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Broomrape (*Orobanche* sp.) Management in Indian Mustard

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Abstract

Broomrape (*Orobanche sp.*) is a root holoparasitic plant resulting in significant yield losses (5-100%) in the crops of leguminous, oilseeds, solanacious, cruciferous and medicinal plants in the drier and hotter regions. In India, ***Orobanche is* a "super sink"** to mustard and become threat to mustard production. The long-term effects of broomrapes are considerably worse because its seeds are quickly dispersed to adjacent fields and remained viable in the soil for up to 20 years. Broomrape can be controlled through physical techniques *viz.*, weeding, soil tillage, flooding, irrigation, solarization and burning; chemical method *viz.*, soil fumigation, herbicide application, and germination stimulants, and biological techniques like use of resistant or tolerant varieties, cropping systems with trap and catch crops, intercropping, biological control with insects or fungi. However, integrated management strategies are very useful as single technique is not effective and inexpensive.

1. Introduction

Among the major pests of agricultural crops, weeds alone caused severe yield losses ranging from as low as 10% to as high as 98%. It should be emphasized that yield losses caused by weeds could vary from crop to crop and from region to region for the same crops, in response to many factors that include weed pressure, availability of weed control technology, cost of weed control and level of management practices. Among different types of weeds, parasitic weeds are serious pests in agricultural fields. Weeds that attack other plants through linkages and draw partially or completely their nutrition from the host are known as parasitic weeds. They attach themselves either to the roots or the shoots of the host plants and survive on food material available in them. They attach themselves either to the roots or the shoots of the host plants and survive on food material available in them. Parasitic weeds can be difficult to eradicate because they often produce large numbers of long-lived seeds. It is also challenging to identify infestations before monetary losses arise because parasitic plants that attack host roots can do significant harm to agricultural plants before they emerge from the soil. The most economically important parasitic weeds

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are the broomrapes (*Orobanche*), striga (*Striga asiatica)* and dodders (*Cuscuta spp.)* damaging different crops. In southern Europe, Central Asia and Mediterranean areas, the most damaging parasitic weeds are broomrapes (*Orobanche spp*., *Orobanchaceae*), obligate root parasites of important dicotyledonous crops that depend entirely on their hosts for all nutritional requirements. *Orobanche*, locally known as margoja, rukhri, khumbhi or gulli is an annual, branched, achlorophyllous, noxious, obligate root holoparasites that reproduces only by seeds. Broomrapes germinate only in response to specific chemicals released by the host plant. After germination, the seedlings attach to the host roots by the production of specialized feeding structures, described as haustoria that form a functional bridge into their hosts. The attached parasite performs as a powerful metabolic sink, commonly referred to as a "super sink," effectively fighting with the host plant for water and mineral nutrition, creating host plant stress, and growth inhibition, resulting to a considerable decrease in crop output and distressed crop quality in infested fields.

The development of efficient control methods is hampered by the unique traits of this pathogenic weed (underground development, adhesion to the host roots). Additionally, a single broomrape plant can produce more than 5,00,000 seeds, each of which is known to survive in the soil for many years. As a result, the parasite has a high genetic capacity for genetic adaptation to environmental changes, such as host resistance, agronomic techniques, and herbicide applications. Two broomrape species (*O. crenata* and *O. ramosa*) attack mainly the crops of apiaceae family such as *Daucus carota*, *Apium graveolens*, *Petroselinum sativum*, *Foeniculum vulgare* and of fabaceae family *viz., Vicia faba*, *Pisum sativum, Lens culinaris, Cicer arietinum* and *Medicago sativa*. In most cases, *O. crenata* and *O. ramosa* attack the crops of solanaceae family like *Lycopersicon esculentum*, *Nicotiana tabacum*, *Solanum tuberosu*m and *Solanum melongena* and cause the yield loss of more than 75%.

2. Biology and Morphology

The accurate identification of the parasitic species and subsequent treatment of the species benefit from a solid understanding of floral biology and molecular morphology. Broomrape's lifestyle has reduced the number of physical traits that aid in field identification. It has decreased leaves, lacks chlorophyll, uniform inflorescences, minuscule and uniform seeds, and barely any variation in the colour and shape of the corollas. Early on, the stem has a bright violet tint at the base and creamy at the top, maturing to a brownish-black colour (Figure 1). The leaves are now only tiny purplish scales. Broomrape can be identified by its branched, yellow-brown, glandular-hairy stems and its blue blooms, which come in a range of shades from light blue to violet. They are tubular, near about 15 mm long and two-lipped, with the lower lip being three-lobed and the upper lip being shallowly two-lobed. An erect spike of flowers appears in spring and summer. The spike is loosely flowered, interrupted below and continuous above. Flowers are 1-2 cm long with petals is broad corolla, 2 lobed upper lip and 3 lobed lower lip. The leaves are scale like, ovate or lanceolate, 6-20 mm long acute and sessile. Most of Orobanche species are unbranched except *Orobanche ramosa*, which has branched stem. The inflorescence, spike and flower colors are differed from different species. Fruit capsule are splits into two parts after ripen. It pollinates with bamble bee. Sexually reproduces the seeds up to 3000-2,00,000 seeds per plant shoot within a short period of time. Seeds are minute having a diameter of about 0.3*0.2 mm and its test weight (1000 seed weight) 0.1-3.0 g. seeds are spreads by wind, water bird, farm animals implement and others. The viability of seeds varies from 2-20 years (Rathore et al., 2014).

Figure 1: Orobanche infestation in mustard

3. Propagation and Dispersal

Orobanche multiplies mainly through seeds that remain viable up to 10 years and germinate on a suitable host under favorable conditions. The long-term impact of the broomrapes is even more serious, given that their seeds can spread easily to other fields, leading to an accelerated increase in infested areas. Seed dispersal is facilitated by persons and agricultural tools, especially by vehicles and farming machines. The seeds can also be dispersed with crop seeds and through forage. Animals can serve as efficient vectors because the seeds remain viable after passing through their alimentary system and are spread easily through manure.

4. Yield Loss

There is significant reduction of plant height, number of branches, number of siliquae per plant, seed per siliqua which ultimately led to seed yield loss ranged from 15 to 25% in mustard varieties due to infection of *Orobanche*. Food and Agriculture Organization (Anonymous, 1993) indicated that *Orobanche crenata* caused 12% losses in faba bean yield in Egypt and Morocco and recently, another Technical Cooperation Programme of Food and Agriculture Organization (TCP FAO), indicated that an average of 30-40% yield losses in faba bean was due to Orobanche in same place. Legumes are more susceptible to Orobanche, its infestation was increasing trend in morocco from last 1981which was 21% but it increased to 51% in 2003.

5. *Orobanche* Management

Management of *Orobanche* is very difficult mainly due to the certain reasons: it grows initially in underground location; its minute small seeds easily dispersed with several agents; longer seed viability; and it lacks a photosynthetic system, which could have been a potential herbicide target. Therefore, a major strategy towards Orobanche management should be taken to prevent its seed production from the existing population infesting crops as well as to deplete its seed bank reserve already present in soil. The following measures are very important to control *Orobanche*.

5.1. Preventive

Prevention is employed for minimizing the spread of Orobanche across and within the regions as well as to reduce its soil seed bank on gradual basis.

a) Clean crop seed should be used

b) Farm implements (ploughs, hoes) from an infested field should be cleaned before taking them to a new field

c) Quarantine should be followed properly

d) Avoid transfer of soil from infested area to a non-infested area

e) Avoid grazing animals in the infested area at least until the Orobanche has been removed

f) Application of natural synthetic stimulants: There are several natural stimulants, such synthetic analogues of *Orobanche* as GR 7, GR 24 and GR 45, which can induce germination. These stimulants should be applied well ahead of crop sown induce Orobanche germination, but, the seedlings wither away in absence of a suitable host plant amounting to "*Suicidal germination*." Orobanche plants those survived may be controlled by tillage, manual weeding or contact herbicide, e.g. paraquat, diquat.

5.2. Cultural

a) Cropping system: Due to allelopathic interactions, it has been shown that intercropping of faba bean and pea with cereals like oat or fenugreek will lessen *O. crenata* infection (Fernandez-Aparicio et al., 2016).

b) Trap crops and catch crops: Trap crops promote broomrape seed germination but do not support parasitism. Catch crops support parasitism but are destroyed prior to broomrape flowering. There are some potential trap crops or "false crops" that offer the advantage of stimulating the germination of the root parasites without being parasitized them. The control of parasitic weeds with trap crops is one of the most economical and practical methods for small-scale commercial farming. The root exudates of many plant species are active in stimulating the germination of the seeds of Orobanche and Phelipanche spp. but for which they are not described as hosts. Examples of trap crops for broomrape include flax, mung bean, maize, fenugreek and sorghum. Berseem as a catch crop in Egypt is harvested repeatedly for forage in order to prevent the full development and seeding of the parasite.

c) Time of sowing: Late planting likely reduces Orobanche infestation in tobacco and other crop hosts. Late planting is a viable option where tobacco is the only remunerative crop.

d) Crop rotation: Crop rotation with trap crops (which promote Orobanche seed germination but do not support parasitism) or catch crops (which support parasitism but destroy Orobanche prior to flowering) can effectively hinder new seed production and hence reduce soil seed bank. A continuous flooding for about 1-2 months prior to planting of tomato is believed to suppress Orobanche species in tomato. Similarly rice-tobacco rotation for quite a long period is useful towards controlling Orobanche in tobacco since its seeds loose viability on flooding.

e) Maintain soil fertility: Broomrapes are frequently found on less rich soils. Nitrogen fertilizers over 120 kg per hectare can reduce the amount of broomrape infection.

f) Organic manure: Organic treatments, such as broiling, cattle, goat, layering, sheep manure and wood chips, have been reported to reduce broomrape infestation.

g) Irrigation: Positive effect of irrigation by reducing the number and dry weight of broomrape, attributing these results to better development of the faba bean's root system.

h) Allelopathy: It results in less *O. crenata* infection in intercrops with fenugreek through the root exudates of fenugreek.

5.3. Mechanical and manual

a) Soil solarization: Soil solarization is an effective measure for controlling Orobanche. It can be adopted in seedling- raising nurseries on small plots of land and for growing profitable cash crops like vegetables. Solarization provided excellent control of *Orobanche aegyptiaca* and *Orobanche ramosa* & *Orobanche crenata* and ensured higher yield. Solarization controlled Orobanche crenata significantly and a yield increase to the level of 331%, 441% and 92% was recorded in faba bean, lentil and field pea, respectively in Syria.

b) Hand pulling: The main purpose of hand weeding is to prevent damage on host crop and seed production of the parasitic weed. It thus prevents enhancement of the parasitic weed seed bank in soil. Usually periodical hand pulling of Orobanche shoots 3-4 times per season before seed setting is advocated in a bid to reduce maximum of its seed population for the coming years. Hand weeding although labour-intensive, is useful particularly under light infestations and should be practiced as early as possible to avoid crop damage.

c) Mulching: Mulching is superior to fumigation as it cheaper and safer and involves no phytotoxicity or herbicide residues.

d) Flooding: Flooding for a long period may unable the viability/longevity of Orobanche seeds. A continuous flooding for about 1-2 months prior to planting of tomato reduces Orobanche infestation in tomato. Similarly flooding required for rice can be utilized for controlling Orobanche in tobacco if rice is included in the rotation.

e) Deep ploughing: Ploughing up to a depth of 20-25 cm during summer has been found effective towards reduction of Orobanche population and enhancement tobacco yield in the following season and Use of implement like SPEAR designed to remove tender Orobanche shoots.

5.4. Biological

Phytomyza orobanchae under the family: Agromyzidae and order: Lepidoptera is very effective to control *Orobanche spp*. It is native to the Mediterranean region, the main area of Orobanche infestation. Almost 47 fungi species are isolated from the species of *Orobanchae,* but a few proved effective against Orobanchae under field conditions. One such fungus is *Fusarium oxysporum f. sp. orthoceras* from which "Product F" was developed in the then USSR. It is mass reared on a medium of barley seeds and wheat straw and incorporated into the soil. It can cause massive damage to Orobanchae. Another important fungus is *Fusarium arthrosporioides*.

5.5. Chemical

a) Sheoran et al. (2014) and Punia et al. (2018) reported that foliar sprays of glyphosate twice; first 25 g ha^{-1} at 30 DAS and second 50 g ha^{-1} at 55-60 DAS provides 70 to 80% reduction in Orobanche shoots emerging from the soil, and 20 to 25% increase in seed yield of mustard. Glyphosate is a non-selective herbicide and kills all the green vegetation over which it is applied. The dose, timing and number of sprays of glyphosate optimized for mustard for Orobanche control are very specific, and therefore must be precisely followed with utmost care.

b) Soil fumigation with herbicides like dazomet (DMTT) granules at 300-350 kg ha^{-1} about 30-40 days before transplanting of tobacco is found effective. Similarly, metham (Vapum) @ 2000 lit ha^{-1} is quite effective against Orobanche.

c) Oxyfluorfen (Goal), selective herbicide to Indian mustard @ 200-250 g ha^{-1} as pre-emergence controls broad-spectrum of weeds along with Orobanche in mustard.

d) Linuron @ 0.5 kg ha^{-1} at 30 DAS caused complete control of Orobanche but simultaneously posed severe phytotoxicity to mustard. Therefore, pre-plant incorporation of Linuron into the soil may be advocated, which could render selective control of Orobanche in tobacco and brinjal

e) Soil-applied sulfonylurea has also been recently found to control Orobanche in tomato

f) MH-T @ 1.5 % spray on matured Orobanche shoots as post-emergence application

g) Allyl alcohol @ 0.1-3.2 % as post-emergence at 15-30 days after transplanting of tobacco proves quite effective against getting Orobanche infections

5.6. Host-plant resistance

In this approach, we focused on the development of herbicide-resistant crops. The control of broomrape without any detrimental effect on the crop or its yield was

achieved by using Glyphosate on 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitor-resistant oilseed rape. Oilseed rape (*B. napus*) that was infected with Orobanche and engineered with the aroA gene encoding a modified EPSP synthase completely prevented the development of the parasite after Glyphosate application to the transgenic plants. Transgenic lines resistant to glyphosate containing the 'cp4 epsps. Gene along with a double mutant 'als' gene could provide long-term control of *O. aegyptiaca* in the highly affected areas.

5.7. Integrated Orobanche *management*

a) Soil solarization+ optimum/ higher nitrogen fertilization + selective and effective pre-emergence herbicide + post-emergence herbicide or hand weeding/ interculture at the later stages.

b) Soil solarization or one or a few trap crops or crop rotation with rice where feasible or prolonged flooding if possible with high temperature (during summer) + optimum/ higher nitrogen fertilization +selective and effective pre-emergence herbicide + hand weeding/ interculture at the later stages.

6. Conclusion

Orobanche, a non-chlorophyllous root parasitic weed, causes serious damage to Indian mustard. Cultural, agronomic management, chemical control methods and host resistance are the most appropriate and affordable measures to control *Orobanche*. The avoidance of dispersal of broomrape, crop resistance, and prevention measures could be effective to reduce its infestations in other agricultural fields. However, integrated management approach is always better to manage Orobanche in field crops.

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