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The effect of field dodder (*Cuscuta campestris* Yunck.) on the leaf and tuber yield of sugar beet (*Beta vulgaris* L.)

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Abstract: In this study, the effect of field dodder (*Cuscuta campestris* Yunck.) on the leaf and tuber yield of sugar beet fields in Kahramanmaraş Province of Turkey was investigated. Field dodder is known to spend its entire vegetation period as a parasite plant on its hosts after germinating from the soil. It causes significant yield and quality loss of many cultivated plants, including sugar beet. In this study, the influence of dodder on leaf chlorophyll a and b, total chlorophyll levels, leaf yield, wet and dry leaf weight, and leaf ash weight of sugar beet was investigated. For this purpose, two varieties of sugar beet (Valentina and 551) were cultivated in two growing areas as groups of infected and uninfected sugar beet. Sugar beet leaf numbers and associated hectare yield decreased considerably when the plants were infected with the parasite. Crop yield per hectare was calculated to be 79,573.9 kg/ha for uninfected plots while it was determined as 57,341.3 kg/ha for the infected ones. Average leaf yield (32,943.6 kg/ha for uninfected versus 18,451.4 kg/ha for infected), tuber sizes (28.116 × 8.244 cm for uninfected versus 18.984 × 6.269 cm for infected), the amounts of chlorophyll a (4.020 and 1.650 mg/g) and chlorophyll b (1.67 and 1.29 mg/g), and total chlorophyll values (5.69 and 2.94 mg/g) were all observed to decline when the crops were infected by field dodder.

Key words: Total chlorophyll, chlorophyll a and b, *Cuscuta campestris* Yunck., sugar beet

1. Introduction

Plants are vital for human nutrition with high numbers of species and numerous cultivars, genotypes, accessions, etc. occurring in most parts of the world. Plants are accepted as one of the most important genetic resources and elements of biodiversity, which support life systems on earth (Sengul et al., 2011; Ercisli et al., 2012; Zia-Ul-Haq et al., 2014).

Sugar is one of the essential nutrients for people and sugar cane and sugar beets are the two most important sources of sugar. Approximately 25% of the total sugar produced in the world is derived from sugar beet and 75% from sugar cane. In Turkey and Europe, due to climatic conditions, sugar beet is produced instead of cane sugar as a strategic product (Pankobirlik, 2010). The major countries for sugar beet production in the world are as follows: Brazil with 40,219,000 t/year, Russia with 37,600,000 t/year, France with 28,913,000 t/year, the United States with 28,473,000 t/year, and Turkey with 19,216,000 t/year (FAO, 2014; www.pankobirlik.com.tr). The quality and the yield of sugar beet, however, are affected by many biotic and abiotic factors. The most important biotic factors are parasites such as weeds, fungi, bacteria, and pests. Weeds can cause significant yield loss and quality by interfering with the nutrient elements, water, dissolved inorganic substances, and sunlight of many cultivated plants. As one of the most common weeds in the East Mediterranean Region of Turkey, dodder (*Cuscuta campestris* Yunck.) is described as an annual and holoparasitic plant. Dodder species have white flowers; the stems are yellow-orange in color and 0.3 mm in diameter. Dodder does not have leaves and contains no chlorophyll. Dodder uses haustorium to take nutrients from the host plants. A dodder plant can produce 3000–25,000 seeds (Yuncker, 1932; Dawson, 1984; Fang et al., 1995). *Cuscuta campestris* Yunck., which has a wide geographical distribution in the world, causes severe damage to many cultivated plants including, but not limited to, carrot, clover, onion, legume, melon, garlic, watermelon, potato, pepper, and sugar beet. It has also been reported that dodder infection may cause 50% to 90% yield loss in some cases (Parker and Riches, 1993; Dawson et al., 1994; Holm et al., 1997; Nadler-Hassar and Rubin, 2003; Lanini and Kogan, 2005; Zharasov, 2009).

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Additionally, dodder infections were found to result in 3.5 to 4 t/ha decrease in yield per year in sugar beets (Aly et al., 2003).

In a study by Davis (1978), it was reported that plants from 21 different *Cuscuta* taxa inhabited Turkey and 2 species were seen in our experimental region of Kahramanmaraş. In Anatolia, 55 hosts of *C. campestris* Yunck. have been identified, of which 27 were determined to be mostly grassy and agricultural plants. The most common host in the world has been found to be *Beta vulgaris* L. (Nemli, 1978; Parker and Riches, 1993; Dawson et al., 1994). Gürsoy (2002) conducted surveys on sugar beet fields in Ankara, Yozgat, Eskişehir, Karaman, Kayseri, Nevşehir, Konya, Aksaray, Kırşehir, and Niğde provinces of Turkey in order to determine problematic weeds in the area. As a result, a total of 170 weed species belonging to 31 families were identified. Among these species, 1 was seedless, 1 was parasitic, 3 were monocotyledons, and 27 were dicotyledons. *Cuscuta campestris*, *C. europaea*, and *C. epithymum* species of dodder were encountered in Anatolia. The species were observed in 25% to 49% of the sugar beet fields studied. In the sugar beet production areas in Tokat Province, the infectious rate of dodder was 32%–36% (Kadıoğlu et al., 2015), while it was 46% in Kayseri Province (Akça and Işık, 2016). In many studies, it was determined that *C. campestris* reduced sugar beet up to 63% and decreased the sugar content by 18.7% to 55.4% (Nemli and Öngen, 1982; Nemli, 1986).

It is seen that the field dodder species causing significant yield loss and quality in culture plants are spread widely in Turkey and all around the world. Therefore, in order to understand the potential danger and to be able to apply preventative measures appropriately, it is very important to determine the level of dodder infections and its influence on the leaf and tuber yields of sugar beet in Turkey. For this purpose, we studied infected and uninfected samples of Valentina and 551 varieties of sugar beets grown in Kahramanmaraş Province (Afşin-Göksun area) in 2016. This study especially focused on chlorophyll, leaf, and tuber measurements, since they are known to provide the most explanatory data about the health of a plant.

2. Materials and methods

2.1. Materials

Valentina and 551 sugar beet varieties were used in the study. The samples were grouped as infected "unhealthy" and the uninfected "healthy" beets. The plants in the infected group were sown in the soil along with dodder (*C. campestris* Yunck.) seeds. Since the seeds of dodder have dormancy, gibberellic acid was applied. The uninfected samples were sown alone in the same type of soil.

2.1.1. Climatic characteristics of the trial area

Kahramanmaraş Province (Afşin-Göksun area) is located in the west of Turkey's East Anatolian Region at 38°02′2 to 38°24′N and 36°48′E and 36°91′E with 1230 m and 1344 m altitude where a terrestrial climate prevails. The total amount of rainfall during the plant growth period in 2016 (April to November) was 27.7 mm^3, the average temperature was 17.3 °C, and the relative humidity was 53.4%.

2.1.2. Soil properties of the trial area

The experimental soil is clayey-loam, with a slightly alkaline character. It consisted of lime, nitrogen, a small amount of available phosphorus, very little organic matter, and a high amount of potassium.

2.2. Methods

2.2.1. Plot plan

The study was conducted in 3 replicates with a split plot arrangement established on 5 May 2016. The main parcels consisted of sugar beet varieties (Valentina and 551) alone and the subparcels were formed by the application of the parasitic plant. Spacing between rows was 45 cm and it was 10 cm between plants. There were 4 rows at a depth of 4 cm in each plot. When the sugar beet plants reached to 2- to 4-leaves phase, plants were thinned in such a way that the distance in the row became 20 cm on average.

2.2.2. Leaf and root yield

All plots were harvested separately on 25 November 2016. The plants were weighed and the leaf and root yield values were calculated. Chlorophyll a and b and total chlorophyll were calculated as described by Arnon (1949). Fresh leaf samples (100–200 mg) were homogenized with 15 mL of 80% (v/v) acetone and then filtered using filter paper. In the filtered samples, measurements were made for total chlorophyll at 652 nm, chlorophyll a at 663 nm, and chlorophyll b at 645 nm with a spectrophotometer. Decay root yield was calculated according to Ada and Akınerdem (2006) and leaf yield according to Kısaoğlu (1987).

2.2.3. Field dodder density

The survey was conducted in the trial plots in September 2016. Number of weeds per m^2 was calculated with the total number of units in each m^2 divided by the total surveyed area. The weed density was calculated by the formula of Density = B/n (Güncan, 2001), where B = total number of individuals in the sample and n = number of samples. The density of dodder was determined using a scale of 1–5 for clover (Tepe et al., 1997), but this scale was adapted to sugar beet as follows:

Dodder density scale

(1) No infection

(2) Slightly infected (sugar beet is healthy and no yield loss is observed)

(3) Mildly infected (visible damage to the sugar beet has begun)
(4) Infected (sugar beet has significant yield loss)
(5) Highly infected (sugar beet died)

2.2.4. Statistical analysis

In order to determine whether there was a statistically significant difference among the obtained results for each parameter of the infected and uninfected samples, variance analyses were carried out using SPSS 20 (IBM Corp. Armonk, NY, USA). Differences between means were tested by the Duncan test and ANOVA. Values of $P \leq 0.05$ were considered significantly different.

3. Results and discussion

3.1. Field dodder density

The densities of field dodder on two sugar beet varieties were calculated. The average dodder density was determined as 34.5 and 36.8 infected leaves/m^2 in Valentina and 551 variety plots, respectively. Both values were considered as intense according to the density scale. No field dodder was observed in healthy (uninfected) plots.

3.2. Leaf chlorophyll a and b, and total values

Mean chlorophyll a level was measured as 1.650 mg/g in infected leaves of sugar beet and as 4.020 mg/g in uninfected varieties, while these values were 1.29 mg/g and 1.67 mg/g for the chlorophyll b of the infected and uninfected plants in the plots, respectively. As for total chlorophyll, however, the values were calculated to be 2.94 mg/g and 5.69 mg/g in the same order. The test of photosynthetic pigments in sugar beet leaves showed a significant difference ($P \leq 0.05$) in chlorophyll a and b and total chlorophyll between the healthy and unhealthy samples (Table 1). According to the result analysis, not only the field dodder infection but also the variety used in the experiment significantly affected the chlorophyll values measured.

Considering the fact that chlorophyll a is the main component of photosynthetic pigments and it is affected more by dodder than chlorophyll b is, it may be speculated that decrease in chlorophyll a levels, which is followed by the downregulation of photosynthetic activity, might be the reason for the decline of the yield. Mishra and Sanwal (1994) also pointed out that mustard crops were affected by dodder and their chlorophyll contents were reduced by 24%, and, conversely, carotene percentages were increased by 24% in leaves. According to Toth et al. (2006), when chlorophyll a decreased in sugar beet leaves, less material was transmitted to the roots. The results of another study showed that dodder infection reduced the chlorophyll content of pepper and sunflower leaves by 83% and 58%, respectively (Cnar and Mosleh, 2008). In the underground section, due to changes in the amount of components transported to the root, the quality and the sugar content of the root were also reduced. Due to its ability to produce a large amount of seeds and to infect various crops, dodder can cause severe damages and it can be distributed vastly, which in turn makes it almost impossible to keep the weed under control (Lanini and Kogan, 2005; Costea and Tardif, 2006; Qasem, 2011; Sharifi et al. 2013). As observed in our experiments, previous studies demonstrated that dodder reduced photosynthesis efficiency of the leaves and organic material production.

3.3. Leaf dry matter, wet leaf, dry leaf, and ash weights

Leaf dry matter content was found to be 16.383% in infected sugar beets and 18.652% in the uninfected. Mean wet leaf weight was 18.351 g in healthy sugar beets while it was 24.117 g in the unhealthy. Mean dry leaf weight was calculated as 5.625 g in the samples grown with the parasite, whereas it was measured as 8.095 g in their counterparts. Mean leaf ash weights, on the other hand, were determined as 3.425 g and 6.692 g in the infected and uninfected groups, respectively (Table 2). According to the analysis results, the differences in leaf dry matter, wet leaf, dry leaf, and ash weights between healthy and unhealthy groups as well as the mean values of each variety were statistically significant ($P \leq 0.05$).

In an earlier report by Yılmaz and Kadıoğlu (2009), mean wet weight of leaf was found as 20.20 g in infected sugar beet and as 27.18 g in uninfected, while dry leaf weights were 4.87 g and 5.06 g in the infected and uninfected plots, respectively. These results were found to be lower than those of Yılmaz and Kadıoğlu (2009). On the other hand, the current study had results similar to those of Çatal and Akınerdem (2013), who showed that dry matter in Rozsa (20.6%), which was the highest value, was followed by Achat (20.4%), Cesira (19.9%), Valentina (19.8%), and Coyote (18.5%). Turgut (2012) found that among the specimens investigated the highest dry matter rate was 17.6% and the lowest was 16.4%.

3.4. Root and leaf yields

Average root yield in the plots infected by field dodder was 57,341.3 kg/ha and it was 79,573.9 kg/ha in the uninfected plots (Table 3). As result, dodder caused 27.9% yield loss in the infected plots. According to the results, the values of the root and leaf yields were changed ($P \leq 0.05$) significantly with the variety and the infection status of the samples.

Güler (1992) reported that the root yield was between 48,540 and 70,500 kg/ha, while it was 49,800 and 55,500 kg/ha in another study (Akınerdem et al., 1993); Radivojević and Došenović (2006) showed that root yield was between 84,700 and 92,350 kg/ha. The decline in nutritional elements of sugar beet, which were taken by the dodder when infected, can cause decrease in the yield and sugar percentage of tubers. It has been demonstrated that dodder reduced the root yield of sugar beet by 8.7%–58.4%, and the sugar beet yield was decreased to about

Table 1. Average values of leaf chlorophyll a, chlorophyll b, and total chlorophyll (mg/g^{-1}) in the plots.

Applications	Varieties	Chl a (mg/g^{-1})	Chl b (mg/g^{-1})	Total chl (mg/g^{-1})
Infected	551	1.05 b	0.62 a	1.67 b
Uninfected	551	3.58 a	0.16 a	3.74 a
P and F		$F_{1,4}$ = 66.70 P < 0.01	$F_{1,4}$ = 0.63 P = 0.4709	$F_{1,4}$ = 33.27 P < 0.001
Infected	Valentina	2.25 b	1.96 a	4.21b
Uninfected	Valentina	4.46 a	3.18 a	7.64 a
P and F		$F_{1,4}$ = 86.47 P < 0.001	$F_{1,4}$ = 2.49 P = 0.1896	$F_{1,4}$ = 16.87 P < 0.05

The difference between the averages shown with different letters in the same column is significant at the level of 0.05.

Table 2. Average values of leaf dry matter content, wet leaf, dry leaf, and ash weights in the plots.

Applications	Varieties	Leaf dry matter content (%)	Wet leaf weight (g)	Dry leaf weight (g)	Leaf ash weight (g)
Infected	551	15.610 b	17.050 b	4.850 b	2.080 b
Uninfected	551	17.415 a	21.485 a	7.060 a	4.475 a
P and F		$F_{1,4}$ = 27.72 P < 0.001	$F_{1,4}$ = 169.0 P < 0.001	$F_{1,4}$ = 22.86 P < 0.01	$F_{1,4}$ = 75.48 P < 0.001
Infected	Valentina	17.157 b	19.652 b	6.40 b	4.770 b
Uninfected	Valentina	19.890 a	26.750 a	9.130 a	8.910 a
P and F		$F_{1,4}$ = 377.09 P < 0.0001	$F_{1,4}$ = Infinity P < 0.0001	$F_{1,4}$ = 1491.01 P < 0.0001	$F_{1,4}$ = 582.0 P < 0.0001

The difference between the averages shown with different letters in the same column is significant at the level of 0.05.

Table 3. Average values of sugar beet root, leaf yield, root length, and width in the plots.

Applications	Varieties	Root yield (kg/ha^{-1})	Leaf yield (kg/ha^{-1})	Tuber length (cm)	Tuber width (cm)
Infected	551	46,445.9 b	17,568.6 b	16.656 b	5.449 b
Uninfected	551	69,787.4 a	30,845.3 a	25.823 a	7.338 a
P and F		$F_{1,4}$ = 45.81 P < 0.01	$F_{1,4}$ = 104.97 P < 0.001	$F_{1,4}$ = 91.02 P < 0.001	$F_{1,4}$ = 17.75 P < 0.05
Infected	Valentina	68,236.7 b	19,334.2 b	21.313 b	7.090 b
Uninfected	Valentina	89,360.5 a	35,041.9 a	30.410 a	9.150 a
P and F		$F_{1,4}$ = 174.7 P < 0.001	$F_{1,4}$ = 161.1 P < 0.001	$F_{1,4}$ = 786.9 P < 0.0001	$F_{1,4}$ = 1147.1 P < 0.0001

The difference between the averages shown with different letters in the same column is significant at the level of 0.05.

3.5–4 t/ha (Aly, 2006). In the studies of Ada et al. (2012) the highest obtained root yield was 73,400 kg/ha from the Valentina variety. Çatal and Akınerdem (2013) showed that the average root yield was 59,940 and the root yields of varieties ranged from 52,950 to 72,200 kg/ha for Rozsa (52,950), Giraf (61,830), Coyote (60,350), Achat (59,250), Fiona (54,060), and Valentina (72,200). The obtained results were found to be lower than those of Radivojević and Dośenović (2006) but somewhat similar to those of Güler (1992), Aly (2006), Ada et al. (2012), and Çatal and Akınerdem (2013).

In this study, leaf yields were calculated as 18,451.4 kg/ha and 32,943.6 kg/ha for the infected and uninfected plots, respectively. Çatal and Akınerdem (2013) showed that leaf yield average was 41,140 kg/ha and that leaf yields of varieties ranged from 34,800 to 49,610 kg/ha. Sağlam

(1996) found that there was a positive correlation between rainfall and leaf yield, whereas Nagy et al. (1983) reported that the yields of root and sugar were increased with late harvest date and the most suitable harvest time was the second half of October. The obtained results were found to be lower than the results obtained by these researchers.

3.5. Root diameter

The root diameter (length × width) was calculated as 18.98 × 6.26 cm in the unhealthy samples and as 28.11 × 8.24 cm in the healthy samples. According to the analysis result, the differences in root diameter between healthy and unhealthy groups as well as the mean values of each variety were statistically significant ($P \leq 0.05$). Akçin et al. (1992) declared that the highest value was 27.1 × 8.4 cm for Türkşeker-1 and Kawepura. Arslan (1994) found the range of the root diameter as 17.5 × 6.5 cm in the first year of his study, whereas these values were determined as 22.6 × 6.7 cm in the second year. In another study conducted by Şatana (1996), there was a significant difference in harvest time and variety in terms of root diameter (length × width), which was the highest on 28 December (20.1 × 5.4 cm) and the lowest on 28 September (21.5 × 4.7 cm). The root diameter (length × width) changed between 27.6 × 8.0 cm and 30.9 × 8.5 cm (Çatal and Akınerdem, 2013). The values obtained in the current study were similar to those of Akçin et al. (1992) and Çatal and Akınerdem (2013), while they were higher than the values determined by Arslan (1994) and Şatana (1996).

3.6. Conclusion

As a result of this study, the average field dodder density was determined as 34.5 and 36.8 infected leaves/m^2 in Valentina and 551 variety plots, respectively. Both values were considered as intense according to the density scale.

Crop yield per hectare was calculated to be 79,573.9 kg/ha for uninfected plots, while it was 57,341.3 kg/ha in the infected ones for Valentina and 551. Eventually, the field dodder caused 27.9% yield loss. Average leaf yield (32,943.6 kg/ha for uninfected versus 18,451.4 kg/ha for infected), tuber sizes (28.116 × 8.244 cm for uninfected versus 18.984 × 6.269 cm for infected), amounts of chlorophyll a (4.020 and 1.650 mg/g) and chlorophyll b (1.67 and 1.29 mg/g), and total chlorophyll values (5.69 and 2.94 mg/g) were all observed to decline when the crops were infected by field dodder. Leaf dry matter content, wet leaf weight, dry leaf weight, and leaf ash weight were also significantly decreased by dodder infection in both varieties. It was shown that the field dodder, which causes significant loss in the quantity and quality of many crops, also had adverse effects on sugar beet production. At the same time in all parameters investigated, the values obtained for the Valentina variety were significantly higher than those of the 551 variety.

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