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Research Article

Assessment of Prevalence, Incidence and Severity of Red Pepper Disease in *Capsicum frutescens* L. at Central Gondar, Ethiopia

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Abstract

Production and productivity of red pepper is highly threatened by different biotic and abiotic factors. Among biotic factors, disease is the most important factor that affects red pepper production in the world wide including Ethiopia. However, the relative distribution and severity of each disease across district has not been well identified to sound management strategies. Therefore, a survey was conducted which aimed to determine the prevalence, incidence and severity of major red pepper disease and investigate the association of disease parameters with crop management practices. A total of 120 farmers' fields were randomly sampled from three districts namely West Denbiya, Esat Denbiya and Takusa in central Gondar zone of Amhara region during 2017 and 2018 cropping seasons. Disease incidence and severity varied across and within districts. Phytophthora root rot, *Fusarium* wilt, Bacterial leaf spot, Powdery mildew, Anthracnose, Cercospora leaf spot and Downy mildew were the most dominant and frequently occurring diseases of red pepper. Variables such as altitude, varieties, seed bed types, planting time and cropping pattern were significantly associated red pepper disease. Two years surveyed data were collected, analyzed and expressed using percentage. Among all surveyed districts, the findings indicated that the dominant red pepper disease severity were recorded from Phytophtora root rot (37.2%), *Fusarium* wilt (32.8%) and Powdery mildew (25.0%) whereas the minimum severity were recorded from bacterial leaf spot (12.8%) and Cercospora leaf spot (14.5%). The present study provides an indication of the prevalence, incidence and severity of red pepper disease on which integrated management strategies could be derived to improve red pepper production in the surveyed districts.

Keywords: Red pepper disease, disease incidence, Phytophthora root rot, *Fusarium* wilt, Cercospora leaf spot.

Introduction

Red pepper (*Capsicum frutescens* L.) is grown in many countries of the world and its production for culinary and vegetable uses had been increased from time to time (Bosland *et al.*, 2000; Koeda *et al.*, 2014). It is the main part in the daily diet of most Ethiopian society. In Ethiopia today, it is extensively produced and used. Red pepper is an important source of capsaicin, a compound that is pungent and serves as digestive stimulant and Vitamins A, C and E (Samira *et al.*, 2013). It also contains appreciable amount of calcium, phosphorus and iron (Kwenin *et al.*, 2011). Pepper has also been widely used as a medicine to alleviate pain like arthritis, to treat asthma, coughs and common cold, and to cure infected wounds. Even today, red peppers are one of the most widely used of all natural remedies, for instance, against arthritis (Kwenin *et al.*, 2011). Red pepper is widely cultivated in different agro-ecologies of Ethiopia.

The total production of red pepper in the country for the year 2009/10 main cropping season was estimated to be 183,402.6 ton. In addition in Amhara region, the total production was 530.1 ton for the same year. Therefore, the contribution of Amhara region for the country production was 29%. The total area cultivated by red pepper small holder farmers for the meher season 2016/2017 in North Gondar zone was 7,853.9 ha. The estimated average production and productivity of red pepper in North Gondar zone was 13,116 ton and 1.57 tons per hectare, respectively which is low compared to Amhara Region an average of 1.76 tons per ha in 2016/17 (Berhane *et al.*, 2018). The production of pepper in the region is dominantly by smallholder farmers using rain by traditional farming practice. Very small amount of red pepper is being produced using irrigation and modern inputs such as fertilizer, improved seeds and implement integrated pest management (Abay, 2010).

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According to Taffesse *et al.* (2012), there has been substantial growth in crops, in terms of area cultivated, yields and production since 2000, but a yield is low by international standards and overall production is highly susceptible to several biotic and abiotic factors. Among biotic factors, diseases are one of the most important limiting factors in red pepper production (Mihajlović *et al.*, 2017) and it causes losses of 25-90%. It suffers from a number of diseases but *Phytophthora* root rot, *Fusarium* wilt, bacterial leaf spot, powdery mildew, anthracnose, *Cercospora* leaf spot and downy mildew are important constraint ones in globe responsible for yield losses (Kumar *et al.*, 2011; Gómez-Rodríguez *et al.*, 2017). Similarly, root-knot nematodes *Meloidogyne spp.* and *Nacobbus aberrans* are one of the main problems in pepper (Djian-Caporalino, 2012). Although quantified data on yield losses due to disease are not available for the country, the importance of disease in red pepper production has been given due attention. Among abiotic factors such as, lack of improved varieties, traditional and backward production methods, improper and inadequate inputs supply, low soil fertility, drought and heat stress, lack of research outputs and extension services on production techniques, poor harvesting and post harvesting practices are also the most important production limiting factors (Alemu and Ermias, 2000; Simon, 2014). Likewise, the major production problems of red pepper were inadequate irrigation, low rainfall, high input price and pests and disease whereas marketing problems includes low produce price, lack of market and transport constraints (Endrias and Girma, 2015).

Total crop failure due to disease has been common in the study area and farmers are sometimes forced to abandon their production due to excessive infection pressure in the field. The diseases were highly expanded and distributed aggressively in northwestern parts of the country from year to year (Mekonen and Chala, 2014). The identity and relative importance of each disease across location has not been well profiled. Therefore, this study was initiated to determine (a) the relative occurrence, distribution, incidence and severity of red pepper disease in major growing districts of central Gondar zone (b) the influence of cultural practice on red pepper disease epidemics, and (c) to provide information which can be used in developing integrated management strategies against red pepper disease.

Materials and methods

Description of study area: The study was conducted in major red pepper growing agroecologies of central Gondar zone, Amhara national regional state, Ethiopia. The study was conducted in three districts of central Gondar zone of Ethiopia namely West Denbiya, East Denbiya and Takusa districts.

It is geographically located in 17°29'32" North latitude and 42°38'25" East longitude. The mean annual rainfall is ranged from 875 to 1025 mm and the temperature ranged from 18°c to 35°c. The zone is dominated by the agricultural sector, which employs about 80% of the working force. The zone is divided into 13 districts, and its boundaries are adjoin with North Gondar zone in the North, Awi zone in the West and West Gojam zone in the South, North wollo zone in the East, South Gondar zone in the Southeast. The zone also has a total population of 3,036,961 (83.39% rural and 16.61% urban) of which 56.35% and 43.65% are women and men, respectively (Wondie *et al.*, 2016). The dominant types of crop which is cultivated around the study area include teff, maize, wheat, chickpea, white cumin and black cumin.

Sampling techniques: Field survey was carried out during 2017 and 2018 main cropping season. A multistage sampling technique was used to select red pepper producer farmers. Out of three districts, nine major red pepper producing kebele were purposively selected based on red pepper production and productivity potential to represent the major red pepper growing areas of the zone. Then, after a total of 120 farmer's field who produced red pepper were selected and inspected for disease prevalence, incidence and severity. The timing of the survey was chosen so as to coincide with the time when the disease is reached maximum stages. Red pepper cultivated fields were sampled randomly at intervals of 5-10 km along roads sides and distances between each farmer's fields depended on the topography and the relative importance of red pepper cultivation within each district. In each farmer's field, $4m^2$(2m×2m) areas were marked out in five randomly selected points moving in, X" fashion of the fields using quadrants was used to cover the whole field and disease data were collected from individual quadrants and the five samples per field were used as one site after averaged. Disease infected plants in each quadrant were collected for diagnostic use. Following each assessment, the number of healthy and disease infected leaves were counted within the area. During the survey period naturally infected different plant parts such as root, stem, leaf and pod which showed suspected typical symptoms of different diseases were collected. A total of 240 samples were collected and brought University of Gondar microbiology laboratories for identification and confirmation of the pathogen.

Disease prevalence, incidence and severity: Prevalence of a disease was calculated using the number of fields that occupied by a particular disease divided by the total number of field assessed and expressed in percentage.

$$\text{DP}\,(\%) = \frac{Number\ of\ fields\ occupied\ by\ particulat\ disease}{Total\ number\ of\ fields\ assesed} \times 100$$

Where, DP is disease prevalence.

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Incidence was calculated by using the number plants that are visibly diseased (showing disease symptoms) proportion to the total number of sampling units assessed. To determine the incidence of red pepper disease at different farm fields used the following formula:

$$DI\ (\%) = \frac{Number\ of\ plants\ that\ are\ visibly\ diseased}{Total\ number\ of\ plant\ examined\ (both\ health\ and\ diseased)} \times 100$$

Where, DI is disease incidence.

Severity was recorded by examining visually the whole plants using percent leaf area affected in the quadrants. Severity was recorded using the modified Cobb's scale (Peterson *et al.,* 1948), by assessing 10 randomly tagged plants. The severity grades were converted into percentage severity index (PSI) for the analysis (Campbell and Madden, 1990; Fininsa, 2003).

$$PSI = \frac{\text{Sum of numerical ratings}}{\text{No: of plants scored} \times \text{maximum score on scale}} \times 100$$

Results and discussion

Red pepper disease prevalence: The prevalence of red pepper disease was investigated during two main cropping season following a planned two times survey across three districts in central Gondar zone. Totally the prevalence of red pepper disease was investigated in three districts of 68 and 53 farmer fields which were assessed in the first and second surveys respectively. The diseases found infecting red peppers after transplanting in the surveyed area were *Phytophthora* root rot (*Phytophtora capsici*), *Fusarium* wilt (*Fusarium capsici*), bacterial leaf spot (*Xanthomonas campestris* pv. *vesicatoria,*), powdery mildew (*Leveillula taurica,*), anthracnose (*Colletotrichum* spp.), *Cercospora* leaf spot (*Cercospora capsici*) and downy mildew (*Peronospora capsici*) diseases (Yesuf and Ayana, 1995; Mekonen and Chala, 2014). Study by Mekonen and Chala (2014) reported that powdery mildew *(Leveillula taurica)* and *Fusarium* wilt (*Fusarium oxysporum*) as being the most widespread fungal diseases of red pepper in Ethiopia. The mean distribution of each disease across the surveyed area was different. Among three surveyed districts of red pepper fields, the maximum mean prevalence of *Phytophtora* root rot was 86.11%, 73.56% and 68.64% while the minimum prevalence of bacterial leaf spot was 41.03%, 37.03% and 31.68% were recorded at East denbiya, Takusa and West denbiya districts respectively (Table 1). Survey indicated that the maximum mean prevalence in all disease was recorded from *Phytophtora* root rot (76.1%) followed by *Fusarium* wilt which recorded 64.78% while the minimum mean prevalence was recorded from bacterial leaf spot (36.58%), followed by anthracnose and bacterial soft rot which recorded 44.43% and 48.23% respectively (Table 1).

On the contrary, among surveyed districts, the overall maximum disease prevalence was recorded at East denbiya district (58.5%) followed by Takusa (57.1%) while the minimum mean prevalence was recorded at West denbiya (50.3%) (Table 1). *Phytophtora* root rot (*Phytophtora capsici*) was the most common disease and found from 82 farmers' fields out of 120 totals sampled red pepper field in both 2017 and 2018 consecutive surveyed years. It was found to be a devastating disease at seedling and fruiting stage of the crop, when the rain fall is continuous and very intensive in the area (Granke *et al.*, 2012). The findings are in line with the findings of Sanogo and Ji (2012). The maximum disease prevalence along the three surveyed districts in two cropping season were found in red pepper fields sampled at East denbiya and Takusa district which resulted as 86.1% and 73.6% respectively. However, during surveyed two cropping season, the minimum disease prevalence was 68.6% recorded at West denbiya districts (Table 1).

Fusarium wilt of red pepper caused by *Fusarium capsici* was widely distributed through in the surveyed area of West Gondar zone. This disease is the major disease of the surveyed district having soils of high water holding capacity with poor drainage. Symptoms of *Fusarium* wilt included wilting of the foliage and internal necrosis of the vascular tissue in the stem of the plant (Bosland *et al.*, 2012). The prevalence was the second major disease found to be very high occurrence in the surveyed area followed by powdery mildew foliar disease which recorded 64.8% and 59.6% respectively (Table 1). The data indicated that the maximum disease prevalence was 71.0 and 66.2% recorded at East denbiya and Takusa districts respectively. However, the surveyed data indicated that the minimum prevalence was recorded on West denbiya districts 57.1% (Table 1). The variation in the prevalence might be related to whether conditions and soil type of the specific surveyed area that tended to favor the growth of the pathogens. This is evidenced by the higher water holding capacity of the vertisoil in East denbiya which enhanced the growth of pathogens. Powdery mildew caused by *Peronospora capsici* was one of economically important foliar red pepper disease that occurred on the three surveyed districts of West Gondar zone. In two consecutive cropping seasons, the maximum prevalence of powdery mildew red pepper disease was recorded from Takusa (69.8%), followed by West denbiya (57.7%) while the minimum prevalence of powdery mildew was recorded at East denbiya (51.4%) (Table 1). Foliar disease of *Cercospora* leaf spot has occurred in all surveyed districts. In two years field survey, mean data indicated that the maximum *Cercospora* leaf spot occurrence was recorded at Takusa followed by East denbiya which resulted in 64.8 and 58.6% respectively. However, the minimum prevalence was recorded at West denbiya (46.4%) (Table 1).

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Table 1. Mean prevalence of major red pepper disease at three districts during 2017 and 2018 consecutive cropping season.

Red pepper disease	East Denbiya		West Denbiya		Takusa		Mean	
	N.F	Pre (%)	N.F	Pre (%)	N.F	Pre (%)	N.F	Pre (%)
Phytophthora root rot	30	86.1	21	68.6	31	73.6	82	76.1
Fusarium wilt	27	71.0	15	57.1	22	66.2	64	64.8
Bacterial leaf spot	6	41.3	5	31.7	4	37.0	15	36.7
Powdery mildew	18	51.4	12	57.7	19	69.8	49	59.6
Anthracnose	11	48.7	7	34.9	9	43.1	27	42.2
Cercospora leaf spot	20	58.6	10	46.4	17	64.8	47	56.6
Downy mildew	16	52.3	9	55.6	10	45.4	35	51.1
Total	42	58.5	30	50.3	48	57.1	120	55.3

Where, N.F number of fields where the disease sample was collected, Pre% is prevalence percentage.

Table 2. Mean disease incidence (DI) of major red pepper at three districts during 2017 and 2018 consecutive cropping season.

Red pepper disease	East Denbiya		West Denbiya		Takusa		Mean
	2017	2018	2017	2018	2017	2018	
Phytophthora root rot	65.4	71.8	50.6	58.4	55.9	65.3	61.2
Fusarium wilt	57.7	61.5	45.8	49.6	49.8	57.4	53.6
Bacterial leaf spot	28.7	35.3	24.8	29.7	25.7	32.1	29.4
Powdery mildew	46.5	40.2	49.3	42.1	52.4	46.6	46.2
Anthracnose	37.4	42.7	36.5	43.5	40.2	49.5	41.6
Cercospora leaf spot	32.4	35.7	31.5	38.5	35.2	45.5	36.5
Downy mildew	51.7	43.8	48.9	39.4	43.3	40.5	44.6

Table 3. Mean percentage severity index (PSI) of major red pepper diseases at three districts during 2017 and 2018 consecutive cropping season.

Red pepper disease	East Denbiya		West Denbiya		Takusa		Mean
	2017	2018	2017	2018	2017	2018	
Phytophthora root rot	38.4	46.6	28.8	33.9	34.7	40.5	37.2
Fusarium wilt	33.2	42.1	26.7	30.2	29.5	34.9	32.8
Bacterial leaf spot	13.5	18.5	7.6	11.2	10.9	15.3	12.8
Powdery mildew	23.7	20.2	26.8	20.3	32.6	26.5	25.0
Anthracnose	13.4	17.4	16.7	18.9	19.5	23.6	18.3
Cercospora leaf spot	9.5	13.5	12.6	16.2	14.3	20.8	14.5
Downy mildew	29.4	24.7	20.2	17.5	25.3	20.9	23.0

Bacterial leaf spot caused by *Xanthomonas campestris* pv. *vesicatoria,* was found in all inspected area. It affects red pepper leaves, fruits and stems of the crop. Symptoms begin on leaves in small water-soaked spots and turn dark brown (Chamberlin and Schmidt, 2012). The maximum bacterial leaf spot prevalence was recorded at East denbiya followed by Takusa 41.3 and 37.0% respectively while the minimum at West denbiya districts (31.7%) (Table 1). The overall surveyed districts showed that the minimum prevalence of the disease (36.7%) was recorded from bacterial leaf spot as compared to other red pepper disease.

Red pepper disease incidence: The mean disease incidence percentage was carried out based on field observations. In West Gondar zone, the maximum disease incidence of *Phytophthora* root rot (*Phytophtora capsici*) was recoded in all of the three surveyed districts.

In 2017 cropping season survey data indicated that *Phytophthora* root rot was widely distributed and caused disease incidence damage by 65.4% in East denbiya followed by 55.95 in Takusa district on farmer's red pepper field while the minimum disease incidence (50.6%) was recorded at West denbiya. In 2018 cropping season, the survey data revealed that *Phytophthora* root rot was highly prevalent in major red pepper growing area of West Gondar zone as compared to 2017 cropping season with the incidence ranging from 58.4 to 71.8%, where the maximum disease incidence percentage was recorded from East denbiya (71.8%) and the minimum disease incidence was noticed in West denbiya (58.4%) (Table 2). The maximum *Fusarium* wilt *(Fusarium capsici)* disease incidence was recorded from East denbiya (57.7%) followed by Takusa (49.8%), while the minimum disease incidence of (45.8%) was recorded in West Denbiya during 2017 cropping season.

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In 2018 main cropping season, the maximum disease incidence (61.5%) was also recorded from East denbiya, followed by Takusa with 57.4% disease incidence (Table 2). The variability in the occurrence of the diseases might be related to environmental conditions and soil type of the specific areas that tended to favor the growth of pathogens. This is evidenced by the higher water holding capacity of the vertisoil of East denbiya, which favour the growth of *Fusarium* wilt in the area. Powdery mildew of red pepper was distributed in all red pepper growing surveyed districts in low to high form with incidence ranged 46.5 to 52.4%. Among the three districts in 2017 cropping season, the maximum disease incidence was recorded in Takusa (52.4%), followed by West Denbiya (49.3%) while the minimum disease incidence of 46.5% in East Denbiya district. Survey data in 2018 cropping season indicated that the maximum incidence was recorded in Takusa (46.6%), while the minimum incidence in East Denbiya was 40.2% followed by West Denbiya (42.1%) (Table 2). During 2017 and 2018 cropping season, the bacterial leaf spot has been distributed in all three districts. However was recorded with a low incidence. Among surveyed districts of West Gondar zone in 2017 cropping season, the maximum bacterial leaf spot incidence value was recorded from East Denbiya (28.7%) while the minimum incidence at West Denbiya recorded 24.8%. The surveyed data in 2018 cropping season indicated that the maximum incidence recorded was 35.3% followed by 32.1% in East Denbiya and Takusa districts respectively (Table 2).

Red pepper disease severity: Survey on the farmer's field in major red pepper growing area of West Gondar zone revealed that *Phytophthora* root rot severity varied from one locality to another due to altitude, cropping pattern, growth stage, planting time, weeding management practice and inoculum sources. Among surveyed districts during 2017 cropping season, the most affected fields were found in East Denbiya (38.4%) severity, followed by Takusa (34.7%) severity, but the minimum *Phytophthora* root rot severity was noticed in West Denbiya which resulted in 28.8% severity. In 2018, cropping season field survey data revealed that the maximum disease severity (46.6%) was recorded in East Denbiya district while the minimum severity (33.9%) was recorded in West Denbiya (Table 3). Among identified red pepper disease, *Fusarium* wilt was the second widely distributed types of red pepper disease, which recorded severity next to *Phytophthora* root rot. In 2017 cropping season, the maximum *Fusarium* wilt disease severity was recorded in East Denbiya (33.2%) and the minimum severity was noticed in West Denbiya (26.7%). Fusarium wilt is one of the major red pepper diseases having high disease severity (32.8%) in the surveyed district next to *Phytophthora* root rot (Table 3).

Powdery mildew was also widely distributed throughout the major red pepper districts of central Gondar zone. In 2017 cropping season, the disease severity revealed that powdery mildew of red pepper was distributed in all surveyed area in low to severe form with the severity ranging from 23.7 to 32.6%, but the medium severity was recorded in Takusa (26.8%). In 2018 cropping season, the maximum disease severity was recorded in Takusa (26.5%), followed by West Denbiya (20.3%) while the minimum severity in East Denbiya recorded was 20.2% (Table 3). Among the three surveyed districts, the lowest bacterial leaf spot disease severity was observed in West Denbiya 7.6%, followed by Takusa having with value of 10.9%, however the highest severity 13.5% was recorded from East Denbiya during in the first surveyed cropping season.

In the second surveyed cropping season, maximum severity ratings were observed about 18.5, 15.3 and 11.2% in East Denbiya, Takusa and West Denbiya districts respectively. However, the occurrence of the disease was found to be very infrequent. The occurrence of bacterial leaf spot was observed in all surveyed districts with low infestation level ranging from 7.6 up to 18.5% of severity index in both cropping season (Table 3). Two years mean PSI indicated that the maximum *Phytophthora* root rot mean PSI 42.5% was recorded in East Denbiya followed by 37.6% PSI in Takusa district. However, the minimum PSI 31.4% was showed in West Denbiya district. It is apparent that among three surveyed districts the maximum mean *Fusarium* wilt mean PSI 37.7% was observed in East Denbiya, followed by Takusa PSI 32.2% while the minimum was from West Denbiya with mean PSI of 28.5%. The highest powdery mildew mean PSI 29.6% was recorded in Takusa while the lowest mean PSI 21.9% was recorded in East Denbiya. The mean severity of bacterial leaf spot ranged from 9.4 to 16%, the maximum bacterial leaf spot mean PSI 16% was recorded in East Denbiya, while the minimum mean PSI 9.4% was recorded in West Denbiya (Table 3).

Association of red pepper disease with different variables: Among three surveyed districts, the distribution, incidence and severity of the above listed disease, the pepper disease of *Phytophthora* root rot, *Fusarium* wilt and powdery mildew and minor leaf disease of bacterial leaf spot were recorded in all three red pepper producer surveyed districts. Most of the disease observed on red pepper farms can be influenced by different factors like altitude, use of varieties, types of seed bed, planting time, growth stage of the crop, and planting pattern. However, in surveyed districts farmers practice were variable and only few farmers apply recommended cultural practices.

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Table 4. Association of mean severity major red pepper diseases for different parameter during 2017 and 2018 cropping season in Central Gondar zone, Ethiopia.

Variables	Class	Major red pepper disease severity						
		PRR	FW	BLS	PM	Ant	CLS	DM
Altitude	Mid (1951-2530)	48.6	38.8	23.0	29.8	26.1	31.5	29.8
	Low (1500-1950)	39.7	42.2	27.8	36.9	33.3	38.3	24.6
Varieties	Improved	28.9	20.9	13.4	18.7	16.9	15.7	17.3
	Local	47.4	25.5	20.7	24.9	25.6	24.2	23.6
Seed bed types	Flat	45.3	40.9	14.2	38.9	27.4	20.8	30.3
	Raised	37.6	34.1	10.6	30.7	20.1	16.3	24.4
Planting time	Early	40.2	36.4	14.7	30.6	20.5	18.0	25.4
	Lately	37.8	35.1	11.4	27.6	18.9	15.3	23.1
Planting growth stage	Seedling	43.8	40.2	14.6	32.5	23.3	19.3	28.4
	Flowering	37.8	36.9	18.9	38.4	30.4	25.1	36.3
Cropping pattern	Monoculture	30.2	26.1	13.2	22.7	15.3	13.4	18.9
	Rotation	28.3	20.3	9.7	17.3	12.3	10.3	15.6

Where, PRR: Phytophthora root rot, FW: Fusarium wilt, BLS: bacterial leaf spot, PM: powdery mildew, Ant: Anthracnose, CLS: Cercospora leaf spot, DM: downy mildew.

The surveyed result indicated that the maximum severity of *Phytophthora* root rot and downy mildew were recorded at mid altitude which ranged from 1500-1850 msl whereas the maximum disease severity of *Fusarium* wilt, bacterial leaf spot, powdery mildew, anthracnose and *Cercospora* leaf spot were recorded at low altitude ranges from 1070-1500 msl (Table 4). This results in line with Mekonnen *et al.* (2015). Among the three surveyed districts, red pepper disease severity were highly recorded where the farmers cultivated local red pepper than red pepper improved varieties (Mengist and Birara, 2019). Particularly all disease prevalence, incidence and severity were recorded on local and improved varieties, however, the farmers who cultivated red pepper improved varieties was found to be minimum with reference to occurrence, incidence and severity as compared to local cultivar (Table 4). The maximum severity of red pepper disease were recorded where the crops transplant in early time as compared to lately.

Red pepper cultivated at flat seed bed was recorded for maximum disease severity as compared to crops cultivated in raised seed bed. The survey result showed that the maximum severity of *Phytophthora* root rot and *Fusarium* wilt were recorded at seedling stage than flowering. On the other hand, the maximum severity of bacterial leaf spot, powdery mildew, anthracnose and *Cercospora* leaf spot and downy mildew were recorded at flowering stage than seedling (Table 4). Among cropping pattern, 72% of the interviewed farmers used crop rotation after producing red pepper; the remaining 28% of the farmers used continuous mono-culturing.

However, the year intervals and the types of the crop which used for rotation differ from farmers to farmers. About 50% of the farmers apply crop rotation only for one year and cultivated wheat after red pepper. However, the remaining 22% of the farmers used crop rotation for two years who cultivated wheat and haricot bean after red pepper cultivation. However, most of fungal and bacterial pathogen that caused red pepper disease once appeared can able to survive in the soil at least five years (Teferi and Wubshet, 2015).

Conclusion

Even though the yield loss caused by each pathogen is not clearly studied and quantified in Ethiopia, these study indicated that the presence of all the above identified disease were destructive to red pepper production in central Gondar, Ethiopia, due to the fact that they were distributed widespread in red pepper producing area. In this study, there were more than seven types of fungal and bacterial pathogens attacking red pepper across surveyed districts. The two years survey data showed that *Phytophthora* root rot and *Fusarium* wilt were widely distributed and caused severe damage to all surveyed districts. The maximum prevalence, incidence and severity of *Phytophthora* root rot and *Fusarium* wilt were recorded in East Denbiya and Takusa districts and it might be attributed by favorable climatic conditions. Among three surveyed districts, the result indicated that East Denbiya was a hotspot area for *Phytophthora* root rot and *Fusarium* wilt on red pepper crops.

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It is anticipated that the disease will continue to threaten red pepper production until relevant integrated disease management approaches were developed. Therefore it's better to use red pepper germplasm for resistance against diseases and immediate possible control measures should be taken especially on *Phytophthora* root rot, *Fusarium* wilt and powdery mildew to save crops. Many efforts were made in the districts to manage the disease through improved agronomic practices and other recommended disease management packages. However, application of improved agronomic practice on red pepper production in the district is very low. Therefore, there is a need to introduce holistic approach to be incorporated integrated disease management in all urgency to manage the complex disease in the districts.

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