RESEARCH ARTICLE

# Effect of an aggressive new race broomrape (*Orobanche cumana* L.) on agronomical and technological traits of the sunflower in Mediterranean environments

Yucel Kilic*, A. Tanju Goksoy

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Sunflower (*Helianthus annuus* L.) is the most important edible oil crop in Turkey as 85% of the edible oil consumed is made from it. A major limiting factor in sunflower-producing countries is infestation by the parasitic plant *Orobanche cumana*. In all regions of Turkey where sunflower is grown, sunflower plants exhibiting various degrees of infestation by this parasite and various invasive groups of this parasite have been observed. The aim of this study was to assess the tolerance of sunflower varieties to the new aggressive parasitic race and to determine its effect on agronomical and technological traits of the sunflower. Our results over a two-year study of agronomically important traits indicate that the hybrids, HA-4 and HA-5 are fully resistant to the parasite under field conditions and had significantly higher seed yield and oil content than the standards. Therefore, new sources of genetic resistance and herbicide-resistant sunflower hybrids are required against highly invasive races for this region.

**Key Words:** *Broomrape; Oil content; Oleic acid; Seed yield; Sunflower*

## INTRODUCTION

Sunflower broomrape (*Orobanche cumana* Wallr.) is a holoparasitic plant occurring in the wild from south-eastern Europe to central Asia and parasitizes few species belonging to the family Asteraceae, mainly *Artemisia* spp. It parasitizes sunflower in many sunflower-producing countries, such as central and eastern Europe, Spain, Turkey, Israel, Iran, Kazakhstan and China and is one of the crops most serious production constraints [1]. The Mediterranean region is one of the most important centers of biodiversity; new records indicate that the genus *Orobanche* is represented by 39 species in Turkey [2]. After infecting sunflower roots, the parasite easily takes nutrients and water from the soil through the plant's roots, thus damaging the crop and reducing yields by up to 100% [3]. This leads to considerable decrease in yield and low quality of produce [4].

Over two decades, the aggressiveness of the parasite increased substantially with the appearance of new physiological races after a relative stable period of broomrape race E. For the host spots infested with race G, it is not recommended to plant race E resistant hybrids because of the drastic yield decreases. Hybrids resistant to race F also register drastic yield decreases in these areas. Broomrape, thus, substantially reduced seed and oil production. Moreover, ıt is not recommended to grow sunflower hybrids with resistance genes for race E or F in locations infested with race G or G+ [5]. South-east Romania is infested with the most invasive races of *O. cumana* (G, H and others). Recent studies show that the most aggressive *Orobanche* race, resistant to the varieties and hybrids commonly used in production, occurs in Adana on Mediterranean coast of Turkey [6].

The invasion of 11 populations of the parasites in Hungary, Romania, Spain and Turkey was assessed after the infection of sunflower inbred lines to differentiate races of the parasite under glasshouse conditions. Analyses of molecular diversity detected race F in Hungary, Spain and Turkey and the most invasive race G in Turkey [7]. Increasingly invasive populations classified as races G and H are becoming predominant in countries surrounding the Black Sea. The new broomrape races detected in the sunflower crop in Turkey seem to be more invasive than the races occurring in other countries [8].

The eastern Mediterranean region of Turkey has very fertile soils and has experienced a gradual increase in acreage and production of sunflower because of the economic interest the crop has stimulated in local farmers. Although no *Orobanche* has been detected in sunflower fields in the region so far, infestation is possible as the parasite naturally occurs in this region. *Orobanche ramose*, *O. aegyptiaca*, and *O. crenata* were identified infecting tomato, lentil and fava bean fields in this region respectively. It is important to train growers on how to prevent the broomrape infestation from spreading to sunflower fields in the eastern Mediterranean region [9]. In countries, such as Romania, Turkey, Ukraine, Bulgaria and Russia, Broomrape races A-E overcoming all the known resistance genes were also identified and have been named F, G and H [10-12]. Broomrape epidemic breaks out every 20 years (1960, 1980 and 2000) and overcomes the resistance of sunflower cultivars grown in that region. The parasitic interaction between sunflower and *O. cumana* generally follows a gene for gene model, with resistance in sunflower [13].

Sunflower grows widely in Turkey and in other countries as it is highly adaptable, the cultivation is highly mechanizable, it is easy to market and it is one of the most preferred vegetable oil for consumption in Turkey. Weeds and the broomrape parasite are the devastating biotic stress factors that limit seed and oil yield in sunflower production [14].

Estimation of the effects of broomrape infestations on the sunflower under field conditions is difficult as non-infected control plots are necessary [15].

The aim of this study was to evaluate the effect of newly-discovered highly-invasive *O. cumana* races that started to appear on the Mediterranean coast of southern Turkey on the yield and quality of sunflower varieties.

## MATERIALS AND METHODS

### Genetic material, experiment location and design

Nine sunflower hybrids were used as genetic material in this experiment and two were registered hybrids that were used as check varieties. Field experiments of the research study were conducted at two locations in Adana, Turkey with a randomized complete block design and four replicates. The field experiments were conducted in the spring of 2018 and 2019 in Sagkaya District (37°09'55.8"N 35°43'11.0"E and 37°11'22.1"N 35°41'45.1"E) and Dedeler Disctrict (37°04'48.8"N 35°33'15.6"E and 37°02'51.6"N 35°33'17.0"E) in Adana Province, Turkey. The Adana Province is located on the Mediterranean cost and has an average annual rainfall of 668,1 mm and a mean monthly temperature of 19°C. In this region, the total rainfall received in the growing period of sunflower (March-July) constitutes about 29% of the annual precipitation (Table 1).

[1]*Department of Field Crops, Uludag University, Bursa, Turkey*

**Correspondence:** *Yucel Kilic, Department of Field Crops, Uludag University, Bursa, Turkey, E-mail: yucel.kilic.turkiye@gmail.com*

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**TABLE 1**

**Some meteorological parameters in the experimental area in Adana in 2018 and 2019**

| | `Average temperature (°C) | | | Total precipitation (mm) | | | Relative humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| Months | 2018 | 2019 | Last Year Average (LYA) | 2018 | 2019 | Last Year Average (LYA) | 2018 | 2019 | Last Year Average (LYA) |
| March | 16 | 13.1 | 13.3 | 38.4 | 71.2 | 85.9 | 71.2 | 71 | 64.7 |
| April | 19.2 | 16.3 | 17.2 | 38.2 | 59.4 | 45.6 | 59.3 | 69.7 | 64.4 |
| May | 23.3 | 23.3 | 21.5 | 38 | 1 | 46.8 | 64.5 | 57.8 | 63.9 |
| June | 25.5 | 26 | 25.4 | 33.4 | 63 | 25.6 | 70.7 | 72.6 | 65.4 |
| July | 28.3 | 27.1 | 28.2 | 0.2 | 63.6 | 7.25 | 69.5 | 73 | 66.5 |

**Cultural practices, measurement parameters and statistical analysis**

At all locations, optimal agro technical practices were applied for sunflower cultivation. The experimental varieties and checks were planted in a well prepared soil in four rows with a length of 7.5 m. Plant spacing was 70 cm between rows and 30 cm between plants within a row, resulting in a total plot area of 21 m². The two rows in the middle of each plot were selected for the hybrids for observations and harvest. For each hybrid, head diameter and seed yield were measured. Oil content as a percentage was determined in the laboratory by Bruker minispec XL Nuclear Magnetic Resonance (NMR). Oleic acid content was also measured by Spinlock SLK-200 NMR. Variance analysis was performed for all data obtained from the field experiment using the JMP-7 software.

Observations on broomrape included Frequency (F), Intensity (I) and Attacking Rate (AR) based on the pustovoit method. The plants were regarded as resistant if frequency was 0%-10% and AR values were 0-1 [13].

Frequency of plants with *Orobanche* (F) was calculated as a percentage as follows:

$$F\% = \frac{Number\ of\ plants\ infected\ with\, Orobanche}{Total\ number\ of\ plants\ in\ a\ row} \times 100$$

The mean number of *Orobanche* per infested plant was calculated as follows:

$$I = \frac{Total\ number\ of\ Orobanche}{Total\ number\ of\ plants\ infested\ with\ Orobanche\ in\ the\ row}$$

$$AR = The\ number\ of\ Orobanche\ in\ one\ plant\ in\ the\ row = {F \times I}/{100}$$

## RESULTS AND DISCUSSION

**Seed yield**

The results indicated that seed yield was significantly affected by year, variety, and location × year interaction ($p \leq 0.01$) (Table 2). Analysis of variance showed statistically significant location × variety × year interaction. The second year (2019) had lower seed yield in sunflower infected with broomrape than the first year (2018). Observed broomrape frequency was higher in 2019 than in 2018 in Dedeler (Table 3).

Infection of sunflower with broomrape affected yield (Figure 1). The Pustovit method showed that varieties Check2 and HA-7 had high tolerance against broomrape attacks in 2018; however, both varieties were susceptible in 2019 due to very high broomrape infection frequency. Varieties Check1, HA-8 and HA-9 were susceptible to broomrape in both years in the broomrape-infected location. Grenz et al., recorded similar reductions in sunflower yield due to *Orobanche* infection [16]. The low broomrape infestation could cause 5%-20% loss of yield and high infestation could cause over 50% loss of yield. Prodan et al., reported that the hybrids with good resistance gave good seed yield due to their behavior during the broomrape attack; although, the degree of broomrape attack was higher in 2020 than in 2021 [17]. Molinero-Ruiz et al., reported that an increase in sunflower yield because of the use of resistant hybrids was most noticeable during high field infestations [18]. Stevan et al., observed that hybrids exhibited different susceptibilities and variable responses to broomrape attack [19]. The seed yield loss in infected sunflower plants varied from 2.6% to 70%. The intensity of damage depends on severity of attack and decrease of the seed yield depends on number of broomrape plants per sunflower plant.

Results presented in Table 3, show that in Dedeler in 2018 and 2019, races H and overcame broomrape resistance standard checks. The effect of the attack depended on genotype, which conferred different tolerances to broomrape.

In this study, broomrape AR ranged between 0.00% and 7.12% in 2018 and between 0.00% and 23.92% in 2019. Gospodinov (1960) reported that if the number of broomrape plants per sunflower plant is from 1 to 10, the seed yield decreases by 13.8%, and if the number of broomrape plants per sunflower plant are from 111 to 130 seed yield decreases by 70%.

**Oil content**

The John's Mathematical Program (JMP) based variance analysis results showed that oil content was significantly affected by year and variety interactions. Additionally, there was a significant effect of location × year × variety interactions on the oil content (Table 2).

Broomrape infection of sunflower affecting oil content was high in 2019 in Dedeler because of high broomrape infection rate. Thus, we concluded that the oil contents decreased in direct proportion to broomrape infection rate and not because of the locations where the infection was either low or absent (Figure 2).

Similar results have also been found by Gisca who observed that oil content in the hybrids favorit, Performer and LG5661 was affected to some extent by the degree of parasite infection [20]. The difference in oil content in sunflower seeds between the uninfected/poorly infested fields and those heavily infested was about 2%-3% (favorit, LG5661) and 5%-6% (performer), respectively. Shindrova et al., reported that the decrease in oil content of sunflower plants infected by broomrape is directly proportional to the intensity of infection [21]. Liu et al., observed that oil content in seeds of the plants infected by broomrape drops by 3%-18% [22].

**Head diameter**

Location, varieties, location × variety, year and location × year interactions had significant effects on head diameter ($p \leq 0,01$). Head diameter decreased significantly with broomrape infestation in both trial years. The lowest head diameter in the second year was 9.75 cm in broomrape infested fields, whereas it was 11.50 cm in the first year (Figure 3). In 2018, only a few varieties were affected by broomrape due to low infestation. The hybrids HA-4, HA-5 and HA-6 were an exception, as they had higher diameter than non-infected plants. This could be attributed to the relatively low frequency of broomrape infection in addition to other factors that influence head diameter. Some differences may occur owing to differences in genotypes and environmental differences. Moreover, in 2019, most of the varieties were affected by higher rate of broomrape infection. The most pronounced effect on head development under broomrape stress was found in the HA-9 variety. In this case, the sunflower head diameter was significantly lower (-34.4%) than that of the checks (Figure 3).

Broomrape infection directly affects yield components, e.g. decreases of up to 20.40% in the sunflower head diameter compared to check varieties [23]. Similarly, lowest values of head diameter ranging from 13.4 to 17.4 cm were recorded under infection conditions by Gisca et. al., [24]. Shindrova et al., reported that in sunflower plants infected by broomrape, decrease in head diameter directly depends on the intensity of infection [21]. Duca reported that broomrape has a negative effect on sunflower development; the infected plants are smaller, the sunflower head diameter is reduced and up to 80% of yield losses are observed [25].

**TABLE 2**

**Combined analysis of variance for yield and quality traits under *Orobanche* spp. infection (across two years)**

| | | | Seed yield | | | Oil content | | | Head diameter | | | High oleic | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source** | **DF¹** | **DF²** | **2018** | **2019** | **2018-2019** | **2018** | **2019** | **2018-2019** | **2018** | **2019** | **2018-2019** | **2018** | **2019** | **2018-2019** |
| Loc | 1 | | ns | ** | | ** | * | | ** | ** | | * | ** | |
| Loc*var | 8 | | ** | ** | | ** | ns | | ** | ** | | ns | ns | |
| Rep (loc) and ran | 6 | | ns | ns | | ns | ns | | ns | * | | ns | ns | |
| Year | | 1 | | | ** | | | ** | | | ** | | | ns |
| Loc (year) | | 2 | | | * | | | ** | | | ** | | | ** |
| Rep (year, loc) | | 12 | | | ns | | | ns | | | ** | | | ns |
| Var | 8 | 8 | ** | ** | ** | ** | ns | ** | ** | ** | ** | ** | ** | ** |
| Year*var | | 8 | | | ns | | | ns | | | ** | | | ** |
| Loc*var (year) | | 16 | | | ** | | | * | | | ** | | | ns |
| Error | 48 | 96 | | | | | | | | | | | | |

**Note:** ns: DF¹: Degrees of freedom for variance analysis of individual years; DF²: Degrees of freedom for combined analysis of variance not significant; *: significance level ($p \le 0.05$); **: significance level ($p \le 0.01$).

**TABLE 3**

**Soil infection by *O. cumana* in some fields affected yield and limited development of the crop in the Adana region**

| | | | 2018 | | 2019 | |
|---|---|---|---|---|---|---|
| **Entry No** | **Hybrids** | **Rep** | **Sagkaya** | **Dedeler** | **Sagkaya** | **Dedeler** |
| | | | **% (Absence of resistance)** | **% (Absence of resistance)** | **% (Absence of resistance)** | **% (Absence of resistance)** |
| 1 | Check 1 | 1 | 0 | 4.09 | 0 | 11.83 |
| 1 | Check 1 | 2 | 0 | 2.58 | 0 | 17.16 |
| 1 | Check 1 | 3 | 0 | 3.95 | 0 | 10.59 |
| 1 | Check 1 | 4 | 0 | 3.06 | 0 | 7.06 |
| 2 | Check 2 | 1 | 0 | 0.05 | 0 | 11.35 |
| 2 | Check 2 | 2 | 0 | 0.85 | 0 | 16.4 |
| 2 | Check 2 | 3 | 0 | 0.36 | 0 | 15.28 |
| 2 | Check 2 | 4 | 0 | 0.66 | 0 | 16.63 |
| 3 | HA-3 | 1 | 0 | 0.02 | 0 | 0.8 |
| 3 | HA-3 | 2 | 0 | 0.28 | 0 | 0.11 |
| 3 | HA-3 | 3 | 0 | 0.04 | 0 | 0.13 |
| 3 | HA-3 | 4 | 0 | 0.12 | 0 | 0.13 |
| 4 | HA-4 | 1 | 0 | 0 | 0 | 0 |
| 4 | HA-4 | 2 | 0 | 0 | 0 | 0 |
| 4 | HA-4 | 3 | 0 | 0 | 0 | 0 |
| 4 | HA-4 | 4 | 0 | 0 | 0 | 0 |
| 5 | HA-5 | 1 | 0 | 0 | 0 | 0.05 |
| 5 | HA-5 | 2 | 0 | 0 | 0 | 0.6 |
| 5 | HA-5 | 3 | 0 | 0 | 0 | 0.2 |
| 5 | HA-5 | 4 | 0 | 0 | 0 | 0.14 |
| 6 | HA-6 | 1 | 0 | 0 | 0 | 0 |
| 6 | HA-6 | 2 | 0 | 0 | 0 | 0.01 |
| 6 | HA-6 | 3 | 0 | 0 | 0 | 0 |
| 6 | HA-6 | 4 | 0 | 0 | 0 | 0.01 |
| 7 | HA-7 | 1 | 0 | 0.04 | 0 | 8.54 |
| 7 | HA-7 | 2 | 0 | 0.89 | 0 | 5 |
| 7 | HA-7 | 3 | 0 | 0.68 | 0 | 4.71 |
| 7 | HA-7 | 4 | 0 | 0.54 | 0 | 6.08 |
| 8 | HA-8 | 1 | 0 | 5.32 | 0 | 18.14 |
| 8 | HA-8 | 2 | 0 | 4.62 | 0 | 10.5 |
| 8 | HA-8 | 3 | 0 | 5.24 | 0 | 16.04 |
| 8 | HA-8 | 4 | 0 | 6.25 | 0 | 17.84 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | HA-9 | 1 | 0 | 7.12 | 0 | 7.13 |
| 9 | HA-9 | 2 | 0 | 6.64 | 0 | 23.73 |
| 9 | HA-9 | 3 | 0 | 6.4 | 0 | 23.92 |
| 9 | HA-9 | 4 | 0 | 5.69 | 0 | 11.2 |


**Figure 1)** *Effect of broomrape on seed yield (kg/ha-1) in sunflower varieties in 2018 and 2019*


**Figure 2)** *Change in oil content (%) of sunflower varieties with broomrape (Orobanche spp.) infection*


**Figure 3)** *Change of head diameter of sunflower varieties with broomrape (Orobanche spp.) presence*

## Oleic acid content

The year's effect on oleic acid content was not significant; although, there was a significant effect of year × variety interactions on oleic acid content. There was no significance in the location × variety × year interaction in both years and locations (Table 2). However, location and location × year interactions had significant effects on oleic acid content. Oleic acid content is determined by *Ol* genes and genetic factors and is also highly influenced by environmental factors [26]. Fatty acid content varies with genetic, climatic, ecological, morphological, physiological and cultural practices (Figure 4) [27].

Oleic acid content of sunflower varieties was not influenced by broomrape infestations. Similar results were reported by Shindrova et al., who found no changes in composition quality of the analyzed fatty acids under broomrape infection [21]. Hosni et al., failed to identify relationship between fatty acid composition and resistance to broomrape infestation [28]. According to Gisca, the content of oleic acid in the hybrids Sandrina, HS5034 and HS3045, with mean resistance and varieties LG-3, Favorit and HS3655 with a high resistance to broomrape, varies mainly in relation to the genotype and cultivation conditions and depends less on infection by the parasite [20]. Sumalan et al. reported that broomrape parasitism on sunflower plants did not show any impact on palmitic and stearic acid contents, the differences being nonsignificant; however, oleic and linolenic acid levels increased in parasitized plants [29]. Akar et al., emphasized that besides having high oleic acid content, sunflower cultivars should also have high yield, high oil content and resistance to *Orobanche* (*Orobanche cumana* Wallr.) and mildew in Turkey [30].

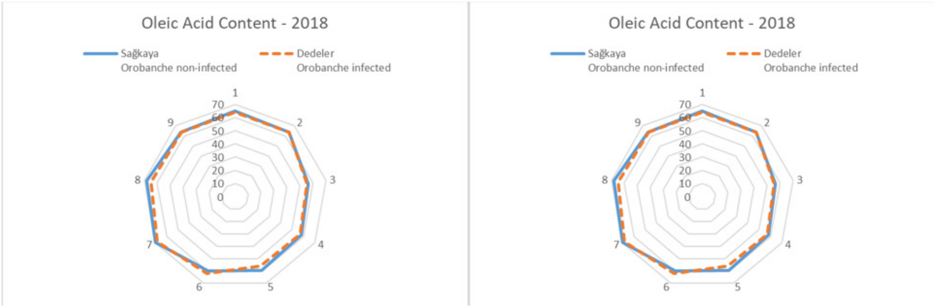


**Figure 4)** *Effect of broomrape (Orobanche spp.) infection on oleic content (%) of sunflower varieties*

## CONCLUSION

The values of the analyzed productivity indices vary a lot depending on the genotypes of sunflower. Some hybrids (e.g. the hybrid HA-3, HA-4, HA-5 and HA-6) are resistant to broomrape and endure its attack with low losses; however, hybrids HA-8 and HA-9 with the highest degree of infection, were the most affected, showing significantly decreased indices for all the studied characteristics.

Our results indicate that tested hybrids expressed different susceptibility and variable response in seed yield, oil content and head diameter to broomrape parasitism. The influence of environmental conditions, locations, production years and broomrape presence on oleic acid content depended on the variety. By testing the new hybrids for broomrape resistance, seed yield and oil content simultaneously, the introduction of new high yielding hybrids resistant to broomrape was possible. Additionally, further research and breeding programs should be undertaken urgently to limit O. Cumana's spread.

## REFERENCES

1. Fernandez-Martinez JM, Perez-Vich B, Velasco L. Sunflower broomrape (*Orobanche cumana* Wallr.). Sunflower. 2015;2015:129-155.
2. Zare G, Donmez AA, Koca AD. A new record for the flora of Turkey: *Orobanche palaestina* Reut. (Orobanchaceae). Hacettepe J Biol Chem. 2010;38:149-154.
3. Kaya Y. Current situation of sunflower broomrape around the world. Symp Sunflower. 2014;2014:9-18.
4. Shindrova P. Broomrape (*Orobanche cumana* Wallr.) in bulgaria-distribution and race composition. Helia. 2006;29(44):111-120.
5. Dicu G, Teodorescu EA, Dumitrescu NC, et al. Research regardig the virulence of broomrape parasit (*Orobanche cumana* Wallr.) in southeastern of Romania. Sci Pap. 2011;2011:256.
6. Kilic Y, Kaya MS. Determining new aggressive broomrape infestation in Mediterranean region of Turkey. Int Sunflower. 2016;2016:728-733.
7. Molinero-Ruiz L, Garcia-Carneros AB, Collado-Romero M, et al. Pathogenic and molecular diversity in highly virulent populations of the parasitic weed *Orobanche cumana* (sunflower broomrape) from Europe. Weed Res. 2014;54(1):87-96.
8. Kaya Y, Evci G, Pekcan V, et al. Determining new broomrape-infested areas, resistant lines and hybrids in Trakya region of Turkey. Helia. 2004;27:211-218.
9. Bulbul F, Aksoy E, Uygur S, et al. Broomrape (*Orobanche* spp.) problem in the eastern Mediterranean region of Turkey. Helia. 2014:32(51):141-152.
10. Fernandez-Martinez JM, Dominguez J, Perez-Vich B, et al. Update on breeding for resistance to sunflower broomrape. Helia. 2008;31(48):73-84.
11. Joita MP, Fernandez-Martinez JM, Sava E, et al. Broomrape (*Orobanche cumana* Wallr.), the most important parasite in sunflower. Gen Plant Breed. 2009;77:49-56.
12. Skoric D, Pacureanu M. Sunflower breeding for resistance to broomrape (*Orobanche cumana* Wallr.). Sunflower Breed Res Dis. 2010;2010:19-30.
13. Vranceanu AV, Tudor VA, Stoenescu FM, et al. Virulence groups of *Orobanche cumana* Wallr. (root parasite), differential hosts and resistance sources and genes in sunflower. 1981;1981:105-112.
14. Kaya Y, Sahın S, Beser N. Determining of yield performances of some imi resistant sunflower hybrids in Trakya region, Turkey. Eurasia Sci Technol Eng Math. 2018;1(3):126-132.
15. Dominguez J. Estimating effects on yield and other agronomic parameters in sunflower hybrids infested with the new races of sunflower broomrape. Sym Dis Tol. 1996;1996:118-123.
16. Grenz JH, Istoc VA, Manschadi AM, et al. Interactions of sunflower (*Helianthus annuus*) and sunflower broomrape (*Orobanche cumana*) as affected by sowing date, resource supply and infestation level. Field Crop Res. 2008;107(2):170-179.
17. Prodan PT, Joita PM, Risnoveanu L, et al. The evolution of some pathogens and broomrape parasite attack and virulence, in sunflower crop, in Dobrogea area, Romania. Ser Agricult. 2022;2022:89-92.
18. Molinero-Ruiz ML, Garcia-ruiz R, Melero-vara JM, et al. *Orobanche cumana* race F: Performance of resistant sunflower hybrids and aggressiveness of populations of the parasitic weed. Weed Res. 2009;49(5):469-478.
19. Steven M, Medic-Pap S, Zivanov D. Resistance of some sunflower genotypes to broomrape (*Orobanche cumana* Warll.) and its influence on seed yield and quality. Field Veg Crop. 2012;2012:201-208.
20. Gisca I. Influence of broomrape on the quantity and quality of sunflower oil. Agric Sci. 2017;2:16-22.
21. Shindrova P, Ivanov P, Nikolova V. Effect of broomrape (*Orobanche cumana* Wallr.) intensity of attack on some morphological and biochemical indices of sunflower (*Helianthus annuus* L.). Helia. 1998;21(29):55-62.
22. Liu L, Li X. The geographical distribution of sunflower diseases in China. Plant Pathol. 1988;37(4):470-474.
23. Glijin A. *Orobanche cumana* Wallr. impact on sunflower grain yield. Amb Env. 2014;73(1):18-21.
24. Gisca I, Joita PM, Clapco S, et al. Influence of broomrape on some productivity indices of sunflower. 2017;2017:68.
25. Duca M. Historical aspects of sunflower researches in the republic of Moldova. Helia. 2015;38(62):79-92.
26. Izquierdo NG, Aguirrezabal LA, Andrade FH, et al. Modeling the response of fatty acid composition to temperature in a traditional sunflower hybrid. Agro J. 2006;98(3):451-461.
27. Baydar H, Erbas S. Influence of seed development and seed position on oil, fatty acids and total tocopherol contents in sunflower (*Helianthus annuus* L.). Turkish J Agric For. 2005;29(3):179-186.
28. Hosni T, Abbes Z, Abaza L, et al. Effect of broomrape (*Orobanche cumana* Wallr.) on some agro-morphological and biochemical traits of Tunisian and some reference sunflower (*Helianthus annuus* L.) accessions. J Plant Dis Prot. 2020;127:831-841.
29. Sumalan RM, Sumalan RL, Copolovici L, et al. Research on sunflower oil quality in the case of *Orobanche cumana* attack. Res J Agric Sci. 2016;48(3):34-38.
30. Akar LO, Goksoy A, Yanikoglu S, et al. Heterosis and combining ability through line x tester analysis for yield, oil and high oleic acid characters in sunflower (*Helianthus annuus* L.). Turkish J Field Crop. 2020;25(2):122-130.