



THE ROLE OF AGRICULTURAL EXTENSION IN COMBATING ROOT ROT DISEASE IN MAIZE (ZEA MAYS L.): AN OVERVIEW

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Abstract. This article was prepared to determine what agricultural extension is doing to help control yellow corn root rot, what problems farmers are having in this control, and how to solve these problems. The other aim of the article was to control root rot chemically, and it was discovered that the fungi responsible for the root rot were *Bipolaris*, *Fusarium*, *Helminthosporium* which are highly capable of causing root rot. All corn varieties were also found to be susceptible to the disease and all the varieties were affected by the root rot under different degrees of infection each variety was given with severity varying from one variety to the other. Chemical control with fungicides showed that *Fusarium* was the fungus most effectively inhibited by chemical fungicides; agricultural research indicated that the chemical fungicides (Beltanol and Topsin) were the most effective in killing the root rot-causing fungi, and were the most effective at inhibiting fungal growth; these fungicides also had a positive effect on the characteristics of corn plants, including plant height. The fungicides (Beltanol and Topsin M) were found to be effective in protecting yellow corn, increasing resistance of the plants and decreasing the fungal infection. The fungicides employed (Beltanol and Tosbin M) were very effective in controlling the disease, and some of the characteristics of the yellow corn were desirable, such as yield and plant height. In addition, agricultural research showed that potassium fertilization caused a decrease in the incidence of the root rot pathogens in yellow corn. All varieties had good growth, plant height, stem length and leaf development with potassium fertilization; and an increase in the number of leaves and a noticeable increase in stem length in the plant treated with pesticides and balanced fertilization in the case of yellow corn.

Keywords: Yellow Corn, Agricultural Extension, Root Rot, Systemic Fungicides

Introduction

The Yellow corn *Zea mays L.* is one of the most important and widely grown crops in the world, and since 1996, it has outstripped rice and wheat in production, increasing at twice the rate of rice and three times the rate of wheat [1]. Asia is the world's second-largest producer of yellow corn, with its share of production accounting for 31% of the global total, and with the production over the last 10 years increasing by a remarkable 27.7% in Asia [2]. In 2020, the global area of yellow corn planted was about 196.08 million hectares and global production was 1,163.21 million metric tons. The United States is the top producer and planted acreage, followed by China and Egypt is the leader among Arab countries [3]. During the summer season of 2019 in Iraq, the planted area of spring and fall crops of yellow corn was estimated at 515.2 thousand dunams, of which 473.1 thousand metric tons were expected to be harvested [4]. The importance of this crop has been growing more and more, being a main

source of vegetable oils, cornmeal, an important forage crop and a key ingredient in industries. Therefore, the detection, diagnosis and research of yellow corn disease has been a major concern to help control and resist these diseases. Of these diseases many viruses restrict its yield, and there are approximately 26 different viruses known to infect yellow corn [5, 6, 7]. Fungi and mycotoxins can affect the yellow corn crop when the plants are grown in the field, as well as during harvest, transportation and storage because of poor storage conditions, which are favorable for fungal growth and mycotoxin production [8-11]. Fungi in the soil infect the yellow corn during germination and emergence and can survive during storage if conditions are favorable for infection. Some *Fusarium* species are common and often found in association with yellow corn production locally and globally with *Fusarium verticillinoides* being the most significant [12].

Fusarium sp., *Helminthosporium sp.* and *Alternaria sp.* are the most important field fungi that infect yellow corn in the field and can cause infection during storage [13-15]. These fungi are found in the atmosphere and soil and are a source of contamination for agricultural products like different crop seeds. The most important diseases of yellow corn are seed rot due to *Fusarium verticillioideis* [16], stalk and cob rot caused by *Diplodia maydis*, cob rot caused by *Fusarium graminearum*, foot rot, wilt and black rot caused by *Macrophomina phaseolina* and root rot and death of seedlings caused by *Pythium sp.* [17-19]. This highlights the importance of agricultural extension services as one of the key institutions capable of addressing the problems farmers face in their fields [20], as agricultural extension, in cooperation with the Plant Protection Department, works to raise awareness among farmers, educate them on the safe use of pesticides, and teach them how to implement integrated pest management [21].

The Economic Importance of Yellow Corn

Yellow corn (*Zea mays L.*) is one of the most important strategic food crops after wheat and rice in the world. It is grown on a significant scale in the Arab world as well as around the world, with the USA being the world's largest producer, followed by China. It is also grown in the Arab region such as Egypt, Morocco, and Sudan. It is cultivated in most of the provinces of Iraq, and is mainly found in central provinces such as Diyala, Kirkuk and Salah al-Din. In the summer of 2019, Iraq's production of spring and fall crops is estimated at 473,100 metric tons and the area under cultivation amounted to 515,200 dunams [4]. In 2020, the global area of yellow corn cultivation was around 196.08 million hectares and the global production of yellow corn was 1,163.21 million metric tons. The US is the top producer and is the biggest area dedicated to production, China is second and Egypt is first of the Arab countries. [3]. Yellow corn is a crucial grain and feed crop and is grown on a large scale in numerous countries throughout the world. In addition to its byproducts from processing, it is eaten directly or indirectly by millions of people across the world and can be used as a flour ingredient for human consumption, used to prepare a wide range of foods, and used in bread making, either on its own, or in blends with wheat flour, as well as being used indirectly in human food production [22]. It has also been used in a variety of industrial products like adhesives, ceramics, asbestos, plastics, textile dyes, printing ink, varnish, and in the rubber industry, as well as green fodder [23]. It is a concentrated feed as it has a high carbohydrate content (81%), some protein (about 10%) and some oils (4%) and also vitamins like B2, B1 and E. It is rich in protein with 93g per kg and contains 3,466 calories per kg, making it an important part of the livestock developing forage crops [24]. The interest in producing yellow corn has also grown worldwide because of its application in the oil and paper industries, which has led

to expansion of cultivated area, as well as the use of modern technologies in cultivation, harvesting, marketing and processing [25-28].

Damage from Root Rot

Root rot is a complex disease and can attack plants when they are young and old. It is a soil-borne pathogen which is significant for losses to barley crops in the South Asian countries [29] infecting corn varieties in all parts of the world and is regarded as one of the most important factors in yield loss. In the U.S., root rot was first detected in 1990. Root rot is a widespread disease in the United States in the Yellamite Valley and is found in all field crops caused by a complex of soil-borne fungi, such as *Pythium*, *Fusarium*, *Rhizoctonia*, *Philophora*, *Helminthosporium*, *Phoma* and *Trichoderma* [30]. The fungus *Phoma terrestris* causes red root rot in yellow corn [31]. In many crops including horticultural and forestry crops, yellow corn is an important host of *Fusarium*, which can cause diseases such as *Fusarium* stem and root rot and *Fusarium* ear rot that can be estimated as 10–30% loss annually in the field [32]. *Fusarium* spp., including *F. gramineum*, *F. culmorum*, *F. cerealis* and *F. poae*, are well known producers of trichothecene mycotoxins [33].

The causes of yellow corn root rot

The fungus *bipolaris sorokiniana* (Sacc.) Shoem

Morphological and Agronomic Characteristics of Pasture Crops

The mycelium of *B. sorokiniana* is normally dark olive brown. The fungus forms conidiophores which are simple, numerous, and singly or in clusters, conidiophores ($6-10 \times 110-120$ microns, septate); the spores are formed horizontally under each septum of the conidiophore. The spore is olive brown in colour and oval to oblong in shape with rounded ends and a prominent scar-like base, have $3-10$ septa, some of which are slightly curved, margins are smooth and markedly thick at the first septum, the spore size is (15-28 x 40-120 microns) [34,35, 29]. The sexual fruiting bodies are spherical pseudothecia, which have an erect beak up to 50–200 microns long. The spores are transparent, filamentous, of uniform shape and flexibly coiled, with $4-10$ inner septa, and size ($5-10 \times 200-250$) microns, inside the curved sacs of the fruiting body (20–35 x 150–250) microns [36].

Pathology and Symptoms

S. dimidiatus is the sexual stage of the fungus, *C. sativus*, while *B. sorokiniana* (Sacc.) is the asexual stage [37, 22]. The cause of many diseases of cereals, on the roots, leaves and stems; is a seed- and soil-borne fungus whose asexual stage, the fungus *C. sativus*, is responsible for infection. The leaf spot and common root rot are the two most common diseases caused by *B. sorokiniana* in wheat and barley crops and the fungus has fifteen susceptible crop species among wheat, barley and yellow corn [38]. The whole life cycle results in substantial yield losses, especially in the warm subtropical region [39]. Crop residues are also a major source of transmission [13] and fungal spores (conidia) from these crop residues remain viable for less than 5 months [40]. The fungus can also be spread by spores in the air or by water, wind, soil and seeds. [41, 42]. Initial symptoms of the fungus are seedling blight and infection takes place at the soil level where the seedlings die – typically before and after emergence.

Pre- and post-emergence damping-off problems

Infected seedlings are stunted, pale green or yellowish to bronze in colour, and watery to the touch; infected plants are spindly, easily pulled out and the root is dark brown with watery patches which can be peeled off the exterior of the root [43, 44]. Highest rates of fungal infections in the field are found at 6–7 cm soil depth and at the soil surface [45-47]. Leaf spots

and leaf blight on leaves are caused by the fungus [48, 49]. It also induces stem canker, leaf blight and root rot [40], black spot on seeds and seedling blight [50-52].

The fungus *Helminthosporium sativum* (Pammel) King et Bakke

The form and growth of the plant

It is a well-known fungus which causes root rot of wheat and is a cause of root rot in corn [53]. The mycelium is usually dark in colour, the spore-bearing structures are long, erect, solitary or clustered, and sporangia are light brown, growing laterally from pores beneath the septa as the structure develops at the apex. Typically, single, brown, translucent, elongated and segmented into several cells by false transverse septa, often with a scar-like sweller at the base typical of the parasite/pathogen of the genus *Helminthosporium sativum* [54-56].

***Fusarium avenaceum* (Corda ex Fr.) is a fungus. Sacc.**

Agronomic and Morphological Characteristics

The fungus produces a light orange coloured mycelial mat on Carnation Leaf Agra (CLA) medium and slowly to rapidly grows in white to light yellow or bright yellow to grayish pink on PDA medium. The medium gets a pinkish colour and can be brown; the shape of the colony on PDA can also vary. Large conidia are long, straight, thin walled, often curved at the apex, containing 3–4 or up to 5 septa and moderately abundant on the fungal substrate, sometimes with a foot-like shape with a basal cell. The spore-producing cells are monophialides or polyphialides, and are formed in some isolates but are generally few in number. The small conidia are slender, one per spore-producing cell, and vary in size, are produced on the substrate. This fungus is also sexually reproducing (as *Gibberella avenacea* Cook.) [56-59].

Pathology and Symptoms

Fusarium avenaceum is a soil-borne fungus which infects plants and attacks stem and root, causing the plants to rot. Transmitted through seed, it causes rot of roots, stem bases, crowns and tillers, and is referred to as foot rot in dry regions [60]. Upon landing on the host surface the fungal spores give rise to a number of germination tubes in 6–12 hours. The pathogenic hyphae then grow, infecting different parts of the female reproductive flower and after 3–4 days penetrating it into the ovary of the flowers. Once they penetrate the tissues, the pathogenic hyphae destroy the cellular contents (cytoplasm and organelles) which results in the atrophy of the tissue [61]. It is one of the most prevalent pathogens in general and produces the toxin, moniliformin, in the grain [62-65].

Chemical Control

In the interest of strategic crops where the crop is grown on a large scale, very large quantities of pesticides are required to control crop pathogens and this is considered undesirable. Several disadvantages are associated with this method such as the toxicity of these pesticides, the difficulty of application and the high cost of the chemicals, but because of the significance of these crops it is practiced in order to achieve rapid control of pathogens and application of seed treatment made it a less difficult and less extensive process. Thus, systemic pesticides have proved very effective in controlling the spread of the disease and have been used for *Fusarium* wilt (FW) control and in combination of FW and root rot (RR) [66, 67]. The use of seed treatment for chemical control of fungal disease has become an effective, economical and reliable means. There is a successful management of seed-borne fungi reported by [68]. fungicides prior to planting [69]. It was also determined that the seeds could be treated with the following fungicides: Captifol, chloronib, thiophenate-methyl, Trevorin, kaptain,

Prothecarb, Dawco 444, metalaxyl, thiabendazole, and thiram—reduced infection by several pathogens of field crops, such as *Pythium sp.*, *Rhizoctonia solani*, *F. oxysporum*, *Fusarium solani* and *Aphanomyces euteiches* [70]. Benzimidazole fungicides are one of the most appropriate and effective for vascular wilt diseases, and some are effective in controlling fusarium wilt, being effective only when the fungicide comes in contact with the roots of the plant.

The author [71] pointed out that fungicides being translocated in infected vessels may help lower infection levels, but will not affect secondary infections of roots, while injecting fungicides (such as benzimidazole derivatives) into the tree trunk will cause the fungicide to be translocated and to accumulate in the leaves, thus lowering vascular infections. The fungicide Topsin-M is a systemic fungicide belonging to the benzimidazole class, and it is known to control a wide variety of fungi at relatively low levels [72]. Several reports have also demonstrated the positive effects of using Topsin-M [73]. As for the fungicide Beltanol, it is a systemic fungicide belonging to the quinoline group. The fungicide was first registered by Fron [55, 75, 76] and its common name is hydroxyquinoline sulfate and its chemical name is hydroxyquinoline-8-sulfate. It has shown effectiveness against infection of *Botrytis cinerea* and *Phytophthora* spp. and as a bactericide. It has also been used as a preventive fungicide to disinfect soil of soil-borne diseases [77 – 79]. Beltanol is a 50% soluble systemic fungicide to control bacteria and fungi that invade the root and vascular system of plants. It and its residues are registered as safe, so its use is recommended as part of integrated pest management programs. The plant takes up the fungicide from the top to the bottom and the bottom to the top and since it is a strong and effective fungicide, it reaches the location of disease initiation and kills the pathogen right away. It can be used to control the growth of bacteria and fungi which affect the roots and tissues of plants, and can kill many species of fungi and bacteria including *Verticillium*, *Phytophthora*, *Fusarium*, *Rhizoctonia*, and others in a wide range of soil types and conditions. It also has the ability to promote and stimulate root and vegetative growth [80, 81, 51, 74].

Fertilization

Plants need a lot of potassium (K) for growth and production [82]. Apart from its role in photosynthesis, potassium is one of the most significant nutrients for plant growth and is essential in activating plant metabolic enzymes, protein and carbohydrate production, and in resistance to diseases and pests [83], Potassium is vital in control of stomatal opening and closing, and in increasing plant growth and productivity [84 -86, 81]. It also has an important role in the transport of carbohydrates and sugars, protein synthesis and nitrate reduction; in the absence of potassium in plants, proteins are not synthesized even in the presence of nitrogen, and the rate of photosynthesis and ATP production are decreased, affecting plant growth [86]. Potassium plays an important role in thickening cell walls, thereby enabling the plant to withstand various stresses such as disease and insect infestation or environmental stresses like salinity, drought, and high temperatures—especially when there is a balance between other elements and potassium [56]. Potassium is also a nutrient mobilizer which assists in moving nutrients from the root to the top tissues including leaves, grains, or fruits, and can move and store metabolites created during photosynthesis in the root/seed and move them to the top tissues, as in the transport of sugars in sugarcane [86]. Potassium needs in yellow corn build up 2–3 weeks before male flowering, and because it does not bind or become immobilized in the soil, it is available for uptake in either broadcast or band applications, so it is more desirable to apply it in a series of applications than as a single large application [87].

In addition to its role in enhancing the plant's drought tolerance [88] and increasing the plant's resistance to extreme cold without affecting plant growth [89, 76], it also has the ability to stimulate plant resistance, reduce the severity of infection, and improve the plant's systemic defenses [90- 92, 58].

Extension services provided to farmers on controlling yellow corn root rot

- 1) Conducting agricultural extension meetings for farmers on controlling yellow corn root rot.
- 2) Providing farmers with information and encouragement to go to the agricultural extension building to receive advice for controlling yellow corn root rot.
- 3) Providing technical assistance for farmers on the control of yellow corn root rot.
- 4) Extension personnel, primarily agricultural, visiting farmers' households to raise awareness about managing the control of yellow corn root rot.
- 5) Promoting safe and appropriate use of pesticides by farmers, including timing, method and rates.
- 6) Extension education field visits to update agriculturalists on yellow corn root rot control
- 7) Creating a media campaign to raise awareness about the importance of controlling yellow corn root rot.
- 8) Setting up demonstration plots to educate farmers on how to control yellow corn root rot [93].
- 9) Reporting the problems of farmers controlling yellow corn root rot to scientific research institutions in order to get the proper remedies.
- 10) Educating farmers, changing their attitude and helping them develop by convincing them of the latest developments in disease control and getting them to understand that the recommended control is in their own best interest.
- 11) Work to inform farmers about the causes of the economic damage resulting from yellow corn root rot infection.
- 12) Educate farmers on the symptoms of infection by yellow corn root rot.
- 13) Inform farmers about methods for early detection of yellow corn root rot infection.
- 14) Enhance Farmers Observation and Understanding to take the right decision at the right stage of the plant on the control measures of yellow corn root rot [94].

Farmers' Problem of Yellow Corn Root Rot

1. Insufficient number of agricultural extension agents trained in controlling yellow corn root rot.
2. Lack of agricultural extension agents' seminars, meetings and sessions on disease control.
3. The absence of periodic assessment of the farmers' efforts on control, by agricultural extension agents.
4. Unprompted follow-up by agricultural extension agents of recommendations with regards to control.
5. High cost of controlling yellow corn root rot.
6. A lack of government support to farmers in controlling crop diseases.
7. The lack of knowledge about effective pesticides among farmers, is a problem.
8. Failure by the responsible authorities to apply pesticides at the appropriate time [95].
9. Farmers' lack of knowledge and skills in controlling yellow corn root rot
10. Lack of training courses for farmers for controlling yellow corn root rot.
11. Misuse and improper choice of pesticides by farmers [96].
12. Conflicts between the schedules of seminars and extension meetings and farmers' fieldwork commitments.

13. Not applying proper agricultural extension tools and resources for the control of yellow.
14. Still, the unwillingness of some farmers to participate in agricultural extension activities [94].

Strategies to overcome challenges of farmers in fighting Yellow corn root rot

- 1) Take into account farmers' limited knowledge of combating yellow corn root rot when planning an extension program.
- 2) The need for novel approaches to control yellow corn root rot by the agricultural extension service.
- 3) Ensure that pesticides are available to farmers at a reasonable cost.
- 4) Organize numerous meetings and seminars on controlling yellow corn root rot [95].
- 5) Use agricultural extension methods that are appropriate and preferred by farmers to obtain information on controlling yellow corn root rot [96].
- 6) Provide periodic training of agricultural extension agents to keep them abreast of advances or new knowledge in the control of yellow corn root rot.
- 7) Train agricultural extension agents to initiate and organize farmers into formal or informal groups/associations and to effectively manage them to ensure regular farmer communication.
- 8) Agricultural extension services should plan and implement further agricultural extension programmes for farmers on the control of yellow corn root rot in the area.
- 9) Review agricultural extension programmes for controlling yellow corn root rot periodically to strengthen their strengths and overcome their weaknesses [93].
- 10) Make careful choices of locations and times for implementation of extension programs to control yellow corn root rot.
- 11) Assistance in giving financial and technical support to farmers [97].
- 12) Respecting farmers' promises.
- 13) Implementing multiple modern tools and resources to fix the success of agricultural extension program to control yellow corn root rot [98].
- 14) Distribute pest control posters, brochures and periodicals
- 15) Make adequate numbers of field agricultural extension agents available to provide farmers with information on control of yellow corn root rot.
- 16) Establishment of sustainable agricultural field extension schools - field based hands-on training throughout the entire agricultural growing season and following the different stages of crop development and all relevant control measures [99- 101].

Conclusion

The study revealed that *Bipolaris sorokiniana*, *Fusarium arenaceum* and *Helminthosporium sativum* are the most significant and common root rot fungi in these countries. *Bipolaris sorokiniana* is the most prevalent pathogen of yellow corn with high pathogenicity on root rot. Moreover, the impact of the fungi across the plant traits was variable with *Bipolaris sorokiniana* causing the greatest damage to the roots of yellow corn. Pesticide tests indicated that the fungicide Biltanol was one of the most effective in inhibiting growth and sporulation of all fungi, and reduced root rot incidence by improving the characteristics of the corn plants and increasing the number of ears produced per growing season. Potassium application to yellow corn plants proved to be very effective in reducing severity of root rot infection and improving most of the traits of the corn varieties. Agricultural extension's role in control of yellow corn root rot and to limit its spread. In light of our knowledge, we are recommended that planting

of disease resistant varieties is recommended to reduce disease losses. Control the disease using the fungicide Biltanol and Topsin-M as they play a significant role in eradicating the root rot disease. Therefore, fertilize with potassium to decrease root rot and to enhance the attributes of most types of corn. Test genetic varieties in the future that are more resistant to the disease and tolerant to pests and adverse environmental factors. Finally, place greater emphasis on providing agricultural extension programs to farmers on management of yellow corn root rot.

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