The Pharma Innovation Journal 2020; 9(3): 606-613

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2020; 9(3): 606-613

www.thepharmajournal.com
Received: 19-01-2020
Accepted: 21-02-2020

SH Peerzada
Division of Plant Pathology, Sher-e-Kashmir, University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

HS Viswanath
Division of Plant Pathology, Sher-e-Kashmir, University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

KA Bhat
Division of Plant Pathology, Sher-e-Kashmir, University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Corresponding Author:
HS Viswanath
Division of Plant Pathology, Sher-e-Kashmir, University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Effect of foliar sprays of different protectant fungicides in curbing the menace of late blight (*Phytophthora infestans*) disease besides fostering tuber size and yield of potato crop

SH Peerzada, HS Viswanath and KA Bhat

Abstract
Late blight is one of the most destructive diseases causing severe yield losses of potato in Kashmir valley. So, In the present study, four different protectant fungicides (mancozeb 75 WP, chlorothalonil 75 WP propineb 70 WP) were evaluated at field level at three different concentrations (1.5%, 2% and 2.5%) by spraying at weekly intervals starting from symptom exhibition to the ten days before dehaulming stage during cropping seasons 2016 and 2017. With this study, it was found that all the fungicides (mancozeb, propineb and chlorothalonil) were equally superior to control (water spray) in reducing the blight incidence from 75.55 to 31.03 per cent. There existed a significant interaction between fungicides and their concentrations. All the three test fungicides at C1-C3 concentration reduced the disease incidence to 24.44-51.17 per cent from 75.55 per cent observed in water sprayed check. Mancozeb 75WP was highly effective in reducing the late blight disease with a least mean disease intensity, incidence and area under disease progress curve(A value) values of 15.07,31.10 and 82.48% respectively at all the test concentrations followed by propineb 70WP and chlorothalonil 75WP, whereas highest amount of disease development was recorded in control (water spray), with mean disease intensity, incidence and AUDPC values of 55.39%, 77.77% and 292.34% respectively during the season 2016. Similar trend of results were obtained during the season 2017 where mancozeb showed highest efficacy against late blight disease with mean disease intensity, incidence and AUDPC values of 15.74%, 31.03% and 84.83% followed by propineb 70 WP and chlorothalonil 75 WP compared to control (water spray) where disease intensity, incidence and AUDPC values were recorded as 53.24%, 75.55% and 293.24% respectively. Apart from the disease control, highest tuber yield and marketable (grade A&B) tuber percent were also recorded in the treatment with mancozeb followed by propineb 70WP and chlorothalonil 75WP, whereas lowest tuber yield and unmarketable tubers (grade C) were recorded in control (water spray) treatment during cropping seasons of 2016 and 2017.

Keywords: Late blight of potato, Protectant fungicides, disease intensity, disease incidence, AUDPC and tuber yield

1. Introduction
Potato (*Solanum tuberosum* L.) is one of the most important food crops worldwide which represents a valuable source of nutrients in a balanced diet. In terms of human consumption, the potato is the third most important food crop in the world, following only rice and wheat. It is a versatile, carbohydrate rich food prepared and served in a variety of ways. Freshly harvested potato contains about 80 per cent water and 20 per cent dry matter of which 60-80 per cent is starch. On dry weight basis, protein content of potato is similar to that of cereals and higher in comparison to other root and tuber crops. It is low in fats and rich in several minerals such as potassium, phosphorus, magnesium and iron, and vitamins and vitamin B1, B3, and B6. Its high vitamin C content promotes iron absorption. Potato is also one of the important food crops in India. India stands second in world's potato production where it is cultivated over an area of 2.13 million hectares with a production of 43.77 million metric tonnes. The area and production of the Potato crop in Jammu & Kashmir state are 6.9 thousand hectares and 1.27 lakh metric tonnes, respectively (Viswanath *et al*., 2018) [17]. However, its yield and quality is adversely affected by frequent occurrence of a number of fungal, bacterial and viral diseases, among which late blight [*Phytophthora infestans* (Mont) de-Bary] is highly destructive. Reports of complete field destruction due to late blight epidemics are relatively common. The fungus is responsible for global annual crop loss of US $ 12 billion. Yield loss due to late blight in India varies from year to year and range from 20-75%.

The pathogen produces water soaked lesions with chlorotic borders that are small at first but expand rapidly under humid conditions, blighting the entire plant in only a few days with subsequent rotting of the developing tubers resulting in heavy yield losses under favourable conditions each year (Flier, *et al.*, 2001) [5] with reduction in global production by approximately 15 per cent. Losses of up to 10 to 75 per cent by the disease have been reported in India.

As Phytophthora is an oomycetes fungus, which belongs to kingdom chromista (pseudo-fungi), most of the fungicides which are used against higher fungi like Ascomycota and basidiomycota cannot be used against this pathogen for disease management. It is already known fact that chemical based disease control strategy is highly effective compared to the other strategies of disease management. Fungicides used for disease control were generally classified based on their nature in two types i.e systemic/translaminar fungicides and protectant (contact) fungicides. Protectant fungicides are prophylactic in nature, which are applied before the occurrence of the disease further checking the symptom development. Most of protectant fungicides eliminate the fungi that come in contact with them. Whereas, systemic fungicides are taken up by a plant and then translocated within plant system and therefore, can be applied even after disease appearance at any stage of disease development. Although many previous studies have been carried on the use systemic fungicides against late blight at post-symptomatic disease development, present study was taken up to evaluate only protectant fungicides instead of systemic fungicides as foliar sprays up to the dehaulming stage of potato for reducing the late blight intensity as well as their effect on tuber yield.

Material and Methods

The experiment was carried out in the field at SKUAST-Kashmir, wadura during 2016 and 2017 cropping seasons in randomized block design with three replicates, planting the tubers in last week of March 2016 and 1ST week of April 2017 by adopting the recommended package of practices for raising the crop (Anonymous, 2004) [1]. Irrigations were given at interval of three weeks after planting the tubers. The field was sub-divided into plots of size 2 m x 2 m with 50 plants at a spacing 20 x 40 cm with one meter border between the plots and the blocks to minimize fungicide drift and limit inter-plot interference. Three fungicides viz protectant fungicides (mancozeb 75 WP, chlorothanil 75WP, propineb 70 WP) were tested at three different concentrations (1.5%, 2% and 2.5%) for their effectiveness against late blight under field conditions. The spray application was initiated at the first appearance of the disease symptoms and repeated till dehaulming with weekly intervals for protectant fungicides (mancozeb 75 WP, chlorothanil 75 WP, propineb 70 WP) ensuring complete coverage of upper and lower leaf and shoot- surface. Late blight was assessed at 10 days intervals from the 1st fungicidal spray and continued till dehaulming adopting the procedure given under section. Data recorded on late blight intensity was used to compute area under disease progress curve "AUDPC "as per the scale mentioned for the disease intensity. Tubers were dug out at maturity when all the vines were dead; the yield data was recorded from individual plots and converted into qtls/ha and the tubers categorized into different grades depending on tuber diameter.

Tuber diametre (cm)	Tuber grade
8 cm and above	A
4cm to 8cm	B
4 cm and below	C

The per cent yield increase (PYI) was calculated as:-

$$PYI = \frac{\text{Tuber yield obtained with Fungicide treatment} - \text{Tuber yield obtained in control plots}}{\text{Tuber yield obtained in control}} \times 100$$

Disease incidence

A number of plants were randomly selected from each treatment in the field for recording the total number of diseased and healthy plants at 10 days interval from first fungicidal spray to ten days before dehaulming stage and mean of all assessments is obtained for all treatments. It was calculated mathematically by using formula,

$$\text{Late blight incidence (\%)} = \frac{n}{N} \times 100$$

Where n is the number of plants showing blight symptoms and N the total number of plants examined. An average of the ten assessments in the fields represented the average disease incidence of the field.

Disease intensity

A number of plants were randomly selected from each treatment in the field and the observation on the extent of the foliage blighted was recorded at 10 days interval from first fungicidal spray to ten days before dehaulming stage using the disease rating scale given by Mohan and Thind (1999) [10] and mean of all assessments is obtained for all treatments.

Disease Score	Score description in terms of foliage infected (%)
0	No visible symptoms
1	1-10
2	11-25
3	26-50
4	51-75
5	>75

$$PYI = \frac{\text{Tuber yield obtained with Fungicide treatment} - \text{Tuber yield obtained in control plots}}{\text{Tuber yield obtained in control}} \times 100$$

Per cent disease intensity recorded was transformed using arc sine transformation and subjected to analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) [6].

The Area under disease progress curve (AUDPC) "A" value: The intensity of foliar blight was determined at 10 days interval from the onset of first symptoms until the end of vegetation period (dehaulming) and expressed in per cent of the infected leaf area as per the scale mentioned above in the disease intensity. The Area under disease progress curve (AUDPC) "A" value was determined as per the method given by Shanner and Finney (1997) using the formula. The AUDPC value was calculated with the following formula.

$$AUDPC\ (A) = \sum_{i=1}^{n-1} \frac{[(X_i + X_i+1)]}{2} (T_i+1 - T_i)$$

Where X = % Disease intensity at different dates ($X_1 + X_2$, $X_2 + X_3$, $X_3 + X_4$ … and so on)

T = Time interval between two observations
n = Total number of observations

Results and discussion

Effect on late blight development

The different fungicidal foliar sprays made at periodical intervals on potato crop cv. Kufri Jyoti were evaluated during 2016 and 2017 cropping seasons for their efficacy in controlling potato late blight with concomitant effects on tuber yield. The results obtained during 2016 cropping season reveal that, among protectant fungicidal foliar sprays (Table-1), all the fungicides viz., mancozeb, propineb and chlorothalonil, were equally superior to water spray check in reducing the blight incidence from 77.77 to 31.10 per cent. There existed a significant interaction between fungicides and their concentrations. All the three test fungicides at C_2-C_3 concentration reduced the disease incidence to 22.22-51.10 per cent from 77.77 per cent observed in water sprayed check.

On an average, foliar spray with mancozeb yielded the minimum blight intensity of 15.07 per cent followed by propineb and chlorothanil sprays exhibiting next lowest blight intensity of 18.00- 19.28 per cent compared to 55.59 per cent obtained in water sprayed check. Among concentrations, in general, the higher concentration of C_3 and C_2 exhibited lower disease intensity of 23.58 -23.96 per cent than the lower concentration C_1 where 33.59 per cent blight intensity was observed. A significant interaction between fungicides and their concentrations in curtailing the blight intensity also existed. Mancozeb foliar spray at C_3 and C_2 concentration was the most effective fungicide recording the lowest blight intensity of 10.33-10.52 per cent followed by foliar spray with either propineb or chlorothalonil at the same concentration of C_3 and C_2 yielding blight intensity of 13.75 and 15.07 per cent compared to water spray check (56.10%).

The areas under disease progress curve ("A" value), computed on the basis of the periodical assessment of blight varied significantly between treatments. On an overall mean basis, mancozeb foliar sprays showed the least "A" value of

Table 1: Effect of foliar sprays with Protectant fungicides on late blight (*Phytophthora infestans*) of potato cv. Kufri Jyoti recorded at 10 days interval during 2016 season

Fungicide	Late blight incidence (%) at fungicide concentration				Late blight intensity (%) at fungicide concentration				"A" value			
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
Mancozeb 75 WP	48.88 (33.86)	22.22 (27.53)	22.22 (28.11)	31.10 (29.83)	24.40 (29.55)	10.52 (18.86)	10.329 (18.71)	15.07 (22.37)	139.71	54.12	53.61	82.48
Propineb 70 WP	51.10 (37.55)	28.88 (29.10)	28.88 (28.11)	36.28 (31.58)	26.33 (30.83)	13.92 (21.87)	13.75 (21.76)	18.00 (24.76)	155.24	74.27	72.39	100.63
Chlorothanil 75 WP	51.10 (37.53)	24.44 (29.10)	24.44 (26.94)	33.32 (31.15)	27.55 (31.57)	15.07 (22.68)	14.90 (22.50)	19.28 (25.68)	158.18	84.06	80.77	107.67
Control (water spray)	77.77(43.75)	77.77 (43.75)	77.77 (43.75)	77.77 (43.75)	56.10 (48.59)	56.10 (48.59)	55.39 (48.17)	55.39 (48.17)	261.27	260.13	266.42	262.81
Mean	57.12 (38.17)	38.32 (32.75)	83.32 (31.72)	-	33.59 (35.13)	23.96 (28.04)	23.58 (27.76)	-	178.75	118.15	118.30	-
	S.Em±	CD(P=0.05%)			S.Em±	CD(P=0.05%)			S.Em±	CD(P=0.05%)		
Fungicide (F)	0.76	2.01			0.65	1.20			1.01	7.51		
Concentration (C)	0.81	1.53			0.76	1.80			2.30	9.94		
F x C	0.83	3.17			0.01	2.89			3.41	14.60		

Figures in parenthesis are arc sine transformed values Spray started with the first appearance of disease on May 8th 2016 and repeated at after every 7 days interval; Disease incidence/intensity recorded at 10 days interval; Mancozeb 75 WP, Propineb 70 WP and Chlorothanil 75 WP evaluated at 1.5 (C_1), 2.0 (C_2) and 2.5 (C_3) per cent concentrations 82.48 followed by propineb and chlorothalonil foliar spray yielding "A" value of 100.63-107.67 compared to 262.81 obtained in water sprayed check plots. In general, the higher test concentrations of C_2 and C_3 yielded the minimum "A" Value (118.15 and 18.30) for the disease as compared to their lower concentration of C_1 (178.75). A significant interaction also operated between different fungicides and their concentrations with regard to their effects on AUDPC. Foliar sprays with mancozeb at C_3-C_2 concentrations exhibited the lowest "A" value of 53.61-54.12 followed by foliar sprays with both propineb and chlorothalonil at the same concentration with "A" value of 72.39-84.06 as compared to 260.13 -266.42 obtained in water sprayed check.

Similar trend was observed during 2017 field experimentation. The results reveal that among protectant fungicidal foliar sprays (Table-2), all the fungicides (mancozeb, propineb and chlorothalonil) were equally superior to water spray check in reducing the blight incidence from 75.55 to 31.03 per cent. There existed a significant interaction between fungicides and their concentrations. All the three test fungicides at C_1-C_3 concentration reduced the disease incidence to 24.44-51.17 per cent from 75.55 per cent observed in water sprayed check.

On an average, foliar spray with mancozeb yielded the minimum blight intensity of 15.74 per cent followed by chlorothalonil (17.78) and propineb (18.45) sprays compared to 53.24 per cent obtained in water-sprayed check. Among concentrations, in general, the higher concentrations of C_2 and C_3 exhibited lower disease intensity of 22.61 -22.75 per cent than the lower concentration C_1 where 33.33 per cent blight intensity was observed. A significant interaction between fungicides and their concentrations in containing the blight intensity also existed. Mancozeb foliar spray at C_2 and C_3 concentrations was the most effective fungicide recording the lowest blight intensity of 10.81-11.02 per cent followed by foliar spray with either chlorothalonil or propineb at the same concentration of C_2-C_3 yielding blight intensity of 12.90-13.95 per cent compared to water sprayed check (53.30%).

The area under disease progress curve ("A" value), computed on the basis

Table 2: Effect of foliar sprays with protectant fungicides on progress of late blight (*Phytophthora infestans*) of potato cv. Kufri Jyoti recorded at 10 days interval during 2017 season

Fungicide	Late blight incidence (%) at fungicide concentration				Late blight intensity (%) at fungicide concentration				"A" value			
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
Mancozeb 75 WP	39.77 (39.06)	26.66 (30.49)	26.66 (30.97)	31.03 (33.67)	25.41 (30.25)	10.81 (19.14)	11.02 (19.39)	15.74 (22.92)	144.18	55.34	54.97	84.83
Propineb 70 WP	51.11 (45.59)	28.88 (32.36)	26.66 (30.97)	35.53 (36.31)	27.07 (31.820	13.44 (21.46)	13.95 (21.88)	18.15 (24.87)	158.69	65.57	65.55	96.60
Chlorothalonil 75 WP	51.10 (45.63)	28.88 (32.36)	24.44 (29.46)	34.81 (35.82)	27.54 (31.52)	12.90 (21.02)	12.90 (21.02)	17.78 (24.48)	169.34	74.96	74.83	106.38
Control (water spray)	75.55 (60.41)	75.55 (60.41)	75.55 (60.41)	75.55 (60.52)	53.30 (46.90)	53.30 (46.90)	53.14 (46.81)	53.24 (46.87)	285.68	290.33	301.00	292.34
Mean	54.36 (47.67)	39.99 (39.02)	38.33 (38.03)	-	33.33 (34.99)	22.61 (27.13)	22.75 (27.52)	-	189.47	121.55	124.09	-
	S.Em±			CD(P=0.05%)	S.Em±		CD(P=0.05%)		S.Em±	CD(P=0.05%)		
Fungicide (F)	1.10			5.37	0.99		2.02		5.12	17.90		
Concentration (C)	0.91			4.59	1.01		2.84		7.14	20.14		
F x C	1.57			7.87	1.35		4.71		8.41	25.31		

Figures in parenthesis are arc sin transformed values Spray started with the first appearance of disease on May 12th 2017 and repeated at after every 7 days interval; Disease incidence/intensity recorded at 10 days interval; Mancozeb 75 WP, Propineb 70 WP and Chlorothalonil 75 WP evaluated at 1.5 (C_1), 2.0 (C_2) and 2.5 (C_3) per cent concentrations of the periodical assessment of blight significantly varied between treatments. On an overall mean basis, mancozeb foliar sprays showed the least "A" valve of 84.83 followed by propineb and chlorothalonil foliar spray yielding "A" value of 96.60-106.38 per cent compared to 292.34 obtained in water sprayeds check plots. In general, the higher concentration of C_3-C_2 yielded the minimum "A" Value (121.55-124.09) for the disease as compared to their lower concentration of C_1 (189.47). A significant interaction also operated between different fungicides and their concentration with regard to their effects on AUDPC' Foliar spray with mancozeb at C_3 and C_2 concentration exhibited the lowest "A "valve of 54.97-55.34 followed by foliar sprays with both propineb and chlorothalonil at the same concentration with "A" valve of 65.55 and 65.57 as compared to 290.33-301.00 obtained in water sprayed check.

Effect on tuber yield

The foliar sprays with different protectant fungicides during 2016 resulted in significant difference in tuber yields (Table-3). On overall mean basis, the foliar sprays with either mancozeb or chlorothalonil resulted in the highest tuber yield of 202.36-203.36 q/ha followed by foliar sprays with propineb which yielded 193.68 q tubers per hectare as compared to only 147.70 q/ha obtained in water sprayed control plots. On an average, the higher concentrations (C_3-C_2) proved superior providing tuber yields of 196.32-198.30 q/ha compared to 165.70 q/ha obtained at C1 concentrations. A significant interaction between fungicide and their concentrations existed in promoting tuber yields. Foliar sprays with either mancozeb or chlorothalonil at C2 and C3 concentration resulted in the maximum tuber yield of 214.66-224.30 q/ha. Foliar spray with propineb at the same concentrations was the next best treatment showing tuber yield of 203.70-204.93 q/ha. An insight into the data (Fig. 1) reveals 45 to 50 per cent gain in tuber yields by the foliar spray of either mancozeb or chlorothalonil at C2-C3 concentration over water sprayed check followed by propineb foliar sprays which yielded a gain of only 40-43 per cent.

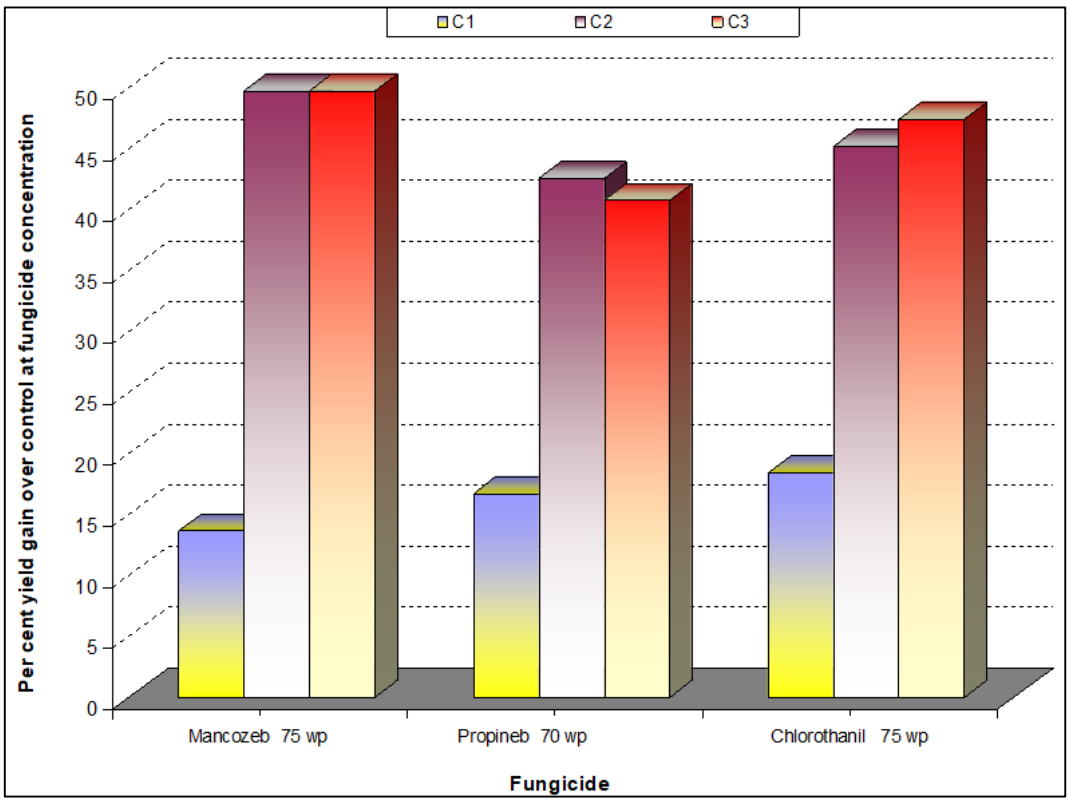

Fig 1: Effect of foliar sprays with protectant fungicides on tuber yield of potato cv. Kufri Jyoti recorded during 2016 season

Table 3: Effect of foliar sprays with protectant fungicides on tuber yield (*Phytophthora infestans*) of potato cv. Kufri Jyoti recorded at 10 days interval during 2016 season

Fungicide	Tuber yield (q ha^{-1}) at fungicide concentration				Per cent yield gain over control at fungicide concentration			
	C1	C2	C3	Mean	C1	C2	C3	Mean
Mancozeb 75 WP	167.79	224.30	218.00	203.36	13.60	49.73	49.72	37.68
Propineb 70 WP	172.40	203.70	204.93	193.68	16.72	42.54	40.74	31.14
Chlorothanil 75 WP	174.90	217.49	214.66	202.36	18.41	45.18	47.43	37.00
Control (water spray)	147.70	147.70	147.70	147.70	-	-	-	-
Mean	165.70	198.30	196.32	-	-	-	-	-
	S.Em±		CD (p=0.05)					
Fungicide (F)	1.46		8.81					
Concentration (C)	1.74		12.06					
F x C	2.81		15.94					

Figures in parenthesis are arc sin transformed values. Spray started with the first appearance of disease on May 8th, 2016 and repeated at after every 7 days interval; Disease incidence/intensity recorded at 10 days interval; Mancozeb 75 WP, Propineb 70 WP and Chlorothalonil 75 WP evaluated at 1.5 (C1), 2.0. (C2) and 2.5 (C3) per cnet concentrations. The fungicidal sprays were further found to significantly influence the size/grade of the tubers (Table-4). On an average, foliar sprays with all the test fungicides viz., mancozeb, propineb or chlorothalonil, significantly increased the proportion of A and B grade tubers to 29.58 and 51.18 per cent, respectively, from 10.17 and 41.49 per cent, respectively, obtained in water-sprayed check. The proportion of unmarketable C grade tubers was, on an average, significantly less (19.22-20.55%) in treatments sprayed with any of the fungicide compared to check (48.39%). A significant interaction between fungicides and their concentrations in improving the tuber grade also existed. Foliar sprays with mancozeb 75WP (C3 concentration) yielded maximum of 39.05 per cent A grade tubers followed by foliar sprays with propineb 70WP at C2 concentration which yielded maximum of 37.35 per cent A grade tubers compared to 8.75-11.39 per cent A grade tubers obtained in water sprayed check treatments. Similarly, the foliar sprays with mancozeb 75WP and chlorothalonil at C1-C2 concentration and propineb 70 WP at C3 concentration provided maximum proportion (51.85-52.22%) of A and B grade tubers compared to check (35.56-45.27%). An insight into the data (Fig. 2) indicates that the proportion of marketable tubers yield was significantly increased by spraying all the fungicides. The unmarketable yield was noticeably decreased by spraying these fungicides. The result obtained in field experimentation during 2017 is presented in (Table-5). On overall mean basis, foliar sprays with either mancozeb or chlorothalonil resulted in the highest tuber yield of 203.57-208.66 q/ha followed by foliar sprays with propineb which yielded 193.35 q tubers per hectare as compared to only 156.20 q/ha obtained in water- sprayed control plots. On an average, the higher fungicidal concentrations (C2-C3) proved superior providing a tuber yield of 200.83-202.63 q/ha compared to 167.87 q obtained with foliar sprays at C1 concentration. A significant interaction between fungicides and their concentrations existed in promoting tuber yields. Foliar sprays with mancozeb at C2-C3 concentration resulted in the maximum tuber yield of 225.62-229.63 q/ha, followed by those with chlorothalonil 75WP (216.23-219.50 qt/ha). Foliar spray with propineb at the same concentrations provided a tuber yield of 204.44-203.18 q/ha. An insight into the data (Fig. 3) reveals 44 to 45 per cent gain in tuber yields by the foliar spray with mancozeb at C3-C2 concentration followed by chlorothalonil 75WP foliar sprays at the same concentration which yielded a gain of only 38-39 per cent. The fungicidal sprays were further found to significantly influence the tuber size/grade of the tuber (Table-6).

Table 4: Effect of foliar sprays with different fungicidal concentration on tuber grade of late blight (*Phytophthora infestans*) of potato cv. Kufri Jyoti during 2016 season

Fungicide	Tuber grade (%) at fungicide concentration									Mean (%)		
	C1			C2			C3					
	Grade			Grade			Grade			Grade		
	A	B	C	A	B	C	A	B	C	A	B	C
Mancozeb 75 WP	18.16	52.18	29.65	29.90	52.15	17.94	39.05	45.98	14.05	29.04	50.10	20.55
Propineb 70 WP	21.22	52.11	26.65	37.35	49.58	13.06	30.18	51.85	17.96	29.58	51.18	19.22
Chlorothalonil 75 WP	18.40	52.22	29.37	35.48	51.11	13.40	34.87	47.17	17.95	29.58	50.17	20.24
Control (water spray)	10.36	43.65	45.98	11.39	35.56	53.04	8.75	45.27	46.15	10.17	41.49	48.39
Mean	**17.03**	**53.79**	**29.16**	**28.53**	**50.85**	**20.61**	**28.21**	**51.31**	**20.27**			
		S.Em+		CD(p=0.05)								
Fungicide (F)		0.13		0.82								
Concentration (C)		0.17		1.43								
F x C												

On an average, foliar sprays with all the test fungicides (mancozeb, propineb or chlorothalonil) significantly increased the proportion of A and B grade tubers to 32.94-34.09 and 48.96-51.55 per cent, respectively from 14.76 and 38.82 per cent, respectively, obtained in water sprayed check. The proportion of unmarketable C grade tubers was, on an average, significantly less 15.28-18.09 per cent in treatments sprayed with any of the fungicides compared to check (48.39%). A significant interaction between fungicides and their concentrations in improving the tuber grade also existed. Foliar sprays with mancozeb 75WP (C3 concentration) yielded maximum of 37.04 per cent A grade tubers followed by foliar sprays with propineb 70WP at C2 concentration which yielded maximum of 36.79 per cent A grade tubers

compared to 12.91-14.52 per cent. A grade tubers obtained in water sprayed check. Similarly, the foliar sprays with mancozeb 75WP and chlorothalonil at C1-C2 concentration and propineb 70 WP at C3 concentration provided maximum proportion (53.00-55.70) A and B grade tubers compared to check (34.55-48.17%). An insight into the (Fig. 4) indicates that the proportion of marketable tubers yield was significantly increased by spraying any of the fungicides. The unmarketable yield was noticeably decreased by spraying these fungicides. Spray started with the first appearance of disease on May 8th 2016 and repeated at 7 days interval, Disease incidence/intensity recorded at 10 days interval. Mancozeb 72 WP, Propineb 70 WP and Chlorothalonil 75 WP evaluated at 1.5 (C1), 2.0. (C2) and 2.5 (C3) percent concentrations.

Figures in parenthesis are percent tuber grade

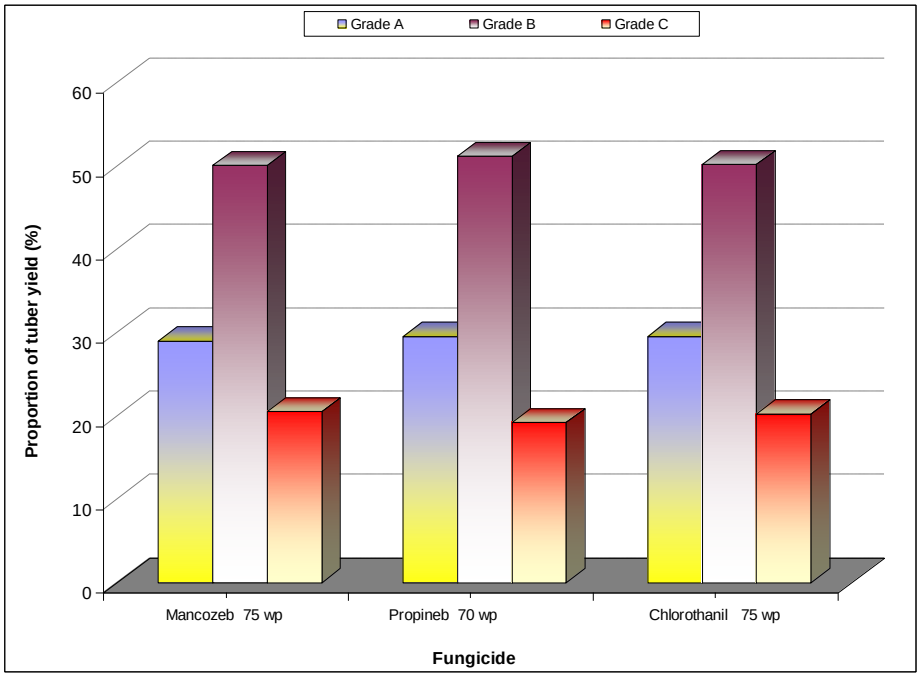

Fig 2: Proportion of marketable and unmarketable yield obtained by spraying different fungicides during 2016 season A and B grade marketable yield, C is unmarketable yield

Table 5: Effect of foliar sprays with Protectant fungicides on tuber yield (*Phytophthora infestans*) of potato cv. Kufri Jyoti during 2017 season

Fungicide	Tuber yield (q ha^{-1}) at fungicide concentration				Per cent yield gain over control at fungicide concentration			
	C1	C2	C3	Mean	C1	C2	C3	Mean
Mancozeb 75 WP	170.64	229.73	225.62	**208.66**	11.20	45.30	43.67	**33.39**
Propineb 70 WP	172.42	203.18	204.44	**193.35**	12.36	28.31	30.19	**23.68**
Chlorothalonil 75 WP	174.97	219.50	216.23	**203.57**	14.02	38.83	37.69	
Control (water spray)	153.45	158.10	157.03	**156.20**				
Mean	**167.87**	**202.63**	**200.83**					
	S.Em±		CD(p=0.05)					
Fungicide (F)	1.86		7.11					
Concentration (C)	2.11		10.99					
F x C	2.89		14.86					

Spray started with the first appearance of disease on may 12th 2017 and repeated at after every 7 days interval; Mancozeb 75WP, Propineb 70 WP and Chlorothanil 75 WP evaluated at 1.5 (C1), 2.0. (C2) and 2.5 (C3) per cnet concentrations

Table 6: Effect of foliar sprays with contact fungicides on tuber grade of late blight (*Phytophthora infestans*) of potato cv. Kufri Jyoti during 2017 season

Fungicide	Potato grade (%) at fungicide concentration									Mean (%)		
	C1			C2			C3					
	A	B	C	A	B	C	A	B	C	A	B	C
Mancozeb 75WP	28.86	45.47	26.84	36.37	53.06	10.52	37.04	53.00	9.95	34.09	50.51	15.77
Propineb 70WP	26.45	44.02	29.52	36.79	53.16	10.03	35.57	49.69	14.73	32.94	48.96	18.09
Chlorothalonil 75WP	28.97	45.80	25.21	33.92	55.70	10.36	36.56	53.15	10.28	33.15	51.55	15.28
Control (water spray)	14.52	52.03	33.44	16.85	49.53	33.61	12.91	53.91	33.17	14.76	36.82	48.40
Mean	**24.70**	**46.83**	**28.75**	**30.98**	**52.86**	**16.13**	**31.01**	**52.43**	**16.53**			
		S.Em±		**CD(p=0.05)**								
Fungicide (F)		0.21		(0.82)								
Concentration (C)		0.32		(1.43)								
F x C		0.48		(1.65)								

Spray started with the first appearance of disease on May 12th 2017 and repeated at after every 7 days interval. Disease incidence/intensity recorded at 10 days interval. Mancozeb 72 WP, Propineb 70 WP and Chlorothanil 75 WP evaluated at 1.5 (C1), 2.0. (C2) and 2.5 (C3) per cent concentrations. Figures in parenthesis are per cent tuber yield

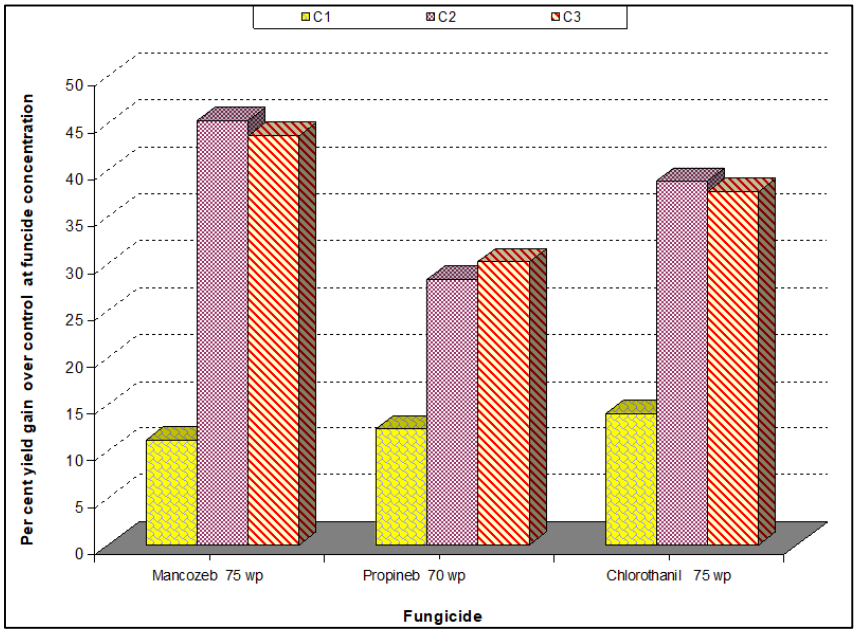

Fig 3: Effect of foliar sprays with protectant fungicides on tuber yield (*Phytophthora infestans*) of potato cv. Kufri Jyoti during 2017 season

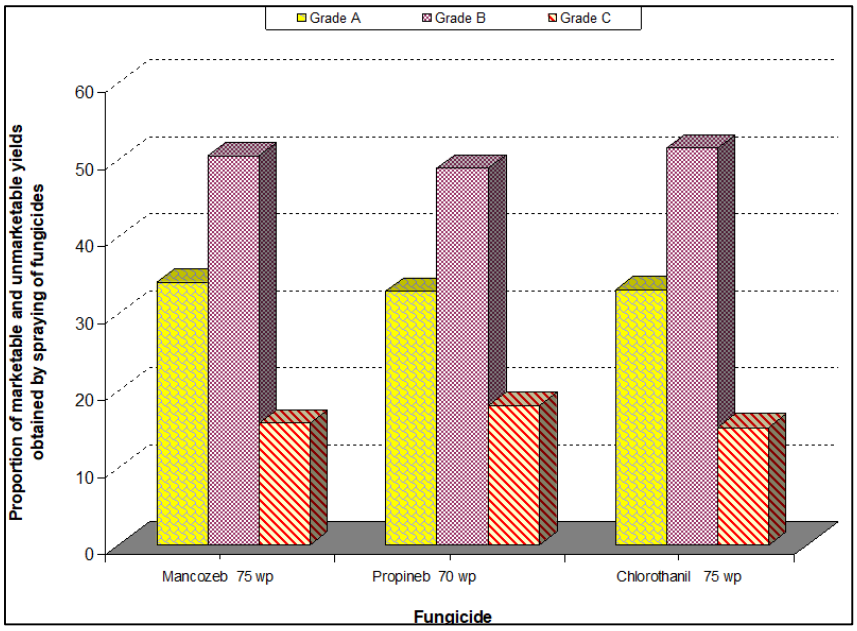

Fig 4: Proportion of marketable and unmarketable tubers obtained by spraying different fungicides during 2017 season A and B grade marketable tuber, C is unmarketable tuber

The use of fungicides for controlling plant diseases caused by fungi are well documented (Nene and Thapliyal, 2002) [11]; however, the control of diseases such as that of potato late blight caused by oomycetous fungi with traditional protectant fungicides has not been so successful necessitating to evaluate newer molecules for its control. Our present study revealed that among the protectant fungicides, mancozeb was found highly effective in reducing the disease intensity, disease incidence and least area under disease progress curve (AUDPC) followed by chlorothalonil and propineb. The efficacy of mancozeb or of probineb and chlorothalonil against many foliar disease pathogens such as *P. infestans* has long been reported (Johnson *et al.*, 2000) Peerzada *et al.*, 2020 [7, 12] also reported that among protectants, mancozeb was inhibitoriest to mycelial growth followed by propineb and chlorothalonil under *in vitro* conditions. They also reported that spore production and spore germinability was also accordingly reduced. The application of fungicides that would help to inhibit mycelial growth and act as antisporulants are likely to control the spread of this disease. The present studies are in accordance with those of many researchers (Johnson *et al.*, 2000; Matheron and Porchas, 2000, Rani *et al.*, 2009) [7, 9, 3]. Chakraborty and Mazumdar, 2012 [4] reported that prophylactic sprays of chlorothalonil/mancozeb were found effective than post-symptomatic sprays but in our study even post-symptomatic sprays with protectants gave good results in reducing the disease. They also reported that the severe late blight can be effectively managed with prophylactic spray of

mancozeb @0.25%. Khadka *et al*., 2016 [8] also reported that mancozeb spraying combined with Dimethomorph and fenamidon showed less disease against late blight of potato. Siddique *et al*., 2016 [15] reported that the highest percentage of disease control and the highest yield were recorded with Mancozeb, where foliar spray with mancozeb increased the tuber yield and tuber grade of potato which was in consonance of our results. The yield gains with the improvement in tuber grades are concomitant effects of the reduced blight intensity and reduced A values. Thind *et al.*, 2004 [16] also reported that formulation containing mancozeb with any one of the systemic fungicides seems to provide better field control of late blight.

From our studies, it can be concluded that even protectant fungicides were highly effective in the management of late blight disease of potato, when they were applied at weekly intervals as post-symptomatic sprays. These protectants can also be combined with other cultural practices thereby integrating them in order to prevent the development of new races of the pathogen due to the chance of resistance development against the available fungicides. With the present study it is evident that protectant fungicides were highly effective in the prevention of disease development as well as reducing the symptom development as post-symptomatic sprays at field conditions. Foliar sprays with protectant fungicides also increased the tuber yield and quality grade tubers thereby producing marketable tuber yield.

References

1. Anonymous. Production recommendation for vegetables (Kashmir Division). Agriculture Technology Information Centre. Directorate of Extension Education. Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, 2004, 9.
2. Anonymous. 3rd Advance Estimate of Area and Production of Horticulture Crops. Statistics and Market Information. National Horticulture Board, Ministry of Agriculture and Farmers Welfare Govt. Of India, Gurgaon, Haryana, 2015. (http//nhb.gov.in).
3. Anwar MM, Parveen A, Hossain MM, Mahamud NU, Roy RK. Efficacy of fungicides in controlling late blight of potato Progressive Agriculture. 2015; 26:103-108.
4. Chakraborty A, Mazumdar D. Developmentof effective spray schedule for the managementof late blight of potato in plains of west Bengal.Potato J. 2012; 39(1):92-94.
5. Flier WG, Turkensteen LJ, Van Den Bosch GBM, Vereijken PFG, Mulder A. Differential interaction of *Phytophthora infestans* on tubers of potato cultivars with different levels of blight resistance. *Plant Pathology*. 2001; 50(3):292-301.
6. Gomez KA, Gomez AA. Statistical Procedures for Agriculture Research. International Rice Research Institute. John Willy and Sons, New York, Chickester, Brisbane, Torento, Singapore, 1984, 643.
7. Johnson DA, Cummings TF, Geary B. Postinfection activity of selected lateblight fungicides. Plant Diseases. 2000; 84:1116-1120.
8. Khadka RB, Rawal R, Marasaini M, Shrestha GK, Chapagain T, Gautam IP *et al*. Evaluation of Different Fungicidesand Clones against Potato Late Blight (Phytophthora Infestans) In Western Nepal. 5thInternational Conference on Agriculture,Environment and Biological Sciences (ICAEBS-16) April 28-29, Pattaya (Thailand), 2016.
9. Matheron ME, Porchas M. Impact of azoxystrobin, dimethomorph, fluazinam,fosetyl-Al, and metalaxyl on growth,sporulation, and zoospore cyst \ germination ofthree *Phytophthora* spp. Plant Diseases. 2000; 84:454-458.
10. Mohan C, Thind TS. Resistance and relative performance of some new fungicides for active management of potato late blight in Punjab. Indian Journal of Mycology and Plant Pathology. 1999; 29(1):23-37.
11. Nene YL, Thapliyal. Fungicides in Plant Disease Control (3rd edition). Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi, 2002.
12. Peerzada SH, Viswanath HS, Bhat KA. *In-vitro* studies on effect of fungicides against mycelial growth and sporangial germination of Phytophthora infestans (Mont) de Bary) causing late blight of potato. International Journal of Chemical Studies. 2020; 8(1):2069-2075.
13. Rani AM, Narayana BM, Singh BP. Efficacy of cymoxanil + mancozeb in controlling late blight of potato in subtropical plant. J Myco. Pl. Pathol. 2009; 39(1):55-58.
14. Shaanner G, Finney RF. The effect of nitrogen fertilization on the expression of slow mildewing resistance in Knox wheat. Phytopathology. 1977; 67:1051-1056.
15. Siddique NA, Aktar MS, Swapon NH. Comparative Efficacy of Different Fungicides against Late Blight Diseases of Potato incited by Phytophthora infestans (Mont.) de Bary and its Management. J Plant Pathol Microbiol. 2016; 7:364.
16. Thind TS, Mohan C, Arora JK, Raj P. Potential of some recently developed fungicides and their combination products for effective management of late blight of potato. Indian Phytopathology. 2004; **57**(1):95-98.
17. Viswanath HS, Bhat KA, Bhat NA, Wani TA, Mohammad Najeeb Mughal. Antibacterial Efficacy of Aqueous Plant Extracts against Storage Soft Rot of Potato Caused by Erwinia carotovora. *Int. J Curr. Microbiol. App. Sci*. 2018; 7(01):2630-2639.