Garlic Rust (Puccinia allii): Effect and Management Options- A Review

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Summary
Garlic rust caused by *Puccinia allii* is potentially damaging to garlic crops, has a wide distribution and limits production of the crop in many countries. Different disease management options are being used to reduce its effect. Cultural disease management methods such as rotation with non-host crops, optimum crop density, adequate supply of moisture, use of healthy planting materials and field sanitation with other crops can reduce the intensity of garlic rust by reducing available inoculum to initiate infection. Use of host plant resistance to manage diseases reported as it is economical, long-lasting, effective, easy to handle and environment-friendly. There are several fungicides which are effective against garlic rust, as a stop-gap measure or as an integral part of the crop management system. Integrated management of garlic rust is possible that a combination of control tactics is applied in many parts of the world. Such an integrated approach does not depend on a single method, which in the case of monogenic host resistance could be non-durable, and should be more sustainable over time.
Keywords: *Allium sativum* L., *Puccinia allii*, Effect, Management

INRODUCTION

Garlic (*Allium sativum* L.) plant are principally used as spice for flavoring and seasoning vegetable and meat dishes, it gives the food a delightful fragrance. In addition, garlic has miracle pharmaceutical effects and used to cure an enormous disease attributed to its rich content of sulfur-containing compounds, i.e., alliin, g-glutamylcysteine, and their derivatives (Chia-Wen Tsai *et al.*, 2012).

World garlic cultivation increased from 1,204,711 ha of land in 2007 with total production from 6.5 to 15.68 million tons to 1,199,929 ha with a production of 17674893 tonnes (FAO, 2012).In Ethiopia, 15,381.01 ha of land was under garlic cultivation with a production of about 6.15 tones/ ha (CSA, 2017). It is the second most widely cultivated Allium species next to onion in Ethiopia (Zewde et al., 2007). Garlic is produced mainly in the mid and highlands of Ethiopia (Getachew and Asfaw, 2000). Garlic can be grown under a wide range of climatic conditions but prefers cool weather and grows at higher elevation (900 to 1200 meters) and grows best within the geographic areas having a mean monthly growing temperature ranging from 12oC to 24oC (Libner, 1989). In most areas elevation from 500-2000 m provide suitable growing conditions, particularly during dry periods (Tindall, 1983). It had also been under commercial production by Horticultural Development Corporation at Debre Zeit, Guder and Tseday State Farms (Getachew and Asfaw, 2000). The crop is produced mainly as a cash crop to earn foreign currency by exporting it to Europe, the Middle East and USA.

Garlic production has been significantly reduced due to fungal disease. Among the fungal diseases, foliar disease, caused by the fungus are some of the most destructive plant diseases worldwide (Woldeab *et al*., 2007; Tome *et al*., 2010). From foliar disease garlic rust caused by *Puccinia allii* is the major destructive disease problem in almost all garlic producing regions of Ethiopia (Tesfaye and Habtu, 2003; Mengesha *et al*., 2016). *Puccinia allii* is an autoecious rust, producing pycnia, aecia, uredinia, telia, and basidia on a single host (Anikster *et al*., 2004). The genus Puccinia is the largest in the order Uredinales. *Puccinia allii* infects garlic at bulb formation stage (Koike et al., 2001). Garlic rust is readily identified by the earliest symptom of small, circular to elongate white flecks that occur on both sides of leaves, as the disease progresses, these small spots expand, and the leaf tissue covering the lesions ruptures and masses of orange, powdery spores (uredospores) become visible as pustules (Schwartz and Mohan, 2008). The disease has been found in every parts of Ethiopia where garlic Are cultivated (Tesfaye and Habtu, 2003; Mengesha *et al*., 2016; Worku, 2017).

The disease does not attack the garlic bulb directly, but it damages on the leaves which indirect effect size and quality of bulbs at harvest thereby reduce its marketability (Koike et al., 2001, Tahir *et al*., 2006). Until recently, this fungus was considered to be of minor importance in garlic production. However, outbreaks in USA in the late 1990's reduced crop yields by up to 75% in some fields (Anikster *et al*., 2004). The disease also occurred in 1999 and 2000, indicating that garlic rust may have become an annual problem in some parts of the United States of America (Koike *et al*., 2001). Heavily infected plants may be more susceptible to secondary infections and there can be direct bulb yield losses.

Worldwide, garlic rust has caused significant losses to garlic, leek, and onion production. Yield losses as high as 83% have also been reported by Ahmad and Iqbal (2002) on garlic due to rust disease in Nepal. Bulbs infected with garlic rust remain small and are of low storage quality (Sartaj and Ahmad, 2005). Garlic rust is the most important disease of the crop in Ethiopia causing a total bulb yield loss as high as 58.75% (Worku, 2017). Because the disease is destructive, different management options are being used to reduce effect of rust to garlic. Cultural disease management methods such as rotation with non-host crops, field sanitation, late planting and intercropping of garlic with other crops can reduce the incidence and severity of garlic rust, by reducing available inoculum to initiate infection. Enhancing soil nitrogen content through cultural practices is also helpful to reduce severity of the disease. Chemical control can be achieve by preventive treatments with mancozeb, propiconazole, tebuconazole orazoxystrobin if sprayed at 10-day intervals (Rochecouste, 1984; Blum & Gabardo, 1993; Koike *et al*., 2001). Planting of resistant cultivars is reported to be efficient, economical, environmentally friendly and simple approach for managing garlic rust. Rust have been controlled as part of an integrated crop management system using resistant cultivars and chemical control to complement the action of one with another although the disease is still sever in many parts of the world. This brief piece of work was, therefore, carried out with the objective to review the effect rust disease on garlic production and its management options.

Life cycle and Taxonomic Position of *Puccinia allii*

Puccinia allii is an autoecious rust, producing pycnia, aecia, uredinia, telia, and basidia on a single host (Anikster *et al*., 2004). The genus Puccinia is categorized under the Kingdom-Fungi, Division/Phylum-Basidiomycota, Class- pucciniomycetes, Order-Uredinales and Family-Pucciniaceae. This genus is the largest in the order Uredinales (Anikster *et al*., 2004). The taxonomic delineation of *Puccinia allii* has been in flux over the last century due to variation in the host range (Anikster *et al*., 2004; Metcalf and Napier, 2002; Lupien *et al*., 2004). Koike *et al*. (2001) and Anikster *et al*. (2004) determined that rust on garlic and chives in the USA was a different species to that on wild leek, leek and garlic in Europe, as leek was not susceptible to infection by the American rust following experimental inoculations. In addition, they found the two clades differed in the number of nuclei in their basidiospores, and by differences in the size of their teliospores (Anikster *et al*. 2004). The rust from the USA that has a majority of two-celled teliospores, and infects garlic and chives is hereafter referred to as P. allii (Koike *et al*., 2001).

The current classification of *P. allii* is considered a species complex rather than a single species and includes *P. porri, P. mixta, Uromyces ambiguus, and P. blasdalei* and *U. duris*. At present two members of this species complex have been clearly defined and are represented by the North American collections from garlic and Middle Eastern collections from leek (Szabo *et al*., 2008). Resolution of *puccinia allii* is complex will require further sampling of rusts on other species of Allium that can be linked to earlier described species (Alistair *et al*., 2016). Generally

Anikster *et al*. (2004) reported great differences in morphology between North American and European/Middle Eastern isolates, suggesting that this rust consists of at least two species.

Geographical Distribution and Economic Importance of Garlic Rust

Puccinia allii is a common cosmopolitan pathogen, present in onions, garlic and leeks, and reported in Europe, Asia, Africa, North and South America, Australia and New Zealand (Koike *et al*, 2001; Anisker et al., 2004; Fuyuru et al., 2009; Alistair *et al*., 2016).Rust on garlic, caused by the fungus *Puccinia allii,* has a worldwide distribution (Koike *et al*., 2001); including Africa, Asia, Australasia, Europe, the Middle East, North and South America (Anikster *et al*., 2004).

It is an important disease affecting leek crops as well as garlic, and occurs in the United Kingdom (Smith et al., 2000) Netherlands (De Jong *et al*.,1995) and USA (Koike *et al*., 2001). In 1998, a devastating outbreak of rust disease affected garlic throughout California. The disease was widespread, and in many fields 100% of the plants were infected. It also occurred in 1999 and 2000, indicating that rust may have become an annual problem in some parts of the State (Koike *et al*., 2001). It is also an important disease reported in different parts of Ethiopia (Mengesha *et al*., 2016; Worku, 2017; Yeshwas *et al*., 2018).

Worldwide, garlic rust has caused significant losses to garlic, leek, and onion production. The outbreak resulted in yield losses of 51% and an economic loss of 27% to the industry (Anikster *et al*., 2004). In the late 1990s, outbreaks in the United States of America reduced crop yields by up to 75% in some fields (Janet and Tammy, 2008). Yield losses as high as 83% have also been reported by Ahmad and Iqbal (2002) on garlic due to the same disease in Nepal. Bulbs infected with garlic rust remain small and are of low storage quality (Sartaj and Ahmad, 2005). According to the authors this disease also causes considerable loss on different Allium crops**.** It is also an important disease in Ethiopia too as it resulted in yield losses of 48% (Worku and Dejene, 2012) and almost 50% (Mengesha *et al*., 2016).Garlic rust is the most important disease of the crop in the highlands of Bale and causing a total bulb yield loss as high as 58.75% (Worku, 2017) **.**

Means of Dispersal and Epidemiology of the Disease

The initiation of rust epidemics depends critically on rainfall that effectively deposits spores travelling long distances (Nagarajan and Singh, 1990). The first sign of infection in a spring-sown crop usually appears between June and August in the temperate regions. The fungus probably survives as either uredospores or teliospores, with uredospores apparently being the most important source of inoculum. Uredospores are wind borne and can be spread long distances. The cyclical production of uredospores during the growing season serves as a continuous inoculum source throughout the life cycle of the crop (Hill, 1995).Teliospores,a secondtype of spores formed by garlic rust fungus, later develop on the same leaves, resulting in black pustules (Timila *et al*., 2005).

Symptoms

Puccinia allii infects garlic at bulb formation stage (Koike *et al*., 2001). Garlic rust is readily identified by the earliest symptom of small, circular to elongate white flecks that occur on both sides of leaves, as the disease progresses, these small spots expand, and the leaf tissue covering the lesions ruptures and masses of orange, powdery spores (uredospores) become visible as pustules (Schwartz and Mohan, 2008; Worku, 2017). The pustules become full of uredospores that spread the disease to plants by rain splash and wind currents. Severely infected leaves are almost entirely covered with pustules, resulting in extensive yellowing, wilting and premature drying of leaves. Teliospores, a second type of spores formed by garlic rust fungus, later develop on the same leaves, resulting in black pustules (Koike *et al*., 2001). The earliest severe rust on garlic and other Alliums can cause extensive loss of foliage and subsequent reduction in bulb size and quality. On infected onion and chives, symptoms consist of small (less than 3.2 mm in diameter), white to tan spots. The orange pustules often form concentric groups on the spot periphery. Disease severity on onion and chives is significantly less severe than on garlic. Generally, this garlic rust can cover entire leaves, causing them to die (Tahir *et al*., 2006).

Host Plant Ranges and Pathogen Survival

Puccinia allii causes rust diseases in onion (*Allium cepa* L.), scallion (*A. chinense* L.) spring onion or Japanese bunching onion (*A. fistulosum* L., porrum group: naganegi), garlic (*A. sativum* L. nin-niku), and Chinese chive (*A. tuberosum* L.) in Japan (Foriya et al., 2009).

In Australia Metcalf (2002) showed in pathogenicity tests that an isolate of *Puccinia allii* from Tasmania could infect chives, garlic, bulb onions, spring onions and shallot. Severe infections produced by this species complex can kill leaves of cultivated species of Allium. Garlic, chives, and leeks are the most susceptible crops. Koike et al. (2001) found no evidence for the disease being maintained or spread by volunteer plants or through an alternate host and concluded that the disease was carried from one season's crop to the next by a living bridge of infected plants, since there are crops in the field all year round; uredospore could therefore be blown from either local or more distant foci of infection. They also persist in the soil on plant debris for several years. Other kinds of spores in the complex life cycle of rusts are produced in other Alliums. It has been reported that the aforementioned pathogens also infect Welsh onions (*Allium fistulosum* L.), chives (*Allium schoenoprasum* L.) and other alliums (Szabo *et al*. 2008).

Management Options

Diseases caused by *Puccinia allii* are controlled primarily through the use of chemical sprays with fungicides, and disease free or treated seeds, adequate nitrogen fertilizer were generally reduces the rate of infection by *Puccinia allii*. Crop rotation, removal and burning of crop debris (if infected), and eradication of weed hosts help in reducing the inoculum potential for subsequent plantings of susceptible crops (Agrios, 2005). For management of garlic rust, the following options have been worked out.

Cultural control

Crop health is affected by cultural practices such as planting time, plant density, cropping sequence, cropping pattern, fertilization, seed-bed preparation, weeding, etc. Such practices can also influence the level of biotic stresses and their effect on the growth and yield of a crop.

Protection often provided by modification the environment to favor crop growth, but discourage the conditions that favor disease development. Cultural methods, which can be manipulated to control disease, include use of healthy planting materials, fertilizer application, crop rotation, optimum planting date, supplying adequate moisture and optimum planting density (Agrios, 2005).

Use of healthy planting materials

Puccinia allii can survive on the bulb of garlic. Hence, use of healthy seed can reduce the severity of the disease on the developing crop (Greisbach and Ocamba, 2009; Janet and Tammy, 2008). Garlic rust pathogen is a fungal microorganism that survives either on crop debris by producing resting spores or alternates with different, perennial hosts, like wild Allium species .Hence, rotating out of Allium crops for two to three years and destroying all volunteers and Allium weeds can be effective in reducing the amount of inoculum in the crop residue in the soil for the next growing season (Schwartz and Mohan, 2008; Greisbach and Ocamba, 2009).

Adequate supply of moisture

The garlic rust occurs most frequently under conditions of high humidity and low rainfall and its incidence is highest in stressed plants (Janet and Tammy, 2008). It is also reported that the disease can cause severe yield losses when excessive rain, fog, or irrigation are present (Greisbach and Ocamb, 2009). According to these authors supply of optimum moisture to the crop is important to reduce garlic rust problem. Garlic rust is highly dependent on moisture, changes in precipitation or dew will directly influence the severity and distribution of the disease.

Optimum plant density

Mohibullah (1991) reported that rust severity could be decreased by 10% by decreasing plant population from 2 to 0.5 million per hectare and consequently garlic yield could be increased by 28%.The maximum value of yield was obtained from plot planted with 10 cm intra row spacing while, the minimize value of yield was achieved by plot planted with 20 intra row spacing at research field of haramaya university, Ethiopia (Mengesha, 2015). A number of studies in various parts of the world have shown that garlic production can be improved through proper spacing that plant spacing significantly increase number of cloves per bulb, bulb size, bulb weight and yield. It has been reported by (Mohammad *et al*, 2014). Naruka and Dhaka (2001) and Alam, *et al*. (2010) indicated that garlic bulb yields increased significantly with increasing intra-row spacings. It is assumed that densely populated plants are ideal habitats for fungal development and transmission to the nearby plant since moisture is retained within the leaves, and it prevents direct sunshine (Jorind, 2012). Therefore, increasing spacing between garlic plants will allow better airflow and keep humidity from building up. Increasing plant spacing can significantly decreases disease incidence and severity level of garlic rust. This might be due to proper aeration resulting in decreased humidity level suitable for fungus growth and decreasing plant population also limits the transmission of rust pathogen to the next plant (Ahmed *et al.;* 2017).

Fertilizer application

Nitrogen (N) is essential for plant growth and development. In addition nitrogen availability can influence the resistance of plants to plant pathogens (Marschner, 1995, Tadesse and Mashila, 2018). Too much nitrogen and too little potash in the soil would promote rate of infection. Lush garlic growth caused by excessive nitrogen will make the crop susceptible to rust infection (Greisbach and Ocamba, 2009). Generally, adequate nitrogen fertilizer reduces the rate of infection (Agrios, 2005).

Host Resistant

Breeding for genetic resistance is one of the best methods to handle fungal diseases, as it is the most economical and environment-friendly control method. However, Koike et al. (2001) tested 34 garlic varieties against garlic rust and noted that acceptable levels of resistance were not observed in any cultivar. Again Yeshewas et al. (2018) screened 16 garlic germplasm for yield and diseases tolerance in east Gojam and reported none of the germplams showed high resistance to rust. Additionally use of resistant varieties is cheaper but such varieties are not available (Worku, 2017). Because garlic is a sterile plant that is propagated asexually by way of vegetative cloves, bulbs, and bulbils, not from seed, which markedly reduces chances for genetic improvement (Aparicio et al., 2011; Kamenetsky and Rabinowitch, 2017). However, recent efforts have shown that fertility restoration is possible (Pooler and Simon, 1994; Kamenetsky *et al*., 2005) allowing genetic studies and classical breeding.

Biological control

Biological control is currently receiving much attention in disease management practices. The over uses of chemicals has created an unprecedented environmental crisis. It is defined as brings about reduction in activities of pathogens by other organisms and typically involves an active human role. The majority of work done on plant disease bio-control was related to soil-borne diseases using either bacteria or fungal antagonists. However, there is no more published source available regarding biological control against garlic rust on garlic (Tahir *et al.*, 2006). In Ethiopia commercial biological control is not available for garlic rust (Worku, 2017).

Chemical control

There are different recommended fungicides that are registered for the control of garlic rust on different Allium crops in different countries. Chemical control can be achieved by preventive treatments with mancozeb, propiconazole, tebuconazole or azoxystrobin, if sprayed at 10-day intervals (Koike *et al*., 2001). Four chemical fungicides were evaluated for their efficacy against garlic rust at Hararghe highlands. There was significant garlic rust severity difference between fungicide-treated and the unsprayed checks. garlic plots treated with propiconazol showed the lowest disease severity (3.72%) whereas plots treated with bayleton showed greater disease severity (73.47%) which is nearest to the control (83.45%) at the 128 days (Mengesha et al., 2016). With the Section 18 registration for tebuconazole, commercial garlic was sufficiently protected during the 1999 and 2000 seasons (Koike *et al*., 2001). All fungicide treated plots gave higher total yield than the unsprayed check plots (Worku, 2012). This author also reported early garlic rust detection and application of fungicide while the disease was less severe is very essential if effective control measure is intended. Using systemic fungicides contains tebucunazole as active ingredient recommended in different countries for the management of garlic rust and other disesease of garlic in different countries (Maria et al., 1998, Koike et al., 2003, Zewde *et al*., 2007). Garlic rust (*Puccinia allii)* severity level on garlic plots sprayed with the three different Nativo SC 300(Trifloxystrobin 100g/l +Tebuconazole 200g/l) spray frequencies (five times in every 7-days, three times in every 14-days and two times in every 21-days) was lower as compared to the unsprayed plots (Worku, 2017). In addition Marketable yield harvested from sprayed plots was consistently greater than the yield harvested from unsprayed plots (Tilahun et al., 2018).

Integrated Disease Management

To reduce yield loss of garlic due to rust integrating all components-cultural practices, host resistant, chemical control, biological control, and optimum crop density into a disease management scheme that are environmentally compatible, economically feasible, and socially acceptable to reduce damage caused by disease to tolerable levels. Integrated disease management (IDM) is a combination of methods such as cultural, biological and host resistance that are environmentally compatible, economically feasible, and socially acceptable to reduce damage caused by disease to tolerable levels. The effect of *Puccinia allii* on garlic can be minimized by integrated use of different control measures.

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