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Effects of Fungicide and Blended NPSB Fertilizer Application on Late Blight Disease and Yield of Potato (*Solanum tuberosum* L.) in Wombera District, North Western Ethiopia

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ABSTRACT

Potato (*solanum tuberosum* L.) *is one of major crops grown in Wombera district. However, the yield of the crop is low due to improper use of fungicide on late blight disease and blanket recommendation of fertilizer. Therefore, a field experiment was carried out during the main cropping season of 2019 in North Wombera District. The objective of the study was to assess the effect of Mancozeb (80%WP) and blended NPSB fertilizer on late blight disease and yield of potato. A potato variety, "Belete" was used as a testing crop for the experiment. Factors, four spraying periods (control without spray, and spraying 3, 6 and 9 weeks after full emergence) and three rates of blended NPSB fertilizer (130, 180, and 230 kg ha^{-1}) were laid out in randomized complete block design (RCBD) with three replications. Analysis results showed that number of marketable tuber number per hill, total tuber number per hill, marketable yield and total tuber yield were significantly affected by the main and interaction effect of spraying Mancozeb (80%WP) and blended NPSB Fertilizer. While unmarketable tuber number showed non-significant effect. The results showed that Mancozeb had positive effects on reducing late blight infestation and increasing tuber yield productivity of potato. The highest marketable tuber yield (43.67tha^{-1}) and total tuber yield (47.67tha^{-1}) were obtained from spraying fungicide 6 weeks after full emergence and 230 kg ha^{-1} blended NPSB fertilizer application.*

Keywords: Blended fertilizer, fungicide, late blight disease and tuber yield

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth most important food crop after maize, rice and wheat in terms of production and consumption all over the world (FAO, 2015). Potato is an important food and cash crop in Eastern and Central Africa, and playing a major role in national food security and nutrition, poverty alleviation and income generation, as well as providing employment opportunities in its production, processing, transportation and marketing (Lung'aho *et al.*, 2007). Potato is also considered as inexpensive and nutritive food security crop, while it produces more dry matter, protein and calories per unit area and time than the major cereal crops (Rai and Yadav, 2005).

In Ethiopia potato in its *Meher* season production area has reached 73,667.64 ha, with total production of 1,044,363.59 ton (CSA, 2018). On the other hand, the productivity of potato in the country is very (14.17 t ha^{-1}). Compared to the world 's average yield of 19 tha^{-1} (CSA, 2018). According to (Hailu Shiferaw; 2014), Ethiopian soils are deficient with most of the macro and micronutrients that are required to sustain optimal growth and development of crops, while the fertility of most of Ethiopian soils has already been declined due to continuous cropping, abandoning of fallowing, reduced use of manure and crop rotation (Westermann, 2005).

The Ethiopian potato research system has released 31 new potato varieties to address some of these production problems (MOA, 2013). All of these varieties originated outside Ethiopia; mainly from the international potato center (CIP). Late blight can destroy a potato field within a few days (Razukas and Jundulas, 2005). If not controlled, losses may reach 100% (Rubio-Covarrubias *et al.*, 2005) and even lower infection levels may make the crop unfit for storage (Heinfnings, 1987). Olanya *et al.*, (2001) indicated that late blight is a major limitation to potato production in high humid elevations of Ethiopia, with estimate average yield losses of about 30-75% on susceptible varieties.

Studies conducted in Uganda, Kenya and Ethiopia on Fungicide and variety reaction suggested that significantly late blight control can be achieved when the protectant fungicide Dithane i.e., *Mancozeb* (80% WP), is applied on a scheduled basis. On-farm research also indicated that three timely applications of a protectant fungicide can be effective for late blight management (PRAPACE/CIP, 1996). The combined uses of fungicide and resistance varieties have evolved as one of the most important options in the management of potato late blight disease (Namanda *et al.*, 2004). Potato cultivars grown in Ethiopia have low levels of general resistance to late blight, and hence the commercial potato producing farmers rely mostly on fungicide applications for the control of late blight disease (Habtamu *et al.*, 2012). So, objective of this research is to determine effectiveness of blended NPSB fertilizer rates and fungicide spray on late blight disease and yield of potato.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in 2019 main cropping season at Addis Alem *Kebele* Farmer Training Center (FTC) in Wombera District, Northwestern Ethiopia. Addis Alem FTC is located 675 km far from northwest Addis Ababa. Wombera District constitutes three agro ecology 17% Dega, 11% Weina Dega and 72% Kolla. The minimum and maximum temperature ranging from 6-35^{o}c and average mean rainfall ranging from 900-1740mm.

Experimental Materials: "Belete" potato variety was used as a test crop. The variety was released in 2009 by Holeta Agricultural Research Centre and registered by Ministry of Agriculture (MoARD, 2009). It can be grown in areas having an altitude of 1600-2800 m.a.s.l and annual rainfall of 750-1000 mm. It requires well drained and fertile soil types for good growth and yield in mid highland area. The detail description of the variety is presented in (Table 2). During its releasing time, the variety was registered as resistant to late blight disease. But, its resistance to late blight disease is gradually broken and now it becomes moderately tolerant to the disease.

Experimental Treatments, Design and Procedures: Factorial combinations of four spraying periods (control without spray, and spraying 3, 6 and 9 weeks after full emergence) of *Mancozeb* and three rates of blended NPSB fertilizers (130, 180, and 230 kg ha^{-1}) were laid out in randomized complete block design (RCBD) with three replications. *Fungicide Mancozeb* (80% WP) at 3 kg ha^{-1} rate was used for controlling potato late blight disease.

Disease free, medium sized and well sprouted seed tubers of the Belete potato variety were planted on 27 May 2019 after receiving sufficient precipitation manually in rows with 75 cm between rows and 30 cm between plants. Soon after planting, a ridge was done to cover the potato tubers by throwing the soil from both sides. Beyond the treatments, all other agronomic practices were applied as per their respective recommendations used for potato in the study area.

Fungicides application was started at 3 weeks after full emergence i.e., 35 days after planting (DAP) and continued at 6 and 9 weeks after full emergence and 21 days interval. Plastic sheet was used to avoid spray drift at time of fungicide application.

Data Collection

Days to first disease symptom appearance: Days from emergence to the first appearance of late blight disease symptom were recorded in each treatment within three middle rows in each plot was visually observed at seven- day intervals starting at 54 DAP.

Disease incidence: Disease incidence was assessed on 10 randomly selected pre tagged plants in the middle three rows and plants showing symptoms of the disease were counted and expressed in percent infection.

Disease severity: Disease severity was assessed as the proportion of leaf area affected by the disease from the 10 randomly selected plants in the middle three rows. Both disease incidence and severity were assessed at seven- days' intervals after the first appearances of the disease symptom, beginning at 54 DAP and finally four (4) recording were done at 56 DAP, 63 DAP, 70 DAP and 77 DAP. Disease severity was assessed by using 1-9 point scale suggested by Henfling (1987). Severity grades were converted into percentage severity index (PSI) for analysis without transformations via the formula suggested by Wheeler (1969)

$$\mathrm{PSI}(\%) = \frac{\text{Sum of numerical ratings}}{\text{No of plants scoredXmaximum on score}} \text{X100}$$

Marketable tuber number per hill : Tubers which are free of mechanical, disease and insect pest damages and medium to large in size are considered as marketable. This was yield produced from ten plants of three middle rows and counted at harvest and those tubers which are healthy, large sized and greater than 50 g were considered as marketable tubers.

Unmarketable tuber number per hill : On the other hand, tubers which are damaged, small in size were considered as unmarketable It was recorded by counting average number of tubers of ten plants from the net plot, and rotten, diseased, insect infected, and green tubers and those with less than 50 g, weight were regarded as unmarketable tuber.

Total tuber number per hill: Mean number of tubers produced from the net plot was counted at harvest and expressed as number of tubers per hill.

Marketable tuber yield (tha^{-1}): Mean weight of marketable tubers produced from the net plot, was recorded at harvest by weighing tubers which were healthy and greater than 50 g. The value were taken in kg/plot and converted to tha^{-1}.

Unmarketable tuber yield (tha^{-1}): Mean weight of unmarketable tubers produced from middle rows was recorded at harvest and those rotten, turned green and less than 50 g, were considered to determine unmarketable tuber yield, (kg per plot) and converted into tha^{-1}.

Total tuber yield (tha^{-1}): The total tuber yield was recorded as the sum of both marketable and unmarketable tuber yields (kg per plot) was weighed and converted to tha^{-1}.

RESULTS AND DISCUSSION

Days to first disease symptom appearance: The days to first disease appearance showed non-significant difference on Mancozeb (80% WP) fungicide sprayed and blended NPSB fertilizer applied treatments and their interactions (Table 4.2). The disease symptom was first appeared 54 days after planting (DAP) and the analysis showed that control/unsprayed, Mancozeb (80% WP) fungicide sprayed 3, 6 and 9 weeks after full emergence and 130,180 and 230 kg ha-1 blended NPSB fertilizer applied treatment did not significant difference on days to first disease appearance (Table 1).

Disease incidence: Analysis of the disease incidence showed significant differences (p<0.001) by main and interactions effects of spray *Mancozeb* (80% WP) 3, 6 and 9 weeks after full emergence and blended NPSB fertilizer applications (Appendix Table 2). The highest disease incidence (69.79%) was observed from sprayed fungicide 9 weeks after full emergence and 230 kg blended NPSB fertilizer applied treatments. On the other hand, minimum disease incidence (24%) was recorded on plots sprayed with *Mancozeb* (WP 80%) 3 weeks after full emergence and 130 kg NPSB fertilizer applied.

The interaction effect of sprayed *Mancozeb* (80% WP) on late blight disease and blended NPSB fertilizer application on disease incidence showed significant effect (Table 4.2). Sprayed *Mancozeb* fungicide 9 weeks after full emergence and blended NPSB fertilizer 230 kg ha^{-1} leads to slightly high infection rates as compared to spray *Mancozeb* (80% WP) fungicide 3 and 6 weeks after full emergence and 130 and 180 kg ha^{-1} blended NPSB fertilizer applied treatments. This means that disease incidence increased as fertilizer rates increased and decreased by timely application of fungicide as shown in (Table 1). Therefore, the results in agreement with the previous idea of Olanya *et al.,* (2001).

Disease severity: The analysis of variance (ANOVA) showed that late blight disease severity was highly significant (p<0.001) affected by the main and interaction effect of spray fungicides *Mancozeb* (80%WP) Wettable Powder on late blight disease and blended NPSB fertilizer application in disease severity (Table 4.2). The highest percent severity index (45.67%) was recorded from sprayed fungicide *Mancozeb* (80%WP) 9 weeks after full emergence and 230 kg blended NPSB fertilizer applied plot. On the other hand, the lowest percent severity index (11%) was observed from sprayed fungicide 3 weeks after full emergence and 130 kg blended NPSB fertilizer applied plot (Table 1). However, unsprayed and spray 9 weeks after full emergence and 230 kg blended NPSB fertilizer applied plot did not significantly differ from each other with respect to disease incidence and severity.

The results of the present study verified the idea of Agrios (2005). Who suggested that it is always advisable to use resistant varieties, even when sprays with fungicides are considered as the main control strategy, this result also coincides with the findings of Olanya *et al.,* (2001) who stated that late-blight severity was very low especially in fungicide-treated plots.

Table 1. Main and interaction effect of spray fungicide and NPSB fertilizer application on days to first disease symptom appearance (DTDSA) , percent disease incidence (PDI) ,and percent severity index (PSI) during 2019 cropping season in Wombera district, Northwest Ethiopia

Treatment		Disease parameters		
Main effect of fungicide spray time (P)		DTDSA	PDI	PSI
Control without Mancozeb spray (P1**)**		55	58.67^{b}	41.33^{b}
3 weeks after full emergence (P2)		55	24^{h}	11^{h}
6 weeks after full emergence (P3)		54.66	53^{c}	31.67^{e}
9 weeks after full emergence (P4)		54.67	57.33^{a}	33.33
LSD (0.05)		0.8	2.41	1.11
SE±		0.75	2.72	1.08
Main effect of NPSB fertilizer (F)				
130 kg (F1)		55	58.67^{c}	41.33^{c}
180 kg (F2)		64	64^{b}	43.33^{b}
230 kg (F3)		54.66	72.33^{a}	47^{a}
LSD (0.05)		0.8	2.41	1.11
SE±		0.75	2.72	1.08
Interaction effect of spray time and NPSB fertilizer				
P1	F1	55	58.67^{c}	41.33^{c}
	F2	55.33	64b	43.33^{b}
	F3	54.66	72.33^{a}	47^{a}
P2	F1	55	24^{h}	11^{h}
	F2	55.66	29^{g}	17^{g}
	F3	54.67	32.67^{f}	20^{f}
P3	F1	54.66	53^{e}	31.67^{e}
	F2	55.33	55.33^{de}	34.33^{de}
	F3	55	64.33^{b}	41^{c}
P4	F1	54.67	57.33^{cd}	33.33^{de}
	F2	54.66	63.33^{b}	42^{bc}
	F3	55.67	69.67^{a}	45.67^{a}
LSD (0.05)		0.8	2.41	1.11
SE±		0.75	2.72	1.08

CV (%)	1.57	3.07	3.06

DI = disease incidence; DSI = disease severity index; PSI= percentage severity index; LSD = list significance difference; SE± = standard error and CV (%) = coefficient of variation.

Marketable tuber number per hill: Marketable tuber numbers per hill was highly significantly (P<0.001) influenced by the main effect fungicide and blended NPSB fertilizer application. similarly spraying fungicide 3 weeks after full emergence and increasing the rate of blended NPSB fertilizer from 130 kg to 230 kg ha^{-1} significantly increased marketable tuber number per hill from (6.67 to 9). But their interaction increases marketable tuber number per hill from (6.67 to 10). Thus, the highest marketable tuber number per hill was produced from spraying fungicide 3, 6 weeks after full emergence and 230 kg blended NPSB fertilizer application ha^{-1}. Whereas the lowest marketable tuber number per hill was obtained from the control/ unsprayed with and 130 kg ha^{-1} blended NPSB fertilizer applied plot (Table 2).

Spry fungicide 3 and 6 weeks after full emergence and increasing blended NPSB fertilizer rate from 130 to 230 kg ha^{-1} increased marketable tuber numbers from 6.67 to10 per hill with non - significant effect on unmarketable tuber number. This application of blended NPSB fertilizer at a rate of 230 kg ha^{-1} increased marketable tuber number by 66.7% compared to the control/ unsprayed fungicide treatment and 130 kg ha^{-1}. This marketable tuber numbers increment might be due to the fact that marketable tuber number increases with higher phosphorus and nitrogen rate because nitrogen can trigger vegetative growth and development.

Sulfur and boron may increase tuber size by facilitating nitrogen and phosphorus absorption, cell division, chlorophyll synthesis and photosynthesis. In addition, fungicide is important for promoting vegetative growth which helps for photosynthesis which is vital of plant possess. This result is in agreement with the findings of Israel *et al.*, (2012), Yourtchi *et al.*, (2013) and Alemayehu *et al.*, (2015) reported that application of nitrogen and phosphorus significantly increased marketable tuber number and total tuber number. Zelalem *et al.*, (2009) also reported that nitrogen and phosphorus fertilization improved both marketable and total tuber number of potato.

Unmarketable tuber number per hill: Analysis of variance (ANOVA) showed that unmarketable tuber numbers per hill was a highly significant ($P<0.001$) influenced by spraying fungicide and blended NPSB fertilizer application. But, the interaction effect of spraying time and blended NPSB fertilizer application did not significantly affect unmarketable tuber numbers per hill. Spraying time and increasing the rate of blended NPSB fertilizer from 130 kg to 230 kg ha^{-1} significantly decrease unmarketable tuber numbers from (7.67 to 3.00) per hill was observed.

Potato plants without blended NPSB fertilizer produced the highest unmarketable tuber numbers per hill (7.67). While those supplied with the highest blended NPSB fertilizer rate produced the lowest unmarketable tuber numbers per hill 3.00 (Table 2). This result is conformity with the previous founding Bruk Namena (2018) who reported that increasing rate of nitrogen and NPSB fertilizer significantly decrease unmarketable tuber number per hill.

Total tuber number per hill: The analysis of variance showed that highly significant ($P<0.002$) differences in total tuber number per hill due to the main effects of spraying fungicide and blended NPSB fertilizer application and their interaction (Table 2). The highest total tuber number (17.33) was recorded from spraying fungicide 3 weeks after full emergence and 230 kg ha^{-1} blended NPSB fertilizer. Increasing the rate of applied blended NPSB fertilizer application from 130 kg ha^{-1} to 230 kg ha^{-1} was highly significantly increased total tuber number per plant from (12.67 to 17.33). On the other hand, the lowest total tuber number (12.67) was recorded from the control/ unsprayed fungicide and 130 kg ha^{-1} blended NPSB fertilizer applied treatment.

Spry fungicide 3 weeks after full emergence and 230 kg ha^{-1} blended NPSB fertilizer rate of increased total tuber number by 74% compared to control / unsprayed treatment and 130 kg ha^{-1} blended NPSB fertilizer application. These is due to the fact that increased rates of blended NPSB fertilizer increased total leaf area, which in turn increased the amount of solar radiation intercepted for photosynthesis and partitioning of more photosynthesis to the tubers Zelalem *et al*., (2009). This result is in line with the findings of (Israel *et al.*, 2012; Yourtchi *et al.*, 2013; and Alemayehu *et al.*, 2015) who reported that application of nitrogen and phosphorus significantly increased marketable tuber number and total tuber number.

Marketable tuber yield (tha^{-1}): Marketable tuber yield was highly significantly ($P<0.001$) influenced by spraying fungicide and blended NPSB fertilizer application and their interaction. The highest marketable tuber yield (43.67tha^{-1}) was obtained from spraying fungicide 6 weeks after full emergence and 230 kg ha^{-1} blended NPSB fertilizer application. On other hand, the lowest yield. (10.0tha^{-1}) was recorded from the control/ unsprayed and 130 $kgha^{-1}$ blended NPSB fertilizer applied treatment (Table 2).

Spraying fungicide 6 weeks after full emergence and 230 kg ha^{-1} blended NPSB fertilizer application increased marketable tuber yield by (76.74%) over (control/ unsprayed fungicide and 130 kg ha^{-1} blended NPSB fertilizer application). Increasing rate of blended NPSB fertilizer also positively influenced marketable tuber number. Yet increasing in marketable tuber yield with increasing rates of blended NPSB fertilizers was due to the positive effect of both nitrogen and phosphorus on marketable tuber weight Israel *et al.*, (2012).

The current finding is in line with investigations of (Yourtchi *et al.,* 2013 and Alemayehu *et al.,* 2015) who reported that nitrogen fertilization significantly influenced marketable tuber yield. (Zelalem *et al.,* 2009 and Israel *et al.*, 2012) have also reported that N and P fertilization significantly influenced productivity of potato measured in terms of marketable and total tuber yields.

The result of the present study is consistent with the report of Namanda *et al.,* (2004) the benefits of appropriate fungicide use strategy were high yield and improved marginal rate of return (MRR) from the reduced cost of fungicide applications as well as increased quality of potato tubers. Although fungicides have been used to manage late blight, the appearance of fungicide resistant strains, high costs and environmental concerns pose a major challenge to their continued use (Kirk *et al.,* 2001). The results of the present study are in agreement with the report of (Mantecón 2009), who reported that yield differences obtained from treated and untreated controls were higher in marketable tubers than in total yield.

Unmarketable tuber yield (tha^{-1}): Unmarketable tuber yield was highly significant (P<0.001) influenced by spraying fungicide and blended NPSB fertilizer application. But, the interaction effect of spraying fungicide and blended NPSB fertilizer did not significantly affect unmarketable tuber yield. Spraying 9 weeks after full emergence and increasing the rate of blended NPSB fertilizer from 130 kg to 230 kg ha^{-1} significantly decrease unmarketable tuber yield from (9.33 to 3.33 tha^{-1}) was observed.

Generally, potato plants with control/unsprayed fungicide and low blended NPSB fertilizer rate produced the highest unmarketable tuber yield (9.33 tha^{-1}). While those sprayed with fungicide and supplied with the highest blended NPSB fertilizer rate are produced the lowest unmarketable tuber yields 3.33 tha^{-1} (Table 2). This might be due to nitrogen accelerate the growth of above ground part of plants, which often leads reduced tuber size and weight of the tubers become unmarketable. In agreement with this study result, (Habtam *et al.,* 2012) reported that further increasing the rate of the nutrient from 100 to 200 kg KCl ha^{-1} further increased unmarketable tuber yield of potato. Moreover, (Minwyelet *et al.*, 2017) also reported that unmarketable tuber yield of potato plants was affected by NPS fertilizer rates.

Furthermore, (Biruk *et al.*, 2015) also reported that increase unmarketable tuber yield of potato as a result of the application of nitrogen and phosphorus fertilizer rate. In contrast with this result, Niguse (2016) reported that the main and interaction effect of phosphorus and potassium fertilizer rates were not significantly affected the unmarketable tuber yield. In accordance with this study result, Zelalem *et al.*, (2009) and Mulubrhan (2004) observed no significant influence of phosphorus application on unmarketable yield. Moreover, Simret *et al., (*2014) reported that potassium had non- significant effect on unmarketable yield of potato.

Total tuber yield (tha^{-1}): Total tuber yield was highly significantly (P<0.001) influenced by fungicide and blended NPSB fertilizer application and significantly affected by their interaction. The highest total tuber yield (47.67tha^{-1}) was obtained from spraying fungicide 6 weeks after full emergence and 230 kgha^{-1} blended NPSB fertilizer applied treatment. The next highest total tuber yield (45.67tha^{-1}) was also obtained from spraying fungicide 3 weeks after full emergence and 230 kg ha^{-1} blended NPSB fertilizer treatment. On the other hand, the lowest total tuber yield (19.33tha^{-1}) was recorded from the control/ unsprayed treatment and 130 kgha^{-1} blended NPSB fertilizer applied (Table 2).

Similarly, marketable tuber yield was increased significantly as the rate of blended NPSB fertilizer increased, this is probably due to sulfur and boron which play an importance role in the synthesis of amino acids, proteins, energy transformation, activation of enzymes which in turn enhances carbohydrate metabolism and photosynthetic activity of plant with increased chlorophyll synthesis (Juszczuk and Ostaszewska, 2011). Also, boron application showed significant increase in tuber yield due to its role in regulation of carbohydrate metabolism and its transport within the plant besides the synthesis of amino acids and proteins (Debnath and Ghosh, 2011).

This result is in agreement with the findings of Yourtchi *et al.*, (2013; Alemayehu *et al.*, 2015), who reported that application of nitrogen significantly increases both marketable and total tuber yield. (Israel *et al.*, 2012; Firew 2014) who have also reported that total tuber yield was significantly influenced by nitrogen and phosphorus. Also, the current investigation is in conformity with the results, Minwyelet *et al.*, (2017) who reported that the application of NPS fertilizer at the rate of 272 kg ha^{-1} produced the highest total tuber yield (47. 53 tha^{-1}), while potato plants without NPS fertilizer produced the lowest total tuber yield (17.32 tha^{-1}).

Table 2. Main and interaction effect of fungicide and NPSB fertilizer application on late blight disease and tuber yield related parameters of potato in 2019 main cropping season in Wombera district, Northwest Ethiopia

Treatment		tuber yield related parameters					
Main effect of fungicide spraying time (P)		MTNH	UNMTNH	TTNH	MTY	UNMTY	TTY
Control without Mancozeb spray (P1)		7.67^{de}	4.67^{b}	14.33^{bcd}	25.33^{d}	6.67^{bc}	32^{d}
3 weeks after full emergence (P2)		9^{a}	4.33^{b}	14.67^{a}	26.33^{d}	5.67^{dc}	32^{d}
6 weeks after full emergence (P3)		8.67^{bc}	4.67^{b}	13.33^{bc}	32.67^{a}	7^{bc}	39.67^{a}
9 weeks after full emergence (P4)		$7e^{f}$	7.67^{a}	12.67^{d}	11^{g}	9.33^{a}	20.33^{f}
LSD (0.05)		0.74	1.73	1.88	2.44	1.75	1.75
SE±		0.19	1.06	1.25	2.11	1.08	1.92
130 kg/ha (F1)		6.67^{f}	7.33^{a}	14.33^{bcd}	10^{f}	9.33^{a}	19.33^{f}
180 kg/ha (F2)		7.67^{ab}	4.67^{b}	14.33^{bcd}	25.33^{b}	6.67^{bc}	32^{a}
230 kg/ha (F3)		$9b^{a}$	3^{b}	16^{a}	40.67^{a}	6.67^{de}	45^{b}
LSD (0.05)		0.74	1.73	1.88	2.44	1.75	1.75
SE±		0.19	1.05	1.25	2.11	1.08	1.92
Interaction effect of spray time and NPSB							
P1	F1	6.67^{f}	7.33^{a}	14.33^{bcd}	10^{f}	9.33^{a}	19.33^{f}
	F2	7.67^{de}	4.67^{b}	14.33^{bcd}	25.33^{b}	6.67^{bc}	32^{d}
	F3	9^{bc}	3^{b}	16^{ab}	40.67^{a}	6.67^{de}	45^{b}
P2	F1	7.33^{ef}	6.67^{a}	13.67^{cd}	15.33^{f}	8.33^{ab}	23.67^{e}
	F2	9^{bc}	4.33^{b}	14.67^{bc}	26.33^{d}	5.67^{dc}	32^{d}
	F3	10^{a}	4^{b}	17.33^{a}	41.67^{ab}	4^{de}	45.67^{ab}
P3	F1	7.67^{de}	7^{a}	13.33^{cd}	21.67^{e}	9.33^{a}	31^{d}
	F2	8.67^{c}	4.67^{b}	13.33^{cd}	32.67^{c}	7^{bc}	39.67^{c}
	F3	9.67^{ab}	3.67^{b}	16^{ab}	43.67^{a}	4^{de}	47.67^{a}
P4	F1	$7e^{f}$	7.67^{a}	12.67^{d}	11^{g}	9.33^{a}	20.33^{f}
	F2	8.33^{cd}	4^{b}	12.67^{d}	26.67^{d}	6.33^{c}	33^{d}
	F3	10^{a}	3.33^{b}	16^{ab}	41.67^{ab}	3.33^{e}	45^{b}
LSD (0.05)		0.74	1.73	1.88	2.44	1.75	1.75
SE±		0.19	1.05	1.25	2.11	1.08	1.92
CV (%)		5.24	20.45	7.69	5.12	16.08	4.01

MTNH=marketable tuber number per hill; UTNH=unmarketable tuber number per hill; TTNH=total tuber number per hill; MTY= marketable tuber yield (tha-1); UTY=unmarketable tuber yield (tha-1); TTY=total tuber yield (tha-1); LSD = list significance difference; SE=standard error; and CV=coefficient of variation.

CONCLUSION

The result of this research indicated that spray *Mancozeb* (80%WP) 3 and 6 weeks after full emergence and 230 kg ha^{-1} blended NPSB fertilizer application were resulted in better performances for some yield and yield component variables that showed significant increase in marketable tuber yield and total tuber yield. While unsprayed plot and spray 9 weeks after full emergence, and 130 kg $ha\text{-}^{1}$ blended NPSB fertilizer application results showed that statistically significant increase in unmarketable tuber number and unmarketable tuber yield.

Disease incidence and disease severity were significantly affected by Mancozeb spray, NPSB fertilizer and interaction. However, days to first symptom appearance is not affected by Mancozeb spray, NPSB fertilizer and interaction.

Generally, spray fungicide at proper time and increasing application rates of blended NPSB fertilizer from 130 kg to 230 kg ha^{-1} resulted significantly increase on marketable, total tuber yields and significant decrement on disease incidence and disease severity. In this resulted maximum marketable tuber yield and total tuber yield were 43.67 tha^{-1} and 47.67 tha^{-1} respectively.

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