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GROWTH, DEVELOPMENT, AND WEED SUPPRESSION CAPACITY OF *Camelina sativa* (L.) Crantz GROWN AS SOLE AND MIXED CROP WITH LEGUMES: PRELIMINARY RESULTS

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Abstract

Camelina sativa (L.) Crantz is a valuable crop with good drought resistance and has been proposed for cultivation in Organic farming system. The development stages of camelina, pea, and vetch grown as sole and mixed crops, and the existing weeds S. halepense and S. viridis in a field plot experiment were under evaluation. The trial was stated in the experimental field of the Agricultural University of Plovdiv, Bulgaria. On the last reporting date the camelina genotypes 'Luna' and 'Lenka' entered the beginning of the flowering stage, and the Bulgarian landrace showed better development and was in the full flowering stage. The pea and vetch were in the full flowering stage as well. The development stages of the mixed cropping systems were the same as the growing stages of their sole crops. The mixed cropping system of the well-developed Bulgarian camelina landrace grown in a mixed cropping system with pea and vetch suppressed the growth and development of the weeds reported. In the sole crops, the reported weeds developed faster and accumulated a greater amount of biomass.

Key words: *Camelina sativa, intercrops, growth, development, weeds.*

INTRODUCTION

One of the underestimated oil crops widespread in the wild environment of Bulgaria and neighboring countries is gaining large interest in the last decade. *Camelina sativa*, known also as false-flax or gold-of-pleasure, originated from southeastern Europe and southwestern Asia (Luo et al., 2019). It`s been used in culinary as valuable cold-pressed oil, a functional food supplement for the prevention of cardiovascular problems in pharmacology, but also the alfa-linolenic acid (aka omega-3) plays important role in the cell renewal of cosmetic products. The high oil content (up to 49%) and good protein (21-30%) justify the use of the meal for feed.

The increased industrial search for alternatives to fossil fuels for jet fuel and biodiesel can be answered with this easy-to-grow crop (Mondor and Hernández-Álvarez, 2022). The short vegetation and good tolerance to climate changes and soil limitations make the camelina low-input crop well-adapted to each environment (Bakhshi et al., 2021; Ahmet et al., 2017).

One of the oldest forms of agricultural production was based on mixed cropping (Plucknett and Smith, 1986). Cropping systems based on carefully designed plant mixtures reveal several advantages under various agricultural conditions (Willey, 1979; Malézieux, 2009). Some advantages of mixed cropping are nutrient use efficiency and yield stability (Lizarazo et al., 2020). As described by Silvertown (1982), in the mixed cropping system, two or more cultivated plants are grown together at the same time on the same land. For example, the forage of the grain legume-cereal mixed crop has higher crude protein content, and higher relative feed value (Strydhorst et al., 2008). According to Lauk and Lauk (2008), the highest yield for a combination of the pea-oat mixture was found. After growing pea-barley and pea-oilseed rape as mixed crops the yield was higher than those of the sole crops (Malhi, 2012).

According to Poggio (2005), mixing plant species may also reduce weed diversity and stand. Mixed cropping of peas together with camelina showed a significant suppressive effect on weed flora. Liebman and Dyck (1993) found that the composition of two or more crops decreases the weed biomass in the intercropping system when compared to the sole crops. According to Leclère et al. (2019) intercropping camelina with pea or barley showed a reduction in weed biomass. Weed suppression was probably due to the mutually enhanced competitiveness of both crops, indicating a mechanism based on the allocation of resources (Saucke and Ackermann, 2006).

There is still limited information about the growing *C. sativa* in mixed cropping systems, therefore this experiment aimed to evaluate some effects of camelina with pea or vetch as intercrops in organic farming conditions.

MATERIALS AND METHODS

The experiment was carried out in the certified biological experimental field of the Agro-ecology Center at the Agricultural University - of Plovdiv, Bulgaria.

Winter camelina (*Camelina sativa* (L.) Crantz) varieties Luna (K 1), Lenka (K 2), and a Bulgarian landrace (K 3) of false flax were used in sole crop and in an intercropping system with winter forage pea (*Pisum sativum* L.) variety Mir and vetch (*Vicia sativa* L.) variety Obrazetc 666.

The experiment was performed by using a randomized block design in three replications with an experimental plot size of 10 m^2. Recommended sowing rates were applied for the sole crop of camelina 800 germinated seeds/m^2, winter pea - 120 germinated seeds/m^2, and vetch - 200 germinated seeds/m^2. Intercropping was sown with a half rate of seeds.

Mineral nutrition was applied to ensure three kilograms of active substance nitrogen with certified organic farming fertilizer Bioazoto 12. The preceding crop was winter rye.

Deep ploughing and cultivating followed by tillage before and after the sowing of camelina were applied.

The development stages of the crops (camelina, pea, and vetch) and the existing weeds (*Sorghum halepense* (L.) Pers. and *Setaria viridis* L.) in the experimental plots were reported.

The observations started after the camelina genotypes entered the rosette stage (R) and ended after the Bulgarian camelina genotype (K 3) entered the full flowering stage.

The number and fresh weight of the weeds in the different cropping systems (sole and intercropped) were examined on 03.06.2022 (7 days after the full flowering stage of the K 3).

For statistical analyses of the collected data Duncan's multiple range test with the SPSS 19 program (Duncan, 1955). Differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSIONS

On Table 1 the obtained data for the crops' development after the rosette stage till full flowering of the Bulgarian camelina genotype is presented.

The first observation was on the 22^{nd} of April. On this date, all camelina genotypes were in the rosette stage. The sole crops pea and vetch as well as the intercropping system of pea with the three camelina genotypes were in the 4^{th}-5^{th} trifoliate stage. When the vetch was grown in a mixture with camelina, its growing stage was 2^{nd}-3^{rd} trifoliate.

On the second observation date (29.4.2022) the three camelina genotypes were still in the rosette stage. The sole crops pea and vetch as well as the intercropping system of pea and vetch with the tree camelina genotypes were in the 4^{th}-5^{th} trifoliate stage.

On the third reporting date (6.5.2022) the camelina varieties Luna (K 1) and Lenka (K 2) were still in the rosette stage. The Bulgarian camelina landrace (K 3) entered the pod setting stage. The sole crops of pea and vetch were in the 5^{th}-6^{th} trifoliate stage.

In the mixed cropping systems, the camelina varieties Luna (K 1) and Lenka (K 2) were still in the rosette stage as well. In the mixed cropping system of pea and vetch with the tree camelina genotypes, the legume plants were 4^{th}-5^{th} trifoliate stage.

On the fourth evaluation date (13.5.2022) the camelina varieties Luna (K 1) and Lenka (K 2) were still in the rosette stage. The Bulgarian camelina genotype (K 3) entered the beginning flowering stage. The sole crops pea and vetch were in the 6^{th}-7^{th} trifoliate stage. There were no observed differences in the development stages for the mixed cropping systems of the camelina varieties and the legume crops. The growing stages were the same as for the sole crops.

On the fifth observation date (20.5.2022) the sole crops of the camelina genotypes Luna (K 1) and Lenka (K 2) were in the pod setting stage. The Bulgarian camelina (K 3) entered the full flowering stage. The sole crops pea and vetch were at the beginning of flowering. The same growth stages were found for the intercropping of camelina with the legumes.

On the last reporting date (27.5.2022) the camelina genotypes Luna (K 1) and Lenka (K 2) entered the beginning of the flowering stage. The Bulgarian variety (K 3) was in the stage of full flowering. The pea and vetch were in the full flowering stage as well. The development stages of the mixed cropping system were the same as the growing stages of the sole crops grown in the study.

Table 1. Crop development after the rosette growth stage till full flowering of the Bulgarian camelina

Variants		22.4.2022	29.4.2022	6.5.2022	13.5.2022	20.5.2022	27.5.2022
Growth stage							
K 1 Luna		Rosette	Rosette	Rosette	Rosette	Pod setting	Beginning of flowering
K 2 Lenka		Rosette	Rosette	Rosette	Rosette	Pod setting	Beginning of flowering
K 3		Rosette	Rosette	Pod setting	Beginning of flowering	Full flowering	Full flowering
Pea		4-5 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering
Vetch		4-5 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering
K 1 / Pea		Rosette	Rosette	Rosette	Rosette	Butonization	Beginning of flowering
		4-5 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering
K 2 / Pea		Rosette	Rosette	Rosette	Rosette	Pod setting	Beginning of flowering
		4-5 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering
K 3 / Pea		Rosette	Rosette	Pod setting	Beginning of flowering	Full flowering	Full flowering
		4-5 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering
K 1 / Vetch		Rosette	Rosette	Rosette	Rosette	Butonization	Beginning of flowering
		2-3 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering
K 2 / Vetch		Rosette	Rosette	Rosette	Rosette	Butonization	Beginning of flowering
		2-3 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering
K 3/ Vetch		Rosette	Rosette	Pod setting	Beginning of flowering	Full flowering	Full flowering
		2-3 trifoliate	4-5 trifoliate	5-6 trifoliate	6-7 trifoliate	Beginning of flowering	Full flowering

On Table 2 are the results regarding the weeds' development after the rosette growth stage of camelina till full flowering of the Bulgarian camelina landrace. The evaluation dates were the same as those for reporting the growth stages of the crops.

The reported weeds were the grass species *Sorghum halepense* L. (Pers.) and *Setaria viridis* (L.). On the first date of observation (22.04.2022), both weeds were in the 2^{nd} – 3^{rd} leaf stage. There were no differences between the sole and the intercrops.

On the second evaluation date (29.04.2022) both weeds were in the 3^{rd}-4^{th} leaf stage. There were no differences between the sole and the intercrops.

Table 2. Weeds' development after the rosette growth stage till full flowering of the Bulgarian camelina

Dates	22.4.2022	29.4.2022	6.5.2022	13.5.2022	20.5.2022	27.5.2022
K 1 Luna						
S. halepense	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
S. viridis	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
K 2 Lenka						
S. halepense	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
S. viridis	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
K 3						
S. halepense	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
S. viridis	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
Pea						
S. halepense	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
S. viridis	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
Vetch						
S. halepense	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
S. viridis	2-3 leaf	3-4 leaf	5-6 leaf	6-7 leaf	Beginning of inflorescence	Inflorescence
K 1 / Pea						
S. halepense	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
S. viridis	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
K 2 / Pea						
S. halepense	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
S. viridis	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
K 3 / Pea						
S. halepense	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	5-6 leaf	6-7 leaf
S. viridis	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	5-6 leaf	6-7 leaf
K 1 / Vetch						
S. halepense	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
S. viridis	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
K 2 / Vetch						
S. halepense	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
S. viridis	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	6-7 leaf	Beginning of inflorescence
K 3/ Vetch						
S. halepense	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	5-6 leaf	6-7 leaf
S. viridis	2-3 leaf	3-4 leaf	3-4 leaf	4-5 leaf	5-6 leaf	6-7 leaf

There were no differences in the weeds' growth stages on the third reporting date (6.5.2022). The weeds were in the growing stage 5^{th}-6^{th} leaf for the variants with sole crops (for the three camelina genotypes) and for the legumes (pea and vetch). On this evaluation date, when the crops camelina and legumes (independently of the variety and crop), the intercropping system leads to suppression of both weeds development. In the intercropping systems of the three camelina varieties together with pea and vetch as well, the growth stage of both weeds was suppressed and they were still in the 3rd - 4th leaf stage.

On the fourth evaluation date (13.5.2022) in the plots with sole crops (camelina or legumes) the weeds were in the growing stage 6th-7th leaf, and in the mixed cropping systems the weeds developed lower leaf number and were in 4th-5th leaf stage.

On the fifth reporting date (20.5.2022) the weeds in the sole-crop camelina, pea, and vetch reached the beginning of the inflorescence stage. In the plots of the variants with the camelina varieties Luna (K 1) and Lenka (K 2) mixed with pea and vetch as well, both weed species were in the 6th-7th leaf stage. The better-developed Bulgarian camelina genotype in intercropping system with pea and vetch depressed the weeds and they were in the 5th-6th leaf stage.

On the last reporting date (27.5.2022) the weeds in the sole-crop camelina, pea, and vetch reached the inflorescence stage. In the plots of the variants with the camelina varieties Luna (K 1) and Lenka (K 2) mixed with pea and vetch as well, both weed species were in the beginning of the inflorescence stage. The better-developed Bulgarian camelina landrace in the cropping system with pea and vetch depressed the weeds and they were in the 6th-7th leaf stage.

Many studies confirm that found that the weed biomass in the intercrop was significantly lower than in the sole crop (Liebman and Dyck, 1993; Szumigalski and Van Acker, 2005; Paulsen et al., 2006; Gu et al., 2022).

On Table 3 is presented the data concerning the weeds' number and weeds' fresh biomass weight.

The highest number of the weed *S. halepense* per m^2 (21.67) was found to be for the sole crop of the camelina variety Luna (K 1). For this variant, the highest weed fresh weight was recorded - 34.04 g. In the plots of pea and vetch as sole crops the number of the weed *S. halepense* was lower (8.67 and 8.00, respectively) but the weight of the weed was greater - 30.70 g for the pea and 27.23 g for the vetch.

Table 3. Number and fresh weight of the weeds in the different cropping systems (sole and mixed)

Treatments	Number / m^2	
	S. halepense	*S. viridis*
K 1	21.67 a	8.37 bc
K 2	12.67 b	5.35 bc
K 3	9.67 bc	8.00 bc
Pea	8.67 bc	14.67 a
Vetch	8.00 bc	9.30 b
K 1 / Pea	11.00 bc	6.36 bc
K 2 / Pea	9.33 bc	8.30 bc
K 3 / Pea	5.67 bc	4.33 bc
K 1 / Vetch	8.00 bc	5.64 bc
K 2 / Vetch	7.67 bc	8.13 bc
K 3 / Vetch	9.67 bc	3.67 c
Treatments	Fresh weight, g	
	S. halepense	*S. viridis*
K 1	36.04 a	5.50 cd
K 2	15.70 bc	4.67 cd
K 3	15.57 bc	5.33 cd
Pea	30.70 a	13.50 ab
Vetch	27.23 ab	15.93 a
K 1 / Pea	12.27 bc	6.90 cd
K 2 / Pea	8.40 c	7.07 cd
K 3 / Pea	5.17 c	3.40 d
K 1 / Vetch	6.57 c	4.63 cd
K 2 / Vetch	6.90 c	9.23 bc
K 3 / Vetch	7.40 c	3.12 d

Means with different letters are with proven differences according to Duncan's Multiple Range test ($p<0.05$).

When the camelina varieties were grown as an intercropping system with pea and vetch the weed *S. halepense* was suppressed and formed lower fresh biomass weight.

Regarding the weed species *S. viridis* the highest number was counted in the sole crops of pea and vetch - 14.67 and 9.30, respectively. The results are with proven differences in comparison to the other treatments. The lowest number of specimens was recorded in the mixed crop system of the Bulgarian camelina variety with vetch - 3.67. The highest weed biomass was recorded for the sole crop vetch - 15.64 g. The results are with proven differences in comparison to the other treatments. The lowest *S. viridis* fresh biomass 3.40 and 3.12 g for the intercropping system of the Bulgarian camelina landrace with pea and vetch respectively were recorded.

CONCLUSIONS

The Bulgarian camelina landrace developed faster when compared to the foreign genotypes (Luna and Lenka varieties). Differences in the growing stages of winter pea did not differ between the sole or intercrop with the three camelina genotypes. Differences in the growing stages of vetch as sole or intercrop with camelina differed only on the first reporting date where the vetch was behind in the development.

In the intercropping system with the Bulgarian camelina genotype (K3) grown together with pea and vetch the development of the weeds *S. halepense* and *S. viridis* was suppressed to a greater extent than the mixed cropping system of the foreign camelina varieties Luna (K1) and Lenka (K2) grown in an intercropping system with the legume crops (pea and vetch). In the sole crops, the reported weeds developed faster. The mixed cropping system of the well-developed Bulgarian camelina landrace (K 3) grown as an intercrop with pea and vetch suppressed the development of the weed *S. halepense*, while the suppression of the weed *S. viridis* was higher.

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