



Effect of temperature and cropping sequence on the infestation pattern of *Bemisia tabaci* in potato

MOHD ABAS SHAH¹, KAMLESH MALIK², ANUJ BHATNAGAR³, SUBHASH KATARE⁴,
SANJEEV SHARMA⁵ and SWARUP KUMAR CHAKRABARTI⁶

ICAR-Central Potato Research Station, Jalandhar, Punjab 144 026 India

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ABSTRACT

In India, more than 85% of the total potato production is realised from the subtropical Indo-Gangetic plains where potato is cultivated during winter. The cotton whitefly, *B. tabaci* is a major pest of potato as it transmits the *Tomato leaf curl New Delhi virus* (potato) causing the Apical leaf curl disease which leads to huge yield losses. The population dynamics of cotton whitefly was studied at 12 locations across the northern plains of India from 2015–17. It was observed that the cotton whitefly appears on potato immediately after crop emergence. The whitefly adults exhibited four different patterns of population dynamics at different locations. Whiteflies remained on the potato crop as long as minimum daily temperature was above 10–12°C after which the whiteflies either disappeared from the crops or their flight activity was considerably reduced as indicated by the yellow sticky trap catch data. The whitefly incidence was higher at locations where potato is preceded by crops preferred by whitefly such as cotton, broad beans, groundnut etc. Perusal of the data on number of eggs laid and ensuing nymphs per plant indicated that the contribution of immigrating adults to the whitefly population is much higher than that of the colonising population for major part of the crop period. Thus, in addition to temperature, cropping sequence acts as a major factor in shaping the pattern of whitefly infestation. The results will help in deciding cropping pattern and better timing of insecticidal applications for healthy seed potato production.

Key words: *Bemisia tabaci*, Migration, Population dynamics, Potato, Seasonal carryover, Threshold temperature

India is the 2nd largest producer of potato in the world (FAOSTAT 2017) with more than 85% of India's potatoes grown in the vast Indo-Gangetic plains of north India (subtropics) during short winter days from October to March in contrast to typical potato growing areas with temperate climate (Khurana and Naik 2003). The cotton whitefly, *Bemisia tabaci* (Gennadius), being a pest of tropical and subtropical areas is a major component of the potato seed production complex in India (Chandel *et al.* 2010). Although it does not inflict any discernible direct damage to potato, it transmits the *Tomato leaf curl New Delhi virus* (ToLCNDV) leading to Potato apical leaf curl disease (Jeevalatha *et al.*

2017) which is one of the most important diseases of potato in India now (Sridhar *et al.* 2016, Bhatnagar *et al.* 2017).

The population dynamics of whitefly infesting potato crops in India has been attempted at various locations e.g. Bhatnagar (2007, 2009) from Gwalior, Lakra (2003, 2005) and Kumar and Gupta (2016) from Hisar, Kishore *et al.* (2005), and Malik and Singh (2007) from Modipuram, and Amitava *et al.* (2010) from Nadia (West Bengal). These studies evaluated the location specific trends of the population dynamics of whitefly with correlation to local weather parameters. However, a comprehensive study with holistic view of the system is lacking. *B. tabaci* being a multivoltine insect has no diapause or quiescent stages, its populations are sustained through the continual exploitation of multiple host resources, both wild and cultivated, over the annual cycle. Therefore, in addition to temperature, cropping sequence also shapes the pattern of whitefly infestation in crops (Murugan and Uthamasamy 2001, Naranjo *et al.* 2009). Quality seed potato production needs to contain the virus infection levels below critical thresholds (Chandel *et al.* 2010); hence the efficient management of whitefly vector on potato is critically important. In the current study, the whitefly infestation pattern was evaluated with respect to ambient temperature and the nature of cropping sequence

Present address: ¹Scientist (mabas.shah@icar.gov.in), ICAR-Central Potato Research Station, Jalandhar, Punjab; ^{2,3}Principal Scientist (malikkamlesh7@gmail.com, dr.anujbhatnagar@gmail.com), ICAR-Central Potato Research Station, Modipuram, Uttar Pradesh; ⁴Senior Scientist (dwr.katare@gmail.com), ICAR-Central Potato Research Station, Gwalior, Madhya Pradesh; ⁵Principal Scientist and Head (sanjeevsharma.cpri@gmail.com), ⁶Director (chakrabarti.sk@icar.gov.in), ICAR-Central Potato Research Institute, Shimla, Himachal Pradesh.

Table 1 Description of study sites with cropping season details for potato crop

Location	State	Latitude (North)	Longitude (East)	Date of Planting	Date of haulm cutting
Bhubaneswar	Odisha	20.2645	85.8091	November, 3rd week	February, 2nd week
Chhindwara	Madhya Pradesh	22.3080	79.1693	November, 2nd week	February, 2nd week
Deesa	Gujarat	24.2598	72.1872	November, 2nd week	February, 3rd week
Dholi	Bihar	25.9964	85.5941	November, 4th week	February, 4th week
Gwalior	Madhya Pradesh	26.2756	78.2201	October, 4th week	January, 4th week
Hisar	Haryana	29.1505	75.7067	October, 1st week	December, 4th week
Jalandhar	Punjab	31.2756	75.5484	October, 1st week	December, 4th week
Kalyani	West Bengal	22.9923	88.4496	November, 2nd week	February, 1st week
Kanpur	Uttar Pradesh	26.4913	80.3045	October, 4th week	January, 1st week
Modipuram	Uttar Pradesh	29.0688	77.7082	October, 4th week	January, 4th week
Patna	Bihar	25.5799	85.0564	November, 2nd week	February, 2nd week
Raipur	Chhattisgarh	21.2398	81.7032	November, 2nd week	February, 3rd week

across the northern plains.

MATERIALS AND METHODS

The study was carried out at 12 locations in 9 states (Table 1) spread across the Indo-Gangetic plains during *Rabi* 2015-16 and 2016-17. The selected locations account for the major part of potato production in India. Potato crop is cultivated during winter when the temperature is favourable for tuberisation. The maximum daily temperature usually does not exceed 30°C while as the minimum daily temperature may fall below 10°C at many locations. There was only scanty rainfall during the winter months with occasional showers during the 3rd week of January in both the seasons. While as a variety of crops were cultivated across the locations, 2-3 crops dominate a particular season e.g. paddy and cotton during the *Kharif* season, wheat and potato during the *Rabi* season, and cucurbits and pulses during the summer. The details of cropping sequences adopted across the locations are given in Table 2.

Potato crops: As per the seed plot technique, the potato crops were planted from 1st fortnight of October to 2nd fortnight of November at different locations. The major cultivars of the particular region were selected for the study which included Kufri Pukhraj, Kufri Bahar, Kufri Jyoti, Kufri Ashoka, Kufri Badshah and Kufri Anand. Weather data were recorded at all the study sites with meteorological observatories in place. The crops were maintained under standard agronomic practices except that no pesticides were applied.

Population dynamics and whitefly sampling: The population dynamics of cotton whitefly was studied at the 12 selected locations for two growing seasons, 2015-16 and 2016-17. The number of whitefly adults per plant (from three leaves, one each from upper, middle and lower section of the plant, averaged over 15 to 20 plants) was monitored in each field during morning hours. To determine the number of eggs laid and the ensuing nymphs, 10-15 potato plants were plucked from each field and brought to laboratory where the number of eggs and

nymphs was counted under stereo-zoom microscope (only at Jalandhar). The flight activity of the whitefly adults was monitored with the help of yellow sticky traps (YSTs) (20 cm × 30 cm) held just over the canopy height. Sampling was done from crop emergence to haulm cutting at weekly interval.

RESULTS AND DISCUSSION

In general, the whitefly adults exhibited 4 different patterns of population dynamics at different location (Fig 1). In type-I, whitefly adult population was highest at crop emergence and continuously declined afterwards. The whitefly population disappeared from the crops by 6-7 weeks after crop emergence. At locations exhibiting type-II pattern, the insect population increased initially and decreased afterwards and remained very low for a few weeks but recovered again towards the end of potato growing season. The whitefly population remained very low or disappeared altogether from the potato crop for 3-5 weeks from December- January. In type-III, the whitefly population remained on the potato crop throughout the season. The population size increases gradually till it peaked towards the mid-season and declined afterwards. Locations exhibiting type-IV population dynamics sustained whitefly population throughout the season. The population size increases gradually, peaking towards the end of season. Bhatnagar (2007, 2009) reported similar trends of whitefly incidence from Gwalior. Similarly, Lakra (2003, 2005), and Kumar and Gupta (2016) from Hisar, although with higher whitefly incidence, Kishore *et al.* (2005), and Malik and Singh (2007) from Modipuram, and Amitava *et al.* (2010) from Nadia (West Bengal) reported similar pattern of whitefly population dynamics as found in the current study for the respective locations.

The lower threshold temperature for fecundity, egg and immature development for whitefly is 10-13°C while as the immature survival is considerably reduced at this temperature (Drost *et al.* 1998). The weather data indicate that the daily minimum temperature (T_{min}) falls below

Table 2 Cropping sequences adopted by farmers at the study sites (Crops with major acreage)

Location	Crops preceding potato	Crops grown along with or after potato
<i>Infestation Pattern: Type I</i>		
Jalandhar	Paddy, maize, sugarcane, tomato, brinjal, chilli, arhar	Wheat, rapeseed and mustard, field peas, brinjal, tomato, chilli
Hisar	Cotton, cluster beans, pearl millet, cauliflower, cucurbits, brinjal, okra	Wheat, rapeseed and mustard, tomato, brinjal, carrot
Modipuram	Sugarcane, paddy, maize, cucurbits, pulses, okra	Sugarcane, wheat, rapeseed and mustard, cauliflower, radish, peas
Gwalior	Paddy, pearl millet, black gram, soybeans	Wheat, chickpea, rapeseed and mustard, onion, garlic
<i>Infestation Pattern: Type II</i>		
Kanpur	Paddy, sorghum, maize, bottle gourd, cucumber	Wheat, chickpea, peas, tomato, French beans, radish, rapeseed and mustard, chilli, onion
Dholi	Paddy, maize, pigeon pea	Wheat, maize, lentil, cauliflower, tomato, chilli, cucurbits, okra, brinjal
Patna	Paddy, maize, pigeon pea	Wheat, lentil, chickpea, pea, brinjal, tomato, okra, cauliflower, green gram
<i>Infestation Pattern: Type III</i>		
Chhindwara	Soybeans, maize, cotton, paddy, sorghum	Wheat, chickpea, sugarcane, pea, chilli, onion, garlic
Raipur	Paddy, maize, pigeon pea, green gram, sesame	Wheat, Bengal gram, green gram, pea, rapeseed and mustard, tomato, brinjal, cauliflower
Bhubaneswar	Paddy, arhar, green gram, sesame	Wheat, maize, green gram, rapeseed and mustard, groundnut, sunflower, sweet potato, chilli
<i>Infestation Pattern: Type IV</i>		
Kalyani	Paddy, jute, cucurbits, okra, brinjal	Wheat, rapeseed and mustard, cucurbits, pulses, brinjal, okra, pea, cauliflower, tomato
Deesa	Groundnut, sesame, green gram, black gram, cotton, cucurbits, maize	Wheat, rapeseed and mustard, cotton, black gram, brinjal, tomato, castor

12°C at locations exhibiting type-I and type-II infestation pattern for 4–6 weeks during the months of December and January. Therefore, it is to be expected that a minimal number of whiteflies survive at locations exhibiting type I and II pattern during December to January with no visible activity. Rainfall is likely to reduce the whitefly population size however; it recovers within 3–6 days. During the study, rainfall was found to have no appreciable effect on whitefly assemblages mainly due to scanty rainfall, if any, at some locations.

The seasonal variation in number of whitefly eggs and nymphs per plant at Jalandhar is shown in Fig 2. The number of eggs laid per plant increased in the last week of October and declined afterwards. The number of nymphs per plant showed a similar trend with a time lag of around two weeks. In general, the number of eggs and nymphs per plant was low; 2–20 and 0–15, respectively. By the end of January, very few surviving nymphs were recovered from potato leaves and almost negligible number of eggs was recorded. Up to 48 whitefly adults were caught on the YSTs on an average in the last week of October probably due to high rate of immigration from preceding crops and weeds however, the trap catch showed a sudden drop by the mid-November and less than 2 whiteflies were caught on the traps after last week of November (Fig 2) due to

sharp decline in temperature.

The cropping sequence determines the extent of whitefly carry-over from crop to crop (Hirano *et al.* 1995, Rafiq *et al.* 2008, Zhang *et al.* 2014). Locations with relatively higher whitefly population size on potato crops particularly during the initial 2–3 weeks e.g. Hisar, Jalandhar, Patna, Bhubaneswar and Kalyani were characterised by cropping sequence in which potato was preceded by crops that were major hosts of whitefly or support high whitefly populations e.g. cotton, cluster beans, soybean, groundnut, cucurbits and solanaceous vegetables (Dhawan *et al.* 2007, Li *et al.* 2011). The opposite of this situation exists at locations such as Modipuram, Gwalior, Kanpur and Raipur where cropping sequence was characterised by such crops preceding potato that do not support large population sizes of whitefly, e.g. paddy, maize, millets etc. (Table 2).

At locations exhibiting type I and type II pattern of whitefly infestation, the whitefly population disappears from the crop as the T_{min} falls below 12°C which may reappear towards the last quarter of crop growth period. The duration of the whitefly free period depends on the time period for which T_{min} remains below 10–12°C which may last 5–8 weeks. Theoretically, whitefly should appear again as soon as the temperature becomes suitable ($T_{min} > 12^\circ\text{C}$) but that happens only at some locations. At such locations,

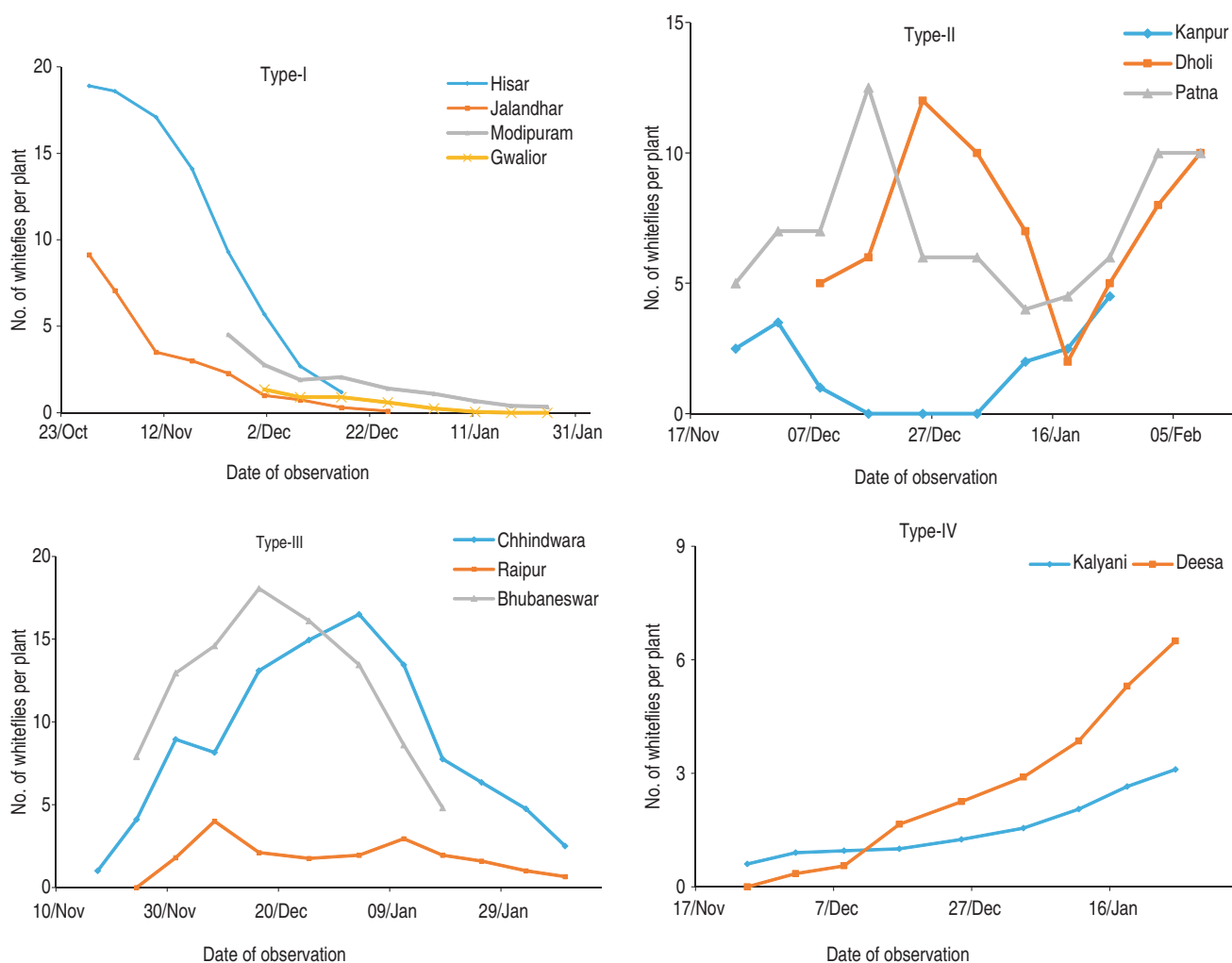


Fig 1 Population dynamics of the adults of cotton whitefly, *B. tabaci* in potato crops

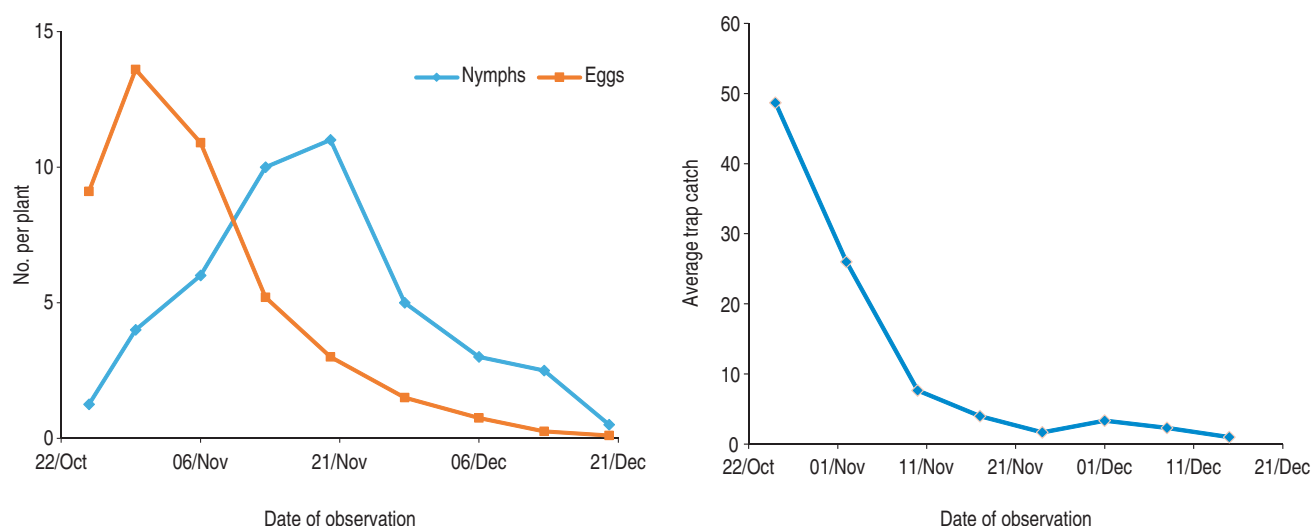


Fig 2 Population dynamics of eggs and nymphs, and average weekly trap catch of adult *B. tabaci* in potato crops at Jalandhar.

the re-rise starts 1–3 weeks earlier than expected due to immigration from early summer crops such as cucurbits, pulses and solanaceous vegetables etc. (Rafiq *et al.* 2008). This is typical for locations with type II pattern of whitefly

infestation e.g. Kanpur, Dholi and Patna (Table 2). The whitefly population will recover more slowly at locations with alternate cropping pattern.

At locations exhibiting type III and type IV pattern

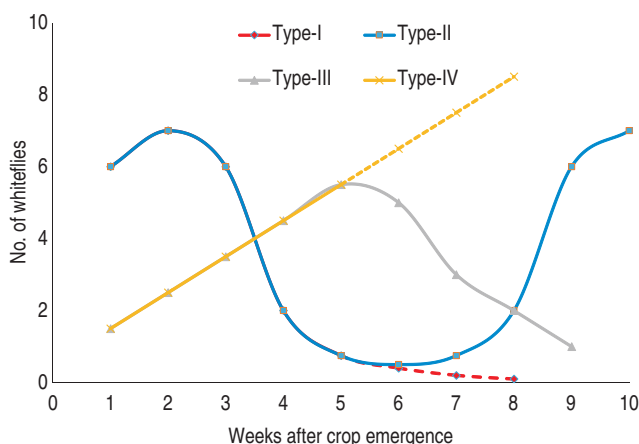


Fig 3 Theoretical framework of the population dynamics of cotton whitefly, *B. tabaci* infesting potato crops in the Indo-Gangetic plains.

of whitefly infestation, temperature remains suitable throughout the potato cropping season and whiteflies should remain on the crop. However, it happens only at some locations e.g. Kalyani and Deesa, exhibiting the type IV pattern. In these locations the adjoining crops support high growth rate of whiteflies (Table 2) therefore, there is a linear increase in whitefly population on landscape level which is reflected on all such crops including potato. In contrast, whitefly population did show sustained growth at locations where potato was not surrounded by crops that support high population growth rate for whiteflies e.g. at Chhindwara, Raipur and Bhubaneswar, exhibiting the type III pattern (Table 2). Potato is regarded as a grade 2 host for whitefly as per the infestation rate (Li *et al.* 2011) while most of the vegetable crops grown alongside potato are grade 2 or 3 hosts. Therefore, it is to be expected that potato crop does not sustain a high whitefly population on its own and thus it is a poor bridge for whitefly to sustain the cold winters. Various studies such as Gerling (1984), Watson *et al.* (1992), Stansly (1996), Legaspi *et al.* (1997), Murugan and Uthamasamy (2001), Sequira *et al.* (2009) etc. have demonstrated how whitefly carry-over from one crop to another, helps successful exploitation by whitefly of these host plants and how weeds mainly act as bridging hosts during unfavourable winter conditions.

To conclude, whitefly infestation in potato crop depends not only on temperature but also the nature of preceding crops and the crops growing along with potato in the locality. The interplay of these factors gives rise to various patterns of population dynamics on potato which can be summarised graphically as shown in Fig 3. The current study indicates that whitefly management could be improved by adopting cultural practices such as not growing cotton and other whitefly preferred host crops in the districts where seed potato production is intended. It will help to considerably reduce the whitefly pressure on the potato crop. Similarly, insecticidal applications if timed as per the population growth trends will improve the efficiency of the management tactics.

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