

RESEARCH ARTICLE

DEVELOPMENT OF A NON-CHEMICAL MYCOHERBICIDE GIBBATRIANTH FOR CONTROLLING *TRIANTHEMA PORTULACASTRUM* (HORSE PURSLANE) A NOTORIOUS AGRICULTURAL WEED: A REVIEW

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ABSTRACT

Horse purslane (*Trianthema portulacastrum* L.) is considered the most troublesome agricultural weed in tropical and sub-tropical areas of the world, including the US, Mexico, Northern and Southern states of India and Pakistan by virtue of its infestation in various vegetable and agricultural fields. Foliar phytopathogenic fungi, the fungi that cause foliage diseases in plants, offers a tremendous opportunity to develop as bioherbicides/mycoherbicides. Globally, a total of 13 fungal pathogens belonging to 10 genera of *Ascomycota*, all except *Myrothecium verrucaria*, are reported on horse purslane from India. Of these, *Gibbago trianthemae*, a foliar pathogen that causes leaf spots and stem blight, has been evaluated for its biocontrol potential to control horse purslane non-chemically in the USA, India and Mexico. The studies carried out on *Gibbago-Trianthema* system has revealed that this pathogen has all the desirable characteristics that makes it a suitable candidate to be developed as a mycoherbicide for horse purslane. The formulation of the fungal pathogen (*G. trianthemae*) consisting of conidial suspension + surfactant Tween 20 has been named Gibbatrianth. *G. trianthemae*, belongs to *Dothideomycetes*, a class under the phylum *Ascomycota* (formerly classified in *Hyphomycetes*, *Deuteromycota*). It is a phaeodictyoconidial fungus, easily cultured on potato dextrose agar and trianthema dextrose agar at 25°C. It produces non-beaked, dark, muriform conidia having both transverse and longitudinal septa, and developing singly through porogenous development. Each conidium germinates producing several germ tubes, and a germ tube in turn produces another conidium at its tip. Germination of conidia in this host-specific pathogen on leaves occurs within 6 to 12 hours post spraying, causing infection through stomata by producing peg like structures called appressoria. This pathogen is a hemibiotroph similar to mycoherbicide *Colletotrichum* upon which maximum bioherbicides are available in the market. Gibbatrianth is the first and the only mycoherbicide developed for controlling horse purslane globally. There is a huge scope for commercial exploitation of Gibbatrianth, a nonchemical herbicide, for controlling horse purslane worldwide, including India, for getting organic vegetables, free from the carcinogenic chemicals.

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INTRODUCTION

Trianthema portulacastrum L., a member of the family *Aizoaceae*, is commonly called horse purslane, black pigweed, carpet weed, gudbur and hogweed. This agricultural weed is indigenous to South Africa and presently occurs in tropical and sub-tropical areas worldwide, and is considered an aggressive weed in food crops and vegetables (Duthie, 1960, Balyan and Bhan, 1986; Aneja *et al.* 2000). Weeds, the plants growing where they are not wanted, are a problem in crop production associated with declines in crop yields and quality, as a source of allergies, and other health hazards to humans and domestic animals. The nuisance value of weeds can be

checked by two ways: Converting a problematic weed into a resource through its multifarious uses - a vegetable, fodder, green manure or medicinal; and controlling these through integrated pest management strategies. Though chemical herbicides are the most effective and immediate solution for the majority of weeds, however, the excessive and continuous use can induce the herbicide-tolerant weed populations, increases herbicide residues in soil, water and food products, thereby impacting human health and longevity, in addition to affecting useful soil microbiota (fungi, bacteria, protozoa) and fauna (earthworms) and can adversely affect nutrient cycling, soil fertility thereby affecting the crop's yields (Schroder *et al.*, 1993; Boyette *et al.*, 1993; Aneja *et al.*, 2000; Yadav & Malik, 2005; Aneja, 2010; Kumar & Aneja, 2016; Chopra *et*

al., 2024). Exploitation of microorganisms, especially foliar phytopathogenic fungi: the fungi that cause foliage diseases in plants, as mycoherbicides (fungal formulations)/bioherbicides (microbial formulations), are now emerging as an effective and eco-friendly alternative to toxic chemicals used in intergrated weed management (IWM). A total of 26 bioherbicides mainly based upon fungal biocontrol agents have been developed globally (Aneja, 2024). The global bioherbicides market size was estimated at USD 3,369.4 million in 2024 and is projected to reach USD 7,873.2 million by 2030, growing at a CAGR of 15.2% from 2025 to 2030 (Market Analysis Report, 2025). The objective of this review paper is to discuss the current status of fungal pathogens recorded globally on the horse purslane weed, and the development of *Gibbago trianthemae* as a mycoherbicide Gibbatrnanth, including its isolation, identification, conidial ontogeny, growth and sporulation on various culture media, impact of environmental factors on growth and conidial germination, mechanism of disease development, host-range studies, biocontrol efficacy, and its potential to be used as a bioherbicide globally.

BIOLOGY, INFESTATION AND ECONOMICS LOSSES OF HORSE PURSLANE

Trianthema portulacastrum L. (Figure 1), a member of the family *Aizoaceae*, is commonly called horse purslane, carpetweed and giant pig weed. It is a profusely branched, succulent, annual, broadleaved, white flowered, terrestrial weed, commonly found in cultivated and wastelands. Plants grow rapidly attaining peak growth within 40-45 days of their emergence. Maximum emergence of seedlings occurs during the rainy season when both the temperature and relative humidity are optimum for seed germination. Enormous seedlings production capacity and very little dormancy allows the mature seeds to germinate immediately, hence producing multiple generations in the same season (Balyan and Bhan, 1986).



Figure 1. *Trianthema portulacastrum* (Horse purslane).

Horse purslane, an indigenous plant to South Africa, currently occurs in India, Sri Lanka, Pakistan, Bangladesh, West Asia, Africa, Mexico and tropical America. It has become a troublesome weed due to its competition for space, moisture, essential nutrients and light. It is an aggressive weed in various agricultural crops and vegetables that includes maize, mustard, pigeon pea, soybean (Figure 2), pearl millet, black gram, mung beans, pigeon pea (arhar), potato, cotton, sugar cane and several others. It has caused heavy reduction in crop yields up to 50-60% in mung bean, 29-87% in soybean, cotton, maize and direct seeded rice, and 80-90% in pearl millet. In addition to infesting several agricultural crops, this weed also occurs along roadsides, abandoned fields and cultivated fields

especially during after the rainy season (Balyan, 1985; Balyan and Bhan, 1986; Balyan and Malik, 1989; Aneja et al., 2000; Calderon- Redzedowski and Redzedowski, 2004; Akhtar et al., 2013; Kumar and Aneja, 2016).



Figure 2. Infestation of *Trianthema portulacastrum* in various crops at Kurukshetra. (A) Pigeon pea. (B) Soybean. (C) Maize. (D) Mustard.

STATUS OF FOLIAR FUNGAL PATHOGENS ON HORSE PURSLANE:

Worldwide, a total of 13 fungal pathogens are known to infect and cause disease (leaf spot and stem blight) on horse purslane, all of these recorded from India, except *Myrothecium verrucaria* (Table 1). Various fungal isolates have been identified by lactophenol cotton blue mounts and cello-tape preparation methods based upon the morphological characteristics, such as septation of mycelia, conidiophore septation and colour, conidial colour, shape, septation and mode of conidial production/development (Aneja, 2025). The fungi include: *Alternaria alternata* (India), *Gibbago trianthemae* (USA, Cuba, Venezuela, India, Pakistan, Mexico), *Cercospora trianthemae* (India), *Colletotrichum gloeosporioides* (India), *Curvularia neoindica* (=Drechslera indica, *Exserohilum indica* and *Bipolaris indica*) (Japan, India, Australia), *C. tuberculata*, *Fusarium oxysporum* (India), *F. chlamydosporum* (India), *F. semitectum* (India), *Phoma herbarum* (India), *Myrothecium verrucaria* (USA) and *Paecilomyces variotii* (India). All these fungal taxa belong to *Ascomycota*, formerly classified in *Deuteromycota* (Aneja and Mehrotra, 2026). A summary of the total fungal pathogens recorded on horse purslane, the disease/s caused, and the country of occurrence, is given in Table 1. Amongst the various fungal pathogens recorded on this weed, two pathogens namely *Myrothecium verrucaria* and *G. trianthemae* cause virulence in nature.

PROTOCOL FOR DEVELOPING A FOLIAR PATHOGEN INTO A BIOHERBICIDE/ MYCOHERBICIDE:

The protocol to be followed for developing a foliar fungal pathogen into a mycoherbicide as diagrammatically represented in Figure 3. The major steps include: Searches are made for the diseased plants, followed by isolation and identification of fungal pathogen/s, proving of pathogenicity and Koch's postulates in vitro and in vivo conditions (under greenhouse), production of inoculum (sporulating structures) on various agar media, incubating at various temperatures and relative humidity, biocontrol efficacy of various strains of a pathogen, study the effect of environmental factors (temperature and R.H.), growth and sporulation, bioherbicidal potential in small scale and large

scale field tests, testing of host-range assay for host-specificity, formulation of a product, registration of the product and finally its commercialisation on a mass scale.

DEVELOPMENT OF *G. TRIANTHEMAE* AS A MYCOHERBICIDE

Symptoms on Horse Purslane: Leaf spots and necrosis are the common symptoms caused by *G. trianthemae* on horse purslane. Although all the stages of leaves showed infection in nature, the mature leaves were more heavily affected. Initially the lesions on the leaves are round pinpoint, which later on turned to round - irregular, necrotic, straw coloured with maroon margins (Figure 4).

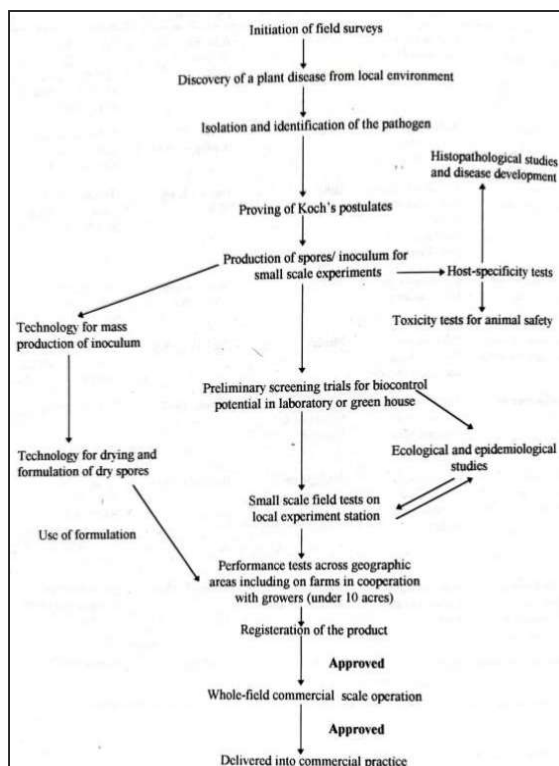


Figure 3. Protocol for the mycoherbicide development based upon a fungal biocontrol agent (Aneja, 1999).

Lesions often coalesced and abscised causing extensive premature defoliation (Mitchell, 1998; Aneja & Kaushal, 1998, 2000; Aneja, 2010, 2014; Gandipilli *et al.*, 2015). In addition to leaf spots, the fungus also caused stem blight, which appeared as pinkish to maroon irregular lesions, mainly on the senescent plants (Félix Gastélum *et al.*, 2021).



Figure 4. Disease symptoms on horse purslane by *G. trianthemae*. (A) Round to irregular maroon leaf spots with dark borders (in nature), (B) Leaf spots observed on inoculated leaves incubated

in a moist chamber at 25°C (in vitro). (Source: Aneja, 2014): Identification, Teleomorph and Systematics of *G. trianthemae*: Gibbago is a phaeodictyoconidial monotypic fungus solely represented by *G. trianthemae*. This fungus was first of all isolated in 1986 by E.G. Simmons, an American botanist/plant pathologist, from parasitized leaves of *T. portulacastrum* collected from Cuba, USA (Texas), and Venezuela (Simmons, 1986). While identifying this genus, Simmons observed that the conidial characteristics are somewhat similar to the four dematiaceous hyphomycetes genera *Alternaria*, *Embellisia*, *Stemphylium*, and *Gliocladium*, having dark multicellular conidia with transverse and longitudinal septa. However, the lack of a basal pigmented halo and a conspicuous scar around the conidium's detachment point from the conidiophore as well as the unique pattern of secondary sporulation (Figure 5), led to the identification of this pathogen as *G. trianthemae* Simmons, sp. nov. (Simmons, 1986). This taxon was classified in the family Dematiaceae, order Moniliales, class Hyphomycetes, division Deuteromycotina, and kingdom Myceteae with other taxa having similar morphological similarities (Alexopoulos *et al.*, 1996). Morphological Features: Colonies (Figure 5) of *G. trianthemae* on PDA+Y medium at 25°C are grey coloured and surface spreading (Aneja and Kaushal, 1998; Aneja, 2010). Conidiophores are macronematous, slightly swollen at the tip and proliferating sympodially (Figure 6). Conidia are yellow-brown, beakless, ellipsoid, smooth walled, muriform having 3-6 complete or partial transverse septa with constrictions and 1-6 complete or partial longitudinal septa, 30-68 µm x 19-38 µm. A conidium germinates by 1-7 germ tubes produced from apical, lateral and basal cells, and apical germ tubes giving rise directly to secondary conidiophores bearing secondary conidia identical with the primary conidia (Figure 6). The fungus shows holoblastic conidiogenesis (Aneja, 2010).



Figure 5: *G. trianthemae*. A colony on PDA+Y medium at 25°C.

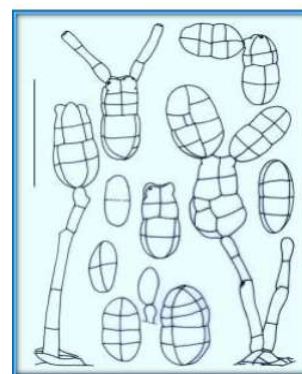


Figure 6. *G. trianthemae* Muriform beakless conidia developing from septate sympodial conidiophores

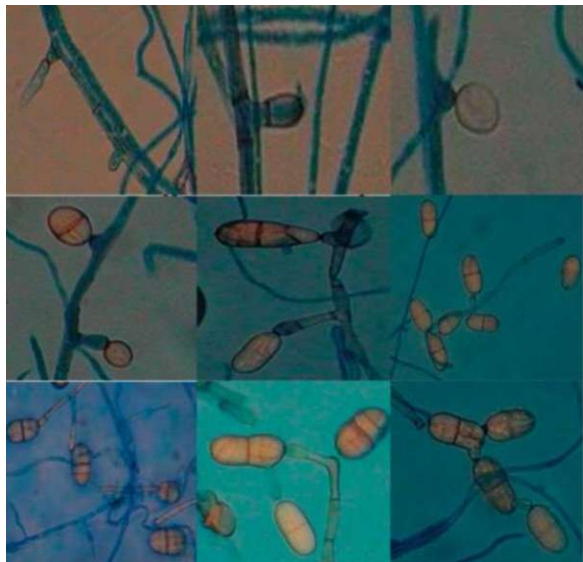


Figure 7. Mode of conidiogenesis in *G. trianthemae*: (A) Initiation of bud; (B) formation of septum between the bud and conidial initial; (C) Globose young conidium prior to the formation of septa; (D) Conidium with first transverse septum; (E) Conidia with transverse & longitudinal septa; (F-H) development of secondary conidia; and (I) Catenate conidia.

Molecular identification: Fungal molecular identification relies on analysing the Internal Transcribed Spacer (ITS) region of the ribosomal DNA (rDNA), a commonly used molecular marker. This region has variable sequences that can be used to differentiate between fungal species (Ariyawansa *et al.*, 2015). Molecular Identification based on ITS sequence data after nucleotide blast using the Basic Local Alignment Search Tool, DNA sequence of strains of *G. trianthemae* has been found similar to the genera: *Stemphylium*, *Dandryphiella* and *Pleospora* in the family *Pleosporaceae*. The phylogenetic analysis of the ITS sequences, also favoured its placement in *Pleosporaceae* (Ariyawansa *et al.*, 2015; Pem. *et al.*, 2019; Félix Gastélum *et al.*, 2021). The Indian and Mexican isolates of *G. trianthemae* have been identified on the basis of ITS rDNA (Kumar *et al.*, 2016; Félix Gastélum *et al.*, 2021).

Teleomorphic state: Gandipilli and Ratnakumar (2017) found perithecia of this fungus associated with infected tissues of horse purslane in India. However, the ascocarp state (teleomorph) has not been reported anywhere in the world.

Phylogenetic classification: This taxon is currently classified phylogenetically in the Phylum: *Ascomycota*, Subphylum: *Pezizomycotina*, Class: *Dothideomycetes*, Subclass: *Pleosporomycetidae*, Order: *Pleosporales*, and Family: *Pleosporaceae* (Wijayawardene *et al.*, 2024; Aneja and Mehrotra, 2026).

Conidial Ontogeny in *G. trianthemae*: The conidial ontogeny/conidial development or conidiogenesis, i.e., the process of conidial formation, in *G. trianthemae* is tretic (porogenous) producing holoblastic conidia (Aneja, 2010; Kumar *et al.*, 2016). A conidium develops through a pore or a narrow channel from a specialized cell, called a conidiogenous cell, that differentiates into a bud, a young unicellular conidium. It is followed by enlargement and formation of septa, both

transverse and longitudinal, creating the muriform or dictyoid structure, a fully grown conidium. The conidia are brown and produced singly as well as in chains (catenate conidia) from the sympodially growing conidiophores, and also from conidia before their detachment from a conidiophore (Figure 7).

Pathogenicity and Koch's postulates: Various isolates of *G. trianthemae* isolates identified from diseased plants having leaf spots and stem blight, on testing were found pathogenic on horse purslane in in vitro and in vivo conditions proving pathogenicity of the pathogen. In order to fulfil Koch's postulates, the pathogen was reisolated from inoculated leaves and identity confirmed by comparing colonial growth, conidiophores and phaeodictyoconidia with the original isolates, following the methodology (Aneja and Singh, 1989; Aneja, 1993), by various workers (Mitchell, 1988; Aneja and Kaushal, 1998; Aneja *et al.*, 2000; Akhtar *et al.*, 2013; Gandipilli *et al.*, 2015; Félix Gastélum *et al.*, 2021).

Growth and Sporulation on Various Culture Media: Growth and sporulation studies conducted on ten agar media at 25°C revealed the best growth of *G. trianthemae* on *Trianthema* extract dextrose agar (TeDA), followed by PDAY > PDA media. However, growth was good on PCA > V-6 juice agar > NA > ME and very poor was on CDAY > CDA and MA media (Figure 8). Best sporulation was observed on TeDA followed by PDA and PDA+Y (8.6 x 10⁵ > 8.0 x 10⁵ > 7.35 x 10⁵ conidia/ml, respectively). Interestingly *G. trianthemae* showed growth but failed to sporulate in all the three broths where oxygen might be a limiting factor. Both growth and sporulation of the fungus were found best on the TeDA, an agar medium based upon cheap natural source, and can be used for mass producing inoculum of *G. trianthemae* to be used in in vitro, in vivo and for field studies (Aneja *et al.*, 2000, Aneja, 2010).

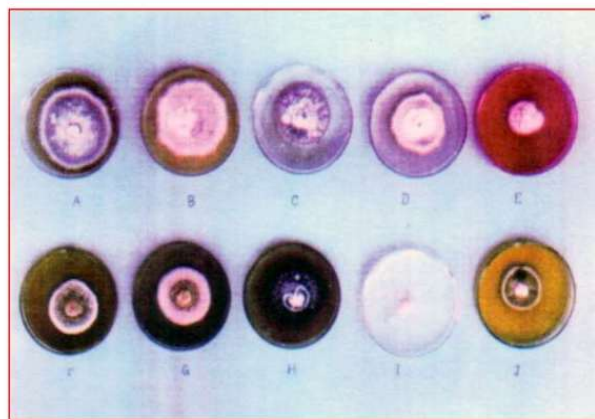


Figure 8. Growth rate of *G. trianthemae* at 25±2°C on 10 agar media.

Inoculum production: For producing inoculum, an aqueous conidial suspension of the fungus is prepared by collecting the mycelium and conidia, grown for 2 weeks at 25°C on PDA plates/TeDA plates, and suspending the mass in sterilized water, followed by filtering through 2 layers of cheese cloth to remove the mycelia. Conidia are counted using a haemocytometer, and suspension density (inoculum concentration) adjusted as per the requirement for inoculation studies (Aneja, 1993). PDA was used for

Table 1. Globally recorded fungal pathogens on *Trianthema portulacastrum*

Pathogen	Disease	Countries	References
<i>Alternaria alternata</i> Keissler	Leaf spot	India	Gupta and Mukherji (2001) Bohra <i>et al.</i> (2005) Ray and Lakshmi (2013) Gandipilli <i>et al.</i> (2017)
<i>Bipolaris maydis</i> (Y. Nisik and C. Miyake) Shoemaker	Minute leaf spot	India	Gandipilli <i>et al.</i> (2017)
<i>Cercospora trianthemae</i> Chiddarwar	Leaf spot	India	Chiddarwar (1962)
<i>Colletotrichum gloeosporioides</i> Penz. & Sacc.	Leaf spot	India	Darshika and Daniel (1998)
<i>Curvularia tuberculata</i> B.L. Jain (teleomorph <i>Cochliobolus tuberculatus</i> A. Sivanesan)	Leaf spot	India	Sreeja <i>et al.</i> (2022)
<i>Drechslera (Exserohilum) indica</i> (Rai, Wadhvani & Tewari) Mouchacca (= <i>Bipolaris indica</i>) (Rai, Wadhvani & Tewari) (= <i>Curvularia neoindica</i> Manamgoda, Rossman & Hyde)	Leaf spot	Japan India Australia	Rao and Rao (1987) Taber <i>et al.</i> (1988) Shivas (1995)
<i>Fusarium chlamyosporum</i> Wollenw. & Reinking	Leaf spot	India	Aneja <i>et al.</i> (2014)
<i>F. oxysporum</i> Schlecht	Leaf spot	India	Darshika and Daniel (1998)
<i>F. semitectum</i> Berk. & Ravenel (<i>F. incarnatum</i> (Desm.) Sacc.)	Leaf spot	India	Darshika and Daniel (1998) Xia <i>et al.</i> (2019)
<i>Gibbago trianthemae</i> Simmons	Leaf spot Leaf and stem blight Stem blight and leaf spot	USA, Cuba, Venezuela India Pakistan Mexico	Simmons (1986) Aneja and Kaushal (1998, 2000), Gandipilli <i>et al.</i> (2015), Chopra <i>et al.</i> (2024), Ratna Kumar and Gaddeyya (2014), Gaddeyya <i>et al.</i> (2017), Sreeja <i>et al.</i> (2022) Akhtar <i>et al.</i> (2013) Félix Gastélum <i>et al.</i> (2021)
<i>Myrothecium verrucaria</i> (Albertini & Schwein) Ditmar. Fr.	Leaf spot	USA	Boyette and Abbas (2001)
<i>Paecilomyces variotii</i> Biourge & Bain	Leaf spot	India	Babu <i>et al.</i> (2004)
<i>Phoma herbarum</i> Westendorp	Leaf spot	India	Ray and Lakshmi (2013)

producing inoculum of *G. trianthemae* in Petri plates incubated under fluorescent lights at 26°C (Mitchell, 1988). In contrast, the Kurukshetra isolates showed better growth and conidial production on TeDA than V-6 agar and suggested TeDA medium to be used for producing inoculum of this pathogen (Aneja *et al.*, 2000, Aneja, 2010).

Effect of Environmental Factors on Conidial Production and Germination: *In vitro* studies conducted on the conidial germination of *G. trianthemae* showed best conidial production at 25°C on trianthema dextrose agar (TeDA). Although production of conidia occurred at 15 and 35°C but was much lesser than at 25°C and germination was nil at 5°, 45° and 55°C. Hundred per cent conidial germination was recorded at 100% R.H. that reduced to 14% (i.e., 7 times) at 50% R.H. thus revealing high impact of relative humidity on conidial germination (Aneja, 2010).

Host specificity: Mitchell (1988) was the first scientist to assay host-range studies of *G. trianthemae*. He studied responses to 19 crop and weed species, such as horse purslane: *Mollugo verticillata*, *Amarantus retroflexus*, *Chenopodium album*, *Xanthium strumarium*, *Cucumis melo* var. *cantalupensis*, *Cucurbita pepo*, *Sorghum bicolor*, *Triticum aestivum*, *Zea mays*, *Aeschynomene virginica*, *Arachis hypogaea*, *Cassia obtusifolia*, *Glycine max*, *Gossypium hirsutum*, *Sida spinosa*, *Jussiaea decurrens*, *Portulaca oleracea* and *Lycopersicon esculentum*. Under greenhouse conditions, *G. trianthemae* caused infection and extensive damage only of horse purslane, thus showing susceptibility towards the pathogen, while all other hosts were found resistant towards the pathogen (Mitchell, 1988). Aneja *et al.* (2000) conducted experiments on host-range studies of this pathogen on 12 plant species which were selected based on the centrifugal phylogenetic relationship with the target weed

The inoculum consisted of conidial suspension (2x10⁵/ml) + Tween-80 (0.02%). The tested plants included: *Trianthema portulacastrum*, *Amarantus viridis*, *Chenopodium album* (weeds), *Triticum aestivum*, *Zea mays*, *Sorghum vulgare*, *Oryza sativa*, *Avena sativa*, *Hordeum vulgare*, *Brassica campestris*, *Cajanus cajan* and *Glycine max*. None of these tested plant species except horse purslane showed the production of leaf spot symptoms, proving host-specificity of *G. trianthemae* (Aneja *et al.*, 2000).

Mechanism of disease development: Disease development involves three steps: penetration, biotrophy and necrotrophy. After 2-3 days of inoculation/spraying of *G. trianthemae* inoculum, the stained sections of the leaves showed that during penetration of the host, a conidium germinates and infects/penetrates the host by producing a peg like structure, called appressorium. Biotrophy or biotrophic growth occurs for a few days which is associated with growth of large primary hypha in the host plasma membrane of epidermal cells and in the apoplast between mesophyll cells and without producing any disease symptoms. Germ tubes within the cortical cells showed the formation of intermediate swelling from which infection hyphae arise which later penetrates into adjacent cells. Hyphae reach cortical cells within 144 - 168 hours after inoculation. Plant tissue at the infected site collapses and extensive ramification of the hyphae in the host's cortical cells results 8-10 days after spraying of inoculum. Extensive cell wall degradation, appearance of symptoms, followed by the death of the infected plants occurred during the necrotrophic growth (necrotrophy) during which the secondary hypha appears to be triggered by certain host factors and secretion of cell wall degrading enzymes (e.g., cellulases and pectinases). *G. trianthemae* possesses an initial biotrophic phase represented by host-specificity and a necrotrophic phase represented by considerable damage and

death of the weed, hence is a hemibiotrophic fungus as per the classification of Goodwin (2001). *G. trianthemae* is similar to *Colletotrichum* spp., having both the characteristics: biotrophy which provides high host specificity; and necrotrophy which causes extensive tissue death, hence is commonly found in the list of commercial mycoherbicides (Templeton, 1992; Aneja, 2009, 2024).

Mycoherbicidal potential: The foliar pathogen *G. trianthemae* causing leaf spots and creating epiphytotic on horse purslane was recorded for the first time in 1969 by E. G. Simmons at the Experimental Farm, University of Massachusetts, USA (Simmons, 1986). The work on discovery of the pathogen was extended further by another American pathologist J.K. Mitchell who started work on the bioherbicidal potential of this pathogen for controlling this notorious weed at the Arkansas Agricultural Experiment Station, Fayetteville, USA (Mitchell, 1988). He found that when the horse purslane plants are sprayed with inoculum containing 1×10^5 conidia/mL or of more density (2×10^5 , 5×10^5 conidia/mL), are killed within 9 days after treatment (at 25-30 °C under greenhouse conditions) with weed growth reduction up to 100%, measured as per cent biomass loss. Aneja extended the work of Mitchell and initiated work at Kurukshetra (India) in 1994 on systemic surveying the terrestrial weeds for infestation and searching for the diseased plants having foliar symptoms (Aneja and Kaur, 1995; Aneja and Kaushal, 1998, 2000). Two pathogens, namely *G. trianthemae* and *Fusarium chlamydosporum* were identified on this weed (Aneja and Kaushal, 1998; Aneja *et al.* 2014). Aneja and his co-workers at Kurukshetra University, Kurukshetra found when an inoculum consisting of an aqueous suspension of conidia 2.2×10^5 /mL amended with Tween 20 (0.02% v/v) was sprayed, the conidial germination took place within 12 hours and producing leaf spots and stem blight symptoms after 3 to 4 days of inoculation. Defoliation of plants started post 20 days spraying and percent infection in leaves was found ranging between 72 and 84% killing the inoculated plants within one month. Additionally, application of inoculum significantly reduced emergence of new leaves, height and biomass per plant of the weed compared to the control plants which were sprayed with water plus surfactant only. Best biocontrol efficacy was achieved when the inoculations were made between 25 to 30°C and 93 to 100% RH under greenhouse conditions, both environmental factors favouring the conidial germination and infection of the host (Aneja and Kaushal, 1998; Aneja *et al.*, 2000; Aneja, 2010; Kumar and Aneja, 2016). The aqueous conidial formulation of this pathogen is named Gibbatrianth based upon the name of the mycoherbicidal agent and the target weed (Aneja, 2014; Aneja *et al.*, 2017). Gandipilli *et al.* (2015) and Gaddeyya *et al.* (2017) studied the efficacy of *G. trianthemae* using the inoculum (conidial suspension 5×10^4 density + Tween-20), in South India (Andhra Pradesh) under *in vitro* conditions. They found the percent disease infection ranging from 71% (post 20 days) to 82% (post 30 days), 91% (post 40 days) and 95% (post 50 days) after inoculation, and killing of the inoculated weed plants within 60 days. The early stage of the weed plant i.e., young leaves, favoured the germination of infective propagules (conidia) and penetration of the host. Studies conducted by Félix Gastélum *et al.* (2021) in Sinaloa (Mexico) observed *G. trianthemae* causing 100 % incidence of stem blight and leaf spot on horse purslane under controlled greenhouse conditions. Six isolates of the taxon, identified on molecular basis, showed considerable variations in virulence,

the disease severity with FAD values ranging from 11% to 58% after 14 days spraying at temperatures ranging from 24 to 36°C (1st experiment) and 21 to 36°C (2nd experiment) and relative humidity of 85% (maintained initially for 48 hours) in greenhouse conditions. Of the 6 identified isolates of *G. trianthemae*, two isolates *Gibbt5* and *Gibbt6*, were aggressive most virulent strains with FAD values of 58 % and 53.8%, respectively, 14 days after inoculation on the tested weed plants.

CONCLUSION

Gibbatrianth, a liquid formulation, named after the fungal biocontrol agent with surfactant and the target weed (Aneja, 2014). It is the one and the only mycoherbicide known from India of the total 26 bioherbicides developed globally (Aneja, 2024). *G. trianthemae* causes leaf spots and stem blight and severe infection on this weed in the United States of America, India, Pakistan and Mexico. This fungal pathogen has been found to be an excellent agent to control horse purslane in different countries (Mitchell, 1988; Aneja *et al.*, 2000; Aneja, 2010; Gandipilli *et al.*, 2015; Kumar *et al.*, 2016; Gaddeyya *et al.*, 2017; Félix Gastélum *et al.*, 2021). It possesses all the desired features needed for its development into a mycoherbicide, such as host -specificity hemi-biotrophic nature (having an initial biotrophic phase followed by a necrotrophic phase), fast growth rate, easy identification through characteristic non-beaked, tetric, phaeodictyoconidia, abundant conidial production on simple cheap culture media (potato dextrose agar and trianthema dextrose agar) for mass inoculum production, and potential to control the weed within a few days to a month at a wide range of temperatures (21-36°C). Based upon the findings of ours and other workers around the globe, I can certainly say that there is a Hugh scope for commercialization of Gibbatrianth for controlling horse purslane based on the indigenous virulent isolate/s of *G. trianthemae* to get chemical herbicides/ weedicides free foods.

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