

Research Article

Potato Late Blight (*Phytophthora infestans*) Disease Management and Yield Loss Assessment in East Gojjam, North Western Ethiopia

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Abstract

Late blight potato disease (*Phytophthora infestans*) is the most devastating and causes 50–70% potato yield loss under favorable environmental conditions. Fungicide application is among the effective management options to control the disease. The experiment was conducted at Debre Markos agricultural research center station (Aneded) in 2023/24 main cropping season to evaluate the efficacy of fungicides to manage late blight disease of potato and to quantify the losses incurred due to the disease in the area. Randomized complete block design with three replications was applied using Jalene variety to the experiment. Banjo forte 400 SC, Ridomil Gold MZ 68 WG, Electis 75% WG, Funguran-OH and Mancozeb 80% WP fungicides were used to execute the experiment. The highest 71.67 percentage severity and the lowest (12.69 t ha⁻¹) marketable tuber yield were obtained from untreated plots, whereas the lowest (20.00%) percentage severity and the highest (27.54 t ha⁻¹) marketable tuber yield were obtained from treatments treated with Redomil gold MZ 68 WG fungicide. Also the area under disease progress curve (AUDPC) was significantly reduced in treatments and the highest 1591.7% and the lowest 545.8% AUDPC value were recorded from untreated control and Redmil MZ 68 WG fungicide treated plots, respectively. This study showed the susceptible variety Jalene treated with Ridomil Gold MZ 68 WG and Banjo forte 400 SC fungicides were more economical and feasible for the management of late blight potato disease and increased yield.

Keywords

Phytophthora infestans, Disease Severity, AUDPC, Varieties, Yield Loss, Cost Benefit Analysis

1. Introduction

Potato late blight (*Phytophthora infestans* Mont.) is among the most destructive diseases of potatoes production worldwide [9]. It is also a significant constraint for potato production in the tropical highlands of East Africa. In Ethiopia, the damaging impact of *P. infestans* is increasingly becoming a serious problem and becomes a threat to food security. The

tuber yield reduction was significantly higher in unmanaged crop, go as high as 90% of total productivity in hilly regions. In Ethiopia, yield losses by *P. infestans* ranges between 29–100%, depending on variety used [20]. Also, yield loss of 100% on unimproved local cultivar, and 67.1% on a susceptible variety has been recorded [3]. It is not cause only economic

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losses of yield but also the quality and quantity of the crop. A number of studies have investigated various methods to control late blight disease [7] including the genetic basis of resistance in host plants [17] and the application of fungicides. The disease is effectively controlled by applying chemical fungicides at suitable rates and intervals depending on the climatic conditions and disease severity [11]. Fungicides are the most important aspect of late blights management in temperate countries [14]. Ridomil Gold was among the most effective of potato late blight disease management [19]. Although control of potato late blight can be achieved through the use of fungicides, the fungicide costs are often prohibitive for the small-scale potato growers, who are the major producers of potato within the region. In addition, periodical fungicide applications, timing and dosage are often made more difficult of small scale growers on fungicide applications [8, 13]. Moreover, development of resistance to commonly used fungicides such as metalaxyl has also made control of the disease very difficult [12]. But because of the variability of the pathogen, race-specific oligogenic resistance has not been useful for its control. The profound ability of the disease, inadequate efficiency of cultural practices, development of resistance to fungicides and breaking of resistance potato varieties within a short period makes the disease management difficult.

In the country, many improved potato varieties which is resistant to late blight and with full package are released for production for wider adaptation. The disease occurs throughout the major potato production areas and it is impossible to produce the crop during the main season without applications of fungicides at the right time with recommended rate [21]. Yield loss assessment studies have been conducted in many parts of the countries. However, in the study area the information is scanty and of aged. Due to this reason the experiment was planned to conduct to quantify the losses incurred by the disease and to disseminate the information for growers.

2. Materials and Methods

2.1. Description of the Study Areas

The study was conducted under rain fed conditions at Aneded district of Debre Markos Agricultural Research Center station during 2022/23 main cropping season. The rainfall pattern is mainly of a unimodal type where the average annual rainfall varies from 900 to 1800 mm while there is a short rainy season (Belg) during February and March in the highland (Dega) agro ecology. The average temperature of the zone ranges from min 7.5 °C to high 27 °C. The major soil types in order of importance include vertisol (black soil), red and gray soils [18].

2.2. Experimental Materials and Design

Susceptible potato variety Jalene and five fungicides; Banjo

forte 400 SC, Electis 75 WG, Funguran OH 50 WG, Ridomil Gold MZ 68 WG and Mancozeb 80% WP were used to execute the experiment. The treatments were arranged in randomized complete block design, with a total of six treatments with three replications. Foliage infection was by natural air-borne inoculum, no artificial inoculum was used. Fungicide application was done per the recommendation of the manufacturer using a manually pumped knapsack sprayer starting on the disease onset date. During fungicide sprays, plastic sheets were used to protect the adjacent plots and untreated plots from fungicide drifts. Plots with no fungicide treatment were included as checks for each fungicide. All agronomic and cultural practices were applied as recommended.

2.3. Disease Assessment

2.3.1. Disease Incidence

Disease incidence was recorded by counting of plants that showing visible symptoms of late blight on the central rows and the data was expressed as a percentage of the total assessed plants.

$$\text{Disease Incidence\%} = \frac{\text{Number of diseased plant}}{\text{Total number of plants inspected}} \times 100$$

2.3.2. Disease Severity

Late blight severity was determined by considering the proportion of the attacked surface on the plant to the total surface of the plant, expressed as a percentage using the Horsfall-Barrat modified rating scale [23].

2.3.3. Area Under Disease Progress Curve (AUDPC)

The AUDPC were based the percentage of leaf area affected by late blight and it was calculated using the midpoint formula [10].

$$AUDPC = \sum_{i=1}^{n-1} 0.5 + (x_i + 1x_{i+1})(t_i + 1 - t_{i+1})$$

Where, x_i =the average coefficient of infection of i^{th} record, x_{i+1} =the average coefficient of infection of $i+1^{th}$ record and, $t_{i+1}-t_i$ = Number of days between the i^{th} record and $i+1^{th}$ record, and n = number of observations.

2.4. Tuber Yield

Marketable tuber yield (t/ha): All the marketable tubers which were free from diseases, insect pests and greater than or equal to 20 g in weight were recorded.

Unmarketable tuber yield (t/ha): The tubers that were diseased, insect attacked and small-sized (< 20 g) were recorded as unmarketable tuber yield.

Total tuber yield (t/ha): The sum of the weights of marketable and unmarketable tubers from the net plot area and

converted to tons per hectare.

Relative Yield loss (RYL%): The percent yield loss was computed using the formula [15].

$$\text{RYL}\% = \frac{(YP - YT)}{YP} \times 100$$

Where RYL=Relative yield loss, YP = Yield from the maximum protected plot, YT = Yield from other treated plots.

2.5. Cost - Benefit Analysis

The difference between treatments, the option economic data will be subjected to analysis using the partial budget analysis method [4].

$$\text{MRR}(\%) = \frac{\Delta \text{NI}}{\Delta \text{CI}} \times 100$$

Where, MRR- is marginal rate of returns,
 ΔNI – change in net income compared with control, and
 ΔCI – change in input cost compared with control.

2.6. Data Analysis

Data were subjected to analysis using SAS software version 9.3 and analysis of variance (ANOVA) was done by generalized linear model to determine the treatment effects [5]. Mean separation was carried out by using Fisher's least significant difference test at 5% significance level (LSD).

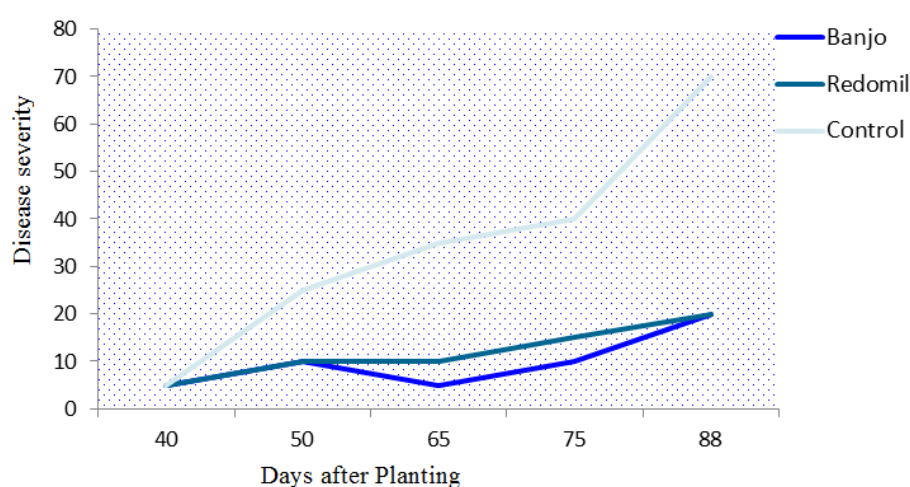


Figure 1. Disease Severity of LB (*Phytophthora infestans*) of Potato disease in the season.

3. Result and Discussion

3.1. Disease Incidence and Severity

The Analysis of variance, ANOVA revealed that, all fungicides used in the experiment significantly (0.05) protected the foliage and increased yield of tubers over control in the seasons with occurrence of late blight disease (Figure 1). All sprayed fungicides significantly reduced the incidence and severity of late blight disease as compared to the unsprayed control plot. The lowest disease incidence was recorded on Ridomil gold (31.67) fungicide spray plots followed by 32.50% disease incidence on Electis 75 WG fungicide sprayed plots. Controlled plots showed 100% disease incidence. Also, Ridomil gold fungicide sprayed plots recorded the lowest disease severity than other treatments. It reduces the disease severity by 9.11%, 18.22%, 54.56%, 72.78% and 291% than Banjo forte 400 SC, Electis 75 WG, Funguran OH 50 WG, Mancozeb 80% WP and control (unsprayed) plots respectively. The same findings were reported that better effect of systemic and contact fungicides to control late

blight of potato [16]. Area under Disease Progress Curve (AUDPC) were also showed significant variations between treatments ($p < 0.05$). The control treatment recorded the highest AUDPC (1591.7) whereas, Ridomil gold sprayed plots recorded the lowest (545.8) AUDPC values. The second lowest AUDPC (617.5) value was recorded on Banjo forte 400 SC sprayed plots. Also, [6] reported; the lowest AUDPC value was recorded from Ridomil sprayed treatments.

3.2. Tuber Yields (t/ha) H

Analysis of variance indicated that total tuber yield showed statistically significant variation ($p < 0.01$) among the fungicides applied (Table 1). Also, significant variations on total marketable tuber yield and unmarketable tuber yield ($p < 0.05$). The highest tuber yield (36.33 t/ha) was obtained from plots sprayed with Banjo forte 400 SC followed by Ridomil Gold sprayed plots which gave (33.09 t/ha); but non-significant variations has been recorded between them. The lowest tuber yield (17.56 t/ha) was recorded from unsprayed (control plots). Thus, all fungicides applied were given significant variations on tuber weight harvested than control plots. This study is in

agreement with study of [6, 2] that yields of potato are higher on fungicide sprayed plots than untreated.

Table 1. Effect of fungicides on disease parameters, yield and yield components potato due to late blight during 2022 & 2023 cropping season.

Treatments	Final DI	Final DS	AUDPC	MTY (t/ha)	UMTY (t/ha)	TTY (t/ha)	% YI	%RYL
Banjo forte 400 SC	35.83b	20.00b	617.5c	27.48a	8.85a	36.33a	116.55	0
Ridomil Gold MZ 68 WG	31.67b	18.33b	545.8c	27.54a	5.56c	33.09ab	117.02	8.92
Mancozeb 80% WP	38.33b	31.67b	936.7b	20.02b	7.68ab	27.70bc	57.76	23.75
Electis 75 WG	32.50b	21.67cd	730.8bc	20.32b	6.52bc	26.84bc	60.13	26.12
Funguran OH 50 WG	34.17b	28.33bc	755.0bc	20.13b	5.08c	25.21c	58.63	30.61
Control	100.00a	71.67a	1591.7a	12.69c	4.87c	17.56d	0.00	51.67
Mean	45.42	31.94	862.92	21.36	6.43	27.79		
CV	12.51	12.99	16.06	15.50	14.89	12.90		
LSD	10.34	7.55	252.04	6.02	1.74	6.52		
R ²	0.97	0.97	0.92	0.82	0.81	0.84		

DI= Disease Incidence, DS= Disease severity, AUDPC = Area under Disease Progress Curve, MTY = Marketable tuber yield, UMTY = Unmarketable tuber yield, TTY= Total tuber yield, YI= Yield increase RYL= Relative Yield Loss.

3.3. Relative Yield Losses

Yield loss incurred for each of the treated and control plots were calculated based on the yield of maximum protected plots and maximum yield recorded i.e. Banjo forte 400 SC sprayed plots (Table 1). Compared to Banjo forte 400 SC fungicide sprayed plots, untreated plots recorded 51.67% yield losses. This finding is in line with [22] estimated losses due to late blight disease reached to 72.96% on susceptible cultivars, however, in the country the disease can causes up to 100% yield loss on local susceptible cultivars [3] Hence, the second and the third highest percent yield loss 30.61% and 26.12% was recorded from plots sprayed with Funguran OH 50 WG and Electis 75 WG as compared to Banjo forte 400 SC sprayed plots. Similarly, marketable tuber yield was increased with the application of Banjo forte 400 SC (116.55%), Ridomil Gold MZ 68 WG (117.02%), Electis 75% WG (60.13%), Funguran-OH (58.63%) and Mancozeb 80% WP (57.76%) as compared with the control plot.

3.4. Association Between AUDPC and Total Tuber Yield

The associations between disease and yield parameters were examined using simple correlation analysis. A linear regression model describes the relationship between dependent variables (response variable) and one or more independent (explanatory) variables. It is used to predict the relationship between AUDPC and total tuber yield. Hence,

AUDPC was significantly ($P < 0.01$) correlated with tuber yield (Figure 1). Henceforth the correlation coefficients between were negatively correlated to each other. The equation of the model, $Y = -0.0134X + 39.321$ indicated, for every one unit increases of AUDPC (% days), a corresponding 0.0134 t ha⁻¹ potato tuber yield loss recorded (Figure 1). The relationship by the regression linear model, 54.78% of the loss in potato tuber yield was predicted due to potato late blight disease. The same result was reported by [1], that the disease parameters and yield parameters were negatively correlated.

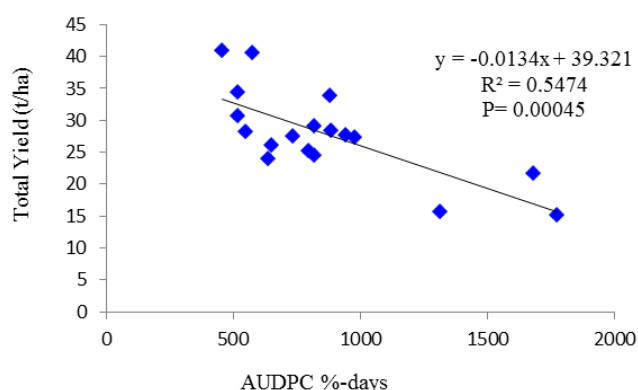


Figure 2. Estimated linear relationship between AUDPC and tuber yield (t ha⁻¹).

3.6. Cost-benefit Analysis

The partial budget analysis was done for a combination of

late blight disease management through different fungicides application (Table 2). The overall net benefit was highest (520,700.0) in Ridomil Gold MZ 68 WG sprayed plots followed by (519,500.0) on Banjo forte 400 SC treated treatments. However the lowest (235,300.0 ETB) net benefit was received from non-treated control treatments. As the same time, Ridomil Gold MZ 68 WG and Banjo forte 400 SC sprayed treatments increased yield in 117.02% and 116.55% in the order mentioned. Generally all disease and yield parameters result indicates that among the five fungicides spray; Banjo forte and Ridomil Gold was the most effective followed by Electis 75 WG and Funguran OH fungicides.

The maximum net benefit of 550,800 and 549,600.0 ETB ha⁻¹ were obtained from Ridomil and Banjo forte 400 SC fungicides sprayed plots respectively. On the other hand, the

lowest net benefit of 253,300 ETB ha⁻¹ was recorded from unsprayed plot. Marginal rate of return was used to described for comparing the costs that vary with the net benefits of all treatment combinations. As the result indicated that, all fungicides applied resulted high net benefit and marginal rate of returns than unsprayed plots. The highest (2460% and 2450%) marginal rate of returns were received from Ridomil gold and Banjo forte 400 SC sprayed plots, in the ordered mentioned. On the other hand, the lowest marginal rate of return (1443%) was obtained from Mancozeb sprayed plots as compared with the other sprayed fungicides. The result of this finding is in agreement with the finding of [22] states, appropriate fungicide applications have resulted effective and economical options for disease control method.

Table 2. Partial budget analysis of applied fungicides on potatoes during 2023 cropping season.

Treatments	Yield (t ⁻¹ ha)	PP (ETB ⁻¹ kg)	GB (ETB ⁻¹ ha)	TIC (ETB ⁻¹ ha)	MC (ETB ⁻¹ ha)	NB (ETB ⁻¹ ha)	MB (ETB ⁻¹ ha)	MRR (%)
Banjo forte 400 SC	27.48	20.0	549,600	30,100.0	11,600.0	519,500.0	284,200.0	24.50
Ridomil Gold MZ 68 WG	27.54	20.0	550,800	30,100.0	11,600.0	520,700.0	285,400.0	24.60
Mancozeb 80% WP	20.02	20.0	400,400	29,000.0	9,500.0	371,400.0	137,100.0	14.43
Electis 75 WG	20.32	20.0	406,400	29,500.0	10,000.0	376,900.0	142,600.0	18.82
Funguran OH 50 WG	20.13	20.0	402,600	30,100.0	10,600.0	372,500.0	138,200.0	18.08
Control	12.69	20.0	253,800	18,500.0	0	235,300.0	0.0	0.0

PP = Price per kg, GB = Gross benefit, TIC = Total input cost, MC = Marginal cost, NB = Net benefit, MB = Net benefit, MRR = Marginal rate of return.

4. Conclusion

The late blight disease of potato is among the damaging and production constraints of potato production and can result upto complete losses of the crop in short periods. All the applied fungicides significantly reduced severity of late blight disease and increased yield of the crop. Moreover, fungicides Ridomil gold and Banjo Forte results a significant reduction of late blight disease and correspondingly increase tuber yields. Also, these fungicides are substantially suppressing potato late blight, giving maximum net benefit and maximum marginal rate of return. Therefore, growers can produce production of potato by applying fungicides in surplus production.

Abbreviations

ANOVA	Analysis of Variance
AUDPC	Area Under Disease Progress Curve

SAS	Statistical Analysis System
LSD	Least Significant Difference

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Author Contributions

Belachew Bekele is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

References

- [1] Admasie, K., Merku, A., & Eshetu, B. (2021). The response of potato late blight to potato varieties and fungicide spraying frequencies at Meket, Ethiopia, Cogent Food & Agriculture, vol. 7, p. 1. <https://doi.org/10.1080/23311932.2020.1870309>
- [2] Ayda, T. (2015). Effect of fungicides and resistant genotypes on severity of potato late blight (*Phytophthora infestans* (mont.) de bary] and yield and yield components in Haramaya, Eastern Ethiopia. MSc. Thesis, Haramaya University, Dire Dawa, Ethiopia, No. 101.
- [3] Bekele, K. & Yaynu, H. 1996. Tuber yield loss assessment of potato cultivars with different levels of resistance to late blight. In: Proceedings of the 3rd Annual conference of Crop Protection Society of Ethiopia. 18-19 May, Addis Abeba, Ethiopia. Eshetu Bekele, Abdurahman Abdulahi and Aynekulu Yemane (Eds.), pp. 149-152. CPSE, Addis Ababa.
- [4] CIMMYT. (1988). From agronomic data to farmer recommendations: An economics training manual (Completely revised ed.). Edition.
- [5] Gomez, K. A. and Gomez, A. A. (1984) Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley and Sons, New York, 680 p.
- [6] Habtamu, K., Alemayehu, C., Bekele, K., & Tiwari, K. P. (2012). Evaluation of different Potato varieties and fungicide combinations for management of Potato late blight (*phytophthora infestans*) in Southern Ethiopia. International Journal of Life, 1(1): 8–15.
- [7] Haverkort, A. J., Struik, P. C., Visser, R. G. F. & Jacobsen, E. J. P. R. (2009). Applied biotechnology to combat late blight in potato caused by *Phytophthora infestans*. Potato research, 52(3), pp. 249-264. <http://dx.doi.org/10.1007/s11540-009-9136-3>
- [8] Kankwatsa, P., Adipala, E., Hakiza, J. J., Olanya, M., & Kidanemariam, H. M. (2002). Effect of integrating planting time, fungicide application and host resistance on potato late blight development in South-western Uganda. Journal of Phytopathology 150: 248–257. <https://doi.org/10.1046/j.1439-0434.2002.00750.x>
- [9] Latijnhouwers, M., Ligterink, W., Vleeshouwers, V. G., VanWest, P. & Govers, F. (2004). A Ga subunit controls zoospore mobility and virulence in the potato late blight pathogen *Phytophthora infestans*. Molecular Microbiology, 51: 925-936.
- [10] Madden, L. V., Hughes, G., & van den Bosch, F. (2007). The Study of Plant Disease Epidemics. American Phytopathological Society, St. Paul, MN.
- [11] Majeed, A., Chaudhry, Z., & Muhammad, Z. (2014). Changes in Foliar Glycoalkaloids Levels of Potato (*Solanum tuberosum*) Triggered by Late Blight Disease Severity. International Journal Agriculture Biology, 16(3), 609-613.
- [12] Mukalazi, J., Adipala, E., Sengooba, T., Hakiza, J. J., Olanya, M. & Kidanemariam H. M. (2001). Metalaxy resistance, mating type and pathogen city of *Phytophthora infestans* in Uganda. Crop Protection 20: 379–388. [http://dx.doi.org/10.1016/S0261-2194\(00\)00145-9](http://dx.doi.org/10.1016/S0261-2194(00)00145-9)
- [13] Nyankanga, R. O., Wien, H. C., Olanya, O. M., & Ojiambo, P. S. (2004). Farmers' cultural practices and management of potato late blight in Kenya Highlands: Implications for development of integrated disease management. International Journal of Pest Management, 50(2), 135–144. <https://doi.org/10.1080/09670870410001691812>
- [14] Olanya, O. M., Adipala, E., Hakiza, J. J., Kedera, J. C., Ojiambo, P., Mukalazi, J. M., Forbes, G & Nelson, R. (2001). Epidemiology and population dynamics of *Phytophthora infestans* in Sub-Saharan Africa: Progress and Constraints. African Crop Science Journal, 9: 181-193. <https://doi.org/10.4314/acsj.v9i1.27638>
- [15] Robert, G. D., & James, H. T. (1991). A Biometrical Approach. Principles of Statistics. (2nd Ed.). New York, USA.
- [16] Samoucha, Y., & Cohen, Y. (1986). Efficacy of systemic and contact fungicide mixtures in controlling late blight in potatoes. Phytopathology, 76(9): 855-859. <https://doi.org/10.1094/Phyto-76-855>
- [17] Sanju, S., Siddappa, S., Thakur, A., Shukla, PK., Srivastava, N., Pattanayak, D., Sharma, S., & Singh BP. (2015) Host-mediated gene silencing of a single effector gene from the potato pathogen *Phytophthora infestans* imparts partial resistance to late blight disease. <https://doi.org/10.1007/s10142-015-0446-z>
- [18] Setotaw, F., Getachew, A., Aemiro, K., Tesfahun, A., & Chilot, Y. (2020). Farming Systems Characterization and Analysis in East Gojjam Zone: Implications for research and development (R&D) interventions. Research Report No. 127. Ethiopian Institute of Agricultural Research.
- [19] Subhani, M. S., Sahi, S. T., Rehman, A., & Wakil, W. (2015). Efficacy of fungicides against Late blight of potato incited by *Phytophthora infestans* (Mont.) de Bary. Academic Research Journal of Agricultural Science and Research, 3(9), 245-250. <https://doi.org/10.14662/ARJASR2015.052>
- [20] Tsedaley, B. (2014). Late blight of potato (*phytophthora infestans*) biology, economic importance and its management approaches. Journal of Biology, Agriculture and Healthcare, vol. 4, no. 25, pp. 215–225.
- [21] Yitagesu, T. (2019). Integrated potato (*Solanum tuberosum* L.) late blight (*Phytophthora infestans*) disease management in Ethiopia. American Journal of BioScience, 7(6), pp. 123-130. <https://doi.org/10.11648/j.ajbio.20190706.16>
- [22] Yitagesu, T., & Asela K. (2023). Yield Loss Assessment of Potato Late Blight Disease in Central Highland Parts of Ethiopia. American Journal of Plant Biology, 8(3): 71-74. <https://doi.org/10.11648/j.ajpb.20230803.14>
- [23] Zadoks J. C., & Schein R. D. (1979). Epidemiology and Plant Disease Management. New York: Oxford University Press Pg. 427. <https://doi.org/10.1007/BF02894891>