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Bacterial Diseases of Plants in Nepal: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Author NSP designed the study, managed the literature and wrote the first draft of the manuscript. Author SN managed the literature searches and the analyses of the study. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Bacterial diseases are the important disease next to the fungal diseases in Nepal. In Nepal, major bacterial diseases are Bacterial leaf blight of rice (*Xanthomonas oryzae* pv. *oryzae*), Bacterial wilt of potato and tomato (*Ralstonia solanacearum*), Citrus greening (*Candiditus liberibacter*), Citrus canker (*Xanthomonas campestris pv. citri*), Soft rot of potato (*Erwinia carotovora pv. atroseptica)* and Black rot of crucifers (*Xanthomonas campestris pv. campestris*) as they are prevailed in most of areas and cause the devastating losses. Others are the minor diseases with less economic importance which includes Bacterial stalk of maize (*Erwinia chrysanthemi pv. zeae*), bacterial postulates of soybean (*Xanthomonas campestris pv phaseoli*), Potato scab (*Steptomyces scabies*). Some of the minor diseases like Stewart's wilt of corn (*Pantoea stewartii*), Bacterial speck of tomato (*Pseudomonas syringae pv. tomato*), Bacterial spot of tomato (*Xanthomonas campestris pv vesicatoria*), Bacterial sheath rot of wheat (*Pseudomonas fuscovagitlcae*), Crown gall (*Agrobacterium tumefaciens*), Bacterial leaf strip (*Xanthomonas rubrilineans*) and Bacterial spots of pumpkin (*Xanthomonas cucurbitae*) are recorded in Nepal.

Keywords: Bacterial diseases; economic importance; major.

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1. INTRODUCTION

Plant disease is the major constraint in production of agricultural crops. In Nepal, bacterial diseases are most prevalent after fungal diseases. Most destructive bacterial diseases are bacterial leaf blight of rice, bacterial leaf streak of rice, wilts of solanaceous crops, citrus greening, citrus canker and black rot of crucifers. And other are considered as a minor diseases. The research works on bacterial disease was initiated in Nepal after the establishment of Plant Pathology Section, in 1954. Now, Nepal Agriculture Research Council (NARC), Institute of Agriculture and Animal Sciences (IAAS) and Agriculture and Forestry University (AFU), Nepal Academy of Science and technology (NAST) and Prubanchal University (PU) are active in phytopathological research in Nepal. Phytopathological researches are mainly focused in the fungal disease and fewer researches are conducted in diseases caused by bacteria, virus and nematode.

2. BACTERIAL DISEASES OF RICE

2.1 Bacterial Blight

Bacterial blight [BB] caused by *Xanthomonas oryzae pv.oryzae* was first observed in the Terai region with the introduction of high-yielding rice varieties. In Nepal, BLB was reported as early as 1968 in Kathmandu valley [1]. However, it spread rapidly in subsequent years and is now prevalent throughout the Terai and hills of Nepal.

2.1.1 Occurrence and economic importance

The disease was reported to occur widely in Terai and inner Terai region of Nepal causing significant yield loss [2]. Disease incidence was reported higher in eastern Terai than in the western part [3]. The combination of wet weather, strong wind and moderate temperature in Kathmandu favoured rapid disease spread [4]. The disease causes severe effect in rice production [5] and can reduce grain yields up to 26% especially during prolonged periods of rainy weather from August to October. Similarly, yield loss of 13-32% was reported on susceptible cultivar Taichung Native-1 [6]. Yield loss ranging from 5-60% in Terai and mid-hill during hot and humid period is common in Nepal [7].

2.1.2 Pathogenic variability

The pathogenic races vary from location to location [8]. There are two major groups of *X. oryzae* pv. *oryzae* in Nepal. One group consists of strains with high molecular polymorphism and many pathotypes that are either virulent to the 11 major resistance genes or virulent only to *Xa21*. Strains in the second group have low molecular polymorphism and are avirulent to *Xa4*, *xa5*, *Xa7*, and *Xa21* [9]. This disease is restricted to hilly region and at altitude of about 1,238 m of Katmandu valley [4]. Nine pathogenic races were identified based on differential interaction on eight rice cultivars [10].

2.1.3 Virulence

The ability of an isolate to cause lesions with different length across the line was interpreted as virulence. The races were virulent to many important resistance genes and the genetic diversity was high (0.98) in the races collected from Nepal [11]. Adhikari et al. [12] found that a line with a four gene combination (NaH56) showed higher level of resistance to *Xanthomonas oryzae pv*. *oryzae* than the other lines. Most strains from South Asia (Nepal and India) were virulent to cultivars containing the bacterial blight resistant gene xa5 [11].

2.1.4 Host resistance

Long term research on host resistance of bacterial blight has been conducted and found different resistant and susceptible varieties in different time and locations. IR36, IR54, IR60, and IR64 showed high levels of resistance to *Xanthomonas oryzae pv*. *oryzae* [5]. The research on resistance of different varieties to the different strains of *Xanthomonas* found higher level of resistance by IR-BB8 which is nearly two-thirds of the strains of *Xanthomonas oryzae pv*. *oryzae* that were evaluated [13].

Rice cultivars BR-34-13, PAU-50-B-25, Lawmi, Sabitri, BW293-21, IR7167-33, Rodina, are resistanct [14]. Burlakoti et al. [7] reported Chandina, Bindeshwori and Chaite-2 cultivars as a moderately resistant. Research carried out under Bhairahawa conditions showed BR 4962-12-4, Barkhe 2001, BRRI Dban-26, NR 1988-2-3-5,JR 7699-44-3-3-1 and Barkhe 2045 as best genotypes having stable and higher level of resistance against bacterial blight [15]. Bhatta et al. [16] reported BLB resistant genes Xa-10, Xa-13, Xa-7, Xa-3, Xa-4, Xa-5, Xa-8 in Nepal. *Xa-3, Xa-4, xa-5, Xa-7, xa-8, Xa-10* and *xa-13* were found on several rice accessions but not *Xa-21.* Nepalese rice accessions lack the Xa-21 genes which is more important for controlling BLB epidemics throughout the world [17].

Hardinath-1, Tarahara-1, Sukhhadhan-1, Sukkhadhan-2, Sukkhadhan3, Hardinath-2, Swarna s ub1, Samba mahasuri sub1 and Mithila were resistant to blast and BLB [18]. Dangal, et.al, carried screening of 134 genotypes out of which 34 genotypes were moderately resistant to BLB [19]. The survey was conducted in three districts of mid-eastern regions of Nepal. Survey on crop disease revealed low disease incidence in Makawanpur, Radha 4 and Sabitri varieties of rice at Baridya and Dang while resistance was found on SukhaDhan 1 and Sukha Dhan 2 grown at Banke district of mid western Nepal [20].

2.1.5 Chemical control

Blitox or Validamycine @ 2-3 gm/litre of water was found effective in controlling BLB [18]. Foliar spray of 100 ppm streptocycline has been recommended against the bacterial leaf blight disease of rice [7].

2.1.6 Cultural control

The daily application of 2-3 handful of cow dung mixed in 10 litre of water upto 14 days of disease occurrence helps to reduce the bacterial leaf blight of rice. Application of aqueous extract of agave is also effective for control of BLB of rice.

2.2 Bacterial Sheath Brown Rot

2.2.1 Occurrence and economic importance

Bacterial sheath brown rot is an important disease of rice in high altitude and high rainfall areas of Nepal. Sheath brown rot caused by *Pseudomonas fuscovaginae* was first reported from Hokkido, Japan and has been found to be induced by chilling temperature. The disease is seed borne and transmitted from seed in early 1990s [21].The greenish, light brown highly fluorescent colonies are isolated from the sample above 1400 m while some suspected colonies were observed in lower altitude like 1010 m [22].

2.2.2 Identifying

At seedling stage, a systemic discoloration occurs, which may spread to the midrib or veins of the leaves. Symptoms typically occur on the leaf sheath at booting stage and on the panicle. Infected seedlings initially show yellow to brown discoloration on the lower leaf sheath.

2.2.3 Control

Avoiding diseased seed and timely sowing to avoid low temperature is crucial for disease prevention. Treatment of the seeds with hot water is needed (65°C to 70°C) for better disease management. Further use of seedlings that are 20−30 days older reduces the disease incidence.

3. BACTERIAL DISEASES OF MAIZE

Maize is second most important cereal crop after rice in Nepal and also the principal staple cereal diet of most of the Nepalese people living in hilly region. In Nepal maize plants are affected by wide range of pathogens primarily fungal and bacterial. Maize is susceptible to few pathogenic bacteria compared to pathogenic fungi. Three bacterial species have been recorded pathogenic to maize crop in Nepal [23].

3.1 Bacterial Stalk Rot of Maize

3.1.1 Occurrence and economic importance

Bacterial stalk rot [*Erwinia chrysanthemi pv. zeae* (Sabet) Victoria, Arboleda & Munoz] was first reported in 1968 at Rampur, Chitwan [24]. Stalk rot is distributed throughout the country, but it is most prevalent in the hot and humid areas [25]. It is mostly confined to Terai and inner Terai as a major disease. It is extended to some pockets of the mountains and Kathmandu valley as minor disease [24]. Bacterial stalk rot caused up to 80% yield loss along with fungal diseases in maize in the plains of Nepal. Sarlahi Seto and E2 Illinois were moderately resistant maize varieties cultivated in Nepal [7].

3.1.2 Identifying

The initial symptom is discoloration of the leaf sheath and stalk at a node. Lesions develop on the leaves as well on the sheath as the disease progresses. As the decay progresses foul odour can be detected and the top of the plant which can be very easily removed from the rest of the remaining plant. Eventually the stalk rots completely and the top collapses. Although it may spread along the plant to infect additional nodes, the bacteria do not usually spread to neighbouring plants unless vectored by an insect. Splitting the stalk reveals internal discoloration and soft slimy rot mostly initiating at the nodes.

3.1.3 Control

Hybrid resistance has been reported but as this disease occurs so infrequently, resistance genes are not routinely breed into hybrids and resistance ratings are not usually reported. Management of bacterial stalk and top rot includes fall cultivation to incorporate residue and avoiding excessive irrigation or flooding.

3.2 Bacterial Leaf Strip and Stewart Wilt of Maize

3.2.1 Occurrence and economic importance

Xanthomonas rubrilineans is the causal organism of minor disease bacterial leaf strip of maize which was first reported by Manandhar in 1976 at Rampur. The Stewart wilt of maize caused by *Erwinia stewartii* (E.F. Smith Dye) Dowson also reported from Rampur for the first time in 1978 [24].

3.2.2 Identifying

Two phases of Stewart's wilt occur. The seedling wilt phase occurs when young plants are infected systemically .The leaf blight phase occurs when plants are infected after the seedling stage.

3.2.3 Control

Planting resistant corn hybrids is an important control measure of this disease.

4. BACTERIAL DISEASE OF WHEAT

4.1 Bacterial Sheath Rot

The bacterial sheath rot of wheat is caused by bacterium *Pseudomonas fuscovagitlcae.* The bacterium was noted from Nigale farm in 1994 and Lumle Agriculture Center in 1995. The bacteria was identified by cultural characteristics biochemical and pathogenicity test. This was the first report of the disease. Annapurna-I, Annapuma-2, Annapuma-3 and WK.685 noted to be highly infected [22].

4.1.1 Identifying

With severe infections, the entire leaf sheath may become necrotic and dry out, and the panicle withers. The sheath may also exhibit general water-soaking and necrosis without definable margins.

4.1.2 Control

Clean the field immediately after harvest, and off-season cultivation of a crop. Make sure to remove plant litter and re-growths. Treating seeds with hot water at 65°C reduce the disease.

5. BACTERIAL DISEASES OF CITRUS

5.1 Citrus Greening

Citrus greening also known as Huanglongbing (HLB) disease is one of the major disease of citrus caused by a vectored pathogen. The causative agent is *Candidatus Liberibacter,* fastidious phloem-restricted, gram-negative bacteria. Transmission is by the Asian citrus psyllid (*Diaphorina citri)* and also by graft transmission [26]. Citrus decline was first reported in Pokhara valley by Thrower in 1968 [27]. Based on visual observation, Knorr et al suspected that the citrus decline was caused by greening disease entered with the planting materials introduced to Horticulture Research Station, Pokhara from Saharanpur, India [28]. HLB has been considered the number one among many biotic factors contributing to low productivity and threat to citrus industry in Nepal [29].

5.1.1 Occurrence and economic importance

Up to 39-55% mandarin trees were found infected with greening disease in Pokhara valley [28]. The symptoms of Citrus Greening was noted on about 55% of citrus trees in Pokhara valley and 100% in Horticulture Research Station in 1980s [30]. More recent HLB is widespread in many citrus pockets of Kaski, Syanja, Tanahu, Lamjung and Dhading districts [29,31]. This disease had resulted to massive decline of citrus orchards especially located below 1000 m altitude where population of vector – psyllid is abundant [32].

5.1.2 Host resistance

Most of the commercial citrus species of Nepal like mandarin and sweet orange are very susceptible to the disease while acid lime is slightly tolerant, but it carry HLB bacterium which source of inoculums of disease [32].

5.1.3 Chemical control

In citrus, greening was epidemic throughout the country. Proper management of orchard followed by copper fungicide spray reduced the infection [7].

5.2 Citrus Canker

Citrus canker is one of the problematic diseases of citrus which affect almost all types of important citrus crops. The disease causes extensive damage to citrus which probably originated in Southeast Asia or India, and now occurs in more than 30 countries [33]. The disease is caused by *Xanthomonas campestris* (=*axonopodis*) pv. citri (*Xcc)* [34].

5.2.1 Management

The local varieties/cultivars of mandarin and sweet oranges were found resistant to citrus canker. The lime was very susceptible and special care should be taken to control it with copper based chemical sprays [35]. Also reported as Copper hydroxide, basic copper chloride, copper oxychloride, and tribasic copper sulfate are the most effective bacterial sprays for protecting leaves and fruit from attack of *X. citri.* In citrus, canker can be managed by proper management of orchard followed by copper fungicide spray reduced the infection [7].

6. BACTERIAL DISEASES OF TOMATO

6.1 Bacterial Wilt of Tomato

Bacterial wilt caused by *Ralstonia solanacearum (*Formerly *Pseudomonas solanacearum* E.F. Smith) is one of the most important and wide spread bacterial diseases of crop plants in Nepal. The disease was first reported in early 1960s in the Kathmandu valley 1300 m above sea level [36].

6.1.1 Occurrence and economic Importance

Bacterial wilt (*Ralstonia solanacearum*) incidence was recorded up to 100% in tomato, in terai and mid-hills under hot and humid conditions [7].

6.1.2 Pathogenic variability

Adhikari et al. [37] isolated the 25 strains of *Pseudomonas solanacearum* and they placed 8 isolates from high hills in biovar 2 and the rest from lowland subtropics in biovar 3. On the basis of pathogenicity tests, 8 strains were of race 3 and 17 strains were of race 1. Race 1 and biovar 3 are first reports from Nepal.

6.1.3 Host resistance

The partially resistant tomato lines are CL1131-0-0-43-4 (CL1131) and Pusa Ruby a susceptible tomato cultivar [38]. Hybrids such as Srijana, CLN 2026 C and CLN 2026 D are the resistant varieties for the bacterial wilt in Nepal [39].

6.1.4 Cultural control

Crop rotation to corn, lady's finger, or cowpea, and cultivar resistance appeared to be useful management strategies to control bacterial wilt of tomato in Nepal [38]. Grafting technology using resistant root stocks has been successful for managing bacterial wilt in solanaceous vegetables.

6.2 Bacterial Spot of Tomato

The first incidence of the disease was observed in cultivar Pusa Ruby and in three different commercial farms at Banke district, Mid-western region with incidence ranging 50-60% in Nepal in 2009 [40]. The dark, circular and water-soaked lesions of about 3 mm in diameter were observed on leaves of tomato plants (*Solanum lycopersicum*).

6.3 Bacterial Speck of Tomato

Bacterial speck of tomato is caused by *Pseudomonas syringae* pv. tomato. In local cultivar Baglung Local (BL) small necrotic flecks surrounded by chlorotic haloes 1·5–3·0 mm in diameter were observed on leaves of tomato plants during the spring of 2007 in an experimental farm in Kirtipur Nepal [41].This was the first report in Nepal. Lamichhane et.al.tested 10 cultivars of tomato for susceptibility of disease, cultivars Thims 16, C.L. and Spectra 737 were found less susceptible in the field, while in the tunnel all the local cultivars (C.L., Panjabi, B.L. and Lapsi Gede) were very low susceptible [42].

7. BACTERIAL DISEASES OF POTATO

7.1 Bacterial Wilt

Ralstonia solanacearum [43], cause wilt of potato and solanaceous crops including other host plants is formerly known as *Pseudomonas solanacearum* EF, is the second most limiting phyto pathological factor to potato production in Nepal. In Nepal, the disease is considered as the most important one that causes a considerable yield loss every year [44].

7.1.1 Occurrence and economic importance

The disease is one of the destructive diseases of potato in hills and high hills. The bacterial wilt of potato was is in the subtropical to cool highlands. Reports indicate that crop infection increased from 5-40% in 1977 to 25 80% in 1980 and tuber rotting in stores ranged from 10 to 20% in Nuwakot, Rasuwa, Sindhupalchok, Dolakha, Kaski, Makwanpur, and Palpa districts [45]. Bacterial wilt was also observed on some government farms and stations at Kakani (1500 m), Kitripur (1350 m), Daman (2500 m), and Nigale (2500 m) of the central hills, and Pokhara (900 m) of the western hills. Burlakoti et al. [7] recorded up to 100%, 90% and 32.5% incidence of wilt in tomato, brinjal and potato, respectively, in Terai and mid-hills under hot and humid conditions. Up to 100% rotting of potatoes in the store has since been recorded in severe cases [44].

7.1.2 Pathogen variability

Isolates belonging to biovar 2 were all from potato plants isolated from the high hills [45]. Adhikari reported the race 3 and the biovar II in the potato from mid to high hill region by hypersensitivity, biochemical, cultural and serological test [46]. Race 3 and biovar II of the pathogen was widely spread over potato growing areas of mid and high hills of Nepal [47]. It was concluded that pathotypes and biotypes of bacterial wilt pathogens of potato were remained the same in Nepal from the last two decades.

7.1.3 Host resistance

According to Dhital, Potato genotypes BR-63.65, BS-63.5, BS-70.23, BS-35.25, BS-35.24, BS-35.22 and BS-36.3 were found free from the disease in two or more tested [48].

7.1.4 Chemical control

Research on chemical control of bacterial wilt of potato shows that use of full rate of Stable Bleaching Powder at 25 kg/ha in infested soil is highly effective for the control of diseases in terms of reduction of disease incidence and pathogen population [49].

7.1.5 Cultural management

Three year crop rotation with no-host crops, eradication of volunteer potato plants and farmers education on crop hygiene and disease management are the way of management of bacterial wilt of potato [48]. Hogger and Shrestha reported flooding paddy fields prior to potato crop reduces bacterial wilt so, farmers in irrigated areas of the mid hills and plains are advised to use a crop rotation with paddy for at least two seasons and use clean seed [50].

7.2 Potato Soft Rot

Potato soft (*Erwinia carotovora* pv *atroseptica*) was reported in the Kathmandu District, of central region of Nepal. The disease was suspected in local cultivars Rato Alu and SetoAlu. The pathogen may have been introduced to this region of Nepal via seed potato tubers from other countries [51].

7.3 Potato Scab

Potato scab is caused by a bacterium-like organism, *Streptomyces scabies*. It is one of the feared diseases of potato in Nepal. The management of the potato scab can be done by dipping tubers in solution of acetic acid+zincsulfate then in the solution of Blitox-50 and Emisan-6 [52].

8. BACTERIAL DISEASE OF CRUCIFERS

8.1 Black Rot of Crucifers

Black rot caused by *Xanthomonas campestris pv. campestris* (Pammel) Dowson (Xcc) is one of the economically important diseases of brassicaceous vegetable crops of Nepal. The disease is found in terai and inner terai regions where cauliflower and other cruciferous vegetables are cultivated. The black rot of crucifers in Nepal has been reported as early as 1977.

8.1.1 Occurrence and economic importance

Black rot is a globally important disease of crucifers. The disease can cause significant losses, particularly in warm and humid environments. Burlakoti reported that black rot caused up to 24.5% infection in local cauliflower and up to 39% in mustard seeds [7]. In Nepal more than 60% yield reduction in cauliflower has been reported [53].

8.1.2 Pathogens variability

Cabbage strains belonged to five races (races 1, 4, 5, 6, and 7), with races 4, 1, and 6 the most common. All cauliflower strains were race 4 and race 6 was the strain of leaf mustard. Nepalese *Xanthomonas campestris* pv. *Campestris* strains clustered separately from other *Xanthomonas* spp. and pathovars [54].

8.1.3 Management

Cabbage variety Copenhagen market 1 was found to be highly infected and least infection was found in Drum head [53]. As black rot of the crucifers is seed borne disease, seed soaking with 0.2% of Copper sulphate and Zinc sulphate found effective.

9. OTHER BACTERIAL DISEASES IN NEPAL

9.1 Bacterial Postulates of Soybean

Bacterial postulates of soybean, caused by bacterium *Xanthomonas campestris* pv. *phaseoli.* Neupane and co-workers have reported the bacterial pustule as a major disease of soybean in the mid hills [55]. Since exact losses due to soybean diseases have not been assessed under Rampur condition estimated yield losses up to 25% have been observed due to bacterial pustule [56]. The occurrence of the bacterial postulates (*Xanthomonas campestris* pv. *phaseoli*) of soybean disease varied with elevation [57]. It was observed Genotype SB 00122 to be highly resistant while PK 327, Pooja, G-8522, F 778817, JARS 87-l, TGX-31 1-230, Cobb, Kavre, G-1946 and TGX-15 19-ID were resistant to the bacterial postulates of soybean [56].

9.2 Crown Gall of Apple

Crown gall of apple, caused by *Agrobacterium tumefaciens* was major problem in pome fruits in Nepal which is the quarantine disease of Nepal. The control of crown gall of apple can be done by treating the root dipping in 750 ppm of agrimycin before transplanting of seedling [7].

9.3 Bacterial Leaf Spot of Pumpkin

Xanthomonas cucurbitae cause the disease bacterial leaf spot of pumpkin. J.R. Lamichhane et al. [58] observed the small necrotic spots with chlorotic haloes on the leaf surface and also scab-like lesions on fruits of pumpkin on variety Arka Chandan in Bhaktapur and Kathmandu districts. This was the first report of the disease on pumpkin in Nepal.

9.3.1 Identify

Field diagnosis of the disease is based on the characteristic symptoms developed on leaves and fruit.

Symptoms on leaves appear as small, dark, and angular lesions.

The lesions may grow and cause serious foliar blight

9.3.2 Control

The most effective method for control of the disease is planting pathogen-free seed

Application of copper compounds during early formation and expansion of fruit may result in substantial fewer symptomatic pumpkins.

10. CONCLUSION

This paper analyzed major works in the bacterial diseases of crops in Nepal. The researches are being conducted in major diseases like Bacterial leaf blight of rice Bacterial wilt of tomato and potato under heading pathogens types, economic importance, occurrence and disease management. Bacterial diseases of plants are usually very difficult to manage. Frequently, combinations of control measures are required to manage the diseases. So, there are some works done in the control measures of diseases in Nepal. Most of the works are on host resistance and few on chemical and cultural management of diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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