

ECONOMIZED WATER VOLUME AND CONCENTRATION OF FUNGICIDE FOR MANAGEMENT OF LATE BLIGHT OF POTATO IN SUBTROPICAL PLAINS OF INDIA

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Potato (*Solanum tuberosum* L.) belonging to the Solanaceae family, is an important vegetable and cash crop cultivated in the world. Potato is the third most important food crop in the world after rice and wheat from the point of human consumption (<https://cipotato.org>). Globally, India is the second largest producer of potato after China with about 53.40 million tons as per first advance estimate during 2021-22 (<https://agriexchange.apeda.gov.in>). Production of potato has been increased however; less productivity is still a challenge. The potato crop is affected by many biotic and abiotic stresses. Among biotic stresses, late blight of potato caused by a fungus like organism, *Phytophthora infestans* (Mont.) de Bary is one of the major causes of concern for affecting yields in the world wherever potato crop is cultivated. The managing cost of *Phytophthora* blight to the potato alone amounted to US \$6.7 billion annually (USA Blight, 2012). In India, estimated yield loss was reported up to 10-20% during 2013-14 (Lal *et al.*, 2016). The state of Uttar Pradesh alone shares about 30-32% production in the total potato production of India. Varietal resistance is the best option for managing late blight disease of potato.

However, due to complex virulence nature of *P. infestans*; the resistance of the varieties is wiped out within a decade. Therefore, the next best option leftover is use of synthetic fungicides. Several fungicides including contact, systemic and trans-laminar have been evaluated from time to time; however, the pathogen has shown a remarkable capacity for change with respect to host genotypes and fungicides. As a result, disease control requires regular application of fungicides at high rates and short intervals throughout the growing season of potato crop (Lal *et al.*, 2015). In Peru, farmers often spray fungicides more than ten times (Bustamante *et al.*, 2008; Perez *et al.*, 2009). The number of sprays depends on disease and various other factors, *viz*, nature of fungicides being used, climatic conditions, pressure, timing of the disease appearance and duration of varieties. In India, generally more number of sprays are required in hilly and plateau regions than the plain regions. It may be due to climatic conditions are more favorable in these areas than plain regions.

Water is a very crucial component for cultivation of any crop. The water table is decreasing day by day due to industrialization

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and growing of intensive cropping system. In general, for effective management of late blight of potato, it is advised that solution of fungicides must run off on the foliage of potato plants. In this process, more water volume is required (up to 1000 L/ha) along with more number of man power for spray. However, due to change in spraying technologies of equipments, water quantities can be adjusted. Many types of spraying equipments are being used for spraying of pesticides solutions viz., foot sprayer, manually operated knapsack sprayer, battery operated knapsack, tractor mounted sprayer, drone operated systems etc. These equipments require different water volume per hectare for proper coverage of potato foliage. The water volume must be economized with new spraying equipments for proper management of late blight of potato. The aim of the present study was to economize water volume and doses of fungicide per hectare for management of late blight disease on potato.

The field experiments were conducted at ICAR-Central Potato Research Institute-Regional Station, Modipuram Meerut (29.1° N, 77.92° E, 300 masl), Uttar Pradesh, India during three consecutive *Rabi* seasons of 2017-18, 2018-19 and 2019-20 years in a Randomized Block Design (RBD) with three replications. The seed tubers of cultivar Kufri Bahar (highly susceptible to late blight disease) were planted in the second week of November in a plot size of 3.0 x 3.0 m² having five rows per plot. The plant to plant distance of 20 cm and row to row distance of 60 cm was maintained. The crop was raised with the application of 180kg N, 80kg P₂O₅ and 100 kg K₂O /ha and other practices were followed as per recommendations for the region. Weedicide metribuzin 70% WP (@ 750 g/ha) was applied within five days after planting in all the years of experimentation.

Highly complex pathogenic race (mating type A1, metalaxyl resistant, race 1.2.3.4.5.6.7.8.9.10.11) of *P. infestans* was cultured on potato tuber slices and incubated at 18°C temperature with 95% relative humidity for 5-7 days in growth chamber. Inoculum was prepared by blending the freshly grown mycelia with sterile distilled water to obtain an aqueous suspension containing sporangia. For releasing the zoospores from sporangia, the suspension was incubated at 8°C temperature in BOD for 30-45 min in dark. The floating zoospores were observed under optical microscope after the set time period and the zoospores concentration was adjusted to 6x10⁴ ml⁻¹ using haemocytometer counting. The Whatman filter paper discs of size 0.3 cm² were submerged in the zoospore suspension and used for challenge inoculation. Forty-five days after planting, the leaves of potato plants in infector rows of each treatment were artificially inoculated by placing single disc on lower side of the leaf (Lal *et al.*, 2021). These rows were planted on the borders of the experimental plot to ensure proper spreading of inoculums across the treatments. The sprinkler system of irrigation was used at regular interval for maintaining the proper humidity in the experimental field.

A total of four sprays of mancozeb 75% WP in different doses with different water volumes per hectare were applied throughout the cropping season. Spraying of chemical was started before 7-8 days of initiation the disease, at appearance of disease and subsequently two other sprays at 7-10 days intervals. Terminal disease severity was recorded after 10 days of 4th spray as per the method of Henfling (1987). Percent disease control was calculated following the standard method. Tuber yield was recorded at the time of harvesting. The disease severity and yield data were subjected to standard

statistical analysis using OPSTAT software. Benefit:Cost ratio was calculated for assessing the economically effective treatment for management of late blight of potato. The 3 fungicide cost @ Rs 425.0/Kg and labour cost @ Rs 300.0/day was taken for calculation. The fixed cost was taken @ Rs 89204.0/ha. The cost of produce was taken @ Rs 8000/t.

The results presented in **Table 1** reveal that all treatments significantly reduced the average terminal disease severity (25.28 to 40.39%) over control (96.39%). Minimum average terminal disease severity (25.28, 25.78 and 26.19%) was recorded with treatment T6 (mancozeb 75%WP @ 2.5Kg/500L water), T4 (mancozeb 75%WP @ 1.5Kg/500L water) and T5 (mancozeb 75% WP @ 2.0Kg/500L water), respectively and were statistically at par with each other. Compared to these, significantly higher average terminal disease severity (40.39 and 40.0%) was recorded with treatment T1 (mancozeb 75% WP @ 2.0 Kg/1000L water) and T3 (mancozeb 75% WP @ 1.0 Kg/500L water). The average highest per cent disease control was observed in treatment T6 (73.78%) followed by T4 (72.68%) and T5 (72.51%). The least average per cent disease control was observed in the treatment T1 and T2 (58.10 and 58.5%, respectively). The average highest tuber yield was recorded in treatment T6 (34.35 t/ha) followed by T5 (33.09 t/ha) and T4 (33.07 t/ha). The treatment T6 (mancozeb 75%WP @ 2.5Kg/500L water) showed highest additional yield over control (6.21 t/ha) followed by T5 (4.95 t/ha) and T4 (4.93 t/ha). The highest gross return (Rs 49, 680.0) was recorded in T6 followed by T5 and T4 (**Table 2**). The lowest cost of treatment (Rs 5650.0) was in treatment T3, whereas highest cost of treatment (Rs 9050.0) in treatment T6. The highest net return over control (Rs 40, 630.0) and B: C (2.80) was recorded in T6 followed by treatment T4 and T5 (**Table 2**).

Mancozeb is a contact fungicide and multisite activity and widely adopted for management of late blight diseases and it was released during 1940s (Perez *et al.*, 2022). This fungicide is classified M03 FRAC code (Fungicide Resistant Action Committee) and considered as low risk group for developing resistant in fungicide. It is easily available in the farmer locality and cheaper in comparison to other contact fungicides used for managing late blight disease of potato. Determining concentration of fungicides and volume of water are essential criteria for successful management of any plant diseases. Especially, wherever technologies of spraying equipments are being changed. The foot sprayer, drum sprayer, knapsack sprayer (manual and battery operated), tractor mounted sprayer and drone based system are being used for management of plant diseases. Therefore, standardization of water volume and concentrations of fungicide as per currently spraying equipments systems are necessary for management of late blight disease. Now, Battery operated knapsack sprayer is being used by huge numbers of farmers. Because, it involved less human drudgery and spray larger area in short time with comparison to manual operated knapsack sprayer. Generally, water volume depends on the crop age and canopy of the growing cultivars. At initial stage of the crop (up to 40 Days After Planting-DAP) less water volume required than the latter stage (>40 DAP) of crop. Therefore, at present study volume of water with mancozeb fungicide was standardized using battery operated knapsack sprayer for effective management of late blight of potato. As, water level of soil is decreasing day by day due to excessive application of water for agricultural uses and other applications. Moreover, excessive application of water for fungicides application, it increases the cost of cultivation

Table 1: Evaluation of different doses of mancozeb 75 % WP in different water volumes for management of late blight of potato during the year 2017-18, 2018-19 and 2019-20

Treatments (per hectare basis)	Concentration (%)	Year 2017-18				Year 2018-19				Year 2019-20				Average	
		Terminal disease severity (%)	Disease controlled (%)	Yield (t/ha)	Terminal disease severity (%)	Terminal disease severity (%)	Disease controlled (%)	Yield (t/ha)	Terminal disease severity (%)	Terminal disease severity (%)	Disease controlled (%)	Yield (t/ha)	Terminal disease severity (%)	Disease controlled (%)	Yield (t/ha)
T1: Mancozeb 75 % WP @ 2.0 Kg/1000 L water	0.2	50.0	45.95	37.57	37.00	37.00	63.00	31.26	34.17	34.17	64.66	22.41	40.39	58.10	30.41
T2: Mancozeb 75 % WP @ 2.5 Kg/1000 L water	0.25	40.0	56.76	40.60	31.33	31.33	68.67	32.94	25.00	25.00	74.14	23.85	30.22	68.65	32.47
T3: Mancozeb 75 % WP @ 1.0 Kg/500 L water	0.2	47.50	48.65	38.05	43.33	43.33	56.67	31.49	29.17	29.17	69.83	23.41	40.00	58.50	30.98
T4: Mancozeb 75 % WP @ 1.5 Kg/500 L water	0.3	35.00	62.16	40.59	28.00	28.00	72.00	32.83	21.67	21.67	77.59	25.78	26.33	72.68	33.07
T5: Mancozeb 75 % WP @ 2.0 Kg/500 L water	0.4	31.00	66.49	40.40	25.67	25.67	74.33	32.69	20.50	20.50	78.79	26.19	26.50	72.51	33.09
T6: Mancozeb 75 % WP @ 2.5 Kg/500 L water	0.5	27.50	70.27	42.56	22.33	22.33	77.67	32.18	17.00	17.00	82.41	28.30	25.28	73.78	34.35
T7: Control		92.50	0.00	34.43	100.00	100.00	0.00	29.14	96.67	96.67	0.00	20.85	96.39	0.00	28.14
SE		1.17		1.39	0.87	0.87		0.94	1.84	1.84		1.07	0.83		0.62
CD (P 0.05)		5.52		4.32	2.72	2.72		NS	5.72	5.72		3.35	2.60		1.93
CV (%)		6.64		6.14	3.68	3.68		5.12	9.11	9.11		7.62	3.55		3.38

Table 2: Economics of different doses of mancozeb 75 % WP in different water volumes for management of late blight of potato

Treatments (per hectare basis)	Average Yield (t/ha)	Additional yield over control (t/ha)	Gross returns (Rs/ha)	Cost of treatment *(Rs/ha)	Net return over control (Rs/ha)	B:C Ratio
T1: Mancozeb 75 % WP @ 2.0 Kg/1000 L water	30.41	2.27	18160	7350	10810	2.52
T2: Mancozeb 75 % WP @ 2.5 Kg/1000 L water	32.47	4.33	34640	9050	25590	2.64
T3: Mancozeb 75 % WP @ 1.0 Kg/500 L water	30.98	2.84	22720	5650	17070	2.61
T4: Mancozeb 75 % WP @ 1.5 Kg/500 L water	33.07	4.93	39440	6500	32940	2.76
T5: Mancozeb 75 % WP @ 2.0 Kg/500 L water	33.09	4.95	39600	7350	32250	2.74
T6: Mancozeb 75 % WP @ 2.5 Kg/500 L water	34.35	6.21	49680	9050	40630	2.80
T7: Control	28.14	-	-	-	-	2.42

*It includes cost of fungicides (@ Rs. 425.0/kg), labour (@ Rs. 300.0 /labour), and potato yield (@ Rs. 8000/ton)

in the category of plant protection operation. It should be applied as per required water volume for optimum coverage of crop foliage. Concentration of mancozeb 75% WP @ 0.3-0.5% was highly effective when it was applied as 2.5 Kg/500 L (T6), 2.0 Kg/500 L (T5) and 1.5 Kg/500 L (T4). These treatments also gave higher B: C ratio with best gross returns. The alone efficacy of mancozeb fungicide and its application in combination with different systemic /contact fungicides were widely adopted for late blight management. Among them, the cymoxanil8%+mancozeb64%WP, metalaxy18%+mancozeb 64% WP, fenamidon10%+mancozeb 50% WDG were reported effective for managing late blight of potato. Mancozeb interferes with enzymes containing sulphydryl groups, disrupting many biochemical processes within the fungal cell cytoplasm and mitochondria. It is also applied in other leaf spot diseases of potato. The bio-efficacy of mancozeb under lab and field against late blight of potato reported by various researchers (Islam *et al.*, 2018 ; Lal *et al.*,2015) Moreover, this fungicide used as to develop new combination of formulation which has less chance to develop resistance against *P. infestans*.

The present study concluded that concentration of fungicides have much more

importance along with proper coverage of plant foliage. The water volume of 500 L/ha is sufficient with battery operated knapsack sprayer. If crop foliage is dense, and late blight is moderate to severe, the spray volume would be required more than 500 L/ha along with optimum concentration of fungicide (mancozeb @ 2.5 Kg/1000 L water), for the effective management of late blight of potato.

CONFLICT OF INTEREST

The authors declare no conflict of interest in this manuscript.

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