International Journal of African and Asian Studies
ISSN 2409-6938 An International Peer-reviewed Journal
Vol.49, 2018

Evaluation of Fungicides with the Combinations of Potato (Solanum tuberosum L.) Varieties to Manage Late Blight (Phytophthora infestans (Mont) de Bary) in Highlands of Guji Zone, Southern Ethiopia

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Abstract
Potato late blight (Phytophthora infestans (Mont.) de Bary) is one of the most devastating plant diseases world-wide and is feared globally by farmers and industry. There is little information on the type of fungicide to be sprayed to control late blight for optimum production of the crop in the study area. Therefore, an experiment was conducted at Bore Agricultural Research Center, Southern Ethiopia during the 2015 and 2017 cropping season to evaluate fungicides with the combination of Potato varieties to manage late blight and to assess the cost and benefits of different fungicides on Gudanie and Jalenie potato varieties. The treatments consisted of two (2) Potato varieties Gudanie and Jalenie currently under production but differ in their late blight reaction and three (3) fungicides Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico and one (1) unsprayed treatments were used as experimental materials. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a 4 x 2 factorial arrangement and replicated three times per treatment. The improved potato varieties called Gudanie and Jalenie were planted as the test crop in a plot size of 3 m * 2.1 m with intra and inter-row spacing of 0.30 and 0.75 m respectively. Data were collected on growth, yield, yield components and disease incidence and severity. The two years combined data analysis results revealed that the interaction effect of fungicides and potato varieties had influenced significantly ($P<0.05$) response on days to 50% flowering, 50% maturity, plant height, number of tubers per hill, stem number per plant, marketable tuber yield and unmarketable tuber yield and total tuber yield. However, interaction effect of fungicides and potato varieties had non-significant ($P>0.05$) effect on days to50% emergency and average tuber weight. The two year data analysis the highest (47.34 t $ha^{-1}$and 46.31 tha^{-1}) marketable tuber yield was obtained from Gudanie variety with Ridomil Gold fungicide spraying at Bore on-station and Ana sora on-farm both locations respectively. The result of 2015 year disease data indicates that maximum (59.52% and 3.67) disease incidence and severity, respectively was recorded by unsprayed treatment of Jalenie variety and also the second year maximum (45.24 % and 2.83) disease incidence and severity by treatment Gudanie variety unsprayed fungicides, respectively. However, the minimum (5.48% and 1.16) disease incidence and severity of late blight was recorded by spraying Ridomil Gold on both Gudanie and Jalenie varieties in 2015 cropping season, respectively. In general, spraying of Ridomil Gold fungicide was more effective by reducing the disease severity and increasing tuber yield. The partial budget analysis revealed that application of Ridomil Gold on Gudanie variety resulted the highest net benefits of Birr 244,462.50 and 235,352 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2549.00 and 2698% . Thus, application of Ridomil Gold on Gudanie variety led to optimum marketable tuber production and economic returns. Therefore, the farmers' in highlands of Guji zone and similar agro-ecology can produce healthy and maximum potato crop of Gudanie by spraying Ridomil Gold fungicide with the recommended rates and frequency.
Keywords: Disease severity and incidence, Sprayed and Unsprayed plot, Marketable tuber yield and Partial budget analysis

1. INTRODUCTION

Late blight of potato (*Solanum tuberosum*, L.) caused by *Phytophthora infestans* (Mont de Bary), is a major worldwide threat to the production of high quality potatoes (Fry and Goodwin 1997). It is economically the most important and most destructive potato disease worldwide. The disease causes annual losses of several billion dollars and it is a global threat for potato growers (Cooke and Lees, 2004). The pathogen apparently originates from Central Mexico (Zimnoch-Guzowska *et al.,* 2003). In the middle of the 19th century the pathogen was introduced into the US and Europe, where it destroyed a great of part the potato crop and is widely known as the cause of the Potato famine in 1845 (Smart and Fry, 2001).

Phytophthora infestans is a hemibiotrophic pathogen attacking living parts of plants from the family *Solanaceae*. The pathogen is economically significant on potato and tomato. The pathogen causes lesions with necrotic cells in the middle, surrounded by a ring of gradually necrotizing tissue. Once infected, plants initially appear healthy, before necrotic lesions develop. Under favorable weather conditions, the pathogen can destroy potato foliage in 10 to15 days and potential yield can be reduced by 50 to 70% (Tymcenko and Jefronova, 1987).

In developed countries, potato late blight control is mainly based on intensive application of fungicides (Song *et al.,* 2003). However, late blight epidemiology is also impaired by natural resistance of varieties provided by introgression of resistance genes. The genetic background of a variety together with environmental conditions that is not conducive for the pathogen results in field resistance. Expression of so-called 'age resistance' is also important, when the pathogen only infects ontogenetically older parts of the plants. Natural resistance plays an important role in plant protection and optimization of fungicide protection. Therefore, breeding for resistance is a critical part of integrated late blight control in potatoes.

Current resistance of commercially used varieties of *Solanum tuberosum ssp. tuberosum L.* to potato late blight can be vertical or horizontal in character (Bradshaw and Mackay, 1994). Specific (vertical) resistance is the resistance to a certain pathogen race. It is oligogenic resistance and confers a relatively high level of resistance and is less environment dependent (years, growing localities); however, it is overcome by the emergence of new virulent races. Fungicides continue to be an important component of late blight control with up to 15-20 applications being used per season.

Late blight caused by *Phytophthora infestans* is generally the most important disease wherever potato is grown Sikka *et al.(*2000), with annual losses of about 42% (CIP 1998).The disease is primarily controlled by rigorous application of fungicides. The aim of this work was to evaluate the efficacy of systemic and contact fungicides on late blight disease and tuber yield of Gudanie and Jalenie varieties. The two systemic fungicides (Ridomil Gold and Matico) and one contact fungicides (Mancozeb) were tested for their effects on late blight of potato and consequent tuber yield in field conditions, applied as foliar sprays at seven day interval. Both types of fungicides were found highly effective in reducing disease severity level and disease progress. However, systemic fungicides more effectively controlled diseases severity and the disease progress than contact fungicides. Compared to control, disease severity and area under disease progress curve (AUDPC) were significantly reduced by systemic fungicide Curzate corresponding to significant increase in tuber yield. Contact fungicides contributed to reduction in disease severity and AUDPC; however, they had no effects on tuber yield. Results recorded efficacy of the tested fungicide groups in the order systemic > contact and among the systemic fungicides as Curzate > Ridomil Gold.

Efficacy of systemic and contact fungicides against late blight of potato in field conditions has been widely documented. Namanda *et al.* (2004) reported that contact fungicide Dithane was effective for reducing late blight disease progress and increasing potato yields. Mantecon (2007) documented systemic fungicides more effective than contact fungicides in reducing early and late blight disease severity and increasing tuber yields. In a study conducted during 1983 to 2007 systemic and contact fungicides programs were evaluated for late blight and tuber yields; both fungicides programs significantly controlled foliar blight of potato and contributed to tuber yield increments with major contribution from systemic fungicides (Dowley *et al*., 2008).

The late blight disease caused by *P. infestans* is considered to be a major constraint for potato production wherever potato is grown. Due to this, commercial potato production would hardly exist without routine use of fungicides. Different varieties have different reaction towards late blight and varieties varied in their response to the fungicide treatments. However, different varieties which type of chemical application and which chemical by itself was not identified for different potato varieties to minimize damage of late blight of potato. This take into account, it is important to determine the safest varieties which incur less frequent chemical application, and frequency of chemical application to minimize damage caused by late blight of potato in high lands of Guji zone. The climatic condition of in highlands of Guji zone is a humid moisture condition, with a relatively longer growing season. During wet, cool weather, crop loss due to late blight can be rapid and unstoppable if preventative controls have not been used. Therefore, this research was conducted with the following objectives: - To evaluate fungicides with the combination of potato varieties to manage late blight and to assess the cost and benefits of different fungicides on Gudanie and Jalenie potato varieties.

2. MATERIALS AND METHODS

2.1. Description of the Experimental Sites

The experiment was carried out during the 2015 and 2017 main cropping season at Bore Agricultural Research Center, Guji Zone of Southern Ethiopia, which is one of the recently established Research Centers of the Oromia Agricultural Research Institute (OARI). The first experimental site were located at Bore research site at the distance of about 8 km north of the town of Bore in Songo Bericha '*Kebele'* just on the side of the main road to Addis Ababa via Awassa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2728 m above sea level. The second experimental site were located at Ana sora on farm at the distance of about 25 km East of the town of Ana sora in Yirba Buliyo '*Kebele'* just on the side of the main road to Negele borana via Adola town. Geographically, the experimental site is situated at an altitude of 2600 m above sea level.

The climatic condition of the area is a humid moisture condition, with a relatively longer growing season. According to climate data from National Meteorological Agency, Awassa Branch Directorate (2015-2017), the

area receives total annual rainfall of 1640.5 mm with a bimodal pattern that extends from April to November. The mean annual minimum and maximum temperatures are 8.58°C and 18.6°C, respectively.

During the crop growing season (2015 and 2017), the total amount of rainfall received were 1105.9 and 981.2mm out of which 300.4 and 289.6mm were received in April and May followed by 281.7 and 219.2mm in May and June respectively. The Average maximum and minimum temperatures of the growing season were 21, 8.7 and 9.6°C, respectively (figure 1 and figure 2).

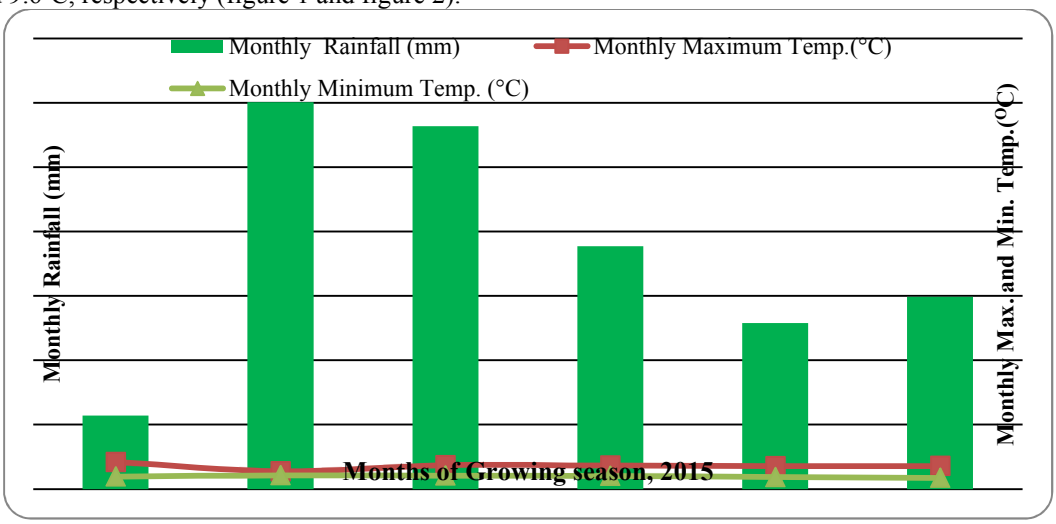

Figure 1.Monthly Rainfall and mean minimum and maximum temperatures during the 2015 growing season at Bore

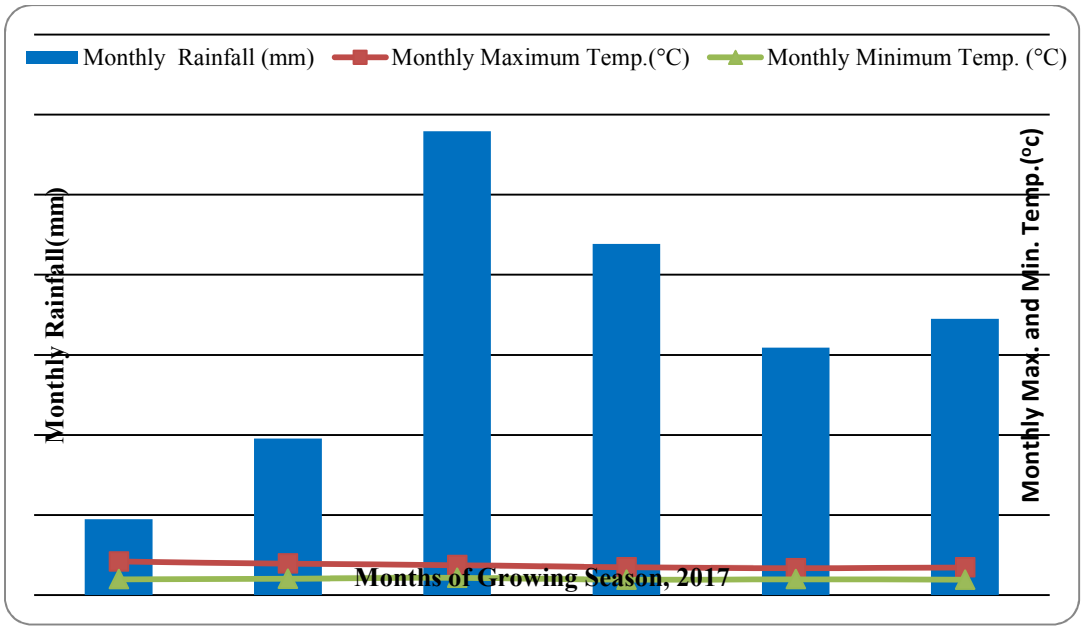

Figure 2. Monthly Rainfall and mean minimum and maximum temperatures during the 2017 growing season at Bore

The soil is clay in texture and strongly acidic with pH value of 5.1 (Arega, 2018). The traditional farming system of the area is characterized by cultivation of enset as a major crop, maize, potato, head cabbage, barley, wheat and faba bean. As far as fruit and timber crops are concerned, apple and bamboo are the cash crops. Moreover, cattle are an integral part of the farming system (BoARDO, 2015).

2.2. Treatments and Experimental Design

The treatments consisted of two (2) Potato varieties Gudanie and Jalenie currently under production but differ in their late blight reaction and three (3) fungicides Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico and one (1) unsprayed treatments were used as experimental materials. All Agronomic practices fertilizers 200 kg ha^{-1} DAP and 100 kg ha^{-1} UREA was used in split and (weeding, Cultivation and Earthingup) was used as recommended. The fungicides were applied on each variety at a rate of recommended in three different spray

schedules viz., every 7 days intervals starting from the on-set of the disease on foliages. The fungicides were applied on each variety at a rate of recommended in three different spray schedules viz., every 7, 14 and 21 days intervals starting from the on-set of the disease at both location by using knapsack sprayer. During the experiment was carried out at first and second year care was taken about fungicide type, how to apply (timing, quantity), intended target, formulation, quantity of water used for formulation, rates of fungicides, mode of action, hazards, safety Clothes etc. In addition, Handlers who may be exposed to the oncentrate through mixing, loading, application, or other tasks must wear (Coveralls over long-sleeved shirt and long pants, Chemical resistant gloves made of any waterproof material, Shoes plus socks, Protective eyewear, Chemical-resistant apron when mixing or loading etc.).

The treatment arrangements are; Ridomil Gold Mz 63.5 WP + Gudanie, Ridomil Gold Mz 63.5 WP + Jalenie, Mancozeb 80% WP + Gudanie, Mancozeb 80%WP + Jalenie, Matico (Metalaxyl 64% + Mancozeb 64% WP) + Gudanie, Matico (Metalaxyl 64% + Mancozeb 64% WP) + Jalenie, Unsprayed + Gudanie and Unsprayed + Jalenie. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a 4 x 2 factorial arrangement and replicated three times per treatment. Each material planted in plot size of 3 m x 2.1 m (6.3m^2). Each plot contained four rows of potato plants, with each row accommodating 7 plants with a total population of 35 plants per plot at the spacing of 0.75 m and 0.30 m between rows and plants, respectively. The net plot size =1.5 m (2 harvestable rows x 0.75 m) = 2.25 m^2. The spacing between plots and adjacent blocks was 1 m and 1.5 m, respectively. Plants in the two outer rows as were not considered for data collection to avoid edge effects. All other agronomic practices were employed as per recommendation for all treatments as proposed.

2.3. Data collected

Days to 50% emergency, flowering, maturity, plant height(cm), stem number, average tuber weight(g), average tuber number per plant, marketable and unmarketable yield and total yield(t ha^{-1}). Disease severity assessed from randomly selected plant at 7-10 days interval. The incidence (%) and severity scale (1-6) were recorded as described by Gwary and Nahunnaro (1998) where, scale 1= trace (0) to 20% leaf infection, scale 2= 21 to 40% leaf infection, scale 3= 41 to 60% leaf infection, scale 4= 61 to 80% leaf infection, scale 5= 81 to 99% leaf infection and scale 6 = 100% leaf infection or the entire plants defoliation.

The percent of incidence was calculated as;

$$\text{Disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total Number of plants assessed}} \times 100$$

Effective fungicides were determined using analysis of disease incidence and severity.

2.4. Data Analysis

The collected data on various parameters of the crop under study was statistically analyzed using SAS statistical package (SAS, 2003) version 9.1.3 using Fishers protected LSD. The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means when the ANOVA showed the presence of significant difference results.

2.5. Partial Budget Analysis

The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. The concepts used in the partial budget analysis were the mean marketable tuber yield of each treatment, the gross benefit (GB) ha^{-1} (the mean marketable tuber yield for each treatment) and the field price of two potato varieties seed (Gudanie and Jalenie) and three fungicides(the costs of Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico).

Adjusted yield (AjY): AjY was the average yield adjusted downward by a 10% to reflect the difference between experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988).

Gross field benefit (GFB): GFB was computed by multiplying field/farm gate price that farmers receive for the potato when they sale it as adjusted marketable tuber yield.

Total variable cost (TVC): Total cost was the field price of two potato varieties seed (Gudanie and Jalenie) and three fungicides (the costs of Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico) for the experiment. The costs of other inputs (fertilizers) and production practices such as labor cost, land preparation, planting, Earthingup, weeding, top killing, and harvesting were considered the same or are insignificant among treatments.

Net Income (NI) or Net Benefit (NB): - was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR).

NB = TR – TVC

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in total

variable cost.

$$MRR\% = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Varaible Cost } (\Delta TVC)} \times 100$$

Dominance Analysis (identification and elimination of inferior treatments): is also used to eliminate those treatments which involve higher cost but do not generate higher benefits. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefit) is dominated treatment (marked as "**D**"). Identification of a candidate recommendation was from among the non-dominated treatments. That was the treatment which gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%).

3. RESULTS AND DISCUSSIONS

3.1. Phenological parameters of Potato

The combined mean analysis results indicated that the interaction effect of fungicides and varieties had significantly ($P<0.05$) influence on potato flowering at Bore on-station and also days to 50% emergency , days to 50% flowering and 90% maturity at Ana sora on-farm in all consecutive two years (Table 5).

Table 5.Combined mean days to 50% emergency, days to 50% flowering and days to 90 % physiological maturity of Potato at Bore on site and Yirba on farm during 2015 and 2017 cropping season.

Treatments	Phenological Parameters potato					
	Bore site			Ana sora		
	DE	DF	DM	DE	DF	DM
Matico + Gudanie	14.33	57.33^{ab}	110.66	24a	55.83^{a}	100.66^{cd}
Mancozeb + Jalenie	14.5	54.00^{c}	109.33	22.67^{bc}	52.33^{bc}	107.33^{ab}
Mancozeb + Gudanie	14.33	55.00^{bc}	108.00	23.5^{ab}	55.83^{a}	102.33^{abc}
Ridomil Gold+ Jalenie	14.33	57.00^{ab}	109.00	21d	53.5^{abc}	104.00^{abc}
Matico + Jalenie	14.17	54.66^{bc}	109.66	21.83^{cd}	52.5^{bc}	108.00^{a}
Ridomil Gold+ Gudanie	14.33	58.00^{a}	110.33	22.67^{bc}	55.17^{ab}	101.66^{bcd}
Unsprayed + Jalenie	14.17	55.66^{abc}	94.33	23^{ab}	51c	98.00^{d}
Unsprayed + Gudanie	14.17	55.00^{bc}	107.33	23.17^{ab}	55^{ab}	98.00^{d}
Mean	14.3	55.83	107.33	23.00	53.9	102.5
LSD (5%)	Ns	2.75	Ns	1.79	16.28	5.87
CV (%)	3.41	2.81	2.20	6.7	25.8	3.27

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; DE=Days to emergency, DM=Days to maturity, DF=days to 50% flowering; LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

3.2. Growth and Yield component parameters of potato

The combined mean analysis of year 2015 and 2017 result indicated that at both locations Bore on-station and Ana sora on-farm application of fungicide had significant ($P < 0.05$) effect on stem number and plant height of potato. However, the combined mean had a non- significant ($P < 0.05$) effect on average tuber weight of potato (Table 6).

Table 6. Combined mean stem number, plant height and average tuber weight of Potato at Bore on site and Yirba on farm during 2015 and 2017 cropping season.

Treatments	Growth and yield component parameters of potato							
	Bore on-station				Ana sora on-farm			
	PH	STMN	NTPP	ATW	PH	STMN	NTPP	ATW
Matico+Gudanie	82.33^{bcd}	8.66^{c}	10.5^{ab}	98.7^{ab}	81.66^{bcd}	5.33^{cd}	7.66^{c}	117.8^{a}
Mancozeb+Jalenie	79.00^{cde}	9.33^{bc}	12^{a}	82.1^{b}	78.33^{cd}	5.33^{cd}	9.00^{c}	119.1^{a}
Mancozeb+Gudanie	93.00^{ab}	11.00^{ab}	9.5^{b}	126.3^{a}	92.66^{ab}	7.66^{ab}	13.33^{b}	101.2^{ab}
Ridomil Gold +Jalenie	83.66^{bc}	8.33^{c}	10.3^{ab}	104.2^{ab}	83.33^{abc}	7.33^{abc}	12.00^{b}	106.2^{ab}
Matico+Jalenie	71.66^{de}	9.00^{c}	10.8^{ab}	99.6^{ab}	71.33^{d}	5.00^{d}	8.66^{c}	102.9^{ab}
Ridomil Gold+Gudanie	95.33^{a}	11.66^{a}	11^{ab}	119.2^{ab}	94.00^{a}	9.00^{a}	17.33^{a}	124.9^{a}
Unsprayed+Jalenie	70.66^{e}	4.33^{e}	10.3^{ab}	87.8a^{b}	70.33^{d}	4.33^{d}	4.66^{d}	77.7^{b}
Unsprayed+Gudanie	78.00^{cde}	6.33^{d}	10.8^{ab}	91.4a^{b}	78.00^{d}	6.00^{bcd}	7.00^{cd}	106.5^{ab}
Mean	81.70	8.58	10.08	101.18	81.20	6.25	9.95	107.02
LSD (5%)	11.64	1.79	2.38	Ns	11.49	2.21	2.85	Ns
CV (%)	8.13	11.92	10.79	29.7	8.08	20.20	16.37	23.3

Means within the same column followed by the same letter (s) are not significantly different at 5% level of

significance; PH = Plant height (cm), STMN=stem number; NTPP= number of tubers per hill, ATW= average tuber weight; LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

3.3. Yield parameters of Potato

The combined mean analysis of year 2015 and 2017 revealed that unmarketable tuber yield, marketable tuber yield and Total tuber yield had significantly ($P<0.05$) affected by fungicide application on varieties (Table 7).

From the two year data analysis the maximum (47.34 t $ha^{-1}$and 46.31 t ha^{-1}) marketable tuber yield was obtained by Gudanie variety with Ridomil Gold fungicide application. Similarly, Jalenie variety gave maximum (39.02 and 39.68 tha^{-1}) marketable tuber yield by Ridomil Gold and Mancozeb fungicide application at Bore and Ana sora on-farm locations, respectively.

The combined data analysis result revealed that Spraying Ridomil Gold on Gudanie and Jalenie variety gave maximum (57.67 t ha^{-1} and 57.54 t ha^{-1}) Total tuber yield at Bore and Ana sora on-farm locations, respectively. However, the lowest (38.37 t ha^{-1} and 33.67 t ha^{-1}) Total tuber yield was recorded on Jalenie variety with control or unsprayed treatment, at Bore and Ana sora on-farm locations, respectively (Table 7).

In agreement with the result of Ghazanfar *et al*. (2010) who reported that the application of Ridomil consistently retarded late blight development and increased the yield. This result is also consistent with that of Harris (1992) who reported that there was an inverse relationship between tuber yields and late blight infection: as the growth of tubers is dependent on the amount of functioning leaves and stops when 75% of the total leaf area is destroyed (Large, 1952).

Therefore from these result farmers around the study area can produce healthy and maximum Potato crop of Gudanie and Jalenie variety by using effective fungicides like Ridomil Gold.

Table 7. Combined mean number of tubers per hill, average tuber weight, unmarketable, marketable and total yield of Potato at Bore on site and Yirba on farm during 2015 and 2017 cropping season.

Treatments	Yield Parameters of potato (t ha^{-1})					
	Bore on-station			Ana sora on-farm		
	UNM	MRT	TYLD	UNM	MRT	TYLD
Matico+Gudanie	8.47^{abc}	36.88^{ab}	45.36^{b}	46.24^{c}	38.65^{ab}	54.70^{a}
Mancozeb+Jalenie	6.48^{c}	34.28^{b}	40.78^{b}	44.02^{c}	39.68^{ab}	53.33^{ab}
Mancozeb+Gudanie	11.36^{a}	39.17^{ab}	50.38^{ab}	44.76^{c}	36.11^{bc}	50.38^{ab}
Ridomil Gold +Jalenie	8.79^{abc}	39.02^{ab}	47.96^{ab}	33.54^{c}	36.98^{bc}	51.94^{ab}
Matico+Jalenie	7.93^{abc}	39.41^{ab}	47.58^{ab}	45.39^{c}	31.63^{bc}	48.57^{ab}
Ridomil Gold+Gudanie	10.32^{ab}	47.34^{a}	57.67^{a}	33.22^{c}	46.31^{a}	57.54^{a}
Unsprayed +Jalenie	7.99^{abc}	30.37^{b}	38.37^{c}	94.18^{a}	20.38^{d}	33.67^{c}
Unsprayed + Gudanie	6.97^{bc}	36.68^{ab}	43.66^{b}	71.42^{b}	29.27^{c}	43.64^{bc}
Mean	66.49	322.76	389.25	51.60	321.79	373.39
LSD (5%)	3.79	12.30	12.17	7.43	8.36	10.87
CV (%)	7.13	3.19	2.65	18.66	9.8	8.31

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; UMRT= unmarketable yield, MRT= marketable yield, TYLD=total yield, LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

3.4. Late blight Incidence and Severity of Potato

The application of Ridomil Gold had give (5.48% and 1.16) over the unsprayed control (59.52% and 3.67) with three sprays seven intervals days during 2015 on Gudanie and Jalenie varieties. Regarding the efficiency of the fungicides against the disease management was shown as followed in table 8 and 9. The result of 2015 year disease data indicates that maximum (59.52% and 3.67) disease incidence and severity, respectively was recorded by unsprayed treatment of Jalenie variety and also the second year maximum (45.24 % and 2.83) disease incidence and severity by treatment Gudanie variety unsprayed fungicides, respectively. However, the minimum (5.48% and 1.16) disease incidence and severity of late blight was recorded by spraying Ridomil Gold Mz 63.5WP on both Gudanie and Jalenie varieties, respectively (Table 8). This result is consistent with that of Kirk *et al*. (2005) who reported that cultivation of resistant cultivar and regular applications of fungicides has reduced the foliar infection of late blight of potato. In agreement with the findings of (Fontem, 2001) who reported systemic fungicides (Ridomil Gold and Matico) provide better control as compared to contact (Mancozeb) fungicides. Furthermore, (Beaumont, 1947 and Goodwin *et al*., 1995) who reported that the amount of inoculums produced depends on the host, pathogen, environment and management conditions

Table 8. Overall combined mean analysis of treatments over locations on disease incidence (%) and severity scale (1-6) of 2015 year across locations as described by Gwary and Nahunnaro (1998)

Fungicide * Variety	Disease Incidence (%)	Disease Severity (scale 1-6)
Matico + Jalenie	17.86^{ab}	1.67^{bc}
Ridomil Gold + Jalenie	6.27^{b}	1.16^{c}
Ridomil Gold + Gudanie	5.48^{b}	1.5^{c}
Matico + Gudanie	19.05^{ab}	1.67^{bc}
Unsprayed + Jalenie	59.52^{a}	3.67^{a}
Unsprayed + Gudanie	45.24^{ab}	2.83^{ab}
Mancozeb + Jalenie	40.47^{ab}	2.83^{ab}
Mancozeb + Gudanie	26.19^{ab}	2.17^{bc}
Mean	28.76	2.18
LSD(5%)=v*f	24.62	1.19
Cv (%)	73.32	46.76

The result of data analysis for year 2017 for disease data indicates that maximum (80% and 4.6) disease incidence and severity, respectively was recorded by unsprayed treatment of Jalenie variety and also the maximum (60% and 3) disease incidence and severity was recorded by treatment Gudanie variety with unsprayed fungicides, respectively. However, the minimum (19.16% and 21.66%) disease incidence and minimum (1.66 and 1.5) disease incidence and severity of late blight was recorded by management of late blight by spraying Ridomil Gold Mz 63.5WP on both Gudanie and Jalenie variety, respectively.

In general, Ridomil Gold and Mancozeb fungicides were more effective by reducing the disease severity and increasing tuber yield. It is generally accepted that these fungicides have the ability to penetrate deep into host tissues and translocate up and down in the plant parts providing a barrier to P. infestans' further growth and development (Fernandez-Northcote *et al*., 2000; Majeed and Muhammad, 2013).The results are also in good agreement with previous reports on the efficacy of fungicides (Mantecon, 2007; Dowley *et al*., 2008; Rahman *et al.,* 2008).

Table 9. Overall combined mean analysis of treatments over locations on disease incidence (%) and severity scale (1-6) of 2017year across locations as described by Gwary and Nahunnaro (1998)

Fungicide * Variety	Disease Incidence (%)	Disease Severity (scale 1-6)
Matico + Jalenie	30.33^{d}	3^{b}
Ridomil Gold + Jalenie	21.66^{e}	1.5^{e}
Ridomil Gold + Gudanie	19.16^{e}	2^{cd}
Matico + Gudanie	43.33^{b}	2.16^{c}
Unsprayed + Jalenie	80^{a}	4.6^{a}
Unsprayed + Gudanie	60^{b}	3^{b}
Mancozeb + Jalenie	36.66^{cd}	2^{cd}
Mancozeb + Gudanie	33.33^{d}	1.66^{e}
Mean	40.56	2.50
LSD(5%)=v*f	8.17	0.40
Cv (%)	17.25	13.83

3.5. Partial Budget Analysis

Partial budget analysis was done based on the view of CIMMYT Economics Program (1988) recommendations, which stated that the application of fungicides with the marginal rate of return above the minimum level (100%) is economical. The results of the study indicated that the application of Ridomil Gold fungicide on Gudanie potato variety had gave promoting benefit over the control at both locations. As the result of this study partial budget analysis revealed that the maximum net benefit of Birr 244,462.50 and 235,352.7 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2549.00 and 2698% was recorded in the treatment that received the application of Ridomil Gold on Gudanie potato variety at both bore on-station and Ana sora on-farm respectively (Table 10). However, the lowest net benefit of Birr 164,052.00 and 101,052.00 ha^{-1}and non- acceptable marginal rates of return (MRR) were obtained in both nil received plots of fungicide on Jalenie potato variety at both Bore on-station and Ana sora on-farm respectively. The application of Ridomil Gold fungicide to Gudanie potato variety at both bore on-station and Ana sora on-farm generated 80,410.5 and 134,300.7 Birr ha^{-1} more compared to in both nil received plots of fungicide on Jalenie potato variety at both Bore on-station and Ana sora on-farm respectively. The application of Ridomil Gold on Gudanie potato variety at both Bore on-station and Ana sora on-farm which gives the highest net benefit and a marginal rates of return greater than the minimum considered acceptable to farmers (>1 or 100%). The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return. Based on this result, the application of Ridomil Gold on Gudanie potato variety at both Bore on-station and Ana

sora on-farm were resulted highest adjustable marketable tuber yield (43200 and 41681.7 kg ha^{-1}) respectively and profitable to the farmers in the study area (Table 10). As fungicides encourage the development of resistance in *P.infestans* and the pathogen requires higher doses for control which disturbs the cost benefit ratio and environment.

Table 10.Partial budget and marginal rate of return analysis demonstration of fungicides with the combination of potato varieties to manage late blight in highlands of Guji Zone, during 2015 and 2017 cropping season

Treatments	Unadjusted Myld	Adjusted Myld	Total var. cost	Gross Return(GR) ETB(Adjusted	Net Benefit(NB)	MRR
Bore on-station	Kg ha^{-1}	Kg ha^{-1}	ETB	Myld*6birrkg^{-1}	ETB	(%)
Unsprayed + Jalenie	30380	27342	9000	164052	155,052.00	
Mancozeb + Jalenie	34280	30852	9795	185112	175317	2549
Matico + Jalenie	39420	35478	10162.5	212868	202,705.5	7453
Unsprayed + Gudanie	36690	33021	10800	198126	187326	D
Mancozeb + Gudanie	39030	35127	11595	210762	199167	1489
Matico + Gudanie	36880	33192	11962.5	199152	187189.5	D
Ridomil Gold + Jalenie	39170	35253	12937.5	211518	198580.5	1168
Ridomil Gold + Gudanie	48000	43200	14737.5	259200	244,462.5	2549
Ana sora on-farm						
Unsprayed + Jalenie	20380	18342	9000	110052	101052	
Mancozeb+ Jalenie	39680	35712	9795	214272	204,477	1301
Matico + Jalenie	31640	28476	10162.5	170856	160693.5	D
Unsprayed + Gudanie	29280	26352	10800	158112	147312	D
Mancozeb + Gudanie	36120	32508	11595	195048	183453	4546
Matico + Gudanie	37270	33543	11962.5	201258	189295.5	15909
Ridomil Gold + Jalenie	36985	33286.5	12937.5	199719	186781.5	D
Ridomil Gold + Gudanie	46313	41681.7	14737.5	250090.2	235,352.7	2698

Where, Potato seed cost = Birr 600 of 1000 $kg^{-1}$of Gudanie variety and Birr 500 of 1000 $kg^{-1}$of Jalenie variety, Ridomil Gold cost = Birr 1575 of 2.5 kg ha^{-1}, Matico cost = Birr 465 of 2.5 kg ha^{-1}, Mancozeb cost = Birr 265 of 3 kg ha^{-1}, Field price of potato during harvesting = Birr 6 birr kg^{-1}, Myld =Marketable tuber yield, MRR (%) = Marginal rate of return and D= Dominated treatment.

4. CONCLUSIONS AND RECOMMENDATION

Potato late blight caused by *Phytophthora infestans* (Mont) de Bary is one of the most significant constraints to potato and tomato productions in cool and wet weather conditions in Ethiopia. However, late blight epidemiology is also impaired by natural resistance of varieties provided by introgression of resistance genes. The genetic background of a variety together with environmental conditions those are not conducive for the pathogen results in field resistance. Effective management of this disease requires implementation of an integrated disease Management approach. Although the most important measures are chemical controls, *P. infestans* could be controlled by fungicide treatment (contact, penetrating or systemic products) that enables destroy, weaken or suppress the pathogen applied throughout the crop cycle.

The study was conducted at Bore on-station and Ana sora on-farm during 2015 and 2017 two cropping season with the aim to evaluate fungicides with the combination of Potato varieties to manage late blight and to assess the cost and benefits of different fungicides and its efficiency on Gudanie and Jalenie potato varieties. The treatments consisted of two (2) Potato varieties Gudanie and Jalenie currently under production but differ in their late blight reaction and three (3) fungicides Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico and one (1) unsprayed treatments were used as experimental materials. The fungicides were applied on each variety at a rate of recommended in three different spray schedules viz., every 7, 14 and 21 days intervals starting from the on-set of the disease on foliages. The experiment was laid down in factorial RCBD with 3 replications each material planted in plot size of 3 m x 2.1 m (6.3m^2).

The two year combined data analysis results revealed that the interaction effect between fungicides and variety had highly significant ($P<0.05$) response on days to 50% flowering, 50% maturity, plant height, number of tubers per hill, stem number per plant, marketable tuber yield, unmarketable tuber yield and total tuber yield. But the Anova result shows non-significant ($P>0.05$) effect on days to emergency by the application of fungicides and variety between each mean.

From the two year data analysis the maximum (47.34 t $ha^{-1}$and 46.31 t ha^{-1}) marketable tuber yield was obtained by Gudanie variety with Ridomil Gold fungicide application at Bore and Ana sora on-farm locations, respectively. Similarly Jalenie variety gave maximum (39.02 and 39.68 t ha^{-1}) marketable tuber yield by Ridomil Gold and Mancozeb fungicide application at Bore and Ana sora on-farm locations, respectively.

The combined data analysis result shows that fungicide Ridomil Gold on Gudanie and Jalenie variety gave maximum (57.67 t ha^{-1} and 57.54 t ha^{-1}) total tuber yield at Bore and Ana sora on-farm locations, respectively. However, the lowest (38.37 t ha^{-1} and 33.67 t ha^{-1}) total tuber yield was recorded on Jalenie variety with control or unsprayed treatment, at Bore and Ana sora on-farm locations, respectively.

The result of disease data shows that the maximum disease incidence and severity was recorded in control treatment of both varieties. The minimum disease incidence and severity was seen on by treatment combination of Ridomil Gold and Gudanie and Jalenie variety in both years. Here also spraying of Manacozeb fungicides on Gudanie and Jalenie variety efficient to control potato late blight under field conditions.

In conclusions, foliar blight and disease progress was significantly reduced by foliar application of Ridomil Gold and Mancozeb fungicides. Increments in tuber yields were only recorded by application of fungicides Mancozeb, Matico and Ridomil Gold. As the partial budget analysis revealed that application of Ridomil Gold on Gudanie variety result the highest net benefits of Birr 244,462.50 and 235, 352.00 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2549.00 and 2698%. Thus, application of Ridomil Gold on Gudanie variety led to optimum marketable tuber production and economic returns. Therefore, the farmers' in highlands of Guji zone and similar agro-ecology can produce healthy and maximum potato crop of Gudanie by spraying Ridomil Gold fungicide with the recommended rates and frequency.

5. REFERENCES

Arega, A. 2018. Response of Potato (*Solanum tuberosum* L.) to Blended NPS and Potassium fertilizers at Bore, Southern Ethiopia. M.Sc. Thesis. Haramaya University, Ethiopia, pp. 20-30.of Agriculture, Haramaya University. 86p.

Beaumont, A. 1947. The dependence on the weather of the dates of outbreak of potato blight epidemics. Trans. Br. Mycol. Soc. 31:45–53.

BoARDO (Bore Agriculture and Rural Development Office). 2015. Agriculture Report of Bore District.

Bradshaw J.E., Mackay G.R., 1994. Potato Genetics. CAB International, Cambridge, 552.

CIP (1998) Annual Report for 1997. Lima, Peru: International Potato Center.

Cooke D.E.L., Lees A.K., 2004. Markers, old and new, for examining *Phytophthora infestans* diversity. Plant Pathology, *53*: 692–704.

Dowley, L.J., Grant, J. and Griffin, D., 2008. Yield losses caused by late blight (*Phytophthora infestan*s (Mont.) de Bary) in potato crops in Ireland. Irish JThenal of Agricultural Food Research. 47:69-78.

Fontem D.A. 2001. Influence of rate and frequency of Ridomil Plus applications on late blight severity and potato yields in Cameroon. Afr. Crop Sci. J. 9 (1): 235- 43.

Fry, W.E. and Goodwin, S.B. 1997. Re-emergence of potato and tomato late blight in theUnited States. Plant Disease 81(12): 1349-1357.

Ghazanfar, M.U., S.T. Sahi, W. Wakil and Z. Iqbal. 2010. Evaluation of various fungicides for the management of late blight of potato (*Phytophthora infestans*). Pak. J. Phytopathol. 22(2): 83-88.

Goodwin, S. B., Sujkowski, L. S., Dyer, A. T., Fry, B. A., and Fry, W. E. 1995. Direct detection of gene flow and probable sexual reproduction of *Phytophthora infestans* in Northern North America. Phytopathology 85:473–479.

Goodwin, S.B., Drenth, A., Oyarzun, P., Ordonez, M.E. and Fry, W.E. 1998. A global marker database for *Phytophthora infestans*. Plant Disease 82(7): 811-818.

Gwary DM., Nahnnaro H. 1998.Epiphytotics of early blight of tomato in Northeater Nigeria crop port 17: 619-624.

Harris P.1992.The Potato Crop. London: Chapman and Hall, pp. 405–419.

Kirk, W.W., F.M.A. El Samen, J.B. Muhinyuza, R. Hammerschmidt, D.S. Douches, C.A. Thill, H. Groza and A.L. Thompson. 2005. Evaluation of potato late blight management utilizing host plant resistance and reduced rates and frequencies of fungicide applications. Crop Protect. 24: 961-70.

Large EC .1952.The interpretation of progress curves for potato blight and other plant diseases. Plant Pathology1:109–117.

Mantecon, J.D. 2007. Potato yield increases due to fungicide treatment in Argentinian early blight (*Alternaria solani*) and late blight (*Phytophthorainfestan*s) field trials during the 1996-2005 seasons. Fungal and Nematode Tests. 55:221.

Namanda S., Olanya O.M., Adipala E., Hakiza J.J., El-Bedewy R., Baghsari A.S., Ewell P. 2004. Fungicide application and host-resistance for potato late blight management: benefits assessment from on-farm studies in s.w. Uganda. Crop Protection, *23*: 1075–1083.

Sikka LC, Ewell PT and Kanzikwera R (2000) Integrated Management of late blight of potato in the highland tropics of sub-Saharan Africa: Experiences from Uganda. African Potato Association Conference Proceedings, vol. 5, pp. 323–328.

Smart C.D., Fry W.E.2001. Invasions by the late blight pathogen: renewed sex and enhanced fitness. Biological

Invasions. *3*: 235–243.

Tymčenko V., Jefronovova T. 1987. Guide of pests and diseases of vegetable and potato. National agriculture publisher, Praha, 181.

Zimmoch-Guzowska E., Lebecka R., Kryszczuk A., Maciejewska U., Szczerbakowa A., Wielgat B. 2003. Resistance to *Phytophthora infestans* in somatic hybrids of *Solanum nigrum* L. and diploid potato. Theoretical and Applied Genetics, *107*: 43–48.