breeding Company)
Harvest date	17/10/2014	21/10/2015
Field emergence (%)	69.0	88.6
Emergence rate (days)	16.1	20.8
Emergence uniformity (days)	4.1	7.8
Leaf yield (t/ha)	39.3	30.7
Root yield (t/ha)	59.9	59.3
Final plant density (thousand/ha)	90.2	109.4
Average mass of root (g)	664.0	542.0

and potassium fertilisers (35.0 kg P/ha and 130.0 kg K/ha) were ploughed in with fall ploughing without upright furrow-slice to a depth of 25–30 cm. After sowing, N fertiliser was applied up to 120 kg N/ha. Chemical plant protection was carried out according to regional standards to keep the crop free of weeds, pests and diseases.

Each plantation in proportion to its area was divided into 15 fairly equal parts. At each of them, a 5 m row section was randomly separated for plant and canopy research.

The following plant and canopy traits were studied: the date of emergence of individual plants (number of days from sowing to emergence), diversification of growth and development of plants in the juvenile period (number of leaves per plant 50 days after sowing (pcs)), living area of each plant (product of the sum of two ½ distance from neighbouring plants from the left and right in a row and the width of the inter-row 45 cm), the location centrality index (the quotient of the shorter to the longest side on the occupied surface (a:b)), the mass of leaves and roots of plants assessed during the harvest period (g)).

Plant emergence was observed every day from its beginning at designated row sections. Successively emerging plants were marked and counted every day. During each day of observations, new emerging plants were marked with a label of a different colour. After the emergence of individual plants and marked dates, a location point (centimetre at a distance of 0–500 cm) was assigned, which allowed their identification in the further growing period and assigning subsequently studied traits.

The dates of emergence of the studied plants allowed calculating the field emergence (FE) and its speed and uniformity. Field emergence is the quotient of the number of plants after emergence and the number of seeds sown from precision sowing expressed as a percentage (%). The rate of emergence and uniformity of emergence were calculated using the Pieper's index:

$$\text{Pieper's index} = \Sigma\,(d_n \times a_n)/\Sigma\,a_n$$

where: d_n – successive day of emergence; a_n – number of plants emerged on a given day; $\Sigma\,a_n$ – total number of emerged plants.

Emergence rate – the average time (in days) of emergence of one plant is the result of the quotient of the sum of products obtained from multiplying the number of emerging plants on a given day (a_n) by the number of days after sowing (d_n), and the total number of plants emerged ($\Sigma\,a_n$).

Uniformity of emergence – the average time (in days) of their duration is also the result of the quotient of the sum of products obtained from multiplying the number of emerging plants on a given day (a_n) by

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the number of days calculated not from the date of sowing (d_n), but from the date of the first emerging plant. The evenness of emergence means the average period (in days) of their duration.

The differences in growth and development during the juvenile period (50 days after the sowing date) of the studied sugar beet plants were assessed by determining the number of leaves of each studied sugar beet plant. At that time, the living area of the studied plants and their location centrality index of the occupied living area were determined.

Before harvest, each plant was identified, with its previously tested traits due to its position in the row. Then the plants were dug, cleaned, topped, and the leaf mass and root mass of individual plants were weighed.

Statistical analysis. The results were statistically analysed using Statistica 13.0 (StatSoft Inc., Palo Alto, USA). Basic statistical parameters, i.e. minimum and maximum values, means, standard deviations (SD) and coefficient of variation (*CV*), were determined and calculated for the studied plant and canopy traits. In order to determine the effect of plant and canopy traits on the final root mass of individual plants, the multiple linear regression method on standardised variables was used.

For each of the two plantations, the multiple determination coefficient (R^2) was calculated, which expresses (in percents) a part of the explained variation in the single root mass (y) by a linear regression dependence on the four studied plant and canopy characteristics (x_1–x_4). Moreover, the values of standardised partial regression coefficients (b_1, b_2, b_3, b_4) were calculated for individual plant and canopy traits expressing the pure (direct) effect of each of them separately on the final root mass of individual plants. The relationship was assessed between the final root mass of individual plants during the harvest period (y) and plant and canopy traits defined as: x_1 – number of days from sowing to the emergence of individual plants; x_2 – developmental stage of plants in the juvenile period; x_3 – plant living area; x_4 – location centrality index on the occupied area.

RESULTS AND DISCUSSION

The study carried out in 2014–2015 at two sugar beet production plantations in Central Poland representing the cultivation of this species in this part of the country shows a big difference in the spatial structure of their canopies. Plantation A cultivated in 2014, despite fast and more even emergence, was characterised by a much smaller field emergence compared to plantation B cultivated in 2015 (Table 3). The emergence of sugar beet plants at plantation A lasted only 8 days from 13 to 20 days after sowing, while at plantation B, the plants emerged for 15 days in the period from 14 to 28 days from the sowing date (Figure 1). Much higher, by 3.7 days, evenness of emergence at plantation A results from a greater number of plants emerging on the first days of emergence. At plantation A, 16.7, 14.3 and 11.8% of all plants emerged on the first, second and third day of emergence, respectively. In total, it was 42.8%. Compared to that, at plantation B, the total number of emerged plants in the first three days of emergence was only 8.3%. At plantation A, emergence ended in the next 4 days, while at plantation B, it lasted for another 12 days. According to the results of Stibbe and Märländer (2002), the individual period of vegetation shaped the range of individual dates of emergence. The earlier emerging plants would have longer vegetation period to produce dry matter than the individual plants that emerged later. It was further shown that heterogeneity of plant size

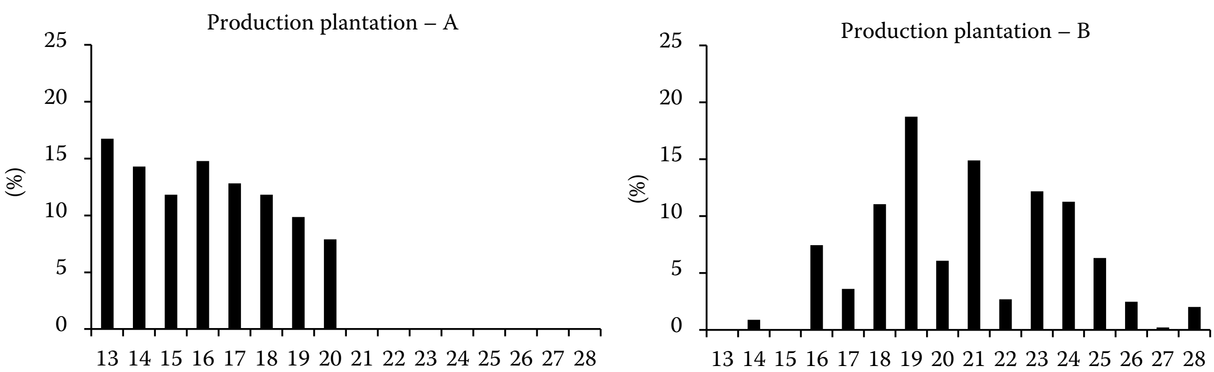

Figure 1. The share of plants with a specific day of emergence after the sowing date at production plantations A and B (2014–2015)

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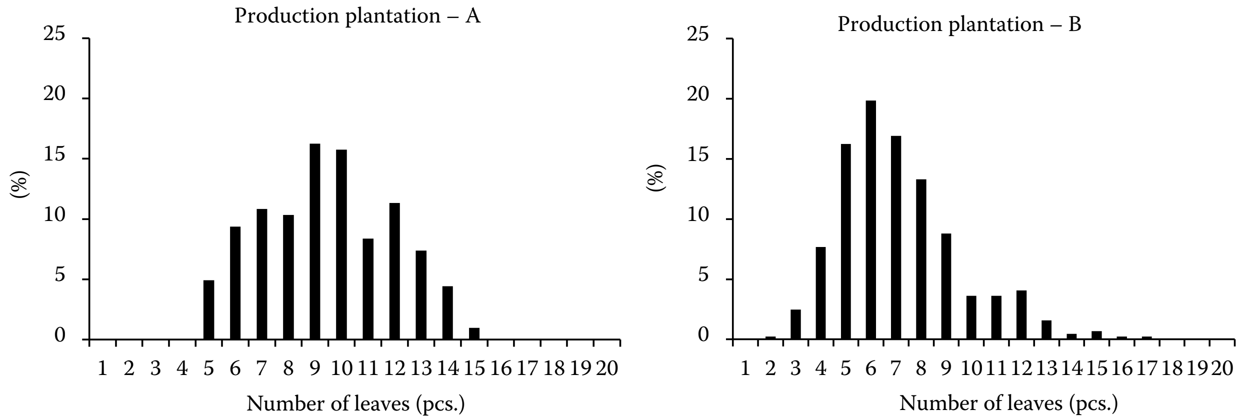

Figure 2. The share of plants with a specific number of leaves 50 days after sowing at production plantations A and B (2014–2015)

would be enhanced by the prolonged field emergence periods. In addition to that, competition for light could be the main reason behind the intraspecific competition, as suggested by Durrant et al. (1993).

The assessment of the studied sugar beet canopies during juvenile development indicates faster growth and development of plants at plantation A compared to plantation B (Figure 2). On day 50 after the sowing date, plants with 7 to 9 leaves dominated at plantation A. The proportion of these plants was 37.4% of the total. A similarly large proportion of 35.5% comprised plants with 10–12 developed leaves. Contrary to that, plantation B was dominated by plants with 4–6 leaves developed, and their proportion was as much as 43.8% of the total. There were 39.1% plants with 7–9 leaves and only 11.3% with 10–12 leaves. Plant development differences across the sugar beet canopies included in the comparison were observed until the end of the growing season. Michalska-Klimczak and Wyszyński (2010) showed that sugar beet canopies with a large share of plants developing fast in the initial phase of vegetation, i.e. with a large number of leaves, were characterised by an increased share of roots with a mass of 900–1 200 g and over 1 200 g at harvest.

Sugar beet canopy consists of rows of plants of different size, growing at irregular plant-to-plant distances. This results from imprecise agriculture, seeder quality and the technique of their exploitation, as well as from variability of plant emergence. The major role in sugar beet yielding is ascribed to the living area of plants (Wyszyński 2006). During the presentation of the item, an arrangement of plants in a row was assumed, 1 cm of row length being taken as equal to an area of 45 cm^2. A sugar beet plant having a 20 cm length of living area side, in fact, occupies a ground surface of 900 cm^2. Figure 3 presents the share of plants (%) with a specific range of varied living area side at production plantations A and B. A living area equal to 900–1 250 cm^2 is taken as optimum for sugar beet (possible to obtain under even plant arrangement in rows). This characterises a small part of the population (31.5%) at plantation A, and noticeably larger part (54.9%) of the popula-

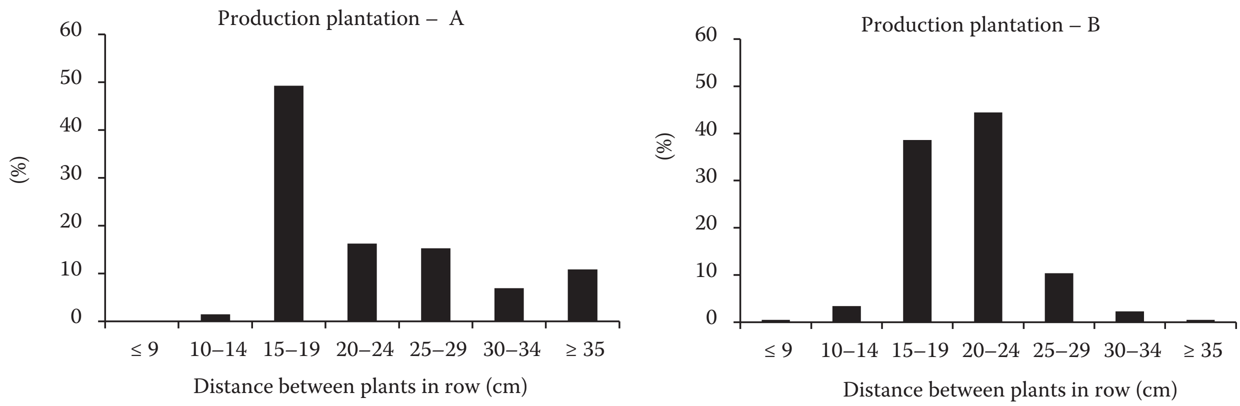

Figure 3. The share of plants with a specific range of varied living area side at production plantations A and B (2014–2015)

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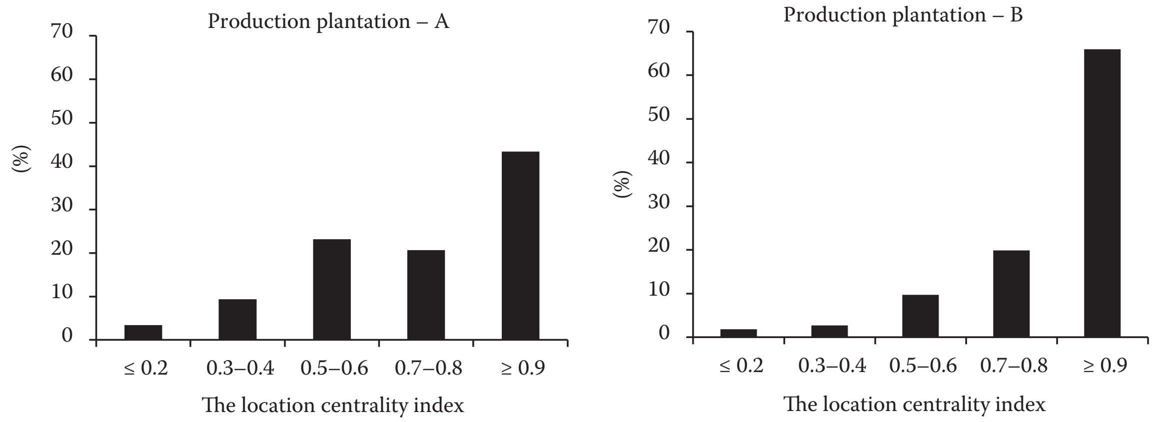

Figure 4. The share of plants with specific intervals of the location centrality index at production plantations A and B (2014–2015)

tion at plantation B. Plantation A was dominated by plants making use of a less-than-optimal living area (50.7%), while plants growing at too large living area represented 17.7%. At plantation B, plants making use of a less-than-optimal living area represented 42.4%, and those growing in a too-large living area accounted for only 2.7% of the total population.

Arrangement of plants across the living area was assessed using the location centrality index. The correct plant location within its living area is when the plant's distance from the other plants in a row is equal (location centrality index ≥ 0.9). The share of plants with correct location centrality within the living area was larger at plantation A and was equal to 65.9%, whereas at plantation B the share of plants correctly localised was lower and equal to only 43.3% (Figure 4). A large share of plants with location centrality index below 0.5 is to be highlighted at plantation A; this means that the distance to the closer adjacent plant in such a case was twice smaller than the distance to the plant further away. Plants with this trait accounted for 12.8% at plantation A, while at plantation B it was only 4.5%.

The structure of sugar beet plants in the studied production plantations in terms of the final mass of leaves and the final mass of roots of individual plants during harvest are presented in Table 4. Plantation A was dominated by 71.4% plants with the final leaf mass of 300–600 g, while at plantation B 72.5% of plants had the final leaf mass less than 300 g. At plantation A, plants with the final root mass of 900–1 200 g and above 1 200 g had a much larger proportion in the canopy compared to plantation B. The proportion of such sugar beet plants at plantation A was 17.7% and 5.9%, respectively; while at plantation B it was only 0.5% and 1.1%. At plantation A, also plants with a final root mass of 600–900 g constituted a larger proportion compared to plantation B. There were 72.0% of such plants at plantation B; while at plantation A they constituted 35.5% of the total. As a result, the yield component of sugar beet roots, which is the average root mass during harvest, was 664.3 g at plantation A and was higher by 122.2 g, i.e. by 22.5% than that obtained at plantation B. It should be emphasised that with much greater field emergence capacity, the final plant density at plantation B was 109.4 thousand/ha and was higher by 19.2 thousand/ha, i.e. by 21.3% from that at plantation A. Faster and more even the emergence of sugar beet plants at plantation A resulted in 22.5% higher final root mass, and despite a smaller plant density, the yield of roots from plantation A was 59.9 t/ha and was higher by 0.6 t/ha compared to plantation B. It was obtained at soils with lower fertility. Soils at plantation A are medium-quality arable podzolic soils, while at plantation B there are good arable brown soils.

The general characteristics of the spatial structure of sugar beet canopies at the studied production plantations are presented in Table 5 using the

Table 4. The share of plants with a specific mass of leaves and mass of root (g) at harvest at production plantations A and B (2014–2015)

Fraction (g)	Leaf mass		Root mass	
	A	B	A	B
≤ 300	15.76	72.46	11.33	4.29
300–600	71.43	26.19	35.47	72.01
600–900	12.32	0.68	29.56	22.12
900–1 200	0.00	0.23	17.73	0.45
≥ 1 200	0.49	0.45	5.91	1.13

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min, max and average values, standard deviation and coefficient of variation for a given plant and canopy traits. Emergence at plantation A started 1 day faster compared to the sowing date and ended 8 days earlier compared to plantation B. The coefficients of variation and standard deviation were smaller at plantation A. The studied production plantations differed in the degree of plant development during the juvenile period, i.e. during 50 days from the sowing date. At plantation A, the plants were more even in terms of developmental stages achieved. The least developed plants had 5 leaves, and the largest ones developed 15 leaves. At plantation B, the range of variability of this trait ranged from 2 to 17 developed leaves. Plantation A was characterised by 2.3 larger plants than the average plant at plantation B, with the coefficient of variation of this trait being 26.3% compared to the coefficient of variation at plantation B (34.5%). Durr and Boiffin (1995) related the sources of variability at sugar beet fields during late June with the onset of competition for light among individual plants. This variability can be observed at various levels. For once, it stems from different emergence times and consequently, the beginning of light capture and duration of growth. On the other hand, this variability can also be related to different biomass of seedling at emergence. Thirdly, it also comes from different cotyledons assimilation rates and thus different seedling relative growth rate (RGR). A larger living area of the sugar beet plants, on average, and a higher diversity of this trait were found at plantation A (Figure 3). This was due to the smaller field emergence and, as a result, smaller plant density at plantation A. Similarly, plantation A was characterised by a less central location of plants on their living area and with greater variability of this trait. High diversity of the living area of individual plants at plantation A was undoubtedly the reason for greater variability in the traits of sugar beet plants: final leaf mass and final root mass of individual plants despite lower variability of plants during juvenile development at this plantation compared to plantation B. Plants at plantation A produced leaves with the average final mass of 435.2 g with a variability range from 100 to 1 590 g and a standard deviation of 165.9 g. At plantation B, the corresponding values were 281.0; from 50 to 1 255 g and 104.2. Variability in the final root mass was even greater. At plantation A, the average final root mass was 664.3 g and varied in the range of 70–1 910 g with a standard deviation of 307.4 and the largest coefficient of variation 46.3% of all the studied plant and canopy traits. At plantation B, with a similar range of variability of this trait but a much smaller standard deviation of 165.1, the coefficient of variation was lower by 15.8 percentage points. According to Boiffin et al. (1992), plant-to-plant heterogeneity at the onset of competition and sugar accumulation in roots are both strongly dependent on the early variability. This is due to the fact that exponential growth pattern leads to biomass ratio holding among plants of different sizes. Additionally, crop development already at a very early stage shapes

Table 5. Range of variation of investigated plants and canopy traits at sugar beet production plantations A and B (2014–2015)

Plant and canopy traits	Production plantation	Range of variation				
		min.	max.	mean	SD	*CV* (%)
Number of days from sowing to emergence (days)	A	13.0	20.0	16.1	2.2	13.9
	B	14.0	28.0	20.8	3.0	14.4
Development stage of plants in the juvenile period – number of leaves per plant (pcs.)	A	5.0	15.0	9.4	2.5	26.3
	B	2.0	17.0	7.1	2.5	34.5
Distance of variable side of the planting space (plant living area) (cm)	A	12.0	80.5	22.9	10.0	43.7
	B	7.0	40.0	20.2	3.7	18.5
Location centrality index	A	0.1	1.0	0.7	0.2	33.7
	B	0.1	1.0	0.8	0.2	23.0
Leaf mass (g)	A	100.0	1590.0	435.2	165.9	38.1
	B	50.0	1255.0	281.0	104.2	37.1
Root mass (g)	A	70.0	1910.0	664.3	307.4	46.3
	B	89.0	1925.0	542.1	165.1	30.5

SD – standard deviation; *CV* – variation coefficient significant growth variability in late June, both at a given field and among different fields. As shown by Durrant and Jaggard (1988), the emergence date and weight variation among individual plants are closely related. Michalska-Klimczak and Wyszyński (2010), in their research, revealed that large variability of plants during the early stage of vegetation resulted in increased plant variability prior to harvest. Limited plant variability at the beginning of vegetation contributes to structure uniformity of root yields. Pocock et al. (1990) noticed that large variability of individual sugar beet plants in a canopy is detrimental, because of losses during harvest and because of the decreased technological value of the crop, related to the disadvantageous chemical composition of both small and large roots.

The studied canopy traits did not equally determine the final root mass (Table 6). At the plantation, A with more even emergence, the rate of emergence (defined as the number of days from sowing to emergence) had the largest share in the formation of the root mass. Increasing the time of emergence of individual plants reduced their final mass. At plantation B with uneven and long-lasting emergence, the degree of beet seedling development in the juvenile period had the greatest impact on the final root mass. The final root mass of individual plants was determined by the speed of their development in the initial growing stage. At both production plantations, the impact of the living area of individual plants on the final mass of their roots was significant, but the strength of the impact of this trait was definitely smaller. However, no significant effect of the centrality of location on the living area on the final root mass was found. The relationship between the plant and canopy traits and the final root mass of individual plants during harvest (one of the two components of root yield) determined at the studied production plantations indicates the importance of speed and uniformity of emergence and development of plants in the juvenile period. At plantation A, where emergence was even, the final root mass was determined by its speed. Rapidly emerging plants extended the growing period and were characterised by a higher final root mass. At plantation B with uneven, longer-lasting emergence, the rate of development of individual plants after emergence expressed in the number of developed leaves 50 days after the sowing date was of great importance in shaping the final root mass during harvest. Plant traits are strongly shaped by order of emergence counted by the number of days after sowing up to the emergence date (Durr et al. 1992). It was shown that sugar beetroots that first emerge after 1 month of growth had from 2.1 to 9.6 larger dry matter weight than the plants emerging towards the end of the emergence period. Time of emergence was found as the most important factor determining plant weight at harvest. In fact, it was stronger than such factors as the average weight of neighbouring plants or mean distance to neighbouring plants. Podlaski and Chomontowski (2020) proposed that variability in the root yield from different plantations cultivating the same plant cultivar and comparable population grown under comparable agro-ecological conditions stemmed from the spread in the rate and uniformity of plant emergences. These differences disappear with the progress of crop development; their effect lasts towards the harvest, nonetheless.

Plant and canopy traits variability in a production plantation towards the end of the vegetation period can be traced back to the irregularities in the dates of plant emergence. Results of field experiments point to the field emergence dynamics as another factor that could be considered in the optimisation of yield and quality of sugar beet. Identification of any agriculturally

Table 6. The determination coefficient (R^2) and partial regression coefficients (b_1, b_2, b_3, b_4) for the relationship of final root mass of individual plants to four analysed traits of the plant and canopy traits at investigated sugar beet production plantations A and B (2014–2015)

Production plantation	Determination coefficient (R^2)	Plant and canopy traits			
		b_1 for number of days from sowing to emergence (x_1)	b_2 for the development stage of plants in the juvenile period (x_2)	b_3 for the plant living area (x_3)	b_4 for the location centrality index (x_4)
A	88.6	–0.639*	0.313*	0.072*	–0.007
B	73.7	–0.164*	0.683*	0.107*	0.017

*significant effects at the level α = 0.05; x_1 – number of days from sowing to the emergence of individual plants; x_2 – developmental stage of plants in the juvenile period; x_3 – plant living area; x_4 – location centrality index on the occupied area

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controllable conditions responsible for introducing plant variability prior to the onset of plant competition is beneficial to the crop because it corresponds to an improvement of fast and homogeneous growth at the early plant development stage. In sugar beet crop management, good preparation of the field for sowing and its careful execution with the use of high-quality seed material will help achieve fast and even plants emergence; it, combined with their rapid development, will ensure a large final root mass of individual plants and at the right plant density, high final root yields and consequently, high technological sugar yields.

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