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ESTIMATION OF TENDRILS PARAMETERS DEPENDING ON THE SOWING METHODS, IN CONTRASTING *PISUM SATIVUM* L. VARIETIES

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ABSTRACT

Morphological traits of tendrils of different pea varieties in pure and mixed sowing were determined in this study. The study presents the description of tendrils in two pea cultivars: the leafed variety with a strong lodging tendency and the semi-leafless variety with a lower lodging degree. Tendril length, surface area and mass in the vegetative phases were determined. The study showed that the stability of stems depends on the variety type. The semi-leafless variety grown in a mixture developed stronger tendrils along nearly the entire stem length, whereas in pure sowing it developed tendrils with higher parameters only in the upper part of the stem. The variety with typical foliage grown in mixed sowing developed shorter tendrils with a smaller surface area, while in pure sowing, showed a higher activity of tendrils. The semi-leafless pea is a dominant and aggressive species in mixed sowing with linseed. The dominance of peas resulted from the development of longer tendrils with a larger surface area. However, the dominance of peas in a mixture did not cause the plants to produce a larger mass or a larger number of pods and seeds.

Key words: pea tendrils, morphological parameters, lodging.

INTRODUCTION

Pea plants are grown for seeds, fodder or as a vegetable; hence the register of cultivars features morphologically different varieties. Leafed varieties have undesirable traits, such as very large foliage, scantily illuminated inner stand, and a high lodging degree during the ripening period. Semi-leafless varieties are less prone to lodging and produce satisfactory seed yield and also forage yield comparable to varieties with standard foliage (Koivisto et al., 2003; Uzun et al., 2005). Semi-leafless cultivars contribute to delaying or reducing of crop lodging thanks to the well-developed tendrils, which keep the plant in a vertical position (Hofer et al., 2009). Skubisz et al. (2007) presented another view, stating that the degree of pea lodging is determined by mechanical properties of the stem. Comparing varieties with different lodging tendencies, the authors showed that the stems of lodging-resistant pea cultivars had better mechanical properties. Furthermore, they showed a significant negative correlation of the stem cracking height to the stem-wall thickness and cross-section area. Zhang et al. (2006) suggested the need for a balance among the factors such as tendrils length, stem stiffness, and lodging performance.

Pogórska-Lesiak and Sobkowicz (2013) believe that lodging is inherent to pea growth. Therefore, they recommended the mixed cultivation of pea plants with cereal plants, as pea mixed sowing ensures the vertical position of plants in a stand, reducing lodging. Based on the observation of lodging in semi-leafless cultivars in pure and mixed sowings, Kontturi et al. (2011) reported that even a small proportion of oats, as a supporting plant, effectively reduced lodging in a mixture of peas and oats. Rauber et al. (2001) claim that pea plants with standard foliage show high yielding levels, and therefore the mixed sowing of peas with typical foliage with oats is more legitimate. Zhang et al. (2006) demonstrated that legumes use mechanical

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properties of their tendrils to reduce lodging. Such a phenomenon can be observed in the semi-leafless pea, which climbs up a cereal or non-cereal plant, attaching its tendrils to the plant's rigid stem. However, the mechanical facilitation of pea growth negatively affects the yielding of the supporting plant, due to the occurrence of interspecific competition in the stand (Klimek-Kopyra et al., 2013). According to numerous studies concerning interspecific competition (Andersen et al., 2004; Chen et al., 2004; Corre-Hellou et al., 2006; Hauggaard-Nielsen and Jensen, 2001), intensified nitrogen fertilisation contributes to an increase in the competitiveness of the cereal plant in mixed cropping.

As reported by Zając et al. (2012), interspecific competition depends not only on the selection of species, but also on weather conditions. Their research indicated that a growing aggression between peas and a non-cereal plant resulted from the insufficient amount of water in the subsoil. Research by Klimek-Kopyra et al. (2013) and Zając et al. (2013) demonstrated that the pea is a more dominant species in a mixture with oil linseed, which results in a high seed yield. Given the presence of pea tendrils, linseed plays a major role as a supporting plant, at the expense of yield. Research conducted to date concerned only the comparison of a semi-leafless pea variety in mixed sowing with oil linseed. However, it is worth investigating the properties of tendrils, which determine the position of the plant in a stand, in both semi-leafless and standard foliage varieties.

The aim of this study was to assess the morphological properties of tendrils, which serve a supporting function in different pea varieties (semi-leafless and with standard foliage), cultivated both in pure and mixed sowing.

MATERIAL AND METHODS

A two-year-long (2010-2011) field experiment was carried out using a randomised block method in four replications at the Experimental Station of the Agricultural University, situated in Prusy near Krakow. Two pea cultivars were compared, namely: the variety set with standard foliage and the semi-leafless variety Tarchalska, in pure and mixed sowing with oil linseed, cultivar Flanders. The pure sowing plants were cultivated in the following distribution: 110 plants/m^2 (pea) and 800 plants/m^2 (linseed), while in the mixed sowing system the proportion was 50:50. The fertilisers were applied in the amounts of 48 kg.ha^{-1} P, 72 kg.ha^{-1} K, whereas the total amount of N was 60 kg.ha^{-1} in pure linseed sowing, 20 kg.ha^{-1} in pure pea sowing, and 40 kg.ha^{-1} in mixed sowing. Biometric tests were performed in three developmental phases: seedling (BBCH 13), flowering (BBCH 65), and full maturity – full-pod phase (BBCH 77). Stipule mass (StM), stipule length (SL), tendril mass (TM), tendril length (TL), and tendril surface area (TSA) were examined in the studied developmental phases. At the full-pod stage, the length and surface area of tendrils were additionally examined. To this end, six plants of equal size were collected from each plot (assuming 10 well-developed tendrils on each node; 1 – basal part of the stem, 10 – top part of the stem). The tendrils were scanned and subsequently analysed using APHALON software. In the full maturity phase (BBCH 97), 10 plants were collected from each plot in order to determine: stem mass-SM (g), number of pods per plant – NP (items), number of seeds per plant – NSP (items), and lodging degree – LD. Lodging was evaluated by means of a 9-point scale, where 1 denotes no lodging, and 9 – a completely flattened plot (Kelbert et al., 2004). When lodgings varied within the same plot, a weighted average was calculated by means of the following equation: $W = (p_1 \times b_1) + (p_2 \times b_2) + (p_n \times b_n)/100$, where W is an average lodging on the plot; p_i – 'i' part of the plot of the same lodging (%); b_i – lodging of the 'i' part of the plot; n – number of plot parts with a different lodging.

RESULTS AND DISCUSSION

Pea tendrils were different between cultivars and sowing systems (Table 1). The semi-leafless pea variety developed larger tendrils, irrespective of the sowing system. In the seedling phase, the mixed sowing of semi-leafless peas had a positive effect on the length, mass, and surface area of tendrils and stipules. Mixed sowing of the pea variety with conventional foliage had a negative impact on the length and surface area of tendrils and the length of stipules. In the flowering phase, the mixed sowing of semi-leafless peas showed an increase in the mass and length of tendrils and their stipules, whereas a decrease in the size of tendrils and stipules occurred in the variety with conventional foliage. In the ripening phase, a considerable increase in tendril parameters was noted in the semi-leafless variety in mixed sowing and in the variety with standard foliage in pure sowing. Lamb et al. (2007) demonstrated that the competition between plants in a stand is not equally strong throughout their growth and development. In the seedling phase, plants compete aggressively for habitat resources, through juvenile to the flowering stage. In the ripening phase, the intensity of these interactions is lowered due to the different duration of the ripening period in plants. Other results were presented by Hauggard-Nielsen et al. (2006), who found that peas grow poorly in a pea-barley mixed sowing during the initial stages of pea growth and development, yet it later dominated in the mixture. The author's own studies have shown an increase in the dominance of peas during juvenile and pod-formation phases. This resulted in the augmentation of tendril size and stipule mass. The research by Zając et al. (2012) did not show any strong biotic interactions between plants, but proved a certain tendency. The Ramrod variety accumulated significantly less biomass in the stems when grown in a mixture with linseed, particularly at the juvenile stage, compared to pure sowing.

Table 1. Development of leaf morphological traits in different pea varieties during three selected vegetative phases depending on the sowing system (annual averages)

Treatments	StM (g)	SL (cm)	TL (cm)	TL (g)	TSA (cm^2cm^{-2})
(BBCH 13)					
T	0.406±0.07	2.01±0.59	2.90±0.67	0.341±0.06	14.2±3.11
T+L	0.535±0.19	2.90±1.95	3.20±0.56	0.472±0.14	16.9±3.99
S	0.423±0.10	2.44±0.60	3.30±0.48	0.254±0.08	7.95±1.81
S+L	0.571±0.11	1.77±0.31	2.30±0.67	0.291±0.31	5.63±1.45
P≤0.05	0.01*	0.11	0.000*	0.055	0.000*
(BBCH 65)					
T	0.562±0.19	6.10±1.91	13.3±1.49	1.40±0.27	28.5±5.14
T+L	0.662±0.18	7.43±0.69	14.2±1.93	1.72±0.71	20.57±3.77
S	0.918±0.44	7.00±1.47	5.20±1.23	0.95±0.65	15.14±3.27
S+L	0.581±0.16	3.50±0.73	3.60±0.52	0.63±0.30	13.57±2.15
P≤0.05	0.02*	0.000*	0.000*	0.000*	0.000*
(BBCH 77)					
T	0.601±0.06	10.9±2.14	14.7±0.48	1.71±0.17	40.7±1.91
T+L	0.969±0.10	8.60±0.51	15.7±1.41	1.99±0.63	51.0±2.65
S	1.037±0.34	10.5±3.10	5.90±0.87	1.46±0.23	27.0±1.02
S+L	0.783±0.14	5.40±1.42	4.90±0.31	0.75±0.13	17.6±2.85
P≤0.05	0.000*	0.000*	0.000*	0.000*	0.000*

The considerably higher parameters of tendrils in semi-leafless peas significantly reduced lodging in mixed sowing (Table 2). However, a significant decrease in the number of pods being set and seeds formed was observed. Mixed cropping of the pea variety with standard foliage produced a positive effect. Linseed successfully protected peas against lodging. However, the mixed sowing of peas contributed to a lower mass of plants, number of pods and seeds. Similar results were obtained by Zając et al.

(2012). The cultivation of linseed with peas caused a decrease in linseed yield. This is also supported by the study of Patra et al. (2004), who demonstrated that a mixture of linseed with lentil and chickpea had a negative impact on linseed biomass, while positively affecting biomass growth in the studied legumes.

Table 2. Morphological traits of pea plants in the generative phase (BBCH 97)

Treatment	SM (g)	NPP (pc)	SNP (pc)	LD
T	13.32±0.91	9.62±1.30	29.00±4.14	6.62±0.51
T+L	11.27±1.69	7.50±1.41	23.37±2.97	4.25±0.46
S	11.53±0.50	7.37±0.51	28.38±2.34	1.75±0.46
S+L	9.47±0.85	5.75±0.71	22.87±1.55	2.25±0.71
P≤0.05	0.000*	0.000*	0.000*	0.000*

The length of tendrils determined the form of a pea stand (Figure 1). Semi-leafless peas in mixed sowing with linseed developed longer tendrils due to the alteration in the stand density. As pea plants were sown at a lower density, this resulted in the elongation of tendrils to enable the plants to attach to one another in order to maintain stability in a stand and curb lodging. Moreover, linseed stems served as a support for tendrils, which twisted around them in the central and upper parts of the stems. In pure sowing, however, with a higher density of the pea stand, tendrils were less strongly developed. In the case of peas with standard foliage, the increased stand density resulted in a greater stability of the stand and the lack of response of the plants to the elongation of tendrils. An opposite situation was observed in pure sowing, where a more intensive elongation of tendrils was recorded as a result of a lower overall density of the pea stand.

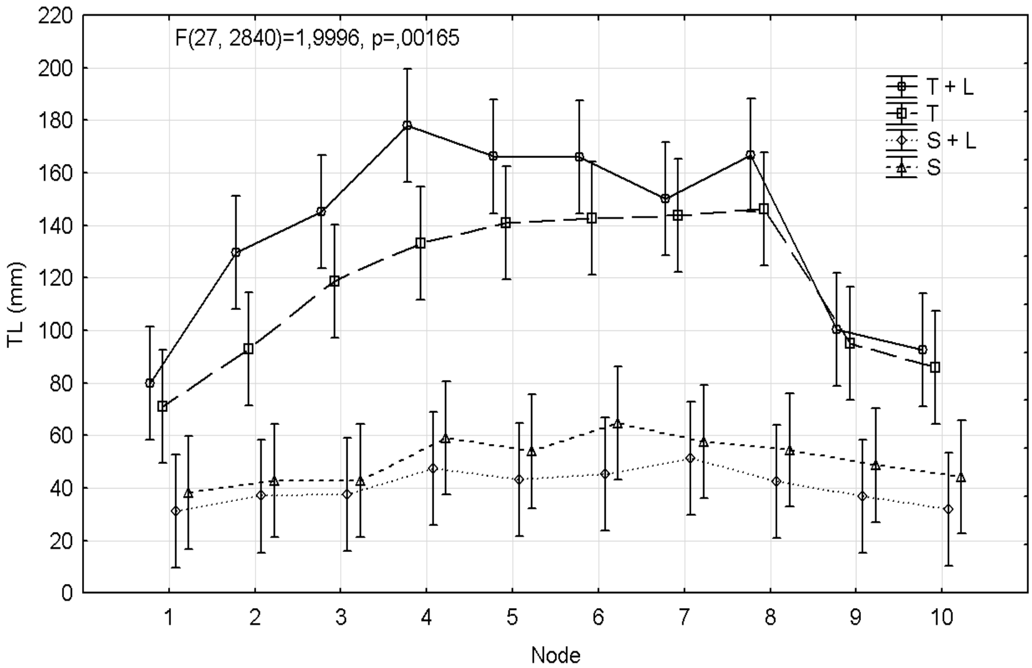

Figure 1. The distribution of tendril length in semi-leafless (a) and leafed (b) peas in different sowing systems

The surface area of tendrils was significantly determined by the cultivar and sowing system (Figure 2). The semi-leafless variety, when cultivated in mixed sowing with linseed, developed stronger tendrils, i.e. longer and with larger surface area, in the nearly entire length of the stem (2-8 node) (Figure 2). In pure sowing, the semi-leafless variety developed tendrils with higher parameters only in the upper part of the stem (5-8 node of the stem). The variety with standard foliage developed shorter tendrils with a smaller surface area in mixed sowing, with a more intensive growth of tendrils noted at 5-7 internodes. In pure sowing, the pea variety with standard foliage displayed an increased activity of tendrils, particularly at 4-8 internodes.

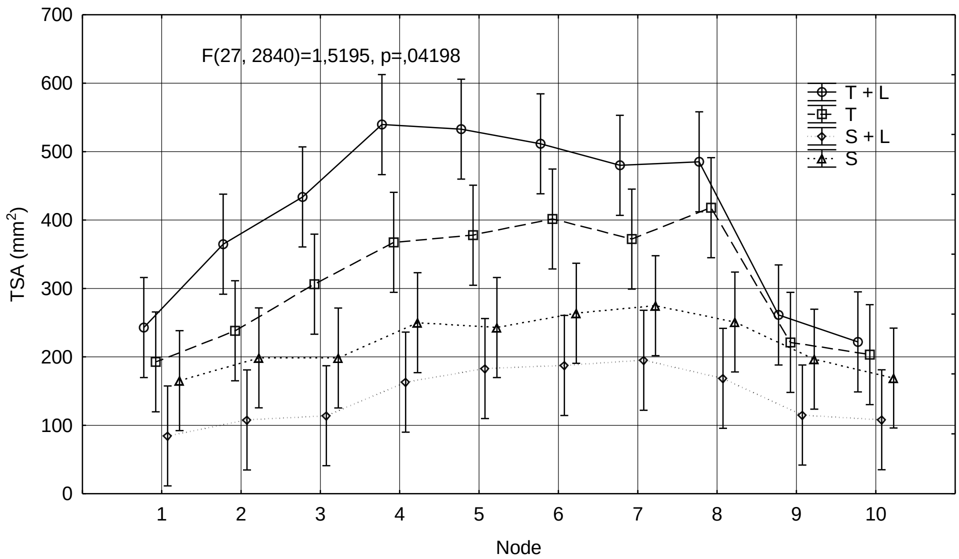

Figure 2. The development of tendril surface area in semi leafless and leafed peas in different sowing systems

Our study confirmed the results of Zając et al. (2012) and Klimek-Kopyra et al. (2013), indicating that the semi-leafless pea is a dominant and aggressive species in a mixture with linseed. The dominance of peas resulted from the development of longer tendrils with a larger surface area.

CONCLUSIONS

The study showed that the stability of pea stems is significantly dependent on the variety type. Semi-leafless varieties are more resistant to lodging due to the high parameters of tendrils, such as surface area, mass, and length.

The sowing system significantly determined tendril parameters. The mixed sowing of peas with linseed significantly increased the length and surface area of tendrils. The semi-leafless variety, in mixed sowing, developed stronger tendrils in the central part of the stem. The leafed variety developed larger tendrils in pure sowing, in the upper part of the stem. The presence of linseed caused a significant decrease in tendril traits.

Higher parameters of pea tendrils did not entail a larger number of pods being set or seeds formed. Linseed successfully protected peas against lodging. However, pea cultivation in mixed sowing contributed to a lower mass of plants, number of pods and seeds.

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