Garlic Rust (Puccinia alli) Disease and Management Practices: A Review

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Abstract: Garlic rust has been found in every parts of Ethiopia where Garlic crop cultivated. The disease does not attack the bulb part directly, but it damages on the leaves which indirect effect on size and quality of bulbs at harvest thereby reduce it is marketability. Until recent, Puccinia alli fungus disease was considered to be of minor importance in Garlic production. Heavily infected plants may be more susceptible to secondary infections and there can be direct bulb yield losses. Worldwide, Garlic rust disease has caused significant losses to Garlic, leek and Onion production. Yield losses as high as 83% have also been reported on Garlic due to rust disease. The bulbs infected with Garlic rust remain small and are of low storage quality. Similarly, Garlic rust is the most important disease of the crop in Ethiopia causing a total bulb yield loss as high as 58.75%. Garlic rust caused by Puccinia alli is potentially damaging to Garlic crops, which 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 inoculums 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. In view of the above points therefore, the main objective of this paper is to review on the Garlic rust (Puccinia alli) disease and management practices in Ethiopia.

Keyword: Garlic rust (Puccinia alli), indirect effect, size and quality, marketability, Onion production & management methods.

1. Introduction
Garlic (Allium sativum L.) is belongs to the family Alliaceae which it is originated in the Central Asia, the region that boarders China, Kazakhstan and Kyrgyzstan. Mediterranean and Caucasus regions are considered as secondary centers (Etoh and Simon, 2002). Garlic is among the important bulb vegetable crop which is used as spice and flavoring agent for foods (Velisek et al., 1997). It also widely
used around the world for its pungent flavor as a seasoning or condiment. It is a fundamental component in many or most dishes of various countries in the world including Ethiopia. Garlic also adds a taste to foods as well as it helps to make them more palatable and digestible. It is an important ingredient in the leading cuisine around the world. In Ethiopia, Garlic is used while preparing foods, particularly some kinds of stew and in making dried foods for storage (Rubatzky and Yamaguchi, 1997).

All parts of the Garlic plant have a vital uses. The cloves are used as seed, for consumption and for medicinal purposes. The leaves, stems (scape) and flowers on the head (spathe) are also edible and are most often consumed while immature and still tender. The papery, protective layers of “skin” over various parts of the plant and the roots attached to the bulb are the only parts not considered palatable (Kero, 2010).

Garlic has been used as condiment and medicine for over 5000 years (Bondnare et al., 1997). As a condiment, it has been used for flavoring soups, stews, pickles, and salads. Dehydrated, powdered granulated Garlic or ‘Garlic wine’ is used for industrial and home purposes. Garlic in the form of ‘Garlic wine’ and granules has been processed at industrial level in South Korea. Garlic is also regarded as a powerful antidote against all kinds of poisons. Allicin, the volatile compound released when a clove is crashed, lowers blood sugar level, cholesterol and lipoproteins; has antibacterial, anti-helmintic, anti-carcinogenic, insecticidal and larvacidal properties (Koch, 1996).

World Garlic cultivation increased from 1,204,711ha of land in 2007 with total production from 6.5 to 15.68 million tons to 1,199,929ha with a production of 17,674,893 tons (FAO, 2012). In Ethiopia, 15,381.01ha of land were 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). It can be grown under a wide range of climatic conditions but prefers cool weather and grows at higher elevation of 900-1200masl and grows best within the geographic areas having a mean monthly growing temperature ranging from 12°C to 24°C (Libner, 1989). In most areas elevation from 500-2000masl provide suitable growing conditions, particularly during dry periods (Tindall, 1983). It had also been under commercial production by Horticultural Development Corporation at Bishoftu, Guder and Tseday State Farms (Getachew and Asfaw, 2000) which is mainly produced as cash crop to earn foreign currency by exporting to Europe, the Middle East and USA.

According to Getachew and Asfaw (2000) reports that the major production constraints of Garlic crops in Ethiopia are lack of improved varieties, Garlic rust (Puccinia alli Rudolphi), downy mildew (Peronospora destructor Berk.), basal rot (Sclerotiumrolfsii Sacc.), white rot (Sclerotiumcepivorum Berk.) and Onion thrips (Thripstbaci Lind.).

Garlic production has been significantly reduced due to fungal disease. Among the fungal diseases, foliar disease which is caused by the fungus is some of the most destructive garlic plant diseases worldwide (Woldeab et al., 2007 and Tome et al., 2010). From foliar disease Garlic rust caused by Puccinia alli is the major destructive disease problem in almost all Garlic producing regions of Ethiopia (Tesfaye and Habtu, 2003 and Mengesha et al., 2016). 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 become visible as pustules (Schwartz and Mohan, 2008).

Garlic rust has been found in every parts of Ethiopia where Garlic crop cultivated (Tesfaye and Habtu, 2003; Mengesha et al., 2016 and Worku, 2017). The disease does not attack the bulb part directly, but it damages on the leaves which indirect effect on size and quality of bulbs at harvest thereby reduce it is marketability (Koike et al., 2001 and Tahir et al., 2006). Until recent, Puccinia alli fungus disease 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 (Aniksteret 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 disease 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.
The bulbs infected with Garlic rust remain small and are of low storage quality (Sartaj and Ahmad, 2005). Similarly, 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).

As general, Garlic rust is a destructive fungal disease which has different management options that being used to reduce it is effects. The commonly used practices are rotation with non-host crops, field sanitation, late planting and intercropping of Garlic crop with other crops can reduce the incidence and severity of the disease. On the other hand Enhancing soil nitrogen content through cultural practices is also helpful to reduce severity of the disease. Similarly, chemical control can be achieved by preventive treatments with mancozeb, propiconazole, and tebuconazole or oxystrobin if sprayed at ten days intervals (Rochecouste, 1984; Blum and Gabardo, 1993 and Koike et al., 2001). Planting of resistant cultivars is also reported to be efficient, economical, environmentally friendly and simple approach for managing Garlic rust and 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. In view of the above points therefore, the main objective of this paper is to review on the Garlic rust (Puccinia alli) disease and management practices in Ethiopia

2. Garlic Rust (Puccinia alli) Disease and Management Practices in Ethiopia
2.1. Garlic Rust Life cycle

The current group of Puccinia alli is considered as a complex species rather than a single species and includes P. porri, P. mixta, and P. blasdalei. 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 alli is complex which requires further sampling of rusts on other species of Allium that can be linked to earlier described species (Alistair et al., 2016). Similarly, Anikster et al. (2004) reported that as there are great differences in morphology between North American and European isolates, suggesting that this rust consists of at least two species.

2.2. Economic Importance of Garlic Rust

Geographical distribution and economic importance of Garlic Rust (Puccinia alli) 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; and Alistair et al., 2016). Rust on Garlic, caused by the fungus Puccinia alli, has a worldwide distribution (Koike et al., 2001). It is an important disease that 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 Garlic 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 and Yeshwas et al., 2018).

Worldwide, Garlic rust has caused significant losses to Garlic, leek, and Onion production which it is 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). In similar report, 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).
2.3. Spreading Means of the Disease

Garlic rust is widespread especially where it can probably be more serious locally than in the lowlands. Economic damage due to the disease is frequently localized and sporadic, but serious losses have been reported from Brazil, Israel, and South Africa. Garlic rust is caused by various Puccinia spp. Physiologic specialization appears to exist, but there has been no adequate study on this. High nitrogen application may increase the disease incidence.

Nagarajan and Singh (1990) reported that the initiation of rust epidemics depends critically on rainfall that effectively deposits spores travelling long distances. 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. Urediospores need at least four hours of 97% relative humidity to germinate and infect but do not survive when immersed in water. Optimum temperatures for infection are between 10°C and 15°C. Temperatures above 24°C and below 10°C inhibit infection. 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 second type of spores formed by Garlic rust fungus, later develop on the same leaves, resulting in black pustules (Timila et al., 2005).

2.4. Symptoms

Puccinia alli 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; and 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).

2.5. Host Plant Ranges and Pathogen Survival

Puccinia alli causes rust diseases in Onion (Allium cepa L.), scallion (A. chinense L.) spring Onion or Japanese bunching Onion (A. fistulosum L.), Garlic (A. sativum L.), 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 alli from Tasmania could infect chives, Garlic, bulb Onions, spring Onions and shallot.

Wilson and Henderson (1966) regard Puccinia alli as widespread, with intergrading morphological traits in various populations infecting many species of Allium. Severe infections produced by this species complex can kill leaves of cultivated species of Allium. Garlic, chives, and Leeks are the most susceptible crops. But Savile (1961) considers the rust on Allium schoenoprasum (chives) as Puccinia mixta and the rust on A. porrum (Leeks) as Puccinia porri. The telialsori of Puccinia alli in the broad sense are covered by the epidermis and appear as a black crust when mature. The telialsori are composed of numerous, darkly pigmented, thick-walled paraphyses that surround locules filled with teliospores. Among the variable traits is the quantity of one-celled teliospores (mesospores) in the telia. Puccinia porri was considered as a separate species because it had more than 50% mesospores, while Puccinia alli had less than 50%. Because this trait intergrades it seems not to be able separate species.

Doherty (1981) and 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; uredospores 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 (Szabo et al. 2008).


Garlic rust disease management strategies can be employed to slow down, or entirely prevent, the disease in a particular location. Any management strategy that reduces the exposure of the variety to large pathogen populations (inoculum pressure) is likely to increase its useful life span. 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 and eradication of weed hosts help in reducing the inoculum potential for subsequent plantings of susceptible crops. 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 (Agrios, 2005).

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).

3.1. 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 variety locally called “Minjar Nech Shinkurt” was collected from the local farmers around Jimma town. The cloves were soaked with water before sowing. 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

3.2 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.

3.3. 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). But, the most recommended plant spacing for Garlic crop is 10cm between plants and 30cm between the rows (Alam et al., 2010). 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 increases 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 plantspacing 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).

3.4 Fertilizer Application

Garlic is heavy feeder and most of the Allium species have low nutrient extraction capacity than most crop plants because of their shallow and un-branched root system. It has a high fertilizer requirement with banding being a preferable application method (Brewster, 1997). Nitrogen is essential for plant growth and development which 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 Ocampa, 2009). As well as the availability of nitrogen is of prime importance for growing plants as it is a major and indispensable source of protein and nucleic acid molecules (Naruka et al., 2005). Not only nitrogen, Phosphorus is also a key element for vegetables as it stimulates the root formation and centre for the components of nucleic acid. Inappropriate application rate of phosphorus affects the growth and development of plant and the bulb formation (Cantwell et al., 2006).

A number of studies in various part of the world have shown that Garlic production can be increased through appropriate cultural practice. Unfortunately there is a dearth of information on Garlic production and productivity in Ethiopia. Generally, adequate nitrogen fertilizer reduces the rate of infection (Agrios, 2005).

3.5. Host Resistant Management System

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 around sixteen Garlic germplasm for yield and diseases tolerance in east Gojam and reported none of the germplasm 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.

3.6. Biological Control Systems

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).

3.7. Chemical Control System

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 azoxystrabrin, if sprayed at ten days 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 disease of Garlic in different countries (Maria et al., 1998, Koike et al., 2003 and Zewde et al., 2007).

Garlic rust (Puccinia alli) 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 seven days, three times in every fourteen 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).

3.9. 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 alli on Garlic can be minimized by integrated use of different control measures.

4. Summary and Conclusions

Garlic rust caused by Puccinia alli is potentially damaging to Garlic crops, which 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 inoculums 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.

5. Recommendations

✔ The effect of Puccinia alli on Garlic can be minimized by integrated use of different control measures.

✔ Integrated disease management 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.

✔ 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.

✔ The use of recommended chemical that are registered for Garlic rust is more effective

✔ Proper planting time and spacing can reduce Garlic rust

6. Acknowledgment

We would heartedly like to thank and praise the Lord Almighty God in giving us strength and wellbeing to successfully complete this review. We sincerely thank the staff of Ambo University Departments of Horticulture for all the necessary moral support and advice. Finally, all the reference materials used in this review paper are dully acknowledged.
7. Conflict of Interest

Regarding the publication of this manuscript, there is no any conflict of interest.

8. References


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