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Sustainable Management Studies on Bacterial Wilt Diseases of Groundnut Crops

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Abstract

The world’s population is rising every year. In order to meet the demands of a still expanding human population, global crop production needs to double by 2050; though, current estimates are far below what is needed (Ray DK et al., 2013). Plant diseases, insects and weeds are decreasing the production of crops global by 36%, and diseases alone have been shown to reduce crop yields by 14% (Agrios GN., 2005). As result, the control of plant diseases contributes to increased crop production. Among plant diseases, soil-borne diseases are considered to be more restrictive than seed-borne and air-borne diseases in the production of several crops and account for 10–20% of yield losses annually (USDA., 2003).

Keywords: Biofumigation, Biological control, Degradation, Resistance, Solarization.

Introduction

Elphinstone et al (2005), extensively compiled the bacterial wilt in and different studies have since been carried out on this topic. Based on their scientific and economic importance in plant diseases, the top ten bacterial species have been listed as: (i) X. axonopodis pathovars, (ii) Erwinia amylovora, (iii) Agrobacterium tumifaciens, (iv) Xanthomonas oryzae pv. oryzae, (v) X. campestris pathovars, (vi) Xylella fastidiosa, (vii) Dickeya (former Erwinia) (dadantanii and solani), (viii) Pectobacterium (former Erwinia) carotovorum (ix) Pseudomonas syringae pathovars and (x) Ralstonia solanacearum, (Mansfied et al., 2012). R. solanacearum (Smith) Yabuuchi et al. (1995) (syn. Pseudomonas solanacearum [Smith], Burkholderia solanacearum [Smith]) causes a vascular wilt disease and has been ranked as the second most significant bacterial pathogen. It is one of the most destructive pathogens recognized to date because it induces rapid and fatal wilting symptoms in host plants. The host amplitude is extensively wide, more than 200 species, and the pathogen is distributed worldwide and induces a destructive economic impact (Kelman A., 1998).

Aim of the study

In the present study attempts were control to bacterial wilt diseases and yield loss of groundnut in different growing areas. Find out different methods to control bacterial wilt pathogens.

Material and Methods

Management with biological, physical and cultural methods of bacterial wilt have been investigated for decades. We in this discussed the following points, (i) methods used to control bacterial wilt and (ii) how these methods are useful for improving crop production through the suppression of bacterial wilt.

1. Biological methods:

Biological Control Agents (BCAs)

Interest in biological control has increased due to concerns in excess of the general use of chemicals (Whipps J., 2001). The profit of biological control agents are (1) potentially self-sustaining, (2) spread on their own after initial establishment, (3) reduced input of non-renewable resources, and (4) long-term disease suppression in an environmentally friendly manner (Quimby FC., et al 2002). The methodology adopted by BCAs is followed by various interactions such as competition for antibiosis, parasitism, nutrients, space and induced systemic resistance (Agrios GN., 2005). Our reference survey exposed that BCAs have been dominated by bacteria (90%) and fungi (10%). Montesinos (2003) found that mainly patented BCAs are made of bacteria. Previous studies showed the potential value of several promising BCAs, which are dominantly avirulent strains of R. solanacearum and Pseudomonas spp., followed by Streptomyces spp., Bacillus spp. and the other species, in controlling bacterial wilt disease.

A total of 109 strains of endophytic or rhizobacteria were in recent times screened for their antibacterial activities against R. solanacearum, and effectual isolates (a total of 22) consisted of Pseudomonas spp. (18 isolates) and Bacillus sp. (2 isolates) (Ramesh R., 2012). Huang et al. (2013) exposed that isolates diseased plants from the rhizosphere performed better in falling disease incidence that those of healthy plants. In their study, the biocontrol efficacies of the antagonists were connected to root colonizing capacities, but not with antibiosis in vitro, suggesting that root colonizing capacity may play a key role in disease suppression.

Organic Matter

Organic amendments of the soil have direct impacts on plant health and crop productivity. They are beneficial because they improve the biological, physical, chemical and biological properties of soil, which can have positive effects on plant growth (Bailey KL. et al., 2003). The degradation of organic matter in soil can directly affect the viability and survival of a pathogen by restricting available nutrients and releasing natural chemical substances with unreliable inhibitory properties (Bailey KL. et al., 2003). Carbon released during the degradation of organic matter contributes to increasing soil microbial activity and thus enhances the likelihood of competition effects in the soil (Bailey KL. et al., 2003). Organic amendments to soil have been shown to arouse the activities of microorganisms that are antagonistic to pathogens (Akhtar M and Malik A., 2000). In addition, organic amendments often contain biologically-active molecules such as vitamins, growth regulators, and toxins, which are able to affect soil microorganisms.

Review of Literature

Plant residue controlling bacterial wilt

Several previous studies have reported that bacterial wilt was suppressed by plant residue extracts of, e.g. chili (Capsicum annum) (Teixeira FR., 2006), Chinese gall (Rhus chinensis) (Yuan GQ. et al., 2012), clove (Szygyum aromaticum) (Amorim EPD., 2011), cole (Brassica sp.) (Arthy JR. et al., 2005), eggplant (Solanum melongena), (Almeida HO. et al., 2007), eucalyptus (Eucalyptus globules) (Paret ML. et al., 2010), geranium (Geranium carolinianum) (Ooshiro A. et al., 2004), guava (Psidium guajava and P. quineense) (Acharya S and Srivastava RC., 2009), hinoki (Chamaecyparis obtusa) (Yu JQ and Komada H. Hinoki., 1999), Japanese cedar (Cryptomeria japonica) (Hwang YH. et al., 2005), lemongrass (Cimbopogon citratus) (Paret ML. et al., 2010), marigold (Tagetes patula) (Terblanche J, de Villiers DA. Et al., 1998), neem (Azadirachta indica) (Pontes ND. et al., 2011), palmarosa (Cimbopogon martint) (Paret ML. et al., 2010), pigeon pea (Cajanus cajan), sunn hemp (Crotalaria juncea) (Cardoso SC. et al., 2006), tamarillo (Cyphomandra betacea) (Ordóñez RM. et al 2006), thyme (Thymus spp.) (Pradhanang PM. et al., 2003), wood wax tree (Toxicodendron xylvestre) (Yuan GQ. et al., 2012), and worm killer (Aristolochia bracteata) (Shimpi SR et al., 2005). The possible mechanisms of action of the plant residues are mainly considered to be antimicrobial activities, followed by the indirect suppression of the pathogen during improved physical, chemical, and biological soil properties (Cardoso SC. et al., 2006).

Animal Waste Controlling Bacterial Wilt

Although a lot of studies have already reported that animal waste controls plant disease, few have shown that animal waste suppresses bacterial wilt disease. For example, the use of pig slurry decreased the population of R. solanacearum in the soil (Gorissen A et al., 2004). The mechanisms underlying the enhanced decline of the population of this pathogen and disease suppression remains unclear; though, shifts in bacterial community profiles have been proposed. Another study recommended that the suppression of bacterial wilt by poultry and farmyard manure were related to higher microbial activity and higher numbers of cultural bacteria and fungi (Islam TMD, Toyota K., 2004). In that study, a lower disease index was connected to the poor survival of the pathogen. However, limitations are linked with the wide use of organic waste. Janvier et al. (2007) have proved that the main key-points for the efficiency of organic materials in the inhibition of plant pathogens normally depend on: (i) the plant-pathogen combination, (ii) the rate of application, (iii) the nature or type of amendment and finally (iv) the degree of maturity of the decomposition stage of the crop residues.

Simple organic compounds controlling bacterial wilt

The suppression mechanism was not attributed to the stimulation of systemic resistance, but to shifts in the soil microbial community structure that led to the more rapid death of the pathogen (Posas MB and Toyota K., 2007). Protection of groundnut against R. solanacearum carried out through a riboflavin induced series of defense responses and secondary metabolism in cell suspensions (Liu F et al., 2010). DL-3-aminobutyric acid (DABA) also decreased that of catalase but increased the polyphenol oxidase activity in groundnut plants, suggesting the induction of resistance to bacterial wilt in the tomato crops (Hassan MAE and Abo-Elyousr KAM., 2013). Another study showed that methyl gallate exhibited burly bactericidal effects on R. solanacearum (Fan W-W et al., 2014).

Physical methods, including biofumigation

A number of physical control methods, *e.g.* soil solarization and warm water treatments, have proved to be effective against *R. solanacearum*. Another study reported that rhizome solarization on ginger seeds for 2 to 4 h reduced bacterial wilt through 90–100% 120 d after planting, and that ginger seeds sterilized with discontinuous microwaving (10-s pulses) at 45°C reduced the incidence of wilt by 100% (Kumar P, Sood AK., 2005). Microbial respiration, soil pH, potassium (K), sodium (Na), boron (B), zinc contents and microbial biomass are reduced by soil solarization and did not significantly affect on other soil chemical properties. A heat treatment at either 45°C for 2 d or a minimum temperature of 60°C for 2 h of the infected soil prior to groundnut planting reduced the total bacterial population by 60–97%, that of *Ralstonia* sp. from 2 to 7×10^8 cfu g^{-1} to 0 to 115 cfu g^{-1}, and the incidence of bacterial wilt by 50–75% (Vongkiatkajorn J, Thepa S., 2007).

Cultural practices Cultivar resistant

The growth of cultivars that are resistant to bacterial wilt is considered to be the environmentally friendly, most economical and effective method of disease control. Breeding for resistance to bacterial wilt has been concentrated on crops of wide economic importance such as the groundnut, tomato, potato, tobacco, eggplant, pepper and have commonly been influenced by factors such as the availability of resistance sources, their diversity, genetic linkage between resistance, and other agronomic qualities, differentiation and variability in pathogenic strains, the mechanism of plant-pathogen interactions, and breeding or selection methodology (Boshou L., 2005).

For instance, the Arabidopsis NPR1 (non-expresser of PR genes) gene was introduced into a tomato cultivar which reduced the incidence of wilt by 70% approximately 28 days after the inoculation and enhanced resistance to bacterial wilt (Lin WC et al., 2004). Somatic hybrids which were produced with the electrical fusion of mesophyll protoplasts of S. melongena cv. Dourga and two groups of S. aethiopicum were found to be tolerant to R. solanacearum (Fock I et al., 2000). Prior et al. (Prior P et al., 1996) showed that resistant plants were deeply invaded by R. solanacearum without displaying wilt symptoms. A proteomic approach was used to illuminate molecular interactions in the cell walls of resistant and sensitive plants inoculated with R. solanacearum (Dahal D et al., 2010). Resistance to bacterial wilt in so many crops is negatively connected with quality and yield. Thus, the release of resistant cultivars may be poor because of other agronomic qualities and are not widely accepted by farmers or consumers.

Crop rotation, multi-cropping

The benefits of crop rotation are maintenance of the soil structure and organic matter, and a reduction in soil erosion that is often connected with continuous row crops (Janvier C et al., 2007). Though continuous cropping with the same susceptible host plant will lead to the establishment of specific plant pathogenic populations, crop rotation avoids this detrimental effect and is often associated with a reduction in plant diseases caused by soil-borne pathogens (Janvier C et al., 2007). In an example of multi-cropping, Yu et al. (Yu JQ., 1999) have reported the suppression mechanisms because the root exudates of Chinese chive which may prevent R. solanacearum from infecting tomato plants of Chinese chive (Allium tuberosum), finally reduced the incidence of bacterial wilt in the groundnut (approximately 60%).

Soil amendment

Previous studies exposed that the application of fertilizers reduced the incidence of bacterial wilt. Calcium (Ca) is the most familiar fertilizer to suppress disease. In the stems of the groundnut plants increased Ca concentrations reduced the severity of bacterial wilt as well as the population of *R. solanacearum* (Yamazaki H et al., 2000). Lemaga *et al.* (2005) reported that the application of nitrogen (N) + phosphorus (P) + K and N + P (application rate of each fertilizer = 100 kg ha^{-1}) reduced bacterial wilt by 29% to 50%. Higher soil pH and Ca content were also role a key factors in the control of bacterial wilt by the rock dust amendment. Many elements in the cell walls influence the susceptibility or resistance of plants to infections with pathogens and silicon is considered to be a beneficial element for plants (Epstein E., 1999). Kiirika et al. (2013) reported that the combined application of silicon and chitosan reduced the incidence of bacterial wilt in the groundnut by inducing resistance. Silicon and chitosan exhibited synergistic effects against the disease (Integrated Pest Management (IPM).

Result and Discussion

Hyakumachi et al. (2013) recently exposed that B. thuringiensis, a well-known bioinsecticide-producing bacterium, induced defense-related genes, such as acidic chitinase, PR-1 and beta-1,3-glucanase showed resistance against a direct inoculation with R. solanacearum. The expression of numerous salicylic acid-responsive defense-related genes was confirmed to be specifically induced (Takahashi H. et al., 2014), and also that suppression by B. thuringiensis may differ from the induced systemic resistance (ISR) elicited by several plant growth-promoting rhizobacteria (PGPR), in which jasmonic acid and ethylene-dependent signaling pathways mediate plant resistance to pathogens (Takahashi H. et al., 2014). Successful trials with BCA in the field are introduced in Table.

Table

To control the bacterial wilt diseases caused by Ralstonia solanacearum following are the various bio-control agents that have been tested in the field:-

Name of Microorganisms	Methods of Inoculation and application rate	Mechanisms	BCE (%)	Yield Production*	Ref.
1. Bacillus amyloliquefaciens SQR-7 and SQR-101 and Bacillus methylotrophicus SQR-29	Pouring, 6.8×10^{10} cfu $plant^{-1}$ (SQR-7), 7.5×10^{10} cfu $plant^{-1}$ (SQR-101), 8.2×10^{10} cfu $plant^{-1}$ (SQR-7)	Production of indole acetic acid and siderophores	18–60 % in tobacco	25–38%	Yuan S. et al., 2014
2. Ralstonia pickettii QL-A6	Stem injection, 10 μL of 10^7 CFU mL^{-1}	Competition	73% in the tomato	NA	Wei Z. et al., 2013
3. Pseudomonas monteilii (A) + Glomus fasciculatum (B)	Stem cuttings were dipped in A (9.1×10^8 mL^{-1}), B (53 infective propagules) was added to each cutting, and A was then poured again	Increased plant nutrient uptake (N, P, K) and reduced the pathogen population	56–75 % in herbs (Coleus forskohli)	54%	Singh R. et al., 2013
4. Brevibacillus brevis L-25 + Streptomyces roche L-9 + organic fertilizer	Mixed with soil at a density of 7.3×10^7 (L-25) and 5.0×10^5 (L-9) cfu g^{-1} of soil	Decreased root colonization by the pathogen	30–95 % in tobacco	87–100%	Liu Y. et al., 2013

5. Bacillus amyloliquefaciens + bio-organic fertilizer (BIO23) B. subtilis + bio-organic fertilizer (BIO36)	Mixed with soil at a density of 5.5×10^6 (BIO23) and 7.0×10^6 (BIO36) cfu g^{-1} of soil	Plant growth promotion	58–66 % in the potato	64–65%	Ding C. et al., 2013
6. Bacillus sp. (RCh6) Pseudomonas mallei (RBG4)	3×10^8 cfu g^{-1} (talc formulation). Leftover suspension was poured around the root zone of the seedling (50 mL $plant^{-1}$)	Production of inhibitory compounds and siderophores	81% in the eggplant	60–90%	Ramesh R. and Phadke GS., 2012
7. Trichoderma viride (A), Bacillus subtilis (B), Azotobacter chroococcum (C), Glomus fasciculatum (D), P. fluorescens (E)	D (53 infective propagules) was added to each stem cutting that was dipped in A (1.2×10^6 CFU mL^{-1}), B (1.8×10^8 CFU mL^{-1}), C (2.3×10^7 CFU mL^{-1}), and E (2.5×10^8 CFU mL^{-1}).In a sample of 200 gm soil, a total of 5 mL of A, B, C, and E was then poured.	Reduced population of R. solanacearum and competition for nutrient uptake (NPK)	7–43% in herbs (Coleus forskohlii)	159–227%	Singh R. et al., 2012
8. B. amyloliquefaciens QL-5, QL-18 + organic fertilizer	Mixed with soil at a density of 1×10^7 (QL-5) or 1×10^7 (QL-18) cfu g^{-1} of soil	Decreased root colonization by the pathogen	17–87 % in the tomato	NA	Wei Z. et al 2011
9. B. amyloliquefaciens Bg-C31	Poured 10 mL of bacterial suspension $plant^{-1}$ (potato dextrose broth culture).	Production of antimicrobial proteins	60–80 % in Capsicum	NA	Hu HQ. et al., 2010
10. Acinetobacter sp. Xa6, Enterobacter sp. Xy3	Poured 20 mL of the bacterial suspension (1×10^9 cells mL^{-1}) $plant^{-1}$ or seedling roots were soaked in the bacterial suspension.	Rhizocompetence and root colonization	57–67 % in the tomato	32–41%	Xue QY. et al., 2009
11. B. vallismortis ExTN-1	Bacterial suspension was mixed into an organic fertilizer (10^6 cfu mL^{-1}) and poured onto soil.	Induction of systemic resistance	48–49 % in the tomato	17%	Thanh D.T. et al., 2009

12. Glomus mossease	A total of 30 g of the inoculum (650–700 spores of G. mossease 100 g^{-1} soil) was added to a planting hole.	Competition for nutrients and decreased pathogen population	25% in the tomato	16%	Taiwo LB. et al 2007

BCE: biological control efficacy, NA: not applicable, Yield*: increase in yield

Some fungal BCAs also have been reported to control bacterial wilt. One another fungal species, Pythium oligandrum, has the efficiency to control bacterial wilt disease, in which cell wall proteins may play an significant role in the stimulation of resistance to R. solanacearum, along with activation of the ethylene-dependent signaling pathway (Hase S., 2006). An antibiotic ingredient “shiitake mycelia leachate” was suppressed the growth of R. solanacearum, in vitro (Pacumbaba RP., 1999). In addition, three endomycorrhizal fungi (Gigaspora margarita, Glomus mosseae, and Scutellospora sp.) (Tahat MM. et al., 2012) and the lichen Parmotrema tinctorum (Gomes AT. et al., 2003) have been recognized as BCAs against R. solanacearum.

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Conclusion

Previous studies exposed that the application of fertilizers reduced the incidence of bacterial wilt. Calcium (Ca) is the most familiar fertilizer to suppress disease. In the stems of the groundnut plants increased Ca concentrations reduced the severity of bacterial wilt as well as the population of *R. solanacearum* (Yamazaki H et al., 2000). Lemaga *et al.* (2005) reported that the application of nitrogen (N) + phosphorus (P) + K and N + P (application rate of each fertilizer = 100 kg ha^{-1}) reduced bacterial wilt by 29% to 50%. Higher soil pH and Ca content were also role a key factors in the control of bacterial wilt by the rock dust amendment. Many elements in the cell walls influence the susceptibility or resistance of plants to infections with pathogens and silicon is considered to be a beneficial element for plants (Epstein E., 1999). Kiirika *et al.* (2013) reported that the combined application of silicon and chitosan reduced the incidence of bacterial wilt in the groundnut by inducing resistance. Silicon and chitosan exhibited synergistic effects against the disease (Integrated Pest Management (IPM).

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