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Management of Potato Late Blight (*Phytophthora infestans*) by the Combination of Potato Variety with Different Fungicide in Horo Guduru Wollega Zone

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Abstract

Potato (*Solanum tuberosum* L.) is one of a major crop produced globally and serves as a source of food. Ethiopia is one of the major potato producers in Africa, with 70% of its arable land in the high-altitude areas between 1,500-3,000 meters being suitable for potato production. Late blight, caused by *P. infestans*, is a devastating disease of potato worldwide. In highlands of western Ethiopia especially at Horo Guduru Wollega Zone Potato late blight caused by *Phytophthora infestans* is a bottleneck for potato production. Integrated management to control devastative pathogen was carried out and three cultivars of potato (Gudene, Jalane and Belete) were used in this experimental study. A randomized complete block design with three replications was employed in a factorial arrangement at Gitilo and Harato research site of Wollega University. Each potato variety including local check was applied with fungicide at different times. Disease incidence and severity was examined with the first appearances of the first late blight symptoms; each plant appearances was visually examined on each plots. The effect of variety and fungicide combinations on disease severity data was integrated into area under disease progress curve. Analysis of Variance (ANOVA) was performed to disease parameters (Disease incidence, Disease severity and AUDPC) and yield parameters using Statistical Analysis System (SAS). Gudane variety was relatively resistant as compared to the rest of the varieties during the main growing season at Gitilo and Harato site.

Keywords

Late Blight, *Phytophthora infestans*, Disease Management, Variety

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1. Introduction

Potato (*Solanum tuberosum L.*) is one of a major crop produced globally and serves as a source of food. The tuber is known to supply carbohydrate, high quality protein and substantial number of essential vitamins, minerals and trace elements [1]. Ethiopia is one of the major potato producers in Africa, with 70% of its arable land in the high-altitude areas between 1,500-3,000 meters being suitable for potato production [2]. At present in Ethiopia, potato area had grown to 160,000-ha, with an average yield around 8 tons/ha [3]. It is one of the most important food and cash crops and also become an important garden crop especially in high and mid altitude areas of Ethiopia [4]. Cultivation of potato voluntarily in fields of colder highlands was limited earlier time; wider adoption of the potato occurred at the end of the 19th century in response to a prolonged famine [5]. In highland and mid altitude of Ethiopia this crop is a very important food and cash crop for small scale farmers. Yield of vegetable crops are generally lowest in tropical Africa as a result of both biotic and abiotic factors, of which the former includes primarily insect pests, diseases and weeds. The most

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important factors responsible for the low productivity of potato are diseases and insect pests. Farmers get lower yield mainly due to pests and sub-optimal fertilization [6].

Late blight, caused by*P. infestans*, is a devastating disease of potato worldwide [7]. Since the Great Famine in Ireland during the mid-1840s, much research and development has been done on blight disease caused by *Phytophthora spp*. in members of the Solanaceae family like potato and tomato [8, 9]. Research groups and networks working on plant breeding and plant protection are expanding our knowledge and ability to limit the damage caused by *P. infestans*. Likewise using proven emerging technologies to identify resistance and transfer it into potato cultivars with desired characteristics [10]. However, resistance breeding is still waiting for the big breakthrough and susceptible varieties require large amounts of fungicides, which can have negative impacts on the environment [11]. In Ethiopia, the disease occurs throughout the major potato production areas and it is difficult to produce the crop during the main rainy season without chemical protection measures [12]. The profound ability of disease to reach epidemic level within a short period of time and inadequate efficiency of cultural practices to reduce high level of disease severity, and rapid development of resistance to fungicides are the most serious problems to manage potato late blight in Ethiopia. While the environmental condition is conducive for pathogen development late blight can destroy potato field within a few day [13]. Yield losses due to this disease are attributed to both premature death of foliage and diseased tubers. The quantitative and qualitative losses of potato tuber yield due to late blight can be considerable, but the degree of infection and loss varies with weather conditions and other factors such as crop rotation [14-16].

Phytophthora infestans has a high pathogenic variability and therefore, specific resistance has contributed little in controlling the disease and varietal resistance only helps in reducing the amount of fungicides required and the rate of disease development [17]. However, a need to explore the other strategies to supplement the existing measures to curb the heavy economic losses inflicted by the disease. Apart from yield losses, the disease reduces the market value of the crop due to brown color that forms in tubers of potato during storage [18-20]. Due to the devastating nature of the disease, it poses a threat to food security since many resource poor farmers cannot afford the numerous fungicide applications required to control it [17]. Successful control of late blight disease needs an accurate control by using efficient fungicides. Thus, the combined uses of fungicide and resistance varieties have evolved as one of the most important options in the management of the disease [21].

Potato cultivars grown in Ethiopia have low levels of general resistance to late blight. Mostly the commercial potato farmers rely on fungicide applications for control of *P. infestans* [12]. Combining fungicide with selected potato cultivars can extend the durability of newly released potato variety in the production systems. This is particularly important in developing countries such as Ethiopia, where the setup of efficient and sustainable breeding programs for potatoes are inadequate. Integration of fungicides with cultivars has been commonly practiced for sustainable production of potatoes in most developed world [21]. Production of potato in main cropping season needs application of fungicide to manage late blight. In addition to the benefits of reducing yield losses due to epidemics of late blight, the combined uses of fungicide with resistant varieties can also contribute to reduce the health risks associated with high fungicide applications. Host resistance is the best option for management of late blight of potato and it is eco-friendly in nature. Generally, after a decade, resistant level of the cultivars is being defeated, due to matching of new virulence genes.

In highlands of Western Ethiopia especially at Horo Guduru Wollega Zone Potato Late Blight caused by *Phytophthora infestans* is the most bottlenecks for potato production. The repeated use of same variety of Potato under favourable environmental condition is a holder for rapid development of potato late blight development. This is for the reason that accumulating pathogen inoculums in the soil and in crop residue including potato tuber is initiating late blight infection to potato. Consequently, Potato late blight is virulent Pathogen which is responsible for the cause of Potato yield reduction in the area and need strong management to solve yield reduction both in quality and quantity due to *Phytophthora infestans*. Even though, Horo Guduru Wollega Zone has potential for the production of Potato poor yield is harvested generallydue to low attention is paid for potato late blight management. For this corroboration no research has been done on the integrated management of Potato late blight caused by *Phytophthora infestans* at Horo Guduru Wollega Zone so far. Combined use of relatively resistant Potato variety with fungicide is slightly cost effective and environmentally friendly. These enhance resistance ability of Potato towards Potato late blight which is an important management for making sure the durability of this crop.

Therefore, the research was laid with the objective of management of Potato Late blight caused by *Phytophthora infestans* through combining Potato variety with suitable fungicides at Horo Guduru Wollega Zone, Oromia Regional State, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The field experimental study was conducted at Gitilo and Harato research site, Horo Guduru Wollega Zone, Oromia Region, Ethiopia from July to October 2018.

Gitillo is located in Western Oromia Regional State at 11km from Shambu the capital city of the Zone. The average altitude of this area is 2780 m.a.s.l. and it is known by 2600 mm mean annual rain fall. The daily maximum, minimum, and mean temperature of the area is 23°C, 21°C and19°C respectively.

Harato study site is located at an altitude of 2200m.a.s.l The mean annual rain fall of the Harato site is 2000mm and the average annual temperature ranges between 18-22°C. Both areas are characterized by mixed farming system.

2.2. Experimental Materials Used

Three cultivars of potato (Gudene, Jalane and Belete) were used in this experimental study. The three cultivars were obtained from Holleta Agricultural Research Center, Ethiopian Agricultural Research Institute and one local variety was obtained from local farmers nearby Wollega University Shambu Campus.

2.3. Experimental Design, Treatments and Applications

A randomized complete block design with three replications was employed in a factorial arrangement at Gitilo and Harato research site, Wollega University. Each potato variety including local check was applied with protectant (Mancozeb) and systemic fungicide (Ridomil gold) four times every ten days and two times every fifteen days interval respectively with recommended rate. Plots consisted of 5 rows with spacing of 0.3 m between plants and 0.75 m between rows, giving an overall dimension of 2.4m X 3.75m. The fungicides were applied as per the recommendation of the manufacturers using a manually-pumped knapsack sprayer of 15-litercapacity. Spraying was started soon after the first late blight lesions were observed on the foliage and continued depending on the recommendation of the fungicide.

2.4. Data to Be Collected

Disease Assessment

Disease incidence and severity was assessed with the first appearances of the first late blight symptoms and each plant appearances were visually examined on each plot. Late blight incidence was evaluated based on number of infected plants or plant parts from the total number of examined counted potato plant and severity was calculated from the area of infected plants starting from disease onset at 7 days intervals from the pre-tagged 10plants/plot from the three central rows of each plot. Number of plants that showed the symptoms of late blight infection was calculated below as described by [22].

$$\text{PDI} = \frac{\text{Number of diseased plants x 100}}{\text{Total number of plants examined}}$$

Where, PDI= Percentage of Disease Incidence.

The data on disease severity was recorded using percent rating scale suggested by [23]. The severity grades were converted into Percentage Severity Index (PSI) according to the formula by [22].

$$\text{PDS} = \frac{\sum \text{Individual numerical rating X 100}}{\text{Total no. of plants assessed X Max. Score in the scale}}$$

where, PDS= Percentage of disease severity

Area under Disease Progress Curve and Disease progress rate

The effect of variety and fungicide combinations on disease severity data was integrated into Area Under Disease Progress Curve (AUDPC), as described by [24].

$$\text{AUDPC}= \sum_{i=1}^{n-1} (yi + yi + 1/2)(t + 1 - ti)$$

where, y_i= disease severity at the i^{th} observation (in percentage), t_i = time (days) of the i^{th} observation, n = total number of observations, y_i + 1 = disease severity at the second observation, and t +1 = second day of observation. Disease progress rate in time was determined by recording the severity of potato late blight in seven days intervals starting from symptoms appearance.

Yield of Potato

Marketable yield: Potato tuber from the nine plants in three central rows of each plot was sorted based on tuber physical appearance; shape, size, biotic and abiotic infection at each harvesting time and tubers having market acceptance was measured on weight balance. The mean weight of marketable tuber per plant from each plot was calculated.

Unmarketable yield: None marketable tuber per plant was measured from the nine plants in three central rows of each plots and this unmarketable yield was recorded through subjective judgement based on shrunken shaped tuber, small sized and discolored tuber and the mean average weight was calculated.

2.5. Data Analysis

Analysis of Variance (ANOVA) was performed to disease

parameters (Disease incidence, Disease severity and AUDPC) and yield parameters using Statistical Analysis System (SAS) version 9.2 software [25] and also confirmed by xlstat.

Least significance difference (LSD) was used to separate treatment means ($P<0.05$) and correlation analysis was performed to find out at the relationship between disease severity with yield of potato tuber in the plot.

3. Results and Discussion

Disease incidence, Severity and AUDPC were studied at Gitilo Research Site. Disease Incidence during the growing season Potato late blight disease was fast spread and development at Gitilo research center because of cool and warm environmental condition which is favoured for pathogen development.

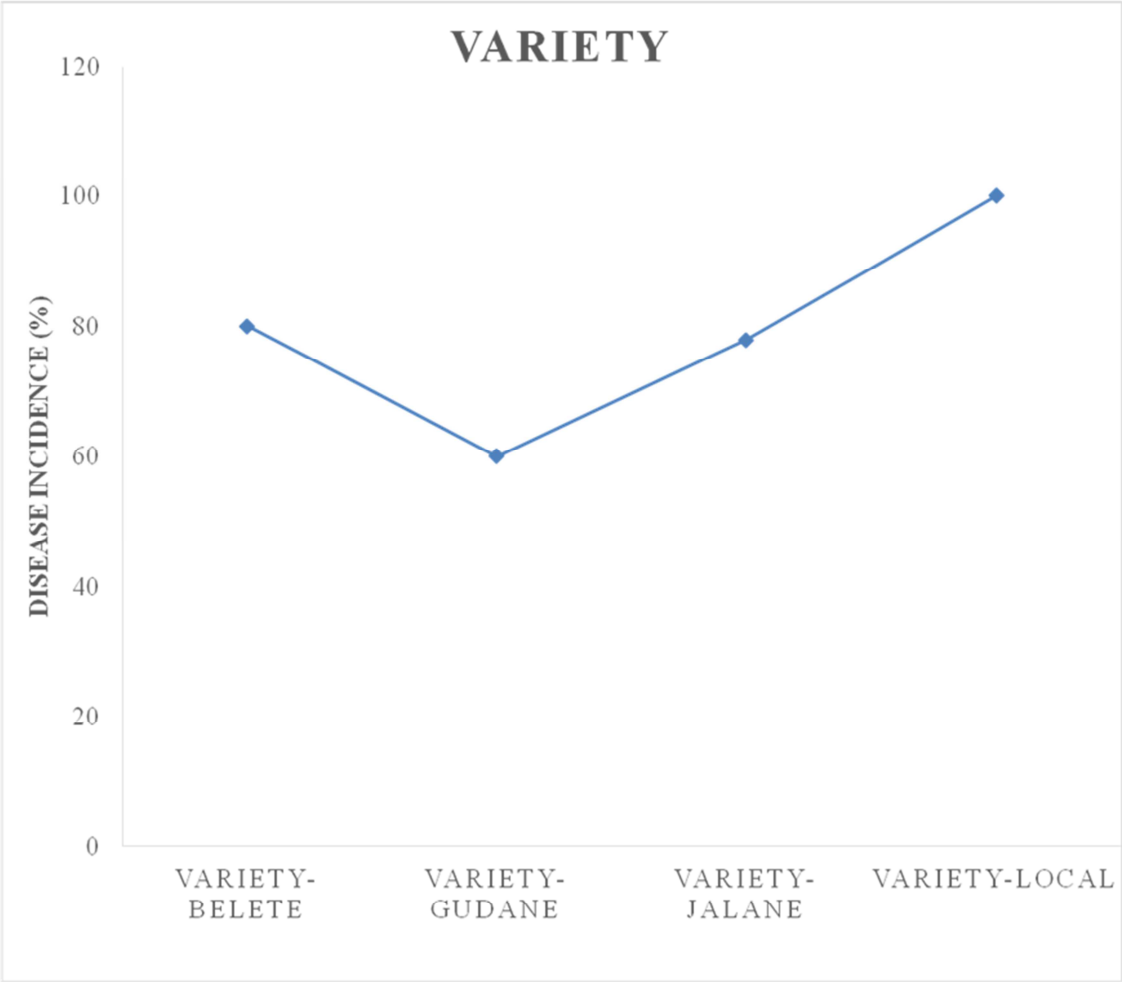

Figure 1. Disease Incidence on the combined effect of potato varieties with fungicides at Gitilo Research Site during main Cropping season, 2018/2019.

Disease incidence was recorded about 100%on local potato variety which was highly susceptible followed byBelete, Jalane and Gudane which was reached 80.02%, 77.9% and 60.03% respectively. Accordingly, Gudane variety was relatively resistant as compared to the rest of the varieties during the main growing season at Gitilo research center (Figure 1). This also indicates that application of fungicide during the main growing season is necessarily important to minimize the amount of Potato yield loss due to late blight infection.

Disease Severity

Disease severity was recorded with highly significant difference with local variety and Gudane Variety. The highest percentage of disease severity was recorded on Local Variety of Potato (30%) and the lowest was recorded from Gudane variety (8.45%) (Figure 2). The severity percentage of variety Belete and Jalane was 7.81% and 8.45% respectively during the main season at Gitilo research site. This indicates that relatively resistant potato variety has performed better while timely application of fungicides in combination with Gudane, Belete and Jalane showed better performance than local variety in minimizing potato yield reduction due to late blight infection.

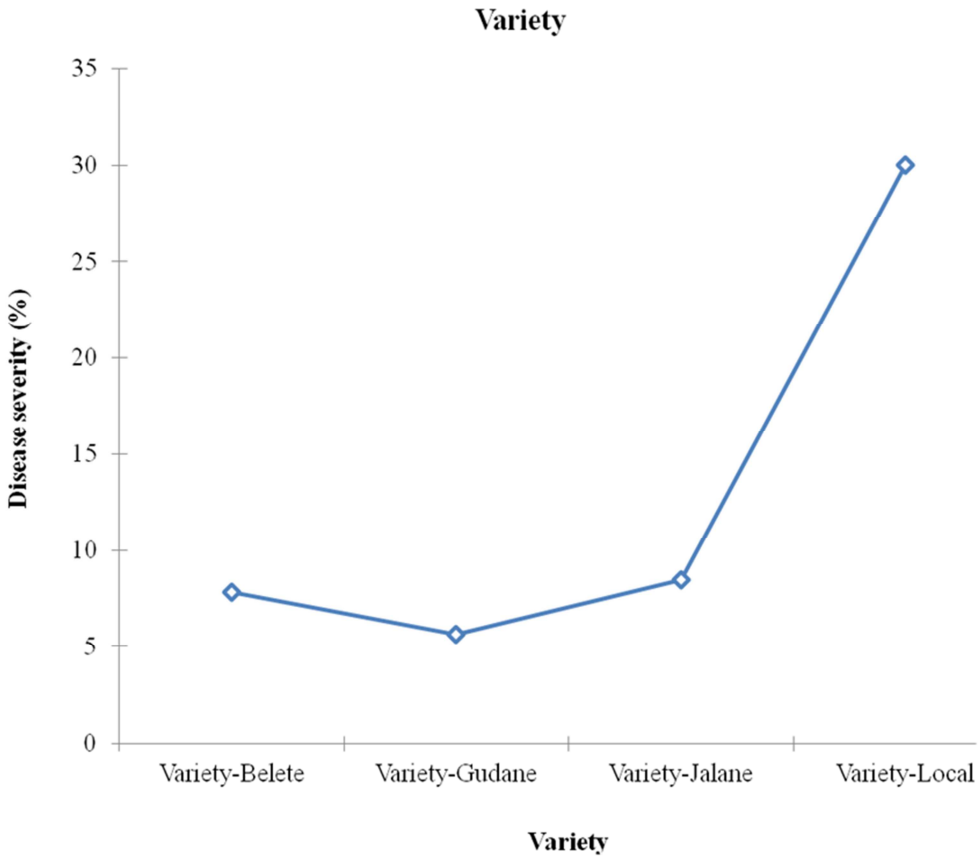

Figure 2. Disease Severity on the combined effect of potato varieties with fungicides at Gitilo Research Site during main Cropping season, 2018.

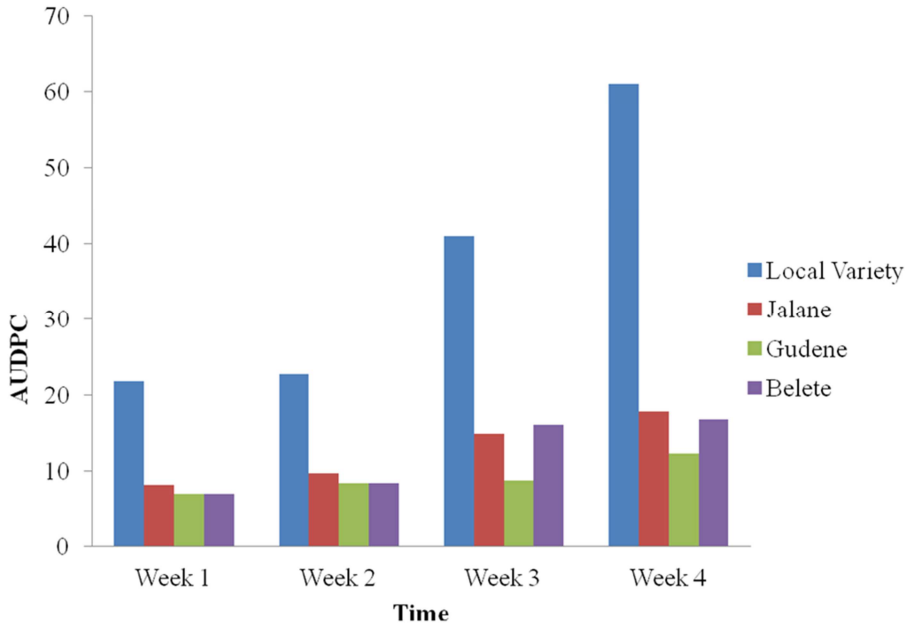

Figure 3. Area under Disease Progress Curve (AUDPC) on the combined effect of potato varieties with fungicides at Gitilo Research Site during main Cropping season, 2018.

Area Under Disease Progress Curve (AUDPC)

The combination of variety with fungicide has significant value on Area under Disease Progress Curve at Gitilo Research site during the cropping season. The highest value of AUDPC was scored on local variety of potato than the relatively resistant variety due to the genetic resistant level of potato variety. Accordingly, the lowest AUDPC was recorded on Gudane variety (12.3) whereas the highest one is scored on local variety of Potato (61), as well as the AUDPC of Belete and Jalane variety was relatively lower as compared to

local variety which indicates that combining fungicide with relatively resistant potato variety can reduce the level of late blight pathogen infection (Figure 3)

Marketable yield of potato tuber

The highest potato tuber yield was obtained from Gudane variety while the lowest one was harvested from local variety of potato during the main growing season at Gitilo research site. This result shows that there is a positive relationship between late blight disease caused by *Phytophthora infestans* and marketability of potato tuber yield. The varieties Belete and Jalane recorded a significant marketable yield of potato tuber as compared to local variety of potato which shows that use of relatively resistant Potato variety combined with fungicide application can enhance the amount of marketable yield of potato tuber at Gitilo research site.

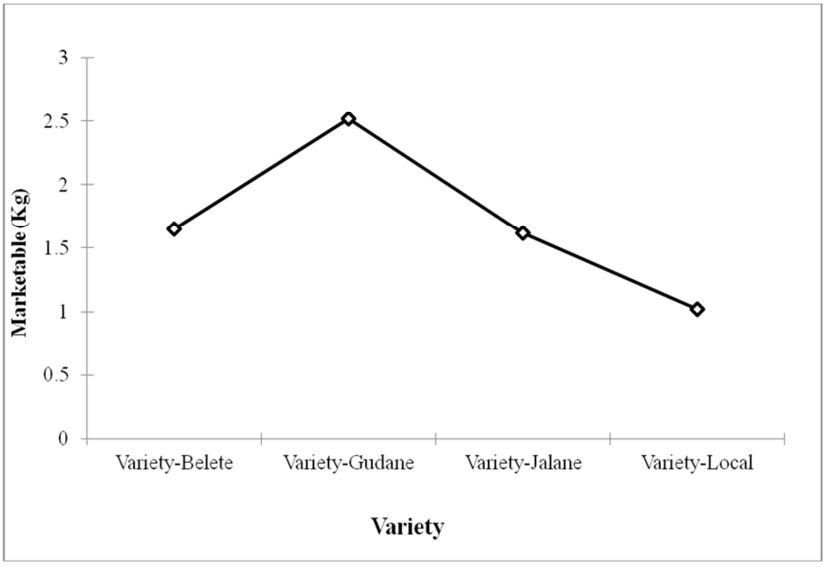

Figure 4. Marketable yield of Tuber on the combined effect of potato varieties with fungicides at Gitilo Research Site during main Cropping season, 2018.

Unmarketable Potato tuber

At Gitilo Research site high amount of unmarketable potato tuber yield was scored on Jalane variety while the lowest unmarketable potato tuber yield was once more recorded from potato local variety (Figure 5). This indicates that potato local variety bears lowest amount of potato tuber yield due to high incidence of disease caused by *Phytophthora infestans* at highland area as the environment is conducive for pathogen development.

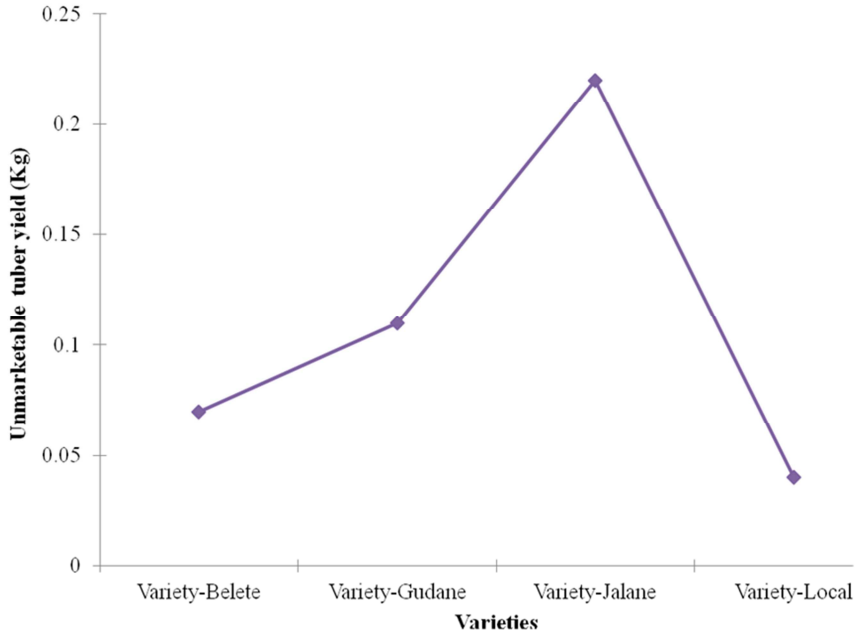

Figure 5. Unmarketable tuber yield on the combined effect of potato varieties with fungicides at Gitilo Research Site during main Cropping season, 2018.

Correlation matrix:

Correlation matrix for the variables Belete, Gudane, Jalane, Local, Disease incidence, disease severity, Marketable yield and un marketable yield is presented in Table 1.

Potato local variety has positive correlation to Disease incidence and disease severity whereas Gudane variety has negative correlation with disease incidence and severity.

Table 1. Correlation matrix of Potato varieties and other variables recorded at Gitilo Research Site during Main Croppin g season, 2018.

Variables	Belete	Gudane	Jalane	Local	DI (%)	DS (%)	Marketable (Kg)	Unmarketable (Kg)
Belete	1.000	-0.333	-0.333	-0.333	0.022	-0.302	-0.057	-0.339
Gudane	-0.333	1.000	-0.333	-0.333	-0.793	-0.428	0.883	0.000
Jalane	-0.333	-0.333	1.000	-0.333	-0.065	-0.265	-0.089	0.931
Local	-0.333	-0.333	-0.333	1.000	0.836	0.994	-0.737	-0.593
DI (%)	0.022	-0.793	-0.065	0.836	1.000	0.886	-0.984	-0.422
DS (%)	-0.302	-0.428	-0.265	0.994	0.886	1.000	-0.803	-0.550
Marketable tuber yield (Kg)	-0.057	0.883	-0.089	-0.737	-0.984	-0.803	1.000	0.280
Unmarketable tuber yield (Kg)	-0.339	0.000	0.931	-0.593	-0.422	-0.550	0.280	1.000

At Harato research site the maximum disease incidence was also recorded on potato local variety (100%) whereas the minimum disease incidence was scored from Gudane variety (60.5%). Almost all incidence of Gudane variety due to late blight infection was similar across the site during the main growing season. Disease incidence which was scored on Belete and Jalane variety at Harato research site was 76.25% and 76.3% respectively. (Figure 5)

At this Harato research site highly significant different value of disease severity was scored between local potato variety (25%) and Gudane (5.65%) which was cultivated in combination with fungicide treatments. The percentage of disease severity scored from Belete (7.81%) and Jalane (8.45%) variety was found lower as compared to the local variety of potato; this might be due to relatively resistant gene of Belete and Jalane variety, to Potato Late Blight disease (Figure 7)

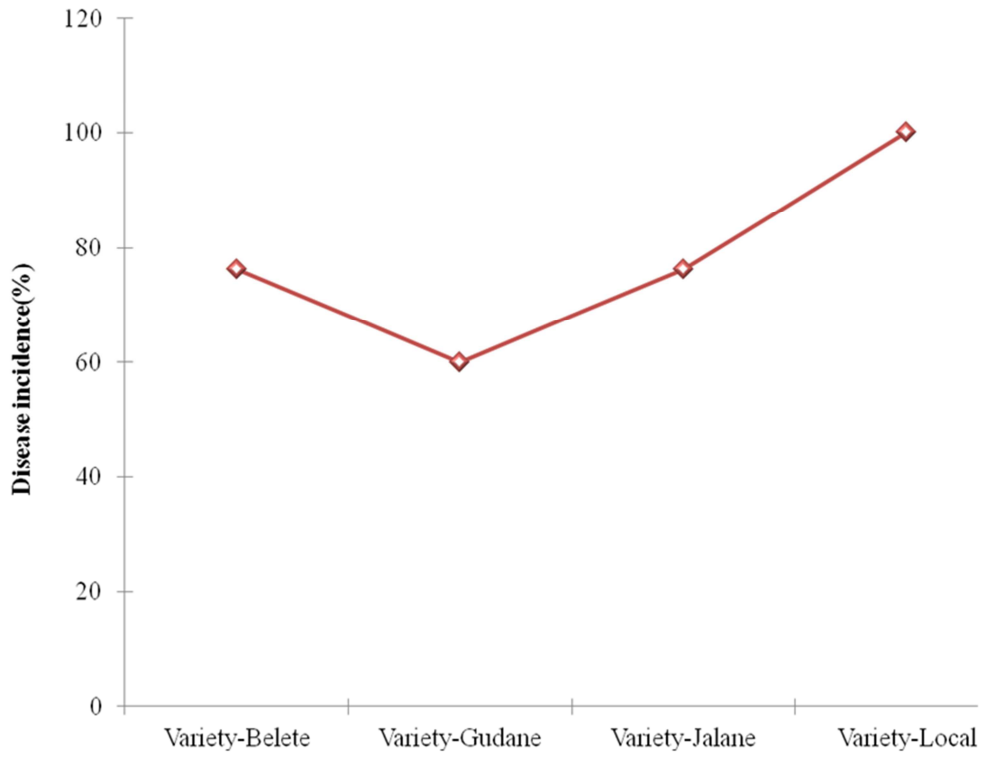

Figure 6. Disease incidence on the combined effect of potato varieties with fungicides at Harato Research site during main Cropping season 2018.

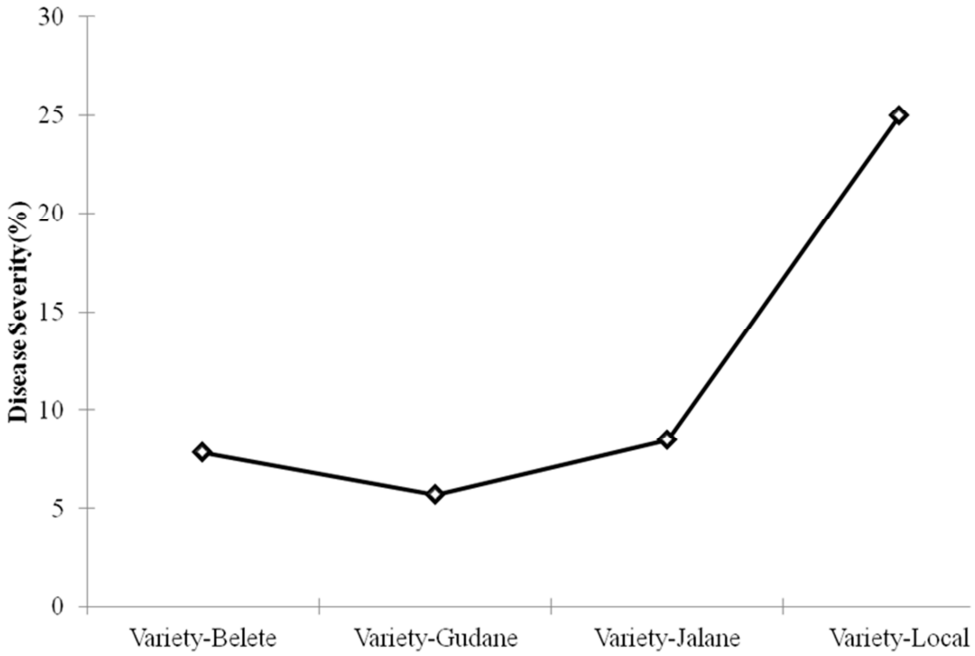

Figure 7. Disease severity on the combined effect of potato varieties with fungicides at Harato. Research site during main cropping season 2018.

Area under Disease Progress Curve at Harato Research Site.

Similary, the combination of Potato variety with Fungicide has significant value on Area under Disease Progress curve at Harato Research site during the cropping season. The highest value of AUDPC was scored on local variety of potato (51) than other potato varieties. AUDPC on Gudene, Belete and Jalane was recorded as 12.3, 16.62 and 17.9 respectively at Harato research site. (Figure 8)

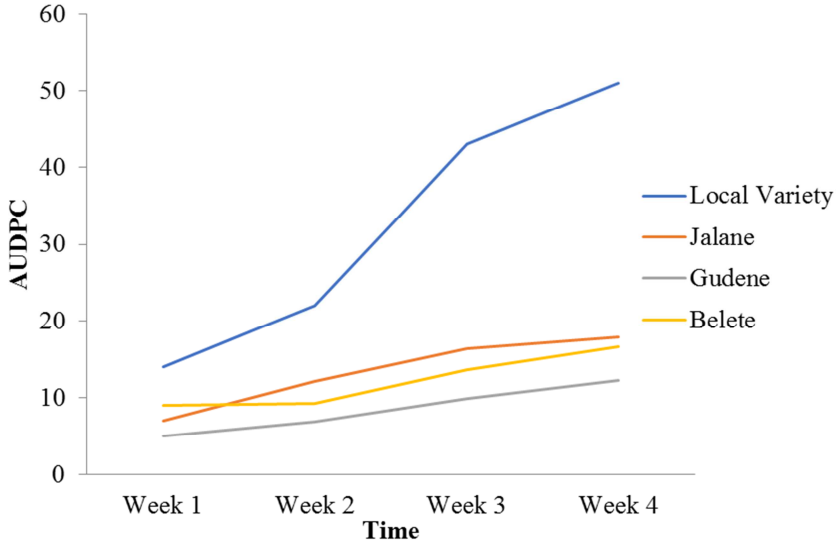

Figure 8. Area under Disease Progress Curve (AUDPC) recorded at Harato Research Site on the combined effect of Potato varieties with fungicides at Harato Research site during main cropping season 2018.

Table 2. Summary statistics of the variables Disease Incidence, Disease severity, Marketable and Unmarketable Tubers

Summary statistics:							
Variable	**Observations**	**Obs. with missing data**	**Obs. without missing data**	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
DI (%)	4	0	4	60.5	100.000	78.145	16.460
DS (%)	4	0	4	5.650	25.000	11.728	8.929
Marketable (Kg)	4	0	4	0.380	0.810	0.658	0.193
Unmarketable (Kg)	4	0	4	0.070	0.320	0.213	0.109

The statistics of the variables Disease Incidence (DI), Disease Severity (DS), Marketable and Unmarketable tubers

is summarized in Table 2. The percentage of disease incidence has shown a wider dispersion with a standard deviation of 16.460 (Table 2.)

Correlation matrix:

Correlation matrix for the variables Belete, Gudane, Jalane, Local, Disease incidence, Disease severity, Marketable yield and un marketable yield is presented in Table 3.

Asimilar trend was observed as that of Gitilo research site;. The potato local variety has positive correlation to Disease incidence and disease severity whereas Gudane variety has negative correlation with disease incidence and severity.

Table 3. Correlation matrix of Potato varieties and other variables recorded at Harato Research Site during Main Cropping season, 2018.

Variables	Variety-Belete	Variety-Gudane	Variety-Jalane	Variety-Local	Disease incidence (%)	Disease Severity (%)	Marketable (Kg)	Unmarketable (Kg)
Variety-Belete	1.000	-0.333	-0.333	-0.333	-0.077	-0.292	0.078	-0.871
Variety-Gudane	-0.333	1.000	-0.333	-0.333	-0.734	-0.454	0.528	-0.138
Variety-Jalane	-0.333	-0.333	1.000	-0.333	-0.075	-0.245	0.355	0.352
Variety-Local	-0.333	-0.333	-0.333	1.000	0.885	0.991	-0.961	0.657
DI (%)	-0.077	-0.734	-0.075	0.885	1.000	0.938	-0.953	0.542
DS (%)	-0.292	-0.454	-0.245	0.991	0.938	1.000	-0.976	0.662
Marketable (Kg)	0.078	0.528	0.355	-0.961	-0.953	-0.976	1.000	-0.485
Unmarketable (Kg)	-0.871	-0.138	0.352	0.657	0.542	0.662	-0.485	1.000

4. Conclusion

Combination of fungicide with relatively resistant potato variety is an important option for the management of potato late blight infection. Recommended rate of fungicide treatment and timely application to potato can reduce Potato Late Blight disease progress with a communing decrease in disease index and enhances in their tuber yields. In this study fungicide decrease infection due to potato late blight in combination with relatively resistant potato variety and improves potato tuber yield. Throughout the locations the combination of Gudane variety with fungicide is relatively resistant to Potato late blight caused by *Phytophthora infestans* during the main season. At Harato research site late blight infection was lower as compared to infection at Gitilo research site. This is due to the fact that Gitilo research site is found at high altitude with high precipitations resulting into a conducive environment to boost late blight development. Local variety was highly susceptible to late blight and early season infection, contributing significantly to lower yield.

At Gitilo high potato tuber yield (2.52kg) was obtained from Gudane followed by Belete (1.65kg) whereas the lowest yield was scored from local potato variety. Even though yield harvested from both location varies, Gudane tuber yield was the highest as compared to the other. Potato tuber yield was higher in the resistant varieties than the local variety which is susceptible. Moreover, integrated management option for Potato Late Blight is needed to be developed in Horo Guduru Wollega Zone where potato is a major crop.

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