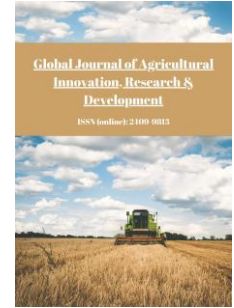




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First Record of the Broomrape Miner *Phytomyza orobanchia* (Diptera: Agromyzidae) in Morocco: Field Infestation Levels, Biological Control Potential Against *Orobanche crenata*, and Low Parasitoid Pressure

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ABSTRACT

Field surveys conducted from January to April 2026 in the Zemamra area (Morocco) assessed the infestation of legume fields by the holoparasitic plant *Orobanche crenata* Forssk and its associated insect fauna. Twelve lentil, chickpea, and faba bean fields were surveyed. Severe infestations of broomrape were recorded across all sites. Parasitism by the agromyzid fly *Phytomyza orobanchia* Kaltenbach (Diptera: Agromyzidae) was consistently observed on broomrape plants, affecting tubercles, shoots, and floral structures. A single broomrape plant contained 1 to 10 larvae, with infestation levels reaching 80–90% of population. Larval mining resulted in tissue destruction, reduced seed production, and weakening or death of host shoots. Developmental stages, including larvae and pupae, were recorded, confirming successful completion of the insect life cycle under both field and laboratory conditions. Population dynamics showed low abundance in February, followed by a steady increase and a peak in early April, consistent with patterns reported in Mediterranean environments. This study represents the first record of *P. orobanchia* in Morocco, extending its known distribution in North Africa. Although the species is widely distributed and reported on more than 20 *Orobanche* species worldwide, its occurrence in Moroccan agroecosystems had not previously been documented. Natural parasitism by *Tetrastichus phytomyzae* Kost. (Hymenoptera: Eulophidae) was low (<4%), indicating limited regulation of fly populations by parasitoids under field conditions. Overall, the results highlight the potential of *P. orobanchia* as a promising biological control agent of broomrape in Morocco, particularly if its early establishment is enhanced before peak parasitoid activity.

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1. Introduction

Several broomrape species (Orobanchaceae) are among the most destructive root-parasitic weeds affecting major crops in Africa, the Middle East, and southern-eastern Europe [1-3]. By diverting water, minerals, and photosynthates from their hosts, they significantly impair plant growth and productivity, with yield losses commonly ranging from 5% to 100% depending on crop type, infestation level, and environmental conditions [1]. *Crenate broomrape* (*Orobanche crenata* Forssk.) is one of the most economically important species, parasitizing a wide range of hosts across several plant families, including Fabaceae, Solanaceae, Brassicaceae, Apiaceae, Asteraceae, and Cannabaceae [2-4]. It is particularly harmful to cool-season legumes in North Africa, southern Europe, and western Asia, where it causes severe reductions in both grain and forage production [5, 6].

In Morocco, *O. crenata* was first recorded in 1943 on faba bean (*Vicia faba*) in the Fez region and has since spread widely to major agricultural zones, including Zaer, Pre-Rif, Chaouia, Saïs, Meknès, Taounate, Sidi Kacem, Chefchaouen, Doukkala, and Abda [4, 7]. Infestation levels have increased markedly, rising from approximately 12% in 1981 to 51% in 2013 [8]. More recently, the parasite has expanded to carrot production systems, affecting about 9,000 ha in the central-northern and northwestern regions, which represent over 60% of the national carrot-growing area [9]. Reported yield losses in carrot range from 15% to 21%, with estimated economic losses of 2,600–3,400 USD ha⁻¹ [10]. Overall, *O. crenata* now poses a serious threat to key crops in Morocco, including faba bean, lentil, chickpea, and carrot, with national yield losses varying between 7% and 90% depending on infestation severity and agroecological conditions [11].

Control of *O. crenata* remains difficult worldwide, and no single method provides consistently satisfactory results [12-14]. This limitation is mainly due to its high reproductive capacity (≈30,000–200,000 seeds per plant) and long-term seed persistence in soil, combined with its close physiological dependence on the host, which reduces the effectiveness of conventional control strategies [14, 15].

Biological control using the fly *Phytomyza orobanchia* Kaltenbach (Diptera: Agromyzidae) has shown promising field results in several regions [14-18]. Successful suppression has been reported in the former USSR, Turkey, Syria, and India [19-21]. *Phelipanche ramosa* occurs natively in North Africa and has also been introduced into Australia and North America [17]. The species is considered highly host-specific to broomrape [12]. Its larvae mine stems and capsules, feed on immature seeds, and reduce seed production by 30–90%, with reported destruction levels ranging from 11% to 90% [1, 17]. Infestation also reduces shoot length and capsule number per plant [14].

Biologically, *P. orobanchia* females lay an average of about 32.9 eggs in broomrape flowers, and larval development comprises three instars lasting approximately 1.1, 1.93, and 2.22 days, respectively, with a total larval period of about 5.3 days [22]. The complete life cycle from egg deposition to the next generation averages 18.9 days (range 17–20 days), allowing up to three generations per year [22, 23]. Pupation occurs in capsules or stems, while the final generation enters diapause in plant tissues, mainly underground [22-25]. At the end of the broomrape growing season, larvae of the last generation move from capsules to aerial and subterranean plant parts, where they form diapausing pupae that persist until the following season [25]. Most of these pupae are found in underground host tissues [24]. However, the third generation is frequently affected by environmental pressures such as agricultural management practices and natural enemy activity (parasitoids), which can markedly suppress populations of *Phytomyza* spp. [26]. Overall, while *P. orobanchia* has the potential to considerably reduce broomrape seed banks, its performance remains highly variable depending on environmental conditions and crop management practices. This paper reports, for the first time, the detection and identification of *Phytomyza orobanchia* Kaltenbach and its parasitoids in Morocco.

2. Materials and Methods

Field surveys were carried out between January and April 2026 in the Zemamra area, Sidi Bennour Province, Morocco (32°37' N, 8°42' W). The study area is located near the Atlantic coast and is characterized by relatively mild climatic conditions, with average winter temperatures of approximately 12 °C and summer temperatures reaching around 30 °C. Annual rainfall averages about 350 mm. The soil in Zemamra is predominantly vertisol,

with an angular structure extending to a depth of approximately 15 cm, known for its high moisture retention and difficulty of cultivation during dry periods. A total of twelve fields were investigated, including three lentil (*Lens culinaris* Medik.) fields (2–3 ha each), four chickpea (*Cicer arietinum* L.) fields (3–5 ha), and five faba bean (*Vicia faba* L.) fields (5–8 ha). These surveys revealed substantial infestations of *O. crenata*, which pose a serious constraint to legume production in the region (Fig. 1). Parasitism of *O. crenata* by different developmental stages of *Phytomyza orobanchia* Kaltenbach (Diptera: Agromyzidae) was consistently observed. In each field, approximately 50 *Orobanche crenata* plants showing signs of infestation and insect damage or feeding were randomly collected following a zigzag transect. The collected plants were placed in labeled cardboard boxes and transported to the laboratory for further examination. Plants were carefully inspected, and insect specimens were collected and preserved for identification. Specimens were prepared for light microscopy using the slide-mounting technique described by [27]. Morphological identification of *P. orobanchia* was carried out using the keys and descriptions provided by Rodendorf [28], Spencer [29], and Piwowarczyk *et al.* [17]. Diagnostic characteristics included: (i) a rounded-rectangular and elongated third antennal segment, approximately 1.5 times longer than wide; (ii) raised frons and parafacial setae in lateral view; (iii) orbital setae of equal length; (iv) a body length of approximately 2.6 mm; (v) acrostichal setae arranged in two rows; (vi) a uniformly gray mesonotum; (vii) a non-retractable ovipositor in females forming a distinct conical structure; and (viii) characteristic male genitalia, particularly the aedeagus.

Collected *O. crenata* plants were maintained under controlled laboratory conditions (25 °C and 65 ± 10% relative humidity). During this period, larvae exited the capsules and migrated to other parts of the host plant for pupation. Observations were conducted to detect the presence of parasitoids and to monitor aestivation behavior until the subsequent season. After pupation, capsules were carefully removed and dissected to confirm the absence of pupae within them. Hymenopteran parasitoids were identified using the keys of Noyes & Hayat [30].



Figure 1: Severe infestation of lentil fields by *Orobanche crenata* in the Zemamra area, Sidi Bennour Province (Morocco).

3. Results and Discussion

The infestation of broomrape by *P. orobanchia* was observed as larval mining in tubers, shoots, and flowers (ovaries containing seeds) (Fig. 2). Larvae were frequently found feeding within tuber tissues and floral structures, leading to reduced seed set, weakened shoots, and in some cases plant mortality. A single broomrape plant could

harbor between 1 and 10 larvae, with infestation levels reaching 80–90% of the population (Fig. 1). In addition, numerous pupae were recorded across different plant parts, indicating successful development and subsequent adult emergence. Pupae were maintained at 25 °C and 65 ± 10% relative humidity, and adult flies emerged within a few days to two weeks (Fig. 3). *Phytomyza orobanchia* was first reported in Egypt in 1976 [22] and has since been recorded on more than 20 species of *Orobanch* [16], mainly distributed in Southern Europe, Western Asia, and Northeastern Africa. Agromyzidae is a relatively well-studied Diptera family in Poland, with about 440 species recorded [31]. However, to the best of our knowledge, this study represents the first record of *P. orobanchia* in Morocco, significantly extending its known distribution in North Africa. The closest confirmed records are from Hungary [32], Germany, and Ukraine [29].

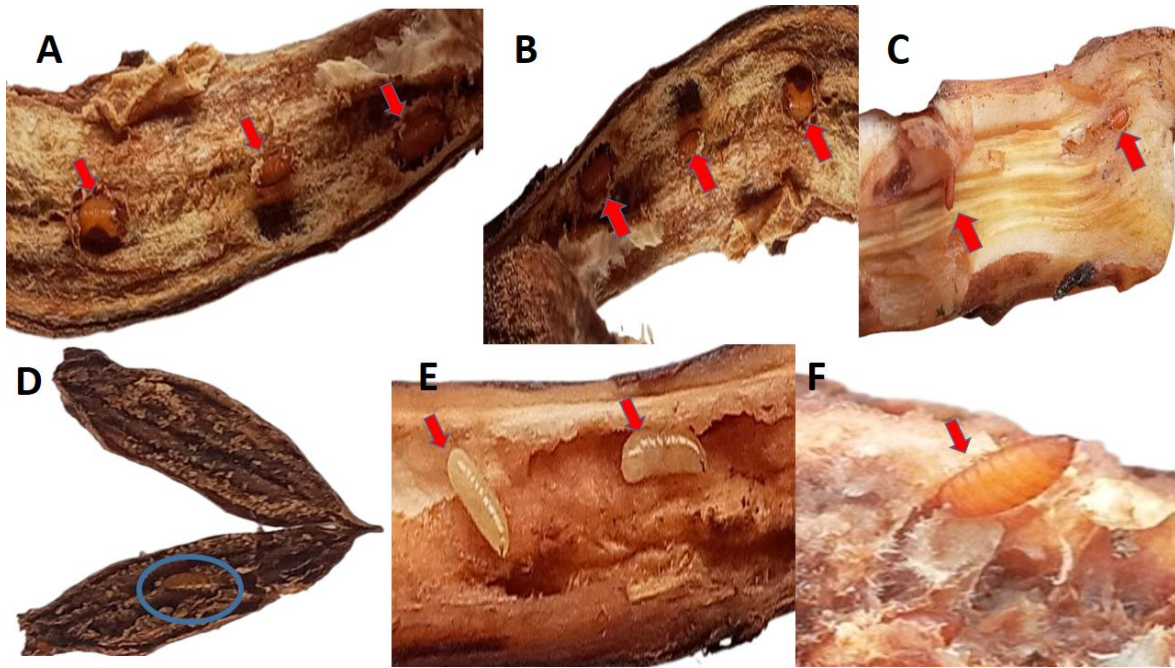


Figure 2: Larval and pupal stages of *Phytomyza orobanchia* within infested lentil pods (A–F): *Orobanche crenata* tubers (A, B), shoots (C), ovary containing seeds (D), and general appearance of larvae and pupae (E, F).

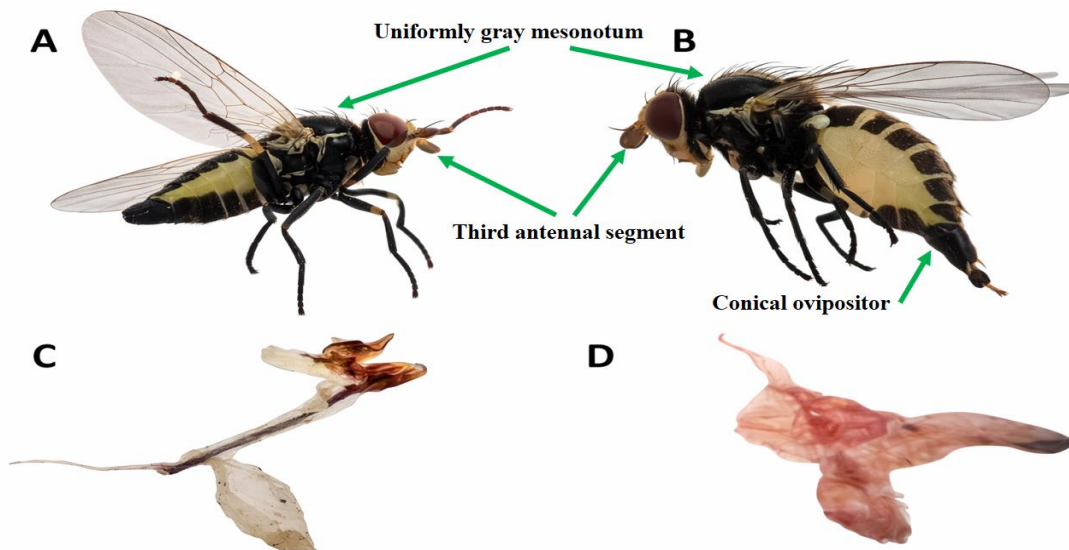


Figure 3: External morphology and genital structures of *Phytomyza orobanchia*. (A) Male adult, (B) Female adult, (C) Male genitalia, (D) Female ovipositor sheath.

The fly population was generally low in February, followed by a progressive increase, reaching its peak at the beginning of April. A similar seasonal pattern was reported in Egypt, where population densities were low in February and peaked in late March [14]. The eggs of *P. orobanchia* are laid inside the shoots of *O. crenata*, where the larvae develop and a considerable proportion pupates within the fruit capsules. Previous studies have reported variable infestation levels depending on geographic regions. In Yugoslavia, up to 19–64 larvae and puparia were recorded per broomrape plant (n = 40 sprouts) [24], whereas in Nubaria (Egypt), infestations ranged from 6 to 42 individuals per plant. In Bulgaria, 100 flowering broomrape shoots produced 2,302 seed capsules [16], indicating high reproductive potential in the absence of effective biological control. The fly has demonstrated strong potential in reducing seed production of different broomrape species. Under natural conditions in Malima (Ethiopia), seed capsule destruction reached 81.4% for *Orobanche ramosa* L. and 71.7% for *O. cernua* [33, 34]. In Hungary and the former USSR, seed reduction in *Orobanche cumana* Wallr. ranged from 60% to 85% due to *P. orobanchia* [1]. Similarly, in Egypt, it was reported that three larvae per capsule were sufficient to completely destroy the seed content of *O. cernua*, whereas a single larva caused only partial seed loss [14]. Based on known biological parameters, *P. orobanchia* can complete its life cycle in approximately 18–20 days under favorable conditions (20–25 °C) [22], allowing up to three to four generations per year; however, in the present study, no direct generational tracking was conducted. Therefore, the observed population increase from February to early April in Morocco most likely reflects a post-diapause population build-up corresponding to an early spring generation, rather than clearly separated multiple generations within the sampling period. Given the mild winter conditions in Morocco (average ≈12 °C), diapause termination is expected to occur earlier and more gradually compared with colder regions such as Hungary or the former USSR, where prolonged low temperatures tend to synchronize emergence and may delay early-season development. However, confirmation of generational structure in Moroccan populations requires detailed cohort-based or degree-day studies, which were not part of the present investigation.

The observed field establishment of *P. orobanchia* in Moroccan agroecosystems aligns with previous reports highlighting the importance of host-specific herbivores and soil- and shoot-associated biocontrol agents in the management of *Orobanche* species [35–37]. Biological control of root parasitic weeds has been widely explored using soil-dwelling and plant-associated microorganisms due to their ability to attack early developmental stages of the parasite, their resilience under variable environmental conditions, and their capacity for long-term persistence in soil ecosystems [38–40]. Among fungal agents, *Fusarium* spp., particularly *F. oxysporum*, have been extensively studied as bioherbicide candidates against broomrapes due to their host specificity and ability to colonize soil niches where parasite seeds germinate [41–44]. However, field efficacy has often remained inconsistent, prompting the development of integrated approaches combining microbial agents, resistance inducers, and environmental management strategies [45–47]. In parallel, bacterial antagonists such as *Pseudomonas* spp., *Bacillus* spp., and *Rhizobium leguminosarum* have demonstrated inhibitory effects on broomrape seed germination and radicle elongation through direct antibiosis or induction of systemic resistance in host plants [48–50]. Symbiotic associations, particularly arbuscular mycorrhizal fungi (AMF), further contribute to suppression of parasitic weeds by modifying host root exudation patterns and reducing germination stimulant (strigolactone) release [51, 52]. Moreover, integrated strategies combining biological agents with chemical inducers such as benzothiadiazole (BTH) or agronomic practices have shown synergistic effects, significantly reducing parasite emergence and biomass under controlled and field conditions [53, 54]. Trap crops and host resistance mechanisms, including reduced germination stimulation, pre-haustorial barriers, and vascular tissue reinforcement, also constitute key components of integrated broomrape management systems [53–55]. In this context, the natural occurrence of *P. orobanchia* in Moroccan fields provides an additional ecological control component that may complement microbial and agronomic strategies, particularly when synchronized with early parasite development stages before seed formation.

A limitation of the present study is that no quantitative measurements (such as seed number per capsule, shoot length reduction, or flower/inflorescence number) were recorded to precisely assess the level of damage caused by *P. orobanchia*. Future research should incorporate these parameters to better quantify the impact of infestation on the reproductive performance and biomass reduction of *O. crenata*.

In the present study, parasitism of *P. orobanchia* by the endoparasitoid *Tetrastichus phytomyzae* kost. (Hymenoptera: Eulophidae) was recorded (Fig. 4), although the observed parasitism rate remained low, not

exceeding 4% of the examined population. This indicates that natural parasitism currently has a limited impact on regulating fly populations under field conditions. On a global scale, *P. orobanchia* is known to be associated with a diverse parasitoid complex. A total of 24 parasitoid species belonging to seven families have been reported attacking this fly, with the most frequently recorded and ecologically important species including *Opius occuliscus* Telenga (Hymenoptera: Braconidae), *T. phytomyzae*, *Diglyphus isaea* (Walker), *Crataepiella carlinarum* (Szelényi & Erdős) (Hymenoptera: Eulophidae), and *Sphegigaster orobanchiae* Kurdjumov (Hymenoptera: Pteromalidae) [56]. These parasitoids can significantly influence the population dynamics of the fly in different agroecosystems. For effective biological control of *O. crenata*, it is essential to minimize the impact of parasitoids and ensure the early and abundant release of *P. orobanchia* at the initial stages of broomrape emergence in spring. Early establishment of the fly population is crucial to maximize its infestation of broomrape shoots and seed capsules before parasitoid pressure increases, thereby improving its potential as a biological control agent. However, although parasitism was low in the present study area, the composition and impact of the parasitoid complex may vary across regions; therefore, any future introduction or augmentation of *P. orobanchia* as a biological control agent should consider and monitor the full parasitoid community to ensure consistent control efficacy under different agroecosystems.

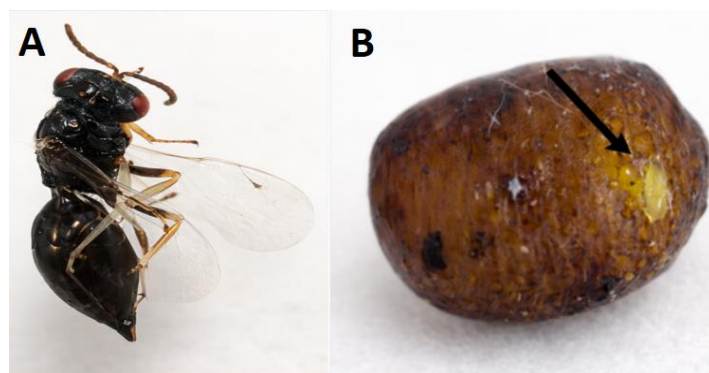


Figure 4: *Tetrastichus phytomyzae* (A) and its host mummies (B).

4. Conclusion

This study provides the first confirmed record of *P. orobanchia* on *O. crenata* in Morocco, extending its known distribution in North Africa. The fly was found to infest all major plant organs (tubercles, shoots, and flowers), where larval mining caused severe damage, including reduced seed production, weakened plants, and occasional plant death. High infestation levels (up to 80–90%) and the presence of larvae and pupae confirm successful establishment and development under field conditions. The fly population showed a clear seasonal pattern, with low abundance in February and a peak in early April, consistent with previous observations in Mediterranean environments. Overall, the results confirm that *P. orobanchia* has a strong potential to reduce broomrape seed production and limit its reproductive capacity. However, natural parasitism by *T. phytomyzae* remained very low (below 4%), indicating a limited regulatory effect on fly populations. Although several parasitoid species are known globally, their impact in this system appears minor. In conclusion, *P. orobanchia* represents a promising biological control agent against broomrape in Moroccan agroecosystems. Its effectiveness could be improved through early field establishment and timely release before peak parasitoid activity. Further field studies are recommended to optimize its use within integrated broomrape management strategies.

Conflict of Interest

There is no competitive interest regarding this manuscript.

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Availability of Data and Materials

Original data for the manuscript can be obtained from the corresponding author upon reasonable request.

Author Contributions

Mohamed El Aalaoui: Conceptualization; data curation; formal analysis; investigation; methodology; validation; visualization; writing – original draft; writing – review and editing. Mohamed Sbaghi: Conceptualization; visualization; writing – review and editing.

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