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Study of PCRA-Based Seasonal Incidence of *Bemisia tabaci* (Asia II 5) and its Management Along with its Effect on Natural Enemies in Potato Crop

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HIGHLIGHTS

- Detailed description of seasonal incidence of *Bemisia tabaci* (Asia II 5) on potato crop.
- PCRA based study of effect of weather parameters on the population dynamics of the *B. tabaci* (Asia II 5).
- First kind of investigation of effect of sequential sprays of systemic insecticides against genetic group of Asia II 5, *Bemisia tabaci* and natural enemies on potato crop.

Abstract: This research aimed to predict the seasonal incidence of whitefly, *B. tabaci* (Asia II 5) with its management by new plant systemic insecticides and their influence on natural enemies on potato crop. Results concluded that the whitefly population was slightly higher in 2020-21 than in 2019-20 and temperature (minimum and maximum), relative humidity (minimum), evaporation, and sunshine hours were key factors in determining the *B. tabaci* population buildup with reasonable accuracy (R^2=0.82). Sequential spray of Diafenthiuron and Thiamethoxam (1.61 adults/3 compound leaves) was noticed to be the most effective treatment with the highest cost-benefit ratio (1:2.55), whereas two sequential sprays of Pymetrozine (3.17 adults/3 compound leaves) was found to be the least effective with the lowest cost-benefit ratio (1:1.61). All of the insecticides sequential spray examined were found to be either harmless or slightly detrimental to natural enemies (spiders and coccinellids). The current study concluded that *B. tabaci* population growth and seasonal incidence were greatly influenced by weather factors and this information validates the monitoring for early decision-making prior to developing insect pest management strategies against *B. tabaci*. Sequential spray of Imidacloprid and Thiamethoxam were shown reliable both from bio-efficacy and economic point of view in managing *B. tabaci* infestations in potato crop and can be incorporated into the IPM module.

Keywords: *Bemisia tabaci*; management; potato; seasonal incidence; whitefly.

INTRODUCTION

Potato, *Solanum tuberosum* L. is the world's most valued and widely cultivated vegetable crop. The crop was attacked by over 100 insect pests [1], with whitefly, *Bemisia tabaci* (Gen.), being a serious pest that hampered potato production particularly in North-Western India [2]. Whitefly has become a serious pest of potato crops all over the world due to its polyphagous nature, high fecundity, environmental adaptability, and diverse methods of crop destruction [3]. It extracts enormous amounts of plant sap from the phloem, resulting in decreased vigour and growth of plant, as well as uneven fruit ripening [4, 5]. The pest releases sticky honeydew on the leaves, which allows the buildup of sooty mould, reduces the ability of plants to photosynthesize, and causes stunted growth. [5]. It also serves as a vector for more than 300 virus species, including the Potato Apical Leaf Curl Virus (PALCV) (Family- Geminiviridae; Genus- Begomovirus), which is a globally important virus for the potato crop [5] and was reported for the first time during the year 2000 from Hisar, India [6]. Potato Apical Leaf Curl Virus (PALCV) can inflict 40-75 per cent damage to potatoes in India, depending on the cultivar [7]. In India, the whitefly has become a major source of concern for potato seed production [8]. Whitefly infestations and associated losses can easily go unnoticed until they reach ETL levels, so their population abundance and seasonal occurrence are of great interest. Weather conditions like rainfall, relative humidity, and temperature have a huge impact on incidence and development of whitefly [9]. As a result, it is critical to keep track of its precise seasonal abundance as well as its relationship to various meteorological parameters for early detection and management. However, chemical control of whitefly is difficult due to the fact that high concentrations and frequent sprays kill the insect natural enemies [10], as well as creates the problem of insecticide resistance, resurgence and pesticide residues [11]. Thus, the present study was looking into the whitefly population build-up, as well as testing insecticides for whitefly management and their effect on natural enemies on potato crop.

MATERIALS AND METHODS

The research was carried out at the Vegetable Research Centre (29˚ 01′ 53″ N, 79˚ 22′ 27″ E, 232 m asl) of GB Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India, during the Rabi seasons 2019-2020 and 2020-2021. Potato cv. *Kufri Surya* was planted in a plot size of 4 × 5 m^2 with six replications and the population of *B. tabaci* was observed on weekly basis on 3 compound leaves (top, middle, and bottom leaves/plant) from ten randomly picked plants, from seedling emergence to maturity. Meteorological data were collected weekly from the Agrometeorology Department, Pantnagar (Figures 1a & 1b) in order to perform a correlation and regression study as per the Snedecor and Cochran (1967) [12].

To compare the bio-efficacy of sequential sprays of various insecticides, trials were set in a Randomized Block Design comprising six treatments, including control, each replicating four times, and two sprays were performed. The experiment began when the natural infestation of *B. tabaci* (Asia II 5) reached at the Economic Threshold Level (ETL). Each experimental unit measured 3 x 2 m^2 in size. The population count of whitefly along with its natural enemies such as coccinellids and spiders were taken from five plants (top, middle, and bottom leaves/plant) from each replication of every treatment a day before (pre-count) and 1, 3, 5, 7, and 14 days after application of the insecticides. To assess the efficacy of different treatments, the mean whitefly adult mortality was separated using Tukey’s HSD at a 5% probability. Pearson's correlation was employed to determine the impact of meteorological variables on the growth of the whitefly population, and Principal component analysis (PCA) and regression analysis equation were used to predict whitefly population using SPSS, Inc. Chicago, Illinois, USA (Version 20). The percentage reduction of natural enemies was classified into three categories [13] to examine the effects of different sequential sprays on natural enemies: N= slightly harmful/harmless (0-50 per cent reduction), M= moderately harmful (51-75 per cent reduction), and T= harmful (>75 per cent reduction) as per the classification of International Organization of Biological Control (IOBC).

To determine the economic profitability of all the sequential sprays of insecticide, cost-benefit ratio was obtained from the formula:

$$\text{Cost:Benefit ratio} = \text{Net monetary return (Rs/ha)/ Treatment cost (Rs/ha)}.$$

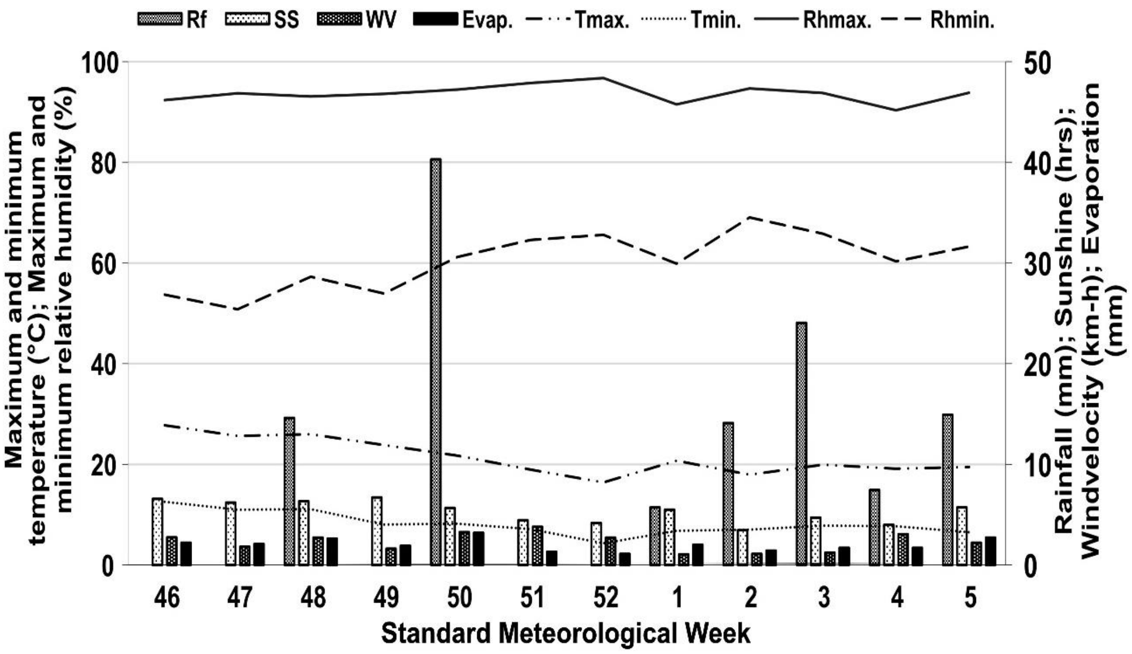

Figure. 1a. Weekly weather parameters: Temperature (maximum and minimum) (°C), Relative humidity (maximum and minimum) (%), Rainfall (mm), Sunshine (hrs.), Wind velocity (km-h) and Evaporation (mm) during the study period 2019-20

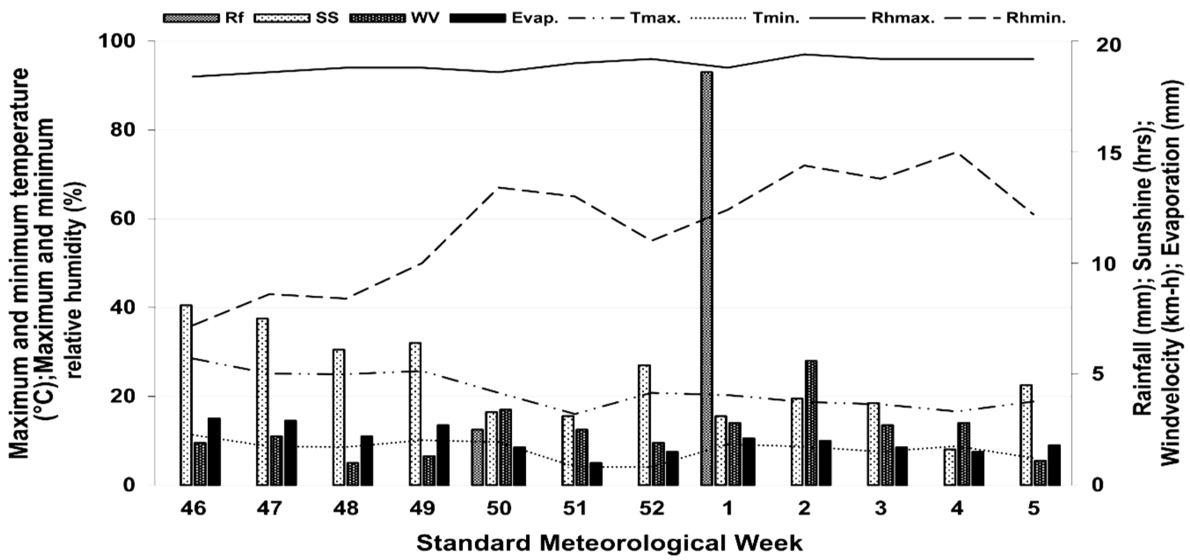

Figure. 1b. Weekly weather parameters: Temperature (maximum and minimum) (°C), Relative humidity (maximum and minimum) (%), Rainfall (mm), Sunshine (hrs.), Wind velocity (km-h) and Evaporation (mm) during the study period 2020-21.

RESULTS AND DISCUSSION

Bemisia tabaci (Asia II 5) seasonal incidence and their correlation with weather parameters

Bemisia tabaci (Asia II 5) infestation on potato (cv. *Kufri Surya*) began shortly after germination (46th standard week) and lasted till crop maturity. The whitefly population increased as crop growth progressed [14]. The population of whitefly attained its peak on potato at 48th SW (9.86±0.11 adults/3 compound leaves) in 2019-20 and 49th SW (13.81±0.32 adults/ 3 compound leaves) in 2020-21. These findings were quite similar to the reports of [15] wherein they found the peak of whitefly activity during the 3rd week of December and stated that the months of high temp., low relative humidity and no rainfall were more suitable for whitefly infestations. The adult population of *B. tabaci* (Asia II 5) on potato varied from 1.08±0.08 to 9.86±0.11 and

0.42±0.04 to 13.81±0.32/3 compound leaves (mean±SE; N=10), during 2019-20 and 2020-21, respectively (Figure. 2). The infestation of *B. tabaci* (Asia II 5) on potato was slightly higher in 2020-21 (Figure. 2; average: 13.81±0.89 adults/3 compound leaves) than in 2019-20 (average: 9.86±0.55 adults/3 compound leaves). The possible reason for this was comparatively higher relative humidity, low rainfall [18] and more sunshine hours. Higher rainfall in the year 2019-20 may resulted in the sabotage of eggs, nymphs and pupae of whitefly [18]. The *B. tabaci* population was noticed to be significantly positively associated with T(max.) [16], T(min.), SS while significantly negatively correlated with RHmin., and evap. [17] (Table 1). The positive correlation is related to the *B. tabaci* population build-up when the temperature rises. The findings were in agreement with the reports of [18] where they found a significantly positive association with temperature (max. and min.), a negatively significant association with minimum relative humidity while sunshine hours were non-significantly correlated with *B. tabaci* population. The current study was in conformity with [19] and [20] who also found a positive association between average temp. and adult whitefly population and a negative association with average relative humidity [21] found a positively significant association between population build-up of *B. tabaci* and temperature (min.), relative humidity (max. and min.), and rainfall which is in close accord with the findings of [22-25]. This might be due to the presence of diverse ecological conditions. So, the findings of the present research concluded that population dynamics and seasonal fluctuation of *B. tabaci* was significantly affected by weather factors (temperature, relative humidity, wind speed, and sunshine) in potato crop. Thus, the study suggests frequent pest monitoring to make timely decision while developing pest control plans.

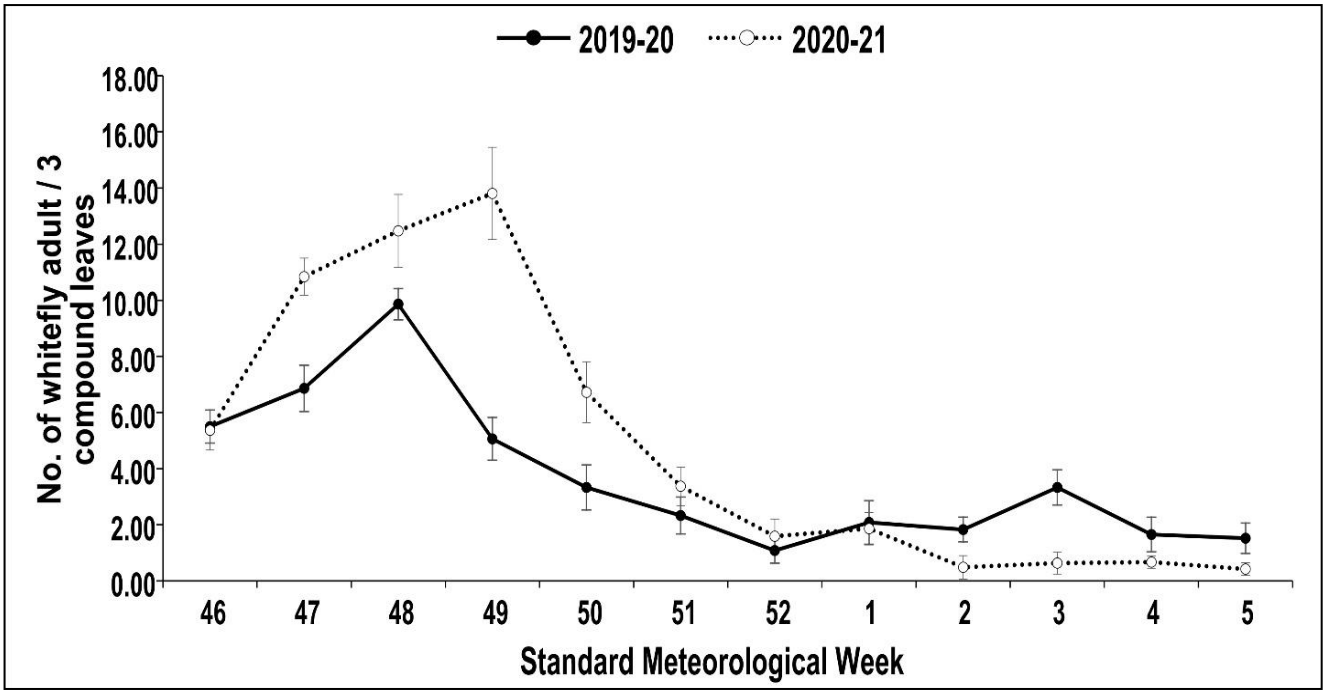

Figure 2. Seasonal incidence of *B. tabaci* during 2019-20 and 2020-21.

PCRA based predictions of *B. tabaci* population in potato

Eight meteorological parameters were used for Principal component regression analysis (PCRA) in attempt to group these associated parameters to the smallest feasible subgroups, indicating the percentage of variance (Table 2). After PCRA analysis, two Principal Components (PCs), PC-1 and PC-2, were obtained with 82.03% variability in the data set. For the development of the regression equation, the variables from PC-1 viz. T(max.), T(min.), SS, and Evap. and PC-2 viz. RH(max.), RH(min.), WV, and Rf were taken with Eigen values greater than one. The variance explained by PC-1 and 2 was estimated to be 62.52 and 19.51%, respectively (Table 2). In PC-2, variables RH(max.), Rf, and WV showed a non-significant correlation with the whitefly adult populations so they were not used in the regression equation [26, 27, 18, 28]. Therefore, a multiple regression equation was developed between the population of *B. tabaci* and T(max.), T(min.), RH(min.), SS, and Evap. from PCA, and the correlation matrix for 2019-2020 and 2020-2021.

***B. tabaci* adult population/3 compound leaves of plant=** 1.88 (Tmax.) + 0.09 (Tmin.) - 0.61 (RHmin) - 6.21 (SS) + 3.27 (Evap.) ($P < 0.05$; $R = .89$; $R^2 = 0.82$ and RMSE= 3.15%).

Table 1. Weather-based correlation matrix (Pearson's) for *B. tabaci* (Asia II 5) population in Potato cv. *Kufri Surya* from 2019 to 2021.

Variables	**PWf**	T(max.)	T(min.)	RH(max.)	RH(min.)	Rf	SS	WV
T(max.)	**0.82****							
T(min.)	**0.63***	0.83**						
RH(max.)	**NS**	-0.67*	-0.83**					
RH(min.)	**-0.79****	-0.94**	-0.63*	NS				
Rf	**NS**	NS	NS	NS	NS			
SS	**0.76****	0.93**	0.60*	NS	-0.95**	NS		
WV	**NS**	NS	NS	NS	NS	NS	-0.59*	
Evap	**-0.65***	0.83**	0.81**	-0.70*	-0.69*	NS	0.74**	NS

PWfly: whitefly adult population per 3 compound leaves on Potato; T(max.): Temperature maximum (°C); T(min.): Temperature Minimum (°C); RH(min.): Relative humidity minimum (%); RH(max.): Relative humidity maximum (%); Rf: Rainfall (mm); SS: Sunshine (hrs); WV: Wind velocity (km-h) and Evap: Evaporation (mm); NS: Non-significant. Correlation data is depicted in the table by bold digits..

Table 2. Principal components (PCs) with Per cent Eigen values and variances of *B. tabaci* (Asia II 5) on Potato

PCs	**Variables**	**Per cent Eigen value**	**Variance**	**Cumulative % of Variance**
1.	Tmax., Tmin., SS, Evap.	5.00	62.52	62.52
2.	RHmax., RHmin., Rf. and WV	1.56	19.51	82.03

Selected insecticides spray schedules for management of *B. tabaci* (Asia II 5) and their effects on natural enemies on potato crops

The results revealed that the first spray of Diafenthiuron 50 WP @ 0.10 per cent followed by a second spray of Thiamethoxam 25 WG @ 0.05 per cent (1.61 adults/3 compound leaves) was superior from all the remaining treatments, resulting in the maximum per cent decrease of adult whitefly population on potato crop (Table 3). The findings of [29-32] are congruent with our findings that Diafenthiuron gave maximum mortality of whitefly adults. [33] demonstrated that Thiamethoxam gave efficient results over whitefly adults for 15 days following treatment. The earlier reports of [34-37] revealed that Imidacloprid and Thiamethoxam were effective at suppressing the whitefly population. In this investigation, the combination of Imidacloprid and Thiamethoxam came in third place in terms of bio-efficacy because Imidacloprid has been found to be less effective against insecticides resistant adult whiteflies [38]. The sequential spray of Pymetrozine 50 WG @ 0.06 per cent (3.17 adults/3 compound leaves) was shown to have the minimum effect on the whitefly population. Other treatment efficacy was ranked as follows: Diafenthiuron and Pymetrozine > Imidacloprid and Thiamethoxam > Pymetrozine and Thiamethoxam. Whitefly control was shown to be the most effective using a combination of insecticides [39]. Sequential spray of Diafenthiuron and Thiamethoxam with a B:C ratio of 1:2.55 outperformed the other treatments, followed by Imidacloprid and Thiamethoxam (1:2.05); Diafenthiuron and Pymetrozine (1:1.89); Pymetrozine and Thiamethoxam (1:1.75); and two sprays of Pymetrozine (1:1.61) (Table 3).

Table 3. Bioefficacy of different sequential sprays of insecticides against *Bemisia tabaci* (Asia II 5) in potato cv. *Kufri Surya* during 2020-21

SI No.	Treatments	Population of adult whitefly/ 3 compound leaves													
		Pre count	Days after first spray					Days after second spray					Over all mean	Overall % reduction	Cost benefit ratio
			1st	3rd	5th	7th	14th	1st	3rd	5th	7th	14th			
1.	Two sprays of Pymetrozine 50 WG @ 0.06% at 14 days interval	7.25 (2.78)	3.05 (1.89)	3.44 (1.99)	3.97 (2.11)	4.25 (2.18)	4.92 (2.33)	1.72 (1.49)	2.33 (1.68)	2.42 (1.71)	2.61 (1.76)	3.01 (1.87)	3.17[b] (1.91)	54.58[a] (47.63)	1:1.61
2.	First spray: Foliar spray of Pymetrozine 50 WG @ 0.06% followed by Second spray: Thiamethoxam 25 WG @ 0.05%	7.79 (2.88)	3.17 (1.92)	3.26 (1.93)	4.05 (2.13)	4.38 (2.21)	5.29 (2.41)	1.66 (1.47)	2.04 (1.59)	2.32 (1.68)	2.59 (1.76)	2.82 (1.82)	3.15[b] (1.91)	57.67[a] (49.41)	1:1.75
3.	First spray: Foliar spray of Diafenthiuron 50 WP @ 0.10% followed by Second spray: Thiamethoxam 25 WG @ 0.05%	7.25 (2.78)	1.53 (1.42)	1.89 (1.55)	2.05 (1.60)	2.64 (1.77)	3.14 (1.91)	0.61 (1.05)	0.86 (1.17)	1.01 (1.23)	1.04 (1.24)	1.33 (1.35)	1.61[a] (1.45)	72.93[b] (58.65)	1:2.55
4.	First spray: Foliar spray of Diafenthiuron 50 WP @ 0.10% followed by Second spray: Pymetrozine 50 WG @ 0.06%	8.62 (3.02)	2.05 (1.60)	2.30 (1.67)	2.54 (1.74)	3.27 (1.94)	3.88 (2.09)	0.99 (1.22)	1.19 (1.30)	1.35 (1.36)	1.55 (1.43)	2.03 (1.59)	2.12[a] (1.61)	69.72[b] (56.61)	1:1.89
5.	First spray: Foliar spray of Imidacloprid 17.8 SL @ 0.04% followed by Second spray: Thiamethoxam 25 WG @ 0.05%	7.29 (2.79)	2.25 (1.66)	2.71 (1.79)	2.98 (1.87)	3.54 (2.01)	4.01 (2.12)	0.87 (1.17)	1.11 (1.27)	1.24 (1.32)	1.46 (1.40)	1.82 (1.52)	2.20[a] (1.64)	67.19[b] (55.05)	1:2.05
6.	Control	7.17 (2.77)	7.89 (2.90)	7.98 (2.91)	7.73 (2.87)	8.14 (2.94)	8.66 (3.03)	8.93 (3.07)	9.97 (3.24)	10.30 (3.29)	10.48 (3.31)	9.94 (3.23)	9.00[c] (3.08)	-	-
	S.E.(m)±	0.096	0.028	0.035	0.047	0.031	0.045	0.022	0.034	0.031	0.036	0.029	-		-
	C.D. (at 5%)	NS	0.086	0.107	0.142	0.930	0.138	0.067	0.104	0.095	0.110	0.089	-		-

*The values in parenthesis have been converted to square root √(x+0.5).
*Means in each column with identical alphabets don't differ significantly (Tukey's HSD, P > 0.05).

Table 4. Spiders and coccinellids population on potato cv. *Kufri Surya* after spray of different sequential spray of insecticides during 2020-21

Sl No.	Treatments	Pre count	Mean numbers of spiders/ plant			Per cent reduction over control	Pre count	Mean numbers of cocinellids/ plant			Percent reduction over control
			after 1st spray	after 2nd spray	Overall			after 1st spray	after 2nd spray	Overall	
1.	**Two sprays of Pymetrozine 50 WG @ 0.06% at 14 days interval**	1.85 (1.53)	1.60 (1.45)	1.83 (1.52)	1.71b (1.49)	21.19 (N)	2.40 (1.70)	1.78 (1.51)	1.40 (1.38)	1.59b (1.45)	30.26 (N)
2.	**First spray: Foliar spray of Pymetrozine 50 WG @ 0.06% followed by Second spray: Thiamethoxam 25 WG @ 0.05%**	1.65 (1.47)	1.53 (1.43)	1.73 (1.49)	1.63ab (1.46)	24.88 (N)	2.70 (1.79)	1.68 (1.47)	1.32 (1.35)	1.50b (1.41)	34.21 (N)
3.	**First spray: Foliar spray of Diafenthiuron 50 WP @ 0.10% followed by Second spray: Thiamethoxam 25 WG @ 0.05%**	1.70 (1.48)	1.42 (1.38)	1.51 (1.42)	1.46a (1.40)	32.71 (N)	2.60 (1.76)	1.35 (1.36)	1.01 (1.23)	1.18a (1.29)	48.24 (N)
4.	**First spray: Foliar spray of Diafenthiuron 50 WP @ 0.10% followed by Second spray: Pymetrozine 50 WG @ 0.06%**	2.00 (1.58)	1.50 (1.41)	1.63 (1.46)	1.56ab (1.44)	28.11 (N)	2.65 (1.77)	1.53 (1.42)	1.20 (1.30)	1.36ab (1.37)	40.35 (N)
5.	**First spray: Foliar spray of Imidacloprid 17.8 SL @ 0.04% followed by Second spray: Thiamethoxam 25 WG @ 0.05%**	1.70 (1.48)	1.53 (1.42)	1.68 (1.47)	1.60ab (1.45)	26.26 (N)	2.45 (1.72)	1.63 (1.46)	1.28 (1.33)	1.45ab (1.40)	36.40 (N)
6.	**Control**	1.80 (1.52)	1.98 (1.57)	2.36 (1.69)	2.17c (1.63)	-	2.35 (1.69)	2.48 (1.72)	2.08 (1.60)	2.28c (1.67)	-
	S.E.(m)±	0.119	0.015	0.017	-	-	0.772	0.030	0.041	-	-
	C.D. (at 5%)	NS	0.043	0.051	-	-	NS	0.087	0.119	-	-

*The values in parenthesis have been converted to square root √(x+0.5).
*Means in each column with identical alphabets don't differ significantly (Tukey's HSD, P > 0.05).IOBC classification of toxicity: N= harmless/slightly harmful (0-50%), M= moderately harmful (51-75%) and T= harmful (reduction>75%).

Overall result showed that all the sequential sprays were categorized as harmless/slightly harmful against spider and coccinellids in which combination of Diafenthiuron and Thiamethoxam (48.24 per cent) gave maximum reduction of spider and coccinellids (Table 4) followed by Diafenthiuron and Pymetrozine (40.35 per cent); Imidacloprid and Thiamethoxam (36.40 per cent); Pymetrozine and Thiamethoxam (34.21 per cent), while two sprays of Pymetrozine (30.26 per cent) gave minimum reduction of spider and cocinellids. These findings are consistent with the findings of [40] who indicated that insecticides such as Imidacloprid and Thiamethoxam had no or less effect on spider population.

CONCLUSION

In order to maintain the population of natural enemies, selective sequential sprays like Imidacloprid and Thiamethoxam [34, 35], with lower toxicity and higher compatibility with bio-control agents must be employed in Integrated Pest Management programmes for whitefly [41] in potatoes which give effective control of whitefly and also beneficial from economic point of view. The current demand is for the use of newer chemical compounds that have novel and distinct modes of action for the resistance management against whitefly, so insecticide class rotation should be encouraged [42], which improves the insecticidal efficacy.

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