

Impact of Higher Carbon Dioxide Concentrations and Elevated Temperatures on the Growth of Field Bindweed (*Convolvulus arvensis* L.) in Turkey

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ABSTRACT

Field bindweed (*Convolvulus arvensis* L.) is one of the worst weeds in Turkey as well as worldwide. Climate change, with increasing temperature and concentrations of greenhouse gases and unpredictable extreme weather events, has been among the foremost problems of the world. The effect of climate change on crop husbandry and weeds is to be investigated. The effect of rising temperature and CO₂ on different populations of *C. arvensis* was studied under greenhouse conditions in the Malatya Province of Turkey, in 2019. For this study, the weed seeds were collected from 14 provinces throughout Turkey during 2018. Two temperature regimes (day/night 26/16°C and 29/19°C) and two CO₂ levels (400±50 and 800±50 ppm) were used. Plant aboveground length, root length, and dry weights of root, aboveground parts, and total plant were not affected by temperature, CO₂, and seed source. However, seed source affected root length differently depending on temperature and root length, and root dry weight as affected by CO₂ level. In addition, seed source and temperature showed significant effect on measured parameters, while no significant effect was determined for CO₂.

Keywords: Climate change, C₃ plant, Plant biomass, Weed.

INTRODUCTION

Field bindweed (*Convolvulus arvensis* L.) is a perennial Eurasian plant from Convolvulaceae family, particularly originating from Mediterranean Basin (Sosnoskie *et al.*, 2020). It has been one of the most harmful weeds, as was reported in 32 different crops in 54 countries (Holm *et al.*, 1991) and mentioned as a major problem in wheat (*Triticum aestivum* L.), cotton (*Gossypium hirsutum* L.), sugarcane (*Saccharum officinarum* L.), potato (*Solanum tuberosum* L.), maize (*Zea mays* L.), vineyards (*Vitis* spp.), orchards as well as non-agricultural areas (Sanaullah, 2020; Memon Asma, 2004; Abad *et al.*, 2020; Steinmaus *et al.*, 2008; Izadi-Darbandi *et al.*, 2018; Andelkovic *et al.*, 2021). In Turkey, it causes significant damage in agricultural

areas, especially in cereals and vegetables (Guncan, 1979; Ozkan and Tepe, 2020; Jabran, 2020).

Field bindweed is commonly well known due to its competitiveness with other species, not only in crop fields but also in other disturbed habitats and industrial areas. In addition to crop yield losses, its climbing habit on the cultivated plants causes difficulties at harvest and the other agronomic applications such as irrigation or pruning (Sosnoskie *et al.*, 2020; Vogelgsang, 1998). Only one individual field bindweed plant is able to reduce the water content in a soil profile up to 60 cm, which can cause complete crop failure in dry years (Vogelgsang, 1998; Swan, 1980). Losses of crop yield due to bindweed have been reported to be about 30% in wheat and 75% in maize (Swan, 1980; Safdar *et al.*,

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2019). Residues or extracts of bindweed, especially from whole plant or root, affected morphology and yield of wheat, with yield loss reaching 88% depending on the amount of residue (Yarnia, 2010). Bindweed densities changed due to crops in rotation, but yield loss was not proportional with bindweed density. It was reported that crop loss was 56, 92 and 74% in wheat, barley (*Hordeum vulgare* L.), and field peas (*Pisum sativum* L.) under measured bindweed densities of 140, 65 and 100 m⁻², respectively (Black et al., 1994). Furthermore, it acts as an alternative host to viruses (*Beet necrotic yellow vein virus*) that cause plant diseases and creates a breeding ground for harmful insects (*Euxoa ochrogaster*) in cultivated plants (Tamaki et al., 1975; Legreve et al., 2005). The other problem with bindweed is difficulty of control, i.e., methods such as tillage or herbicides cannot control bindweed patches to an expected level or duration (Sosnoskie et al., 2020; Bayat and Zargar, 2020). This perennial weed is able to reproduce by its seeds and underground parts and can survive under a wide range of temperature and other environmental conditions (Sosnoskie et al., 2020; Ozkil and Uremis, 2019; Karkanis et al., 2018; Bajwa et al., 2020).

Human activities have an essential role in regulating energy flow and ecosystem carbon cycle due to weather, climate, atmosphere composition and shaping of climate changes (Norby and Luo, 2004). It was reported that the atmospheric CO₂ concentration increased by 47% from 1750 to date, and the global temperature is 1.09°C higher in 2011–2020 compared to pre-industrial time (1850–1900), and it is much higher on land, i.e. 1.59°C (IPCC, 2021). The global average surface temperature in July 2022 was 1.15°C above the average for the comparison period of 1880–1920. The atmospheric CO₂ concentration has reached 417.51 ppm, which was 408.76 in 2019 and 280 ppm before the industrial revolution (CO2earth, 2022).

Changes in the global climate have a significant impact on the biology, spread and

control of weeds, invasive alien plant species, parasitic plants and crops (Grenz et al., 2007; Ziska et al., 2011; Diez et al., 2012; Uludag, 2012). Weeds show generally faster growth and earlier maturation than crops. Weeds, especially C3 types, respond directly to increasing CO₂ levels, which mostly stimulate photosynthesis and growth (Patterson, 1995). Not only the invasion of perennial weeds will be greater than that of annual weeds, and plant community composition will change significantly with climate change, but also control of perennial weeds will be difficult due to increasing accumulation of resources in storage organs by increased photosynthesis (Patterson, 1995; Ziska, 2014). On the other hand, C3 plants can be affected negatively by elevating temperatures, although they have advantages to increasing CO₂ levels. For example, yield of rice, a C3 crop, decreases due to increasing night temperatures and floret sterility due to high temperatures (Korres et al., 2016).

Different factors such as light, CO₂, temperature, herbicides and soil can contribute to morphological or physiological diversity of bindweeds (Gianoli, 2001). Root and shoot weight and their ratios were different among the five biotypes of bindweed (Degennaro and Weller, 1984). Decreasing light caused declining flower production, leaf area, and dry matter of shoots, roots, and rhizomes in *Convolvulus arvensis* and *Centaurea repens* species (Dall'armellina and Zimdahl, 1988). Supporting help (poles) for bindweed increased length of plant and root/shoot ratio, but not total dry weight (Den Dubbelden and Oosterbeek, 1995). All these studies did not consider climate change, i.e. they were conducted under the climatic conditions during the experiments. Although C3 and C4 plants have a general pattern in change under climate change, it should be noted that bindweed has very large morphological or physiological flexibility that might cause different responses by varying populations/individuals. The aim of this study was to determine the response of

different populations of bindweed under different temperatures and elevated CO₂ in controlled conditions.

MATERIALS AND METHODS

Site, Plant Materials and Experimental Studies

Seeds of bindweed were collected from several agricultural areas (orchards, vegetables and field areas) in different provinces of Turkey in 2018 (Table 1). The seeds were manually inspected to find out and remove damaged ones, then, they were cleaned and stored at +4°C until used in experiments. The studies were carried out in a fully automated greenhouse at Faculty of Agriculture of Malatya Turgut Ozal University, Malatya, Turkey in 2019. The experiment was arranged according to a

completely randomized plot design with four replications. The light intensity in the rooms varied 70-140 $\mu\text{mol m}^{-2}$.

In the experiment, two temperature regimes (day/night 26/16°C and 29/19°C) and two carbon dioxide concentrations (400±50 and 800±50 ppm) were used where lower values for ambient and the higher ones represent future scenarios. The dormancy of the seeds was removed via soaking seeds in 90°C water for 5 seconds (Karaman and Tursun, 2021). Then, five seeds were sown in each pot at the depth of 2-3 cm with a 2:1 peat-perlite mixture. The plants were thinned to one per pot in the 4-6 leaf stage. Due to the creeping feature of the field bindweed, the plants in the pots were allowed to creep individual support poles. Plants were irrigated when required (almost twice a week).

After two months, plant length was determined by measuring the longest stem

Table 1. Provinces in Turkey where field bindweed (*Convolvulus arvensis* L.) seeds were collected and their altitudes above sea level.

Provinces	Altitude (m)	Region	Climate Class (Köppen) ^a
Malatya	966 m	Eastern Anatolia	BSk
Erzurum	1900 m		Dsb
Sanliurfa	510 m	Southeastern Anatolia	Csa
Ankara	858 m	Central Anatolia	Csa
Karaman	1058 m		BSk
Kayseri	1060 m		Csa
Konya	1023 m		BSk
Samsun	10 m	Black Sea	Cfa
Adana	26 m	Mediterranean	Csa
Hatay	89 m		Csa
Denizli	390 m	Aegean	Csa
Usak	911 m		Csa
Tekirdag	25 m	Marmara	Csa
Canakkale	12 m		Csa

^a BSk: Semi-Dry Steppe Climate (Cold); Cfa: The climate is warm in winter, very hot in summer and rainy in all seasons.; Csa: Warm winter, very hot summer and dry climate (Mediterranean climate); Dsb; Heavy winter, dry and hot summer (Kottek *et al.*, 2006; Mecitalbayrak, 2019).



and root length was calculated via measuring all underground parts. Aboveground parts and underground parts were dried separately at 105°C for 24 hours before weighing (Hitchcock, 1931).

Data Analysis

The data underwent one-way Analysis Of Variance (ANOVA) with GLM model using IBM SPSS 25 statistical package program. The difference between treatments was determined using the Duncan multiple comparison test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Five parameters, namely, shoot length, root length, shoot dry weight, root dry weight and whole plant dry weight were analyzed statistically under varying temperature, CO₂, and seed source. There was no common effect of temperature, CO₂, and seed source on any parameters analyzed. However, root length was affected by seed source in connection with temperature or CO₂ levels ($P < 0.05$). In addition, effect of seed source on root dry weight depended on CO₂ levels ($P < 0.01$). Temperature affected all five parameters significantly at probability level of 0.001, while seed source affected length parameters at 0.05 probability level and dry weight parameters at 0.001. On the contrary, CO₂ did not affect any parameter significantly.

The highest shoot length was 99.66 cm (Karaman) and the shortest was 75.88 cm (Adana), all remaining plants were from the same statistical group between these two sources (Table 2). In addition, effect on length was partly reflected in their dry weights, although there were more statistical groups between those two extremes. The maximum root length was 116.82 cm (Konya) and the shortest one was 76.72 cm (Sanliurfa) but these are not reflected to root dry weight unlike shoot length and dry weight. The same seed source did not give a

consistence length or dry weight for shoot or root. It is similar to an earlier study where five biotypes of bindweed did not follow the same pattern for shoot and root fresh weights (Degennaro and Weller, 1984). Whole plant dry weight was similar to shoot dry weight for the heaviest and lightest ones, because shoot dry weight was bigger than root dry weight. There was not any pattern for seed source in spite of statistical differences. Similar results were reported for three populations from Jordan that had differences among morphological characters including aboveground and belowground dry weights; but no relation was found regarding features of sites of plant sources, except crop type (Ghosheh and Hurle, 2011). It is mentioned that shoot dry weight and total biomass were two variables for differentiating biotypes, which affect adaptation to different environments and human intervenes (Mehrafarin *et al.*, 2008; Mehrafarin *et al.*, 2009; Mehrafarin *et al.*, 2011).

All parameters were significantly affected by increase in temperature (Table 3). Only 3°C increase from 26 to 29°C caused an increase in biomass and length of both aboveground and belowground parts. Similarly, in another study, the temperature rise from 25.7 to 29.1°C caused increase in plant height, shoot dry weight, and leaf area of C3 crop rice (*Oryza sativa* L.) and annual and perennial C3 weeds, *Monocharia vaginalis*, *Scirpus planiculmis*, *Eleocharis kuroguwai* as well as C4 and CAM (Crassulaceae acid metabolism) weeds (Bir *et al.*, 2018). These are not expected results because C3 plants such as bindweed do not get much positive effect from the temperature rise: rapid growth of bindweed including belowground parts happens at 14°C with over 2°C night temperatures in Canada (Weaver and Riley, 1982). The difference between Turkish populations and Canadian population might be due to the fact that populations from Turkey were selected naturally under high temperatures in native area compared to Canadian populations that were exposed to lower temperatures in

Table 2. Effect of seed source on length and dry weight of bindweed (*Convolvulus arvensis*).

Seed Source	Shoot length (cm)	Shoot dry weight (g)	Root length (cm)	Root dry weight (g)	Whole plant dry weight (g)
MALATYA	90.22±4.35AB	2.11±0.15AB	103.35±7.12AB	0.89±0.09AB	2.99±0.22AB
ADANA	75.88±4.35B	1.36±0.15C	104.44±7.12AB	0.70±0.09ABC	2.06±0.22C
DENIZLI	81.69±4.35AB	1.61±0.15BC	105.38±7.12AB	0.49±0.09C	2.10±0.22C
USAK	83.50±4.35AB	1.62±0.15BC	108.10±7.12AB	0.72±0.09ABC	2.33±0.22BC
TEKIRDAG	85.75±4.35AB	1.66±0.15BC	108.66±7.12AB	0.53±0.09C	2.18±0.22C
CANAKKALE	91.35±4.35AB	1.64±0.15BC	99.32±7.12AB	0.52±0.09C	2.16±0.22C
ERZURUM	92.07±4.35AB	2.29±0.15A	101.07±7.12AB	0.77±0.09ABC	3.06±0.22A
SANLIURFA	80.38±4.35AB	1.83±0.15ABC	76.72±7.12B	0.65±0.09BC	2.47±0.22ABC
ANKARA	84.47±4.35AB	1.86±0.15ABC	91.97±7.12AB	0.73±0.09ABC	2.58±0.22ABC
KARAMAN	99.66±4.35A	2.29±0.15A	104.44±7.12AB	0.81±0.09ABC	3.10±0.22A
KAYSERI	87.54±4.35AB	2.09±0.15AB	90.88±7.12AB	1.05±0.09A	3.13±0.22A
KONYA	79.04±4.35AB	1.59±0.15BC	105.97±7.12AB	0.66±0.09BC	2.25±0.22BC
SAMSUN	85.97±4.35AB	1.92±0.15AB	116.82±7.12A	0.69±0.09BC	2.60±0.22ABC
HATAY	90.66±4.35AB	1.84±0.15ABC	94.88±7.12AB	0.97±0.09AB	2.8±0.22ABC

^a (A-C) Mean values with similar letters in the same column is not statistically significant (Duncan P> 0.05). The value of ± is the standard error.

Table 3. Effect of increasing temperature on shoot length (cm), root length (cm), shoot dry weight (g), root dry weight (g), and whole plant dry weight (g) of bindweed.

	Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Whole plant dry weight (g)
26°C	68.49±13.57B	77.13±20.98B	1.62±0.58B	0.53±0.27B	2.14±0.75B
29°C	104.11±21.52A	124.59±38.65A	2.05±0.72A	0.93±0.51A	2.97±1.12A
Percentage increase (%)	34	38	21	43	18

introduced areas. However, it needs to be studied experimentally.

Furthermore, the increase in root length with elevated temperature was affected by seed sources (Figure 1). Root length increased in all provinces but not the same amount. Percentage increase of root length changed between 61.91 (Denizli population) and 18.64% (Hatay population) with 39.08% median for all populations. The highest root length under 29°C were measured for six populations, Samsun, Denizli, Tekirdag, Malatya, Adana, and Karaman between 129.88 to 153.00 cm (in statistically the

same group) and the lowest Sanliurfa (90.63 cm). Under 26 °C, the longest root established in Usak population and the shortest for (Denizli, Sanliurfa an Ankara Provinces (53.13 to 69.69 cm).

The effect of CO₂ on root and shoot parameters was not significant, but root length and root dry weight of bindweed were affected by CO₂ differently depending on seed sources. The change in root length varied between 89.5 and 110.38 cm in Ankara, Karaman, Konya, Malatya and Tekirdağ with CO₂ increase (400 and 800

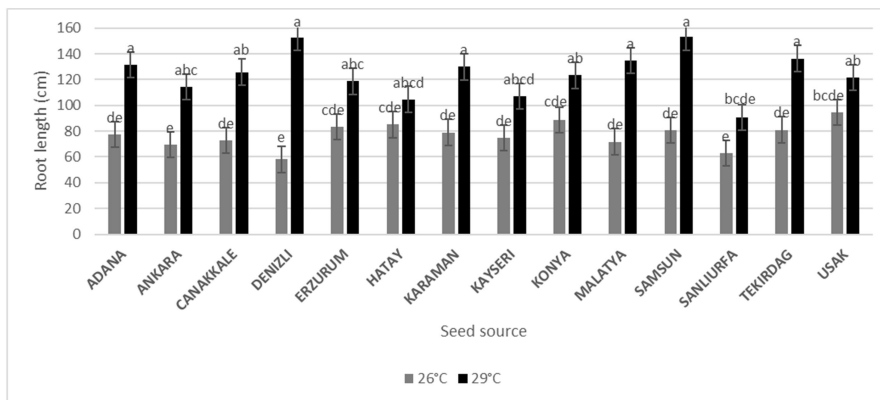
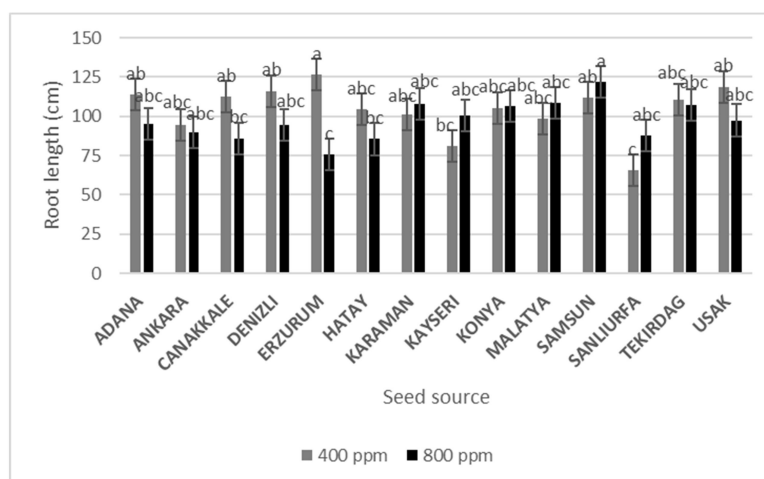


Figure 1. The effect of temperature on root length (cm) according to seed source.

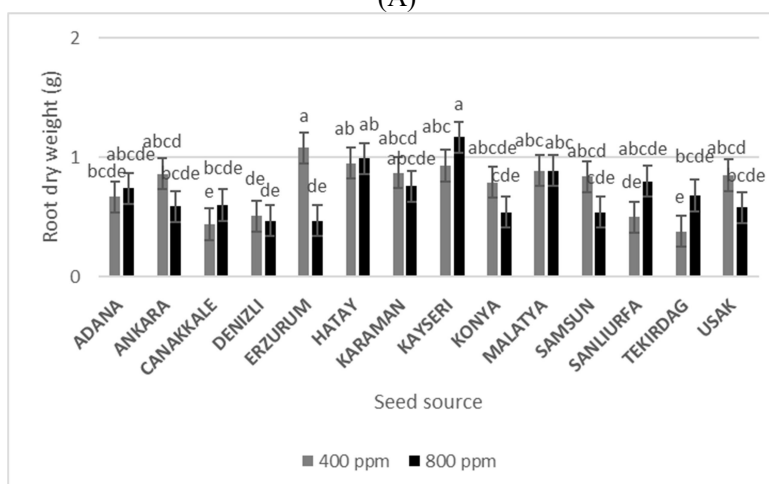
ppm) and was statistically in the same group (Figure 2-A). Root length decreased for six populations between 18.38 cm and 51.25 cm; but increased for three populations between 9.63 cm and 22.06 cm. Root length and root dry weight data were not consistent among seed sources. Dry weight of bindweed root was similar for both CO₂ levels for Denizli, Hatay, and Malatya populations varying between 0.47 and 0.99 g (Figure 2-B). Dry weight increased with increasing CO₂ for only Adana, Canakkale, Kayseri, Sanliurfa, and Tekirdag populations. It was reported that there was 32.9% genetic variation among five Turkish populations although it was higher (53.8%) within populations (Sunar *et al.*, 2015). We believe that this variation among populations is not small and may help to explain differences among seeds from different populations.

Overall results of these experiment show that the effect of CO₂ is not significant on bindweed, although root length and root dry weight were significantly affected by CO₂ elevation and the effect differed among seed sources. However, the effects on root length and dry weight were not parallel. A study showed that a C4 species of grain sorghum (*Sorghum bicolor*) showed beneficial effect from elevated CO₂ as well as C3 species such as bean (*Phaseolus vulgaris*) (Korres *et al.*, 2016). On the other hand, the effect of increasing temperature caused increasing growth of bindweed, which is not easy to explain the physiological and anatomical

reasons. However, some experimental results agree with our results. Broad leaf (C3 plant) species responded positively to elevated CO₂, but bindweed was the less responsive species (Ziska, 2003). Effect of elevated CO₂ on photosynthesis and yield of foxtail millet, a C4 crop species, was similar to C3 plants (Li *et al.*, 2019). These two examples show that not all C3 or C4 plants behave the same way. In our study, a C3 plant, bindweed, behaved mostly similar to a C4 plant. The combined effect of CO₂ and rising temperature on C3 gramineae plants were additive (Mueller, 2016). Reich *et al.* (2018) after a 20-year experiment in grassland, reported that the CO₂ effect may can reverse effects on the development of C3 and C4 plants over time. However, it caused debates (Wolf and Ziska 2018; Nie *et al.*, 2018). In addition, the response of fast-growing herbaceous C3 species to elevating CO₂ was stronger compared to slower grown C3 and C4 species (Poorter and Navas, 2003). Response of bindweed populations to varying environmental conditions can be due to variability of growth and reproduction capability of bindweed (Degennaro and Weller, 1984). Thus, populations from native rangelands of Turkey and alien rangeland of Canada might respond differently, although they have not been compared in a common garden experiment, but the genetic variation among bindweed populations can be mentioned as a reason. Our findings and earlier literature suggest that ecologic, physiologic, and



(A)



(B)

Figure 2. The effect of increasing CO₂ depending on seed source A) on root length (cm) and B) on dry weight (g).

genomic, even epigenetic studies should be run in parallel to explain precisely the climate change effect on bindweed or any other plant species. Our analysis and interpretation of the biomass data provides insights different from those of Reich *et al.* (2018), but we agree with their suggestion for conducting long-term experiments.

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تأثیر مقادیر بیشتر دی اکسید کربن و دماهای بالا بر رشد نیلوفر صحرایی (*Convolvulus arvensis* L.) در ترکیه

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چکیده

نیلوفر صحرایی (*Convolvulus arvensis* L.) یکی از بدترین علف های هرز در ترکیه و همچنین در سراسر جهان است. با افزایش دما و غلظت گازهای گلخانه ای و رویدادهای شدید جوی غیر قابل پیش بینی، تغییرات اقلیمی از مهمترین مشکلات جهان بوده است و تأثیر تغییر اقلیم بر تولید محصولات زراعی و علف های هرز باید بررسی شود. (به این منظور)، در سال ۲۰۱۹ اثر افزایش دما و CO₂ بر جمعیت های مختلف *C. arvensis* در شرایط گلخانه ای در استان مالاتیا ترکیه، بررسی شد. برای این مطالعه، در طول سال ۲۰۱۸، بذر علف های هرز از ۱۴ استان در سراسر ترکیه جمع آوری شد و دو رژیم دمایی (شب/روز برابر ۱۶/۲۶ °C و ۱۹/۲۹ °C) و دو سطح CO₂ (۵۰ ± ۴۰ و ۵۰ ± ۸۰۰ ppm) استفاده شد. طول بوته، طول ریشه و وزن خشک ریشه، قسمت های بالایی گیاه و کل گیاه تحت تأثیر دما، CO₂ و محل جمع آوری بذر قرار نگرفت. با این حال،

محل جمع آوری بذر به طور متفاوتی بر طول ریشه تأثیر گذاشت که به دما و طول ریشه و وزن خشک ریشه زیر تأثیر سطح CO₂ وابسته بود. علاوه بر این، محل جمع آوری بذر و دما تأثیر معنی داری بر پارامترهای اندازه گیری شده نشان دادند، در حالی که برای CO₂ اثر معنی داری مشاهده نشد.