



Inter- and Intra-specific Competition of Potato with Four Common Weed Species and Their Impact on Tuber Yield

Taseer Ahmad¹ · Khawar Jabran¹



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Abstract

Weeds compete with crops including potato and cause a huge yield and quality reduction. This competition varies according to weed type and their infestation level. The objective of this study was to explore the inter- and intra-specific competition of potato and four of its major weeds, i.e., *Amaranthus retroflexus*, *Chenopodium album*, *Salsola kali*, and *Solanum nigrum*, under varying densities. The weeds and potato plants were grown in pots by maintaining weed densities of 0, 2, 4, and 6 weed plants, together with the potato plant densities of 0, 1, 2, and 3, with all possible interactions and a control (only weed or potato plants). The results showed that with an increase in the density of *A. retroflexus*, potato height and yield started decreasing, and there was a 9–49% tuber yield reduction due to *A. retroflexus* interference depending on its density. The *A. retroflexus* height and biomass were positively influenced under low inter-specific competition with potato compared to when grown alone (intra-specific competition). The maximum *C. album* height and biomass were observed under low intra-specific (only 2 *C. album* plants) and inter-specific competition conditions (2 *C. album* × 1 potato). There was a 9–48% reduction in tuber yield when potato was exposed to competition from different densities of *C. album*. The height and biomass of *S. kali* were significantly higher under low inter- and intra-specific competition. Tuber yield loss due to *S. kali* interference was 32–63% under inter-specific competition conditions. The highest height and dry weight of *S. nigrum* were recorded under low competition/densities (2 *S. nigrum* × 1 potato). Yield loss under inter-specific competition of potato with *S. nigrum* was 22–43% depending on the densities of *S. nigrum*. In general, the weeds performed well under low competition and caused a decrease in tuber yield, showing their ability to compete at inter-specific competition conditions. The results of this study could be helpful in providing insights into the competition of potato with their common weeds, enabling a focus on the management of the most competitive ones.

Keywords Annual weeds · Competition · Densities · Goosefoots · *Solanum tuberosum*

Introduction

Weeds and crops compete for resources such as water, light, nutrients, and space throughout the crop-growing season (MacLaren et al. 2020; Ahmad et al. 2023). Weeds often compete more effectively by capturing resources more efficiently, exhibiting an aggressive growth habit and strong competitiveness, leading to a reduction in crop yield (Horvath et al. 2023). The economic loss caused by weeds ranges from US \$ 100 million to US \$ 26 billion annually worldwide (Ahmad et al. 2023).

The competitiveness of weeds depends on the composition of weed flora, its diversity, and abundance in a specific cropped area (Nkoa et al. 2015). Weed species belonging to families such as Poaceae, Amaranthaceae, Solanaceae, and Convolvulaceae are of particular importance because they cause a high weed-crop competition and reduction in crop yields. Weed species from these families such as redroot pigweed (*Amaranthus retroflexus* L.), lamb's quarters (*Chenopodium album* L.), common saltwort (*Salsola kali* L.), and black nightshade (*Solanum nigrum* L.) are commonly known due to their abundance and presence in a wide range of diverse climates. These weeds are noxious in nature, have universal distribution, and are mostly crop specific (Zaidi 2000). These weeds successfully invade cropped areas and cause a huge yield reduction in different crops including potato (*Solanum tuberosum* L.) (Siddiqui and Jabran 2025). In potato, weeds cause huge competition and significantly influence the yield and damage the quality of tuber by destructing tuber shape (Abdallah et al. 2021; Jabran et al. 2023; Siddiqui et al. 2024).

Amaranthus retroflexus is one of the most troublesome potato weeds. It is found in high numbers in the potato crop under both organic and conventional potato production systems (Nikolic et al. 2013). Under favourable conditions, this weed may grow up to 2 m in height and produce millions of seeds, enabling it to compete extensively for resources as well as causing a shading effect due to its greater height (Safavi et al. 2023). It is capable of damaging crop yields even if present at low densities. For example, the presence of only 1.41 *A. retroflexus* plants/m² starts causing threshold damage in maize (*Zea mays* L.) crops (Dogaru et al. 2012).

Chenopodium album is a common weed of potato fields and is highly adaptable to different environmental conditions (Ahmadvand et al. 2009). This weed is found extensively throughout the world due to its aggressive growth, high seed production, and tall height. *Chenopodium album* infests a wide range of agro-economic and horticultural crops and is capable of reducing crop yields by up to 90% (Bajwa et al. 2019; Kupdhoni et al. 2023). It reduces the rapeseed (*Brassica napus* L.) yield by 45% when 12 weed plants per metre of crop row were present (Valizadeh and Mirshekari 2011). *Solanum nigrum* is an important weed of potato and is abundantly found in irrigated cropping lands worldwide (Shah et al. 2010). It has physiological properties similar to potato, making its control challenging, as it competes for similar resources and can thrive under the same environmental conditions. *Salsola kali* is a weed native to Türkiye; it establishes easily, even

in arid conditions, and its presence in cropped areas prevents the establishment of other plants (Blankers 2014). Weeds such as *C. album*, *A. retroflexus*, and *S. nigrum* have strong association with potato crop (Fernández-Quintanilla et al. 2018), while *S. kali* is found extensively in the studied area due to its local infestations (Jabran K, personal communication). The presence of these weeds causes a huge competition for resources, reducing the growth and yield of potato (Jabran et al. 2023).

The study of competition between different weeds and crops has been conducted previously and reported (Moechnig et al. 2003; Guglielmini et al. 2017; Qasem 2018), but less literature is available on potato-weed interactions especially on the weed species included in this study, i.e., *A. retroflexus*, *C. album*, *S. kali*, and *S. nigrum*. A better understanding of the potato and the weeds in this study would allow for better decision-making regarding their control. Hence, the objectives of the current study were to assess (1) the effect of varying planting densities of *A. retroflexus*, *C. album*, *S. kali*, and *S. nigrum* on potato growth and yield; (2) the intra-specific response of targeted weeds to determine their competitiveness; and (3) the effect of different densities of potato on the growth of targeted weeds.

Materials and Methods

This research work was conducted in the screenhouse of the Department of Plant Production and Technologies, Nigde Omer Halisdemir University, Nigde (37.9712° North and 34.6776° East), Türkiye, during the years 2022 and 2023. The average temperature of the screenhouse was 25–30 °C during the experiment. Plants benefited from the natural light condition, and the average humidity was 40–60% inside the screenhouse.

The seeds of the selected weed plants were collected from the crop-growing area of the Department of Plant Production and Technologies, Nigde Omer Halisdemir University, Nigde, Türkiye. No permission was required for seed collection as the seed collection area belongs to the Department of Plant Production and Technologies, Nigde Omer Halisdemir University, Nigde, Türkiye, and no endangered species were involved in the research. The seeds were dried under shade, cleaned, and stored at room temperature for use in the experimentation. Potato seeds of the cultivar “Petek” were sourced from the Doğa Seed Company (Doğa Arge Merkezi San. Tic. A.Ş.), Nevşehir, Türkiye. The Petek cultivar is a late-maturing variety primarily utilized for both cooking and frying purposes (Tarım and Orman Bakanlığı 2022).

A soil and peat mixture was used to fill the pots (15 L; 33 cm × 25 cm). The experiments began on June 5, 2022, and June 1, 2023, in the first and second years of the study, respectively. Different plant sowing densities of potato and all four weed species were used according to the treatments to determine their inter- and intra-specific interactions by using a randomized complete block design (RCBD) for each experiment (Table 1). The weeds and potato plants were seeded in pots by maintaining weed densities of 0, 2, 4, and 6 weed plants together with the potato plant densities of 0, 1, 2, and 3 with all possible interactions and a control (only weed or potato plant). Weed densities of 0, 2, 4, and 6 weeds per pot were referred

Table 1 Number of treatments used for each experiment during both years 2022 and 2023

Treatment	Experiment 1	Experiment 2	Experiment 3	Experiment 4
T1	1 potato plant only	1 potato plant only	1 potato plant only	1 potato plant only
T2	2 potato plants only	2 potato plants only	2 potato plants only	2 potato plants only
T3	3 potato plants only	3 potato plants only	3 potato plants only	3 potato plants only
T4	2 <i>C. album</i> plants only	2 <i>A. retroflexus</i> plants only	2 <i>S. kali</i> plants only	2 <i>S. nigrum</i> plants only
T5	2 <i>C. album</i> + 1 potato	2 <i>A. retroflexus</i> + 1 potato	2 <i>S. kali</i> + 1 potato	2 <i>S. nigrum</i> + 1 potato
T6	2 <i>C. album</i> + 2 potato	2 <i>A. retroflexus</i> + 2 potato	2 <i>S. kali</i> + 2 potato	2 <i>S. nigrum</i> + 2 potato
T7	2 <i>C. album</i> + 3 potato	2 <i>A. retroflexus</i> + 3 potato	2 <i>S. kali</i> + 3 potato	2 <i>S. nigrum</i> + 3 potato
T8	4 <i>C. album</i> only	4 <i>A. retroflexus</i> plants only	4 <i>S. kali</i> plants only	4 <i>S. nigrum</i> plants only
T9	4 <i>C. album</i> + 1 potato	4 <i>A. retroflexus</i> + 1 potato	4 <i>S. kali</i> + 1 potato	4 <i>S. nigrum</i> + 1 potato
T10	4 <i>C. album</i> + 2 potato	4 <i>A. retroflexus</i> + 2 potato	4 <i>S. kali</i> + 2 potato	4 <i>S. nigrum</i> + 2 potato
T11	4 <i>C. album</i> + 3 potato	4 <i>A. retroflexus</i> + 3 potato	4 <i>S. kali</i> + 3 potato	4 <i>S. nigrum</i> + 3 potato
T12	6 <i>C. album</i> only	6 <i>A. retroflexus</i> plants only	6 <i>S. kali</i> plants only	6 <i>S. nigrum</i> plants only
T13	6 <i>C. album</i> + 1 potato	6 <i>A. retroflexus</i> + 1 potato	6 <i>S. kali</i> + 1 potato	6 <i>S. nigrum</i> + 1 potato
T14	6 <i>C. album</i> + 2 potato	6 <i>A. retroflexus</i> + 2 potato	6 <i>S. kali</i> + 2 potato	6 <i>S. nigrum</i> + 2 potato
T15	6 <i>C. album</i> + 3 potato	6 <i>A. retroflexus</i> + 3 potato	6 <i>S. kali</i> + 3 potato	6 <i>S. nigrum</i> + 3 potato

to no competition, medium, low, and high competition, respectively. The nitrogen, phosphorus, and potassium (NPK) fertilizer at the rate of 140 kg ha⁻¹ was applied at the time of sowing. Four replications were used for each treatment. The pots were irrigated regularly to fulfill the plants' water needs. The treatments used for each experiment are summarized in Table 1:

Data Recording

Data for weed and potato plant heights were recorded at the flowering stage (BBCH 60–69 DAS) (Nemes et al. 2008). Plant heights of both potato and targeted weed species were recorded by using a meter scale, from the soil surface to the uppermost leaf tip. After that, weeds were cut separately from each pot and kept in an oven for 72 h at a temperature of 70 °C, and their dry weights were recorded using an electronic weighing scale (ATX24, SHIMADZU). At the completion of the maturity stage (BBCH 91–97 DAS), the potato tubers were separated from the soil in each pot (Nemes et al. 2008). The data for tuber yield was recorded by measuring the weight of the obtained tubers.

Yield loss due to weeds was determined by using the formula given by Soltani et al. (2016):

$$\text{Yield loss due to weeds} = \frac{\text{WFY} - \text{WCY}}{\text{WFY}} \times 100 \quad (1)$$

Here, WFY is the crop yield in weed-free pots and WCY is the crop yield in weedy pots.

Data Analysis

Data on potato height and tuber yield, as well as weed height and dry biomass, were analysed using Statistix 8.1 software. Analysis of variance (ANOVA) was performed, and the means were compared using the least significant difference (LSD) test at a 5% probability level. The data for this study (the recorded parameters) was not different across the years as established by the ANOVA; hence, the data from the years were pooled and presented as means of the two sets of the experiments.

Results

Crop-Weed Relationship Between *Amaranthus retroflexus* and Potato Crop

The highest *A. retroflexus* height was observed under low competition; i.e., two plants of *A. retroflexus* and one potato plant were grown per pot (Figure 1A). With the increase in the density of potato and *A. retroflexus*, the height of *A. retroflexus* started decreasing due to high competition for space and other resources. The dry weight of *A. retroflexus* was significantly influenced by plant densities under both inter- and intra-specific competition (Figure 1B). The highest dry weight of *A.*

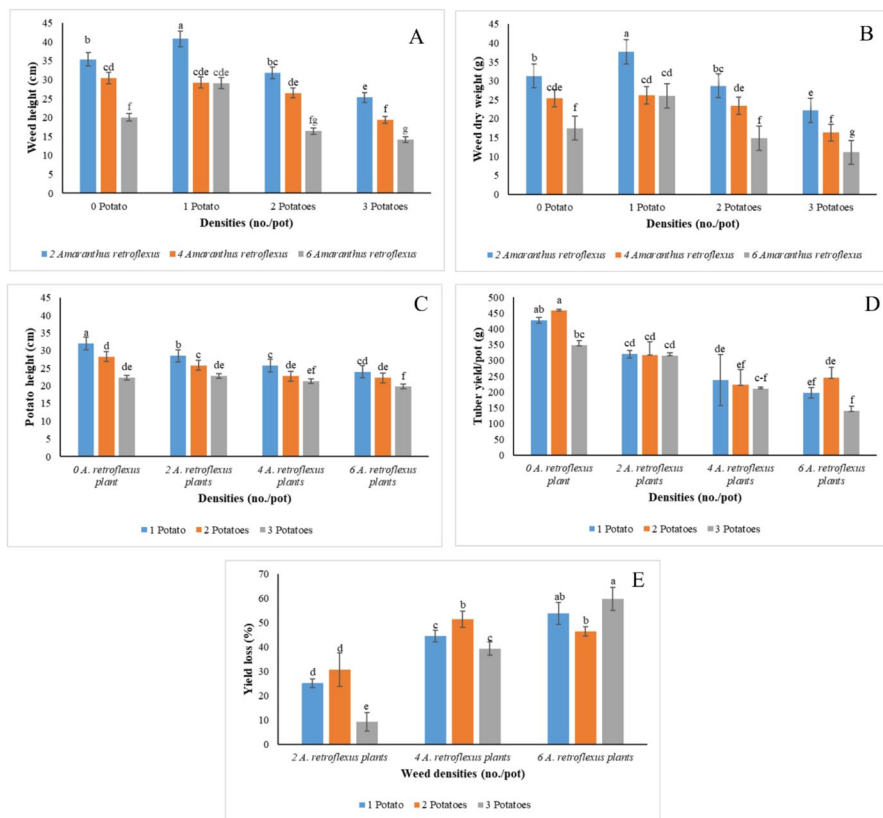


Figure 1 *Amaranthus retroflexus* height (A), dry weight (B), potato height (C), tuber yield (D), and yield reduction (E) under different potato plants and *A. retroflexus* densities. Different letters on each bar indicate significant differences among the values for the grouped samples ($p < 0.05$ according to a one-way analysis of variance, ANOVA)

retroflexus was observed under low inter-specific competition (1 potato $\times$ 2 *A. retroflexus*) as compared to intra-specific competition. With the increase in competition, the dry weight of *A. retroflexus* decreased significantly, and the lowest dry weight was observed at high densities or competition, i.e., when 6 *A. retroflexus* $\times$ 3 potato plants were grown together.

The highest potato height was observed when one potato was grown per pot without *A. retroflexus*, i.e., no competition (Figure 1C). With the increase in the density of potato (intra-specific competition) and *A. retroflexus* (inter-specific competition), potato height started decreasing and reached the lowest at medium and low competition, i.e., four and six *A. retroflexus* plants per pot. The tuber yield per pot was significantly influenced by inter-specific competition with *A. retroflexus*, while it was non-significant under intra-specific competition of potato at different densities (Figure 1D). Yield loss due to *A. retroflexus* interference varied, and a 9–60% reduction in tuber yield was observed

compared to when potato was grown without competition (Figure 1E). Yield loss was only 9.26% under low inter-specific competition (3 potato + 2 *A. retroflexus*). At high competition, these values were not varied significantly and showed 46.5–59.8% yield loss at all potato densities, i.e., when 1, 2, or 3 potatoes + 6 *A. retroflexus* plants were grown together.

Crop-Weed Relationship Between *Chenopodium album* and Potato Crop

The maximum *C. album* height was observed under intra-specific competition, i.e., when two plants of *C. album* were grown per pot without potato (no competition) and this value was at par with the low competition (2 *C. album* × 1 potato) (Figure 2A). With the increase in the density of potato and *C. album*, the height of *C. album* started decreasing likely due to high competition for space and other resources. The dry weight of *C. album* was the highest at low competition, i.e., when two plants of *C. album* were grown in competition with one potato plant, proving that under low inter-specific competition, *C. album* performed better (Figure 2B).

The potato height was significantly impacted under both inter- and intra-specific competition conditions, and the maximum height was observed when one potato plant was grown per pot without *C. album*, i.e., no competition (Figure 2C). With the increase in the density, intra-specific competition (between potato) and inter-specific competition (between potato and *C. album*), potato height started decreasing and became the lowest at high competition, i.e., when 3 potatoes × 6 *C. album* plants were grown together. The tuber yield per pot was significantly influenced by inter-specific competition with *C. album*, while it was non-significant under intra-specific competition of potato at different densities (Figure 2D). The *C. album* interference caused a huge impact on the tuber yield, and a 9–51% reduction in tuber yield was observed compared to when potato was grown without competition (Figure 2E). The maximum yield losses of 47.1–49.7% were observed under high competition (1, 2, or 3 potatoes × 6 *C. album*). The yield loss was minimum and ranged from 9.3 to 18.3% under low competition (1, 2, or 3 potatoes × 2 *C. album*).

Crop-Weed Relationship Between *Salsola kali* and Potato Crop

The height of *S. kali* was decreased under inter- and intra-specific competition. Under high inter-specific competition, the height of *S. kali* was significantly lower as compared to intra-specific competition (Figure 3A). With the increase in the density of potato and *S. kali*, the height of *S. kali* started to decrease and reached a minimum at high competition (1, 2, or 3 potato × 6 *S. kali*) due to high competition for space and other resources. Dry weights of *S. kali* were the highest at low inter-specific competition (1, 2, or 3 potato × 2 *S. kali*) as compared to grown alone (intra-specific competition) (Figure 3B). The maximum dry weight was observed under low competition, i.e., when 1 potato × 2 *S. kali* plants were grown together. The dry weight

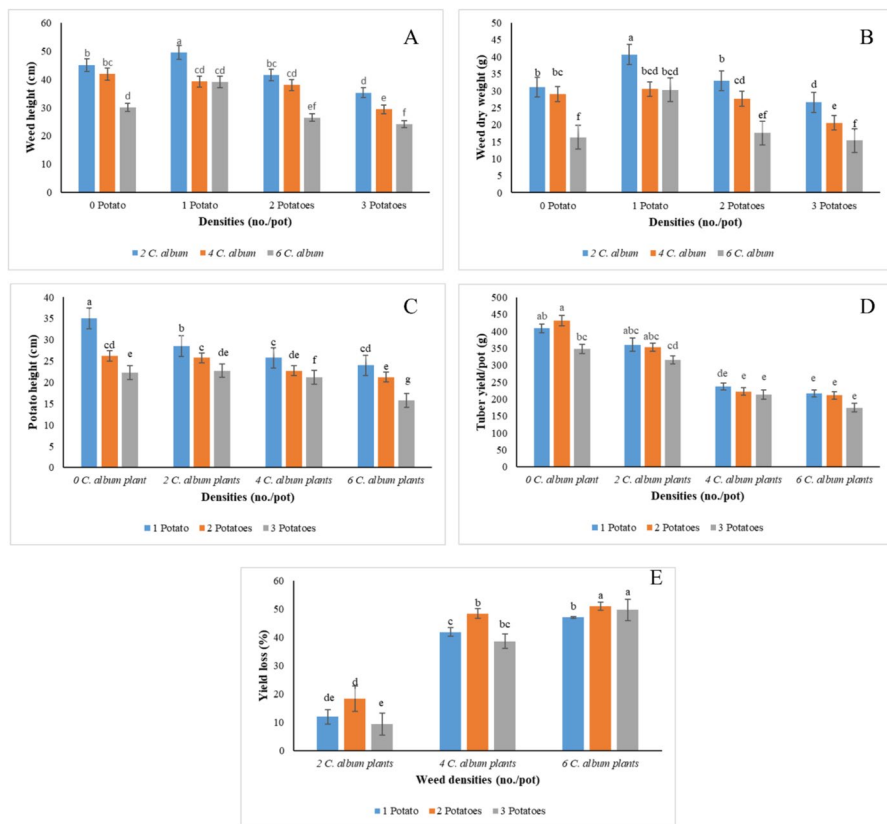


Figure 2 *Chenopodium album* height (A), dry weight (B), potato height (C), tuber yield (D), and yield reduction (E) under different potato plants and *C. album* densities. Different letters on each bar indicate significant differences among the values for the grouped samples ($p < 0.05$ according to a one-way analysis of variance, ANOVA)

of *S. kali* decreased significantly with the increase in densities/competition, and the lowest dry weight was obtained when six plants of *S. kali* × 3 plants of potato were grown together.

The highest potato height was observed when one potato was grown per pot without *S. kali*, i.e., no competition (Figure 3C). With an increase in the density of potato and *S. kali*, potato height started decreasing and reached a minimum at high competition (1, 2, or 3 potato × 6 *S. kali*). The tuber yield per pot was significantly influenced by inter-specific competition with *S. kali*, while it was non-significant under intra-specific competition of potato at different densities (Figure 3D). Yield loss due to *S. kali* interference varied, and a 32–63% reduction in tuber yield was observed compared to when potato was grown without competition (Figure 3E). The maximum yield loss (46.9–63.4%) was observed at high competition (1, 2, and 3 potatoes × 6 *S. kali*), while under low competition (1, 2 and 3 potatoes × 2 *S. kali*), yield losses were 32.7–45.1%.

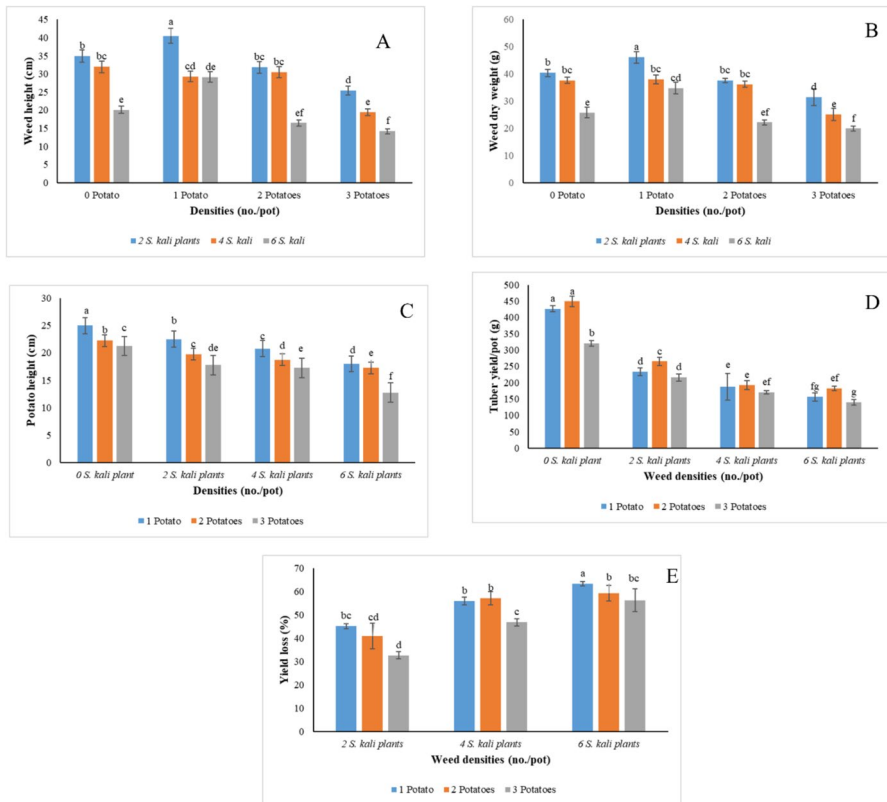


Figure 3 *Salsola kali* height (A), dry weight (B), potato height (C), tuber yield (D), and yield reduction (E) under different potato plants and *S. kali* densities. Different letters on each bar indicate significant differences among the values for the grouped samples ($p < 0.05$ according to a one-way analysis of variance, ANOVA)

Crop-Weed Relationship Between *Solanum nigrum* and Potato Crop

The densities of both potato and *S. nigrum* had a significant effect on weed height, and the maximum height of *S. nigrum* was observed under low densities (2 *S. nigrum* × 1 potato) (Figure 4A). The dry weight of *S. nigrum* was influenced by both inter- (*S. nigrum* and potato) and intra-specific (between *S. nigrum* plants) competitions at different densities (Figure 4B). The highest dry weight of *S. nigrum* was recorded under low competition/densities (2 *S. nigrum* × 1 potato). The dry weight of *S. nigrum* was significantly lower at high densities or competition (6 *S. nigrum* × 3 potatoes).

The potato height varied under intra- and inter-specific competition with *S. nigrum*. The maximum potato height was observed when one potato was grown per pot without *S. nigrum*, i.e., no competition (Figure 4C). With the increase in the density of potato and *S. nigrum*, potato height started decreasing, and the

lowest height was observed when the potato was grown with high densities of *S. nigrum*. Tuber yield varied significantly under inter- and intra-specific competition (Figure 4D). The maximum tuber yield was observed when the potato was grown alone (i.e., without competition) and at medium sowing densities, i.e., when only two potato plants were grown in one pot, and this value was at par when only one potato plant was grown in one pot. The tuber yield was decreased with the increase in competition and densities although potato densities had a non-significant impact on the tuber yield. Yield loss under inter- and intra-specific competition of potato with *S. nigrum* showed a significant impact, and yield decreased by 22–43% in the presence of all densities of *S. nigrum* (Figure 4E). The maximum yield losses of 39–42.4% were observed at high densities or competition (1, 2, and 3 potatoes $\times$ 6 *S. nigrum*), while the impact of potato densities was non-significant. At low competition (1, 2, and 3 potatoes $\times$ 2 *S. nigrum*), yield losses ranged from 21.7 to 24.2%.

Among the four weeds, *S. kali* proved to be the most competing weed and caused the highest potato tuber yield reduction that ranged from 32 to 63% (Table 2). Keeping in view the tuber yield reduction, *S. nigrum* proved to be the second most competitive weed after *S. kali* and caused a minimum of 32% and a maximum of 43% yield reduction. *A. retroflexus* and *C. album* caused a similar decrease in the tuber yield, i.e., 9–49%.

Discussion

The results of the current study showed that the densities of *A. retroflexus*, *C. album*, *S. kali*, and *S. nigrum* had a significant impact on the growth and tuber yield of the potato crop. The highest tuber yield was observed when the potato was grown alone without competition with any of the targeted weed species, i.e., *A. retroflexus*, *C. album*, *S. kali*, and *S. nigrum*. Tuber yield decreased significantly when competing with the weeds, especially at medium and high densities, i.e., four or six weeds per pot. The potato is highly susceptible to weed interference, and high weed interference may cause up to 65 and 80% marketable and total yield reduction, respectively (Siddiqui et al. 2024). The highest emergence of annual broadleaved weeds especially *C. album* and *A. retroflexus* is usually observed in the potato-growing areas, due to crop-weed association, and a widespread impact is observed if these weeds are not controlled properly (Zaidi 2000; Ciuberkis et al. 2007). *Amaranth retroflexus*, *C. album*, and *S. nigrum* are the most densely observed weeds in potato-growing areas (Kilic 2016).

The intra-specific competition had less impact on the plant height of both, i.e., weeds and the potato plant, under both low and high densities of competition. The high densities of potato and weeds decreased the plant height and tuber yield. The height and dry matter of the weeds were also decreased with the increase in competition. This is because weeds are strong competitors, performing more efficiently when grown in a mixture (under inter-specific competition) as compared to when

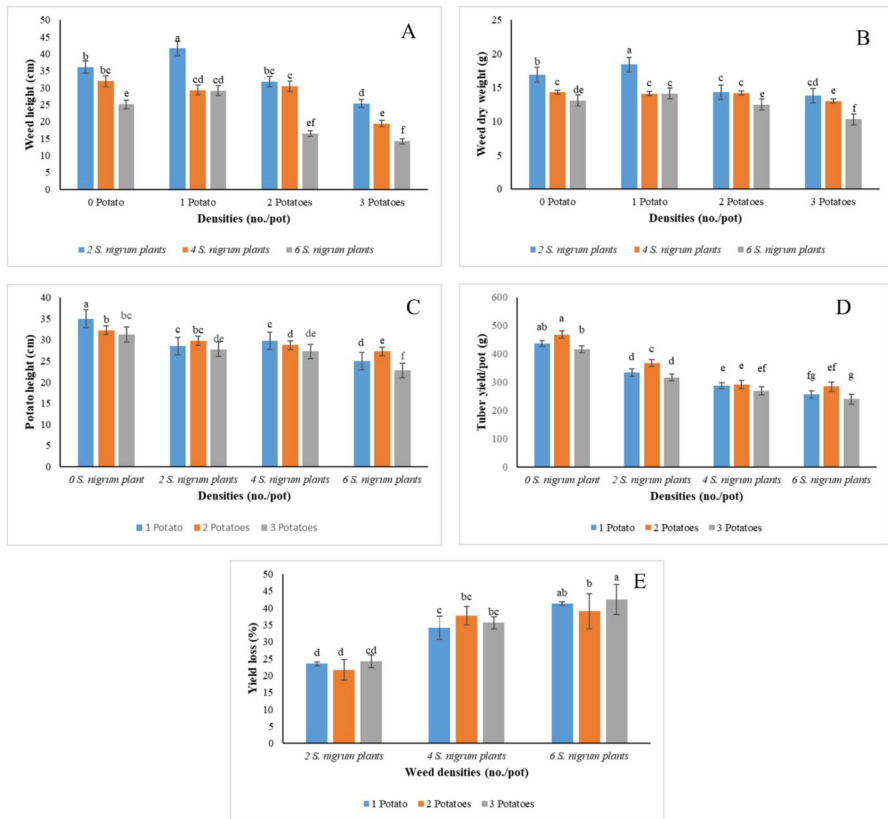


Figure 4 *Solanum nigrum* height (A), dry weight (B), potato height (C), tuber yield (D), and yield reduction (E) under different potato plants and *S. nigrum* densities. Different letters on each bar indicate significant differences among the values for the grouped samples ($p < 0.05$ according to a one-way analysis of variance, ANOVA)

grown alone (intra-specific competition) (Oladokun 1978; Basinger et al. 2019; Sharpe 2020).

The highest tuber yield reduction was observed when potato and *S. kali* were grown in competition as compared to other studied weeds because the tuber yield is highly dependent on weed species and their densities/competition (Yadavi et al. 2016). The *S. kali* is a highly competitive weed and has the ability to occupy the whole cropped area by suppressing the growth of neighbouring weeds and other flora (Santín-Montanyá et al. 2020). Also, its tangling growth habit with spiny leaf structure causes difficulties in field operations and hinders harvesting operations (Klopper 2000). The yield loss due to *A. retroflexus* and *C. album* was almost similar due to their belonging to the same family and shared morphological characteristics (Hadi and Noormohamadi 2012). Also, their ability to grow in a wide range of environmental conditions and tall height makes them compete extensively with the main crop and capture more resources (Hamidzadeh et al. 2021). The *S. nigrum*

Table 2 Tuber yield loss due to weed species

Sr. no.	Weed species	Tuber yield loss (%)
1	<i>Amaranthus retroflexus</i>	9–49
2	<i>Chenopodium album</i>	9–48
3	<i>Salsola kali</i>	32–63
4	<i>Solanum nigrum</i>	22–43

gained an advantage owing to the same family as potato and caused a significant amount of yield loss at each planting density (Jain et al. 2011). The reason is that *S. nigrum* can compete better for resources as compared to potato due to some shared similar characters and being advantageous to potato.

Overall, the selected weed species, *C. album*, *A. retroflexus*, and *S. nigrum*, are widely observed weeds in potato-growing area (Kilic 2016; Fernández-Quintanilla et al. 2018), while *S. kali* has its local infestation. Both the factors studied, i.e., weed densities/competition and species type, have a significant impact on the growth and tuber yield of potato. Under intra-specific competition, the yield reduction was lower, and it increased with the increase in competition with the weeds. The weeds have strong competitive abilities when grown with the plants of other species as it has been observed under low intra-specific competition, where all the weeds showed low performance, and the height and dry matter were decreased. These observations could be helpful in weed management by determining the competitive abilities of the commonly observed weeds and prioritizing the management of the most problematic species on a sustainable basis.

Conclusions

Weeds significantly affect the growth and yield of the potato crop, and the degree of competition and yield loss depends on densities and types of weeds. This research concluded that potato-weed competition started even when the potato plants were exposed to low weed densities, and the intensity of this competition was increased with an increase in weed densities. Either on the plant height or tuber yield, the intra-specific (potato-potato) competition had a lower impact than the inter-specific (potato-weed) competition. The highest rate of tuber yield decrease (32–63%) was caused by *S. kali*, followed by *S. nigrum* (22–43%), proving the high competitive ability of these two weeds. The other two weeds in the study, i.e., *A. retroflexus* and *C. album*, decreased the tuber yield by 9–49%. The results of the current study can help to improve management strategies by prioritizing the most problematic or competitive species. Moreover, the results will allow farmers to better plan specific herbicide strategies based on the competitiveness of weeds.

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Data Availability Data will be available upon request to the corresponding author.

Declarations

Competing Interests The authors declare no competing interests.

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References

- Abdallah IS, Atia MA, Nasrallah AK, El-Beltagi HS, Kabil FF, Abdeldaym El-Mogy MM, EA, (2021) Effect of new pre-emergence herbicides on quality and yield of potato and its associated weeds. *Sustainability* 13(17):9796. <https://doi.org/10.3390/su13179796>
- Ahmad T, Jabran K, Cheema ZA, Bajwa AA, Farooq M (2023) A global perspective of education in weed science. *Weed Sci* 71(6):536–548. <https://doi.org/10.1017/wsc.2023.49>
- Ahmadvand G, Mondani F, Golzardi F (2009) Effect of crop plant density on critical period of weed competition in potato. *Sci Hortic* 121(3):249–254. <https://doi.org/10.1016/j.scienta.2009.02.008>
- Bajwa AA, Zulfiqar U, Sadia S, Bhowmik P, Chauhan BS (2019) A global perspective on the biology, impact and management of *Chenopodium album* and *Chenopodium murale*: two troublesome agricultural and environmental weeds. *Environ Sci Pollut Res* 26:5357–5371. <https://doi.org/10.1007/s11356-018-04104-y>
- Basinger NT, Jennings KM, Monks DW, Jordan DL, Everman WJ, Hestir EL et al (2019) Interspecific and intraspecific interference of *Palmer amaranth* (*Amaranthus palmeri*) and large crabgrass (*Digitaria sanguinalis*) in sweetpotato. *Weed Sci* 67:426–432. <https://doi.org/10.1017/wsc.2019.27>
- Blankers E (2014) *Salsola tragus*, *Salsola kali*, *Salsola iberica*. Public Lands History Center at Colorado State University, September, *Salsola australis*, p 2014
- Ciuberkis S, Bernotas S, Raudonius S, Felix J (2007) Effect of weed emergence time and intervals of weed and crop competition on potato yield. *Weed Technol* 21:612–617. <https://doi.org/10.1614/WT-06-101.1>
- Dogaru VG, Budoi GŞ, Săndoiu DI (2012) Determination of the *Amaranthus retroflexus* damage threshold in maize crop. *Adv Agric Bot* 4:1–5
- Fernández-Quintanilla C, Peña JM, Andújar D, Dorado J, Ribeiro A, López-Granados F (2018) Is the current state of the art of weed monitoring suitable for site-specific weed management in arable crops? *Weed Res* 58:259–272. <https://doi.org/10.1111/wre.12307>
- Guglielmini AC, Verdú AMC, Satorre EH (2017) Competitive ability of five common weed species in competition with soybean. *Int J Pest Manag* 63:30–36. <https://doi.org/10.1080/09670874.2016.1213459>
- Hadi MRHS, Noormohamadi G (2012) Competitive effects of redroot pigweed (*Amaranthus retroflexus*) and lambsquarter (*Chenopodium album*) on potato. *Sci Res Essays* 7:2781–2787
- Hamidzadeh MS, Alebrahim MT, Tobeh A, Mohebodini M, Werck-Reichhart D, MacGregor DR, Tseng TM (2021) Redroot pigweed (*Amaranthus retroflexus* L.) and lamb's quarters (*Chenopodium album* L.) populations exhibit a high degree of morphological and biochemical diversity. *Front Plant Sci* 12:593037. <https://doi.org/10.3389/fpls.2021.593037>
- Horvath DP, Clay SA, Swanton CJ, Anderson JV, Chao WS (2023) Weed-induced crop yield loss: a new paradigm and new challenges. *Trends Plant Sci* 28:567–582. <https://doi.org/10.1016/j.tplants.2022.12.014>

- Jabran K, Ahmad T, Siddiqui AO, Üremiş İ, Doğan MN (2023) Weed management in potato. In Çalışkan ME et al (Eds) *Potato Production Worldwide* pp. 121–131. Academic Press. ISBN 9780128229255, <https://doi.org/10.1016/B978-0-12-822925-5.00013-X>.
- Jain R, Sharma A, Gupta S, Sarethy IP, Gabrani R (2011) *Solanum nigrum*: current perspectives on therapeutic properties. *Altern Med Rev* 16(1):78–85
- Kilic OK (2016). Determination of weed species, distribution and density in potato fields (*Solanum tuberosum* L.) in Niğde Province. *Plant Prot Bull* 56(4):417–428. <https://doi.org/10.16955/bitkorb.286358>
- Klopper, R. R. (2000). *Leaf structure in southern African species of Salsola L.* Global. (2901486055). Retrieved from <https://www.proquest.com/dissertations-theses/leaf-structure-southern-african-species-salsola-l/docview/2901486055/se-2>
- Kupdhoni R, Khan MAR, Islam MN (2023) *Chenopodium album*: a review of weed biology, status and the possibilities for biological control. *Turk J Weed Sci* 26(2):144–158
- MacLaren C, Storkey J, Menegat A, Metcalfe H, Dehnen-Schmutz K (2020) An ecological future for weed science to sustain crop production and the environment. A review. *Agron Sustain Dev* 40:24. <https://doi.org/10.1007/s13593-020-00631-6>
- Moechnig MJ, Boerboom CM, Stoltenberg DE, Binning LK (2003) Growth interactions in communities of common lambsquarters (*Chenopodium album*), giant foxtail (*Setaria faberi*), and corn. *Weed Sci* 51:363–370. [https://doi.org/10.1614/0043-1745\(2003\)051\[0363:GIICOC\]2.0.CO;2](https://doi.org/10.1614/0043-1745(2003)051[0363:GIICOC]2.0.CO;2)
- Nemes Z, Baciu A, Popa D, Mike L, Petrus-Vancea A, Danci O (2008) The study of the potato's life-cycle phases important to the increase of the individual variability. *Analele Universitatii Oradea, Fascicola Biologie* 15:60–63
- Nikolic L, Ilić O, Džigurski D, Ljevnaić-Mašić B (2013) Analysis of weed flora in conventional and organic potato production. *Biol Nyssana* 4:9–14
- Nkoa R, Owen MD, Swanton CJ (2015) Weed abundance, distribution, diversity, and community analyses. *Weed Sci* 63(SP1):64–90. <https://doi.org/10.1614/WS-D-13-00075.1>
- Oladokun MAO (1978) Nigerian weed species: intraspecific competition. *Weed Sci* 26:713–718. <https://doi.org/10.1017/S0043174500064882>
- Qasem JR (2018) Competition of redroot pigweed (*Amaranthus retroflexus* L.) and nettle-leaved goosefoot (*Chenopodium murale* L.) with tomato (*Lycopersicon esculentum* Mill.) cultivars. *J Hort Sci Biotechnol* 93:634–643. <https://doi.org/10.1080/14620316.2017.1421052>
- Safavi M, Rezvani M, Zaeferian F, Golmohammadzadeh S, Sindel BM (2023) Seed germination requirements of *Amaranthus retroflexus* L. populations exposed to environmental factors. *Botany* 101:99–111. <https://doi.org/10.1139/cjb-2022-0077>
- Santín-Montanyá MI, Gandía ML, Casanova C, Sánchez-Jiménez FJ, Tenorio JL (2020) The influence of soil tillage system on *Salsola kali* L. emergence during the fallow period within cereal fields. *Soil Use Manag* 36:594–603. <https://doi.org/10.1111/sum.12629>
- Shah FA, Falloon RE, Bulman SR (2010) Nightshade weeds (*Solanum* spp.) confirmed as hosts of the potato pathogens *Meloidogyne fallax* and *Spongospora subterranea* f. sp. subterranea. *Australas Plant Pathol* 39:492–498. <https://doi.org/10.1071/AP10059>
- Sharpe SM (2020) Kochia (*Kochia scoparia*) and wild oat (*Avena fatua*) intraspecific and interspecific interference. *Agron* 11(1):62. <https://doi.org/10.3390/agronomy11010062>
- Siddiqui AO, Jabran K (2025) Weed tolerance and suppressive ability of potato cultivars to natural weed infestations. *J Crop Health*. <https://doi.org/10.1007/s10343-025-01117-9>
- Siddiqui AO, Işık D, Jabran K (2024) Impact of weed competition on morphological and biochemical traits of potato: a review. *Potato Res* 67:451–462. <https://doi.org/10.1007/s11540-023-09647-3>
- Soltani N, Dille JA, Burke IC, Everman WJ, VanGessel MJ, Davis VM, Sikkema PH (2016) Potential corn yield losses from weeds in North America. *Weed Technol* 30:979–984. <https://doi.org/10.1614/WT-D-16-00046.1>
- Tarım and Orman Bakanligi, (2022) Patates ana ürün tescil raporu-1. Accessed online on 04-09-2024. https://www.tarimorman.gov.tr/BUGEM/TTSM/Belgeler/Duyuru%20Belgeleri/2022/Duyuru%20Belgeleri/Nisan%20Ay%C4%B1%20Toplant%C4%B1lar/Patates/2022_patates_tescil%20raporu1_06_04_2022.pdf.

- Valizadeh N, Mirshekari B (2011) Determination of economical yield loss threshold of *Chenopodium album* at interference with rapeseed (*Brassica napus*). J Food Agric Environ 9:409–412. <https://doi.org/10.1234/4.2011.2135>
- Yadavi A, Asadi M, Maghsoudi E (2016) Effects of density and relative time of pigweed (*Amaranthus retroflexus*) emergence on yield of potato (*Solanum tuberosum*). Cercet Agron Moldova 2(166):115–122. <https://doi.org/10.1515/cerce-2016-0020>
- Zaidi PH (2000) Physiology of herbicide resistance. In: Hemantaranjan A (ed) Advances in plant physiology, Scientific Publishers, Jodhpur, India, 3:221–230

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Authors and Affiliations

Taseer Ahmad¹  · Khawar Jabran¹

✉ Taseer Ahmad
taseerskg@gmail.com

¹ Department of Plant Production and Technologies, Nigde Omer Halisdemir University, Nigde 51200, Türkiye