Research Article

Assessment of Antixenosis Potential against *Myzus Persicae* (Sulzer) Homoptera: Aphididae in Potato

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Abstract | Potato (*Solanum tuberosum* L.) is an important vegetable food crop in Pakistan. *Myzus persicae* is an insect pest of potato, feeding on phloem tissues of leaves of potato plant and significantly reduces the yield of potato. Antixenosis experiments were performed to assess the resistance potential of eight different potato cultivars against *M. persicae* under glasshouse conditions for three different durations of time (12, 24 and 48 hours) during spring and autumn potato growing seasons of 2016. Both the experiments were conducted using a completely randomized design. Each experiment having eight treatments and each treatment was replicated 10 times. The replicated pots containing each of the eight potato cultivars were infested with 100 and 200 adult of *M. persicae*. Significant antixenosis effects among the tested potato cultivars were observed while the different durations of *M. persicae* infestation on potato cultivars also displayed significant antixenosis effects against *M. persicae* during the spring and autumn experiments in 2016. During both experiments, Sarpo Mira displayed the lowest number of adults per plant on release of 100 and 200 adults per plant. Sarpo Mira showed *M. persicae* infestation of 3.3 and 2.4 per plant per pot on release of 100 adults per plant during spring and autumn seasons, respectively while an infestation of 5.3 per plant 4.7 per plant on Sarpo Mira was observed on release of 200 adults of *M. persicae* during spring and autumn seasons, respectively. FD-70 had the highest number of *M. persicae* (13.7 per plant) in the pots released with 100 *M. persicae* during spring season while Asterix showed the highest number of *M. persicae* (13.8 per plant) in pots infested with 200 *M. persicae* during autumn season. Sarpo Mira also appeared to be the most resistant potato cultivar against *M. persicae* at 12, 24 and 48 hours post infestation of *M. persicae*. Overall, this study revealed the resistant potential of potato cultivar Sarpo Mira against *M. persicae*.

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Introduction

Potato (*Solanum tuberosum* L.) of Solanaceae family is a major vegetable food crop in Pakistan. It contains key nutrients including vitamin C, Potassium, carbohydrates and fiber (Weaver and Marr, 2013). Potato's starch consists of amylopectin and amylose (Wikman et al., 2013; Bertoft, 2017). A small proportion of the starch in potato is resistant to enzymatic degradation in the small intestine of human promoting food digestion in human body (Higgins, 2004). The initial step in characterization of resistance is the selection of Antixenosis.

The attack of many insect pests (e.g. aphids, psyllids and potato tuber moth) causes significant production

loss to potato crop in Pakistan. The green peach aphid [*Myzus persicae* (Sulzer)] is considered to be the most damaging pest to the crop (Meng et al., 2014). Widespread distribution of *M. persicae* in Pakistan and Khyber Pakhtunkhwa has previously been reported (Khan et al., 2011) and in many other countries around the globe (Spooner et al., 2004). Densities and population dynamics of *M. persicae* varies in different areas under potato crop in Pakistan mainly due to variations in agro-climatic conditions and presence or absence of natural enemies of *M. persicae* (Niaz and Ayub, 2007; Sabbaghan and Soleymannejadian, 2007; Carlo and Batyr, 2008).

Myzus persicae sucks sap from the phloem tissues of potato's leaves leading to reduced plant growth and development which ultimately results into major production losses of the crop. *Myzus persicae* also transmits viruses like potato leaf roll virus (PLRV) and potato virus Y (PVY) into the plant (Robert et al., 2000; Basky, 2002; Abbas et al., 2014).

Myzus persicae is commonly controlled with the application of synthetic pesticides like Cypermethrin, bifenthrin and azadirachtin (Zafar et al., 2015). However, application of such pesticides creates a number of problems such as environmental pollution and resistance development by the *M. persicae* (Foster et al., 2000; Bass et al., 2014). Screening of resistant cultivars of potato against the attack of *M. persicae* could be one of the most desirable and environmental friendly approaches for the control of this potato pest.

Plant resistance against insect pests is either present in plants inherently due to various resistant traits or induced through the transfer of resistant genes. In the present study, antixenosis is one of the resistance mechanism in plants which affects the behaviour of insect pests. The antixenosis technique for assessing resistance of potato germplasm has been undertaken previously to identify resistance of potato against aphids (Mottaghinia et al., 2010). The objective of the present study was to investigate the antixenosis resistance capacity of eight commercial potato cultivars against one of its worst insect pest *M. persicae*.

Materials and Methods

Provision of plant material and rearing of M. persicae

To examine the antixenosis potential of potato cultivars against green peach aphid (*Myzus persicae*) in a transparent glasshouse, tubers of eight different potato cultivars were obtained from Potato Research Station, Abbottabad, Khyber Pakhtunkhwa, Pakistan. The eight potato cultivars were Desiree, Patrones, Rocco, Sarpo Mira, Asterix, SH-5, FD-70 and Sahiwal Red. Desiree being a susceptible cultivar of potato to *M. persicae* (Leroux et al., 2008; Mottaghinia et al., 2010) was used as standard for comparison with the other seven cultivars.

Samples of *M. persicae* were collected from a field of potato crop near Nowshehra (Latitude 34° 0'57.0888" N, Longitude 71°58'31.6164"E), Khyber Pakhtunkhwa and were reared on plants of Desiree in individual trays caged by nylon mesh cloth in a glasshouse at the Institute of Biotechnology and Genetics Engineering, University of Agriculture Peshawar.

The experiments were performed during spring and autumn growing season of potato in 2016 in the glasshouse, where plants were grown in pots filled with typical soil mixed with farm yard manure (10 kg per pot) in 21.5cm-diameter plastic pots. The temperature inside the glasshouse was maintained at 30/25°C day/night and at the prevailing photoperiod 14:10 hours (day/night). Antixenosis was determined following the protocols used by Flinn et al. (2001).

Tubers of each potato cultivar were planted at an equal distance (12.5 cm) at the periphery of each of the experimental pot (19.0 × 21.5 cm diameter). The material was replicated in twenty experimental pots.

In the first experiment during the spring, each of the pot containing 08 seedlings of each potato cultivar (each seedling at four leaves growth stage) was infested by releasing 100 adults of *M. persicae* into the center of each pot and in the parallel experiment, 200 adults of *M. persicae* were released into the center of each pot containing 08 seedlings (each seedling at four leaves growth stage) using a piece of paper. Similar procedure was performed for the repeated experiment during the autumn in 2016. The plants were covered with nylon mesh cages. Number of *M. persicae* on all replicated plants of all potato cultivars were counted 12, 24 and 48-hour post *M. persicae* infestation.

Experimental design and statistical analyses

The experiments in both the growing season were arranged in a completely randomized design. The number of *M. persicae* on all potato cultivars were

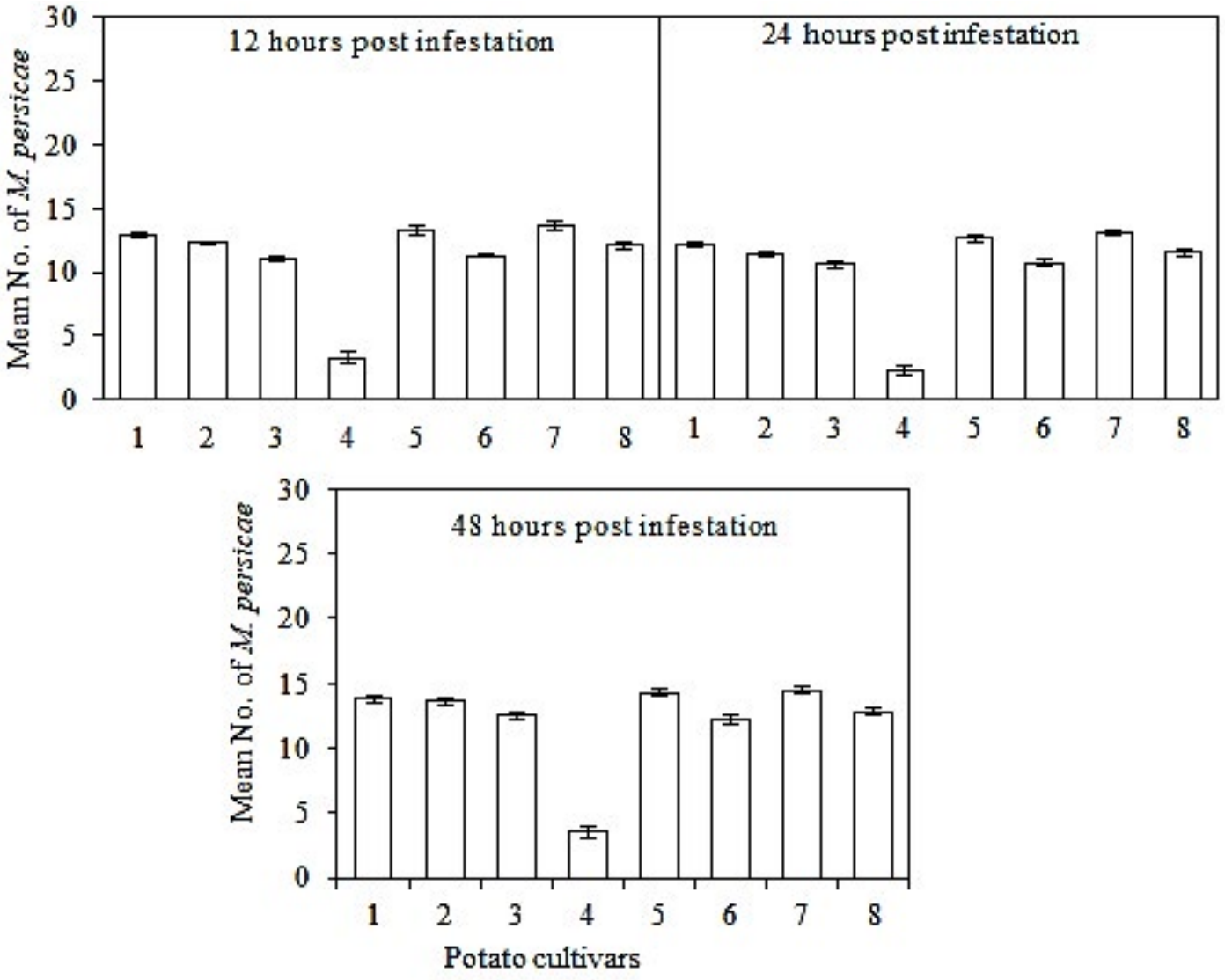

Figure 1: *Antixenosis response of eight different potato cultivars (1 is Desiree, 2 is Patrones, 3 is Rocco, 4 is Sarpo Mira, 5 is Asterix, 6 is SH – 5, 7 is FD – 70 and 8 is Sahiwal Red) against Myzus persicae in pots infested by 100 Myzus persicae at 12, 24 and 48 hours post infestation during spring 2016. The data sets are the means (± SD) calculated for 10 replicates of each of the eight cultivars.*

counted at 12, 24 and 48 hours post infestation. Data recorded during the spring and autumn were separately analyzed using Statistix 8.1. Mean data (with standard deviation bars) was constructed on total number of aphids on each of the eight potato cultivars. Means were separated using least significance difference (LSD) test at 0.5 level of significance.

Results and Discussion

Antixenosis test in spring 2016

Results showed that significant ($P < 0.05$) antixenosis effects was observed among different potato cultivars infested with 100 *M. persicae* insects for different time durations. The lowest number of *M. persicae* (3.3) were observed on Sarpo Mira at 12 hours post infestation in pots of 100 *M. persicae*. Other potato cultivars Rocco, SH – 5, Sahiwal Red, Patrones and Desiree has shown higher levels of infestations of >10 at this time duration. The cultivar FD-70 and Asterix, however, has shown higher levels of infestation of >13 at 12 hours post infestation. Similarly, Sarpo Mira showed the least infestation of 2.3 and 3.6 at 24 and 48 hours post infestation in pots of 100 *M. persicae* adult. The remaining potato cultivars showed the same trend to *M. persicae* at the higher level of infestation after 24 and 48 hours. The cultivar Sarpo Mira showed high resistant against *M. persicae* (Figure 1).

Similarly, results for pots of 200 *M. persicae* per pot showed that significant antixenosis effect ($P < 0.05$) were observed among potato cultivars infested with *M. persicae* insects for different time durations. Similarly, significant effects of different durations of *M. persicae* infestation on potato cultivars were also observed. The lowest number of *M. persicae* (5.3) were observed

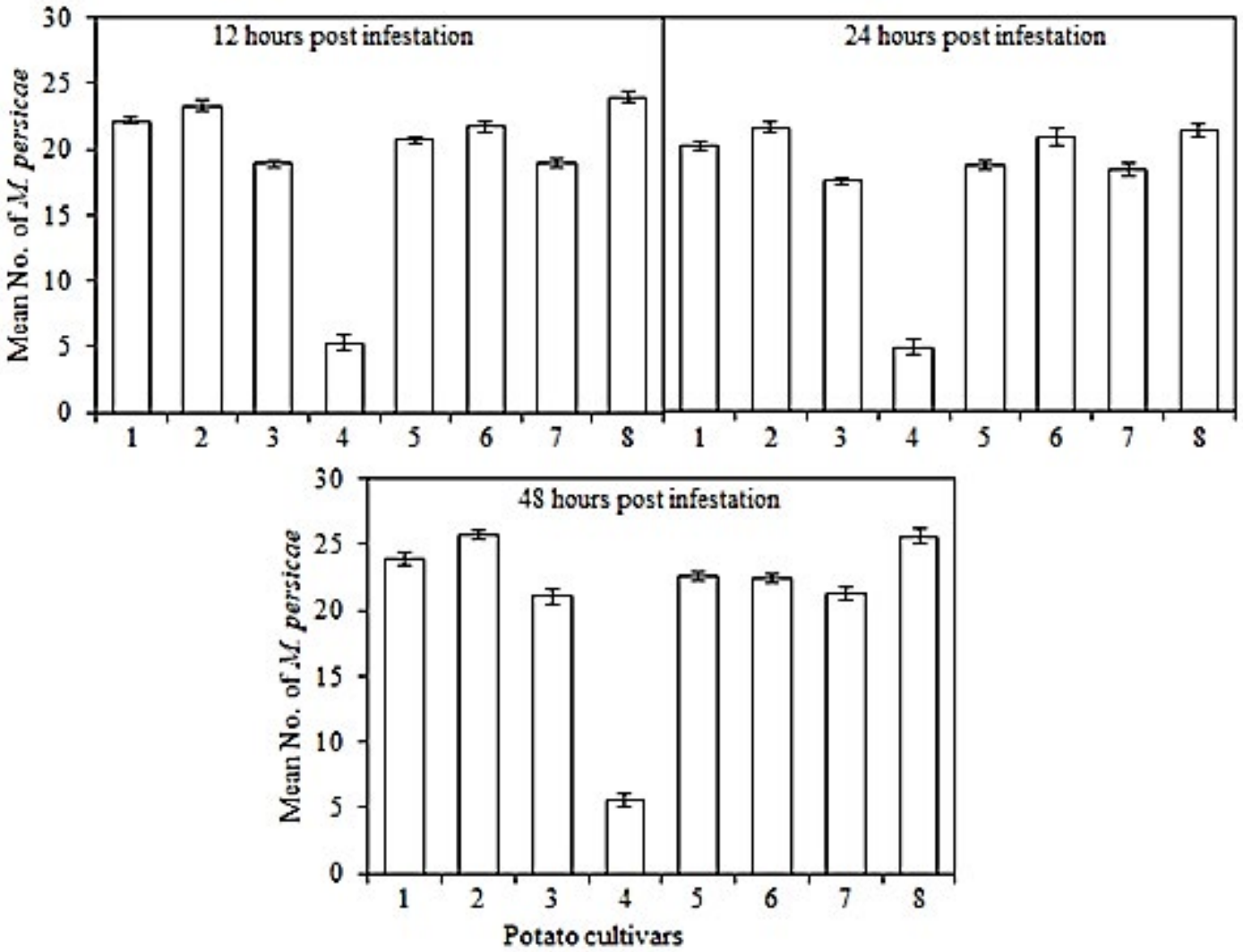

Figure 2: *Antixenosis response of eight different potato cultivars (1 is Desiree, 2 is Patrones, 3 is Rocco, 4 is Sarpo Mira, 5 is Asterix, 6 is SH – 5, 7 is FD – 70 and 8 is Sahiwal Red) against Myzus persicae in pots infested by 200 Myzus persicae at 12, 24 and 48 hours post infestation during spring 2016. The data sets are the means (± SD) calculated for 10 replicates of each of the eight cultivars.*

on Sarpo Mira at 12 hours post infestation in pots of 200 *M. persicae*. Other potato cultivars Rocco, FD – 70, Asterix, SH – 5 and Desiree has shown higher levels of infestations of >18 at this time duration. The cultivar Sahiwal Red and Patrones, however, has shown higher levels of infestation of >23 at 12 hours post infestation. Similarly, Sarpo Mira showed the least infestation of 4.9 and 5.6 at 24 and 48 hours post infestation in pots of 200 *M. persicae* adult. The rest of the potato cultivars were all found to show the same response to *M. persicae* after 24 and 48 hours of infestation. The potato cultivar Sarpo Mira was found to be less attacked by *M. persicae* (Figure 2).

Antixenosis experiments in autumn 2016

Significant ($P < 0.05$) antixenosis effects was observed among different potato cultivars infested with 100 *M. persicae* insects for three different time durations. Similarly, significant effects of three different time durations of *M. persicae* post infestation on potato cultivars were also observed. The lowest number of *M. persicae* (2.4) were observed on Sarpo Mira at 12 hours post infestation in pots of 100 *M. persicae*. Other potato cultivars Rocco, SH – 5, Sahiwal Red and Patrones has shown higher levels of infestations of >10 at this time duration. The cultivar FD-70, Asterix and Desiree however, has shown higher levels of infestation of >13 at 12 hours post infestation. Similarly, Sarpo Mira showed the least infestation of 2.0 and 2.9 at 24 and 48 hours post infestation in pots of 100 *M. persicae* adult. The remaining potato cultivars followed the same trend and showed the higher level of infestation after 24 and 48 hours count of *M. persicae*. The cultivar Sarpo Mira thus appeared resistant against *M. persicae* (Figure 3).

In pots of 200 *M. persicae* per pot, significant antixenosis effects ($P < 0.05$) were also observed among potato

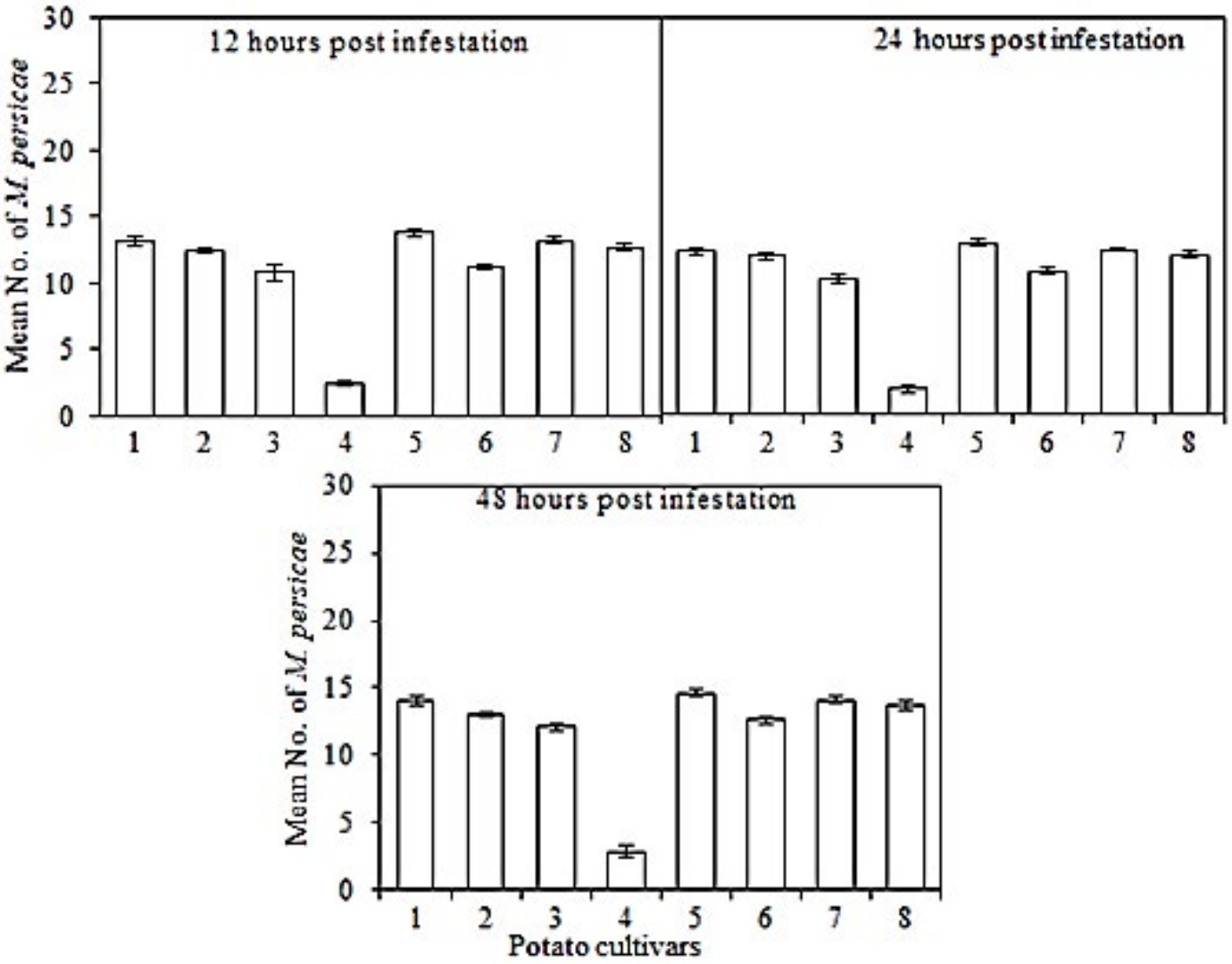

Figure 3: *Antixenosis response of eight different potato cultivars (1 is Desiree, 2 is Patrones, 3 is Rocco, 4 is Sarpo Mira, 5 is Asterix, 6 is SH – 5, 7 is FD – 70 and 8 is Sahiwal Red) against Myzus persicae in pots infested by 100 Myzus persicae at 12, 24 and 48 hours post infestation during Autumn 2016. The data sets are the means (± SD) calculated for 10 replicates of each of the eight cultivars.*

cultivars infested with *M. persicae* for different time durations. Similarly, significant differences among three different time durations of *M. persicae* post infestation on potato cultivars were observed. The lowest number of *M. persicae* (4.7) were observed on Sarpo Mira at 12 hours post infestation in pots of 200 *M. persicae*. Other potato cultivars Rocco, Asterix, and Desiree showed the higher levels of infestations of >19 at this time duration. The cultivar Sahiwal Red, FD-70, SH-5 and Patrones, however, showed the higher levels of infestation of >22 at 12 hours post infestation. Similarly, Sarpo Mira showed the least infestation of 4.1 and 5.1 at 24 and 48 hours post infestation in pots of 200 *M. persicae* adult. This trend was also found for the rest of the potato cultivars after 24 and 48 hours of *M. persicae* infestation. *M. persicae* was found to show less infestation on Sarpo Mira cultivar due its greater resistance to the aphid (Figure 4).

The natural phytochemical and morphological characteristics that might be present in the different tested potato cultivars could play an important role against *M. persicae* infestation (Pickett et al., 1992; Eigenbrode et al., 2002; Leroux et al., 2008). To assess the antixenosis resistance of eight different commercial potato cultivars against *M. persicae* infestation two different densities of *M. persicae* (100 and 200 adults per pot) for different time duration (12, 24 and 48 hours after infestation) were used. The experiments were conducted in spring and autumn growing season of potato. Results revealed that the potato cultivar Sarpo Mira cultivar showed the highest antixenosis resistance against *M. persicae*, while the remaining potato cultivars displayed susceptibility against this insect pest. Resistance capacity of the tested cultivars of potato against *M. persicae* could be attributed to the different phytochemical or morphological traits of the potato cultivars as has

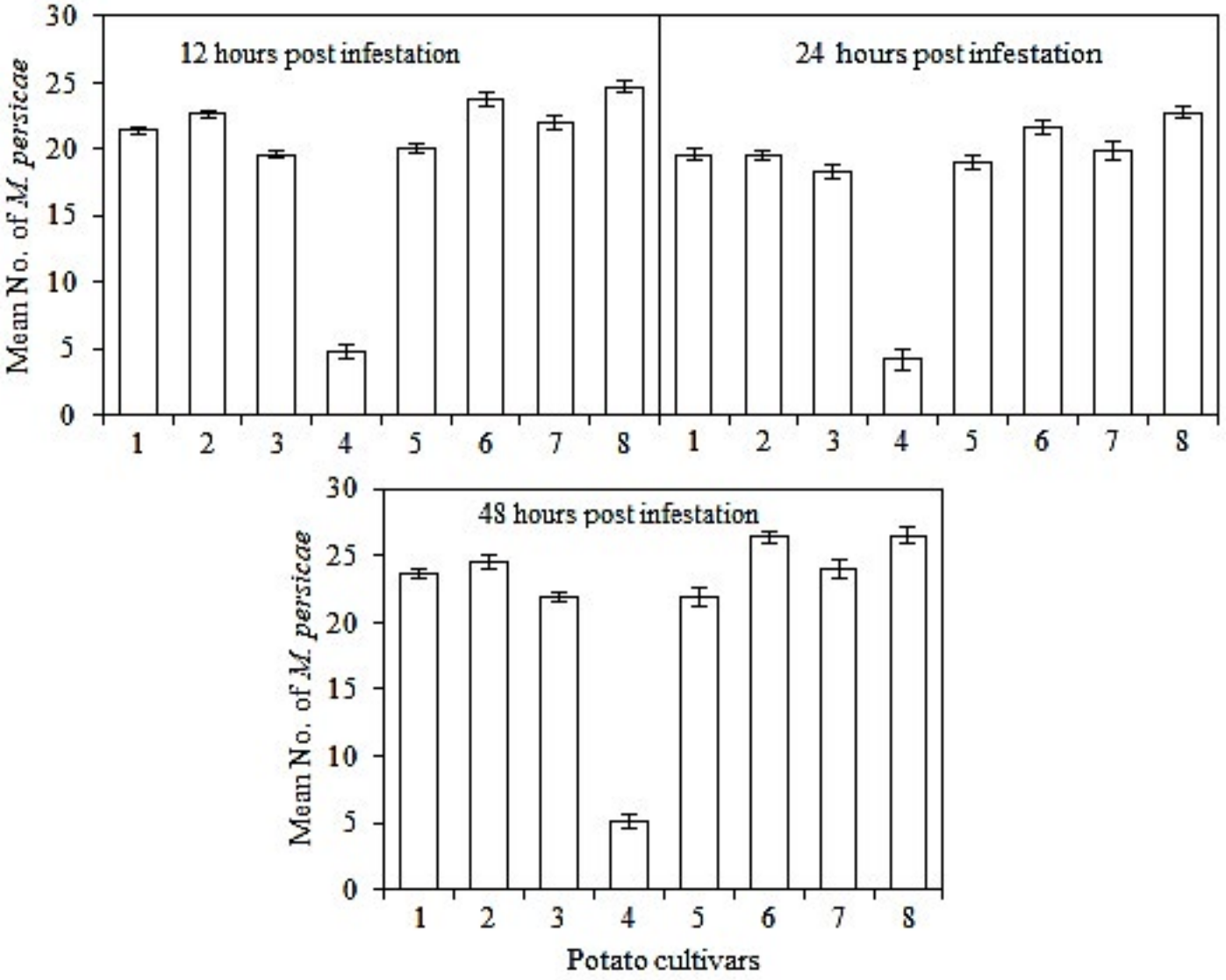

Figure 4: *Antixenosis response of eight different potato cultivars (1 is Desiree, 2 is Patrones, 3 is Rocco, 4 is Sarpo Mira, 5 is Asterix, 6 is SH – 5, 7 is FD – 70 and 8 is Sahiwal Red) against Myzus persicae in pots infested by 200 Myzus persicae at 12, 24 and 48 hours post infestation during Autumn 2016. The data sets are the means (± SD) calculated for 10 replicates of each of the eight cultivars.*

been reported in earlier studies like Pickett et al. (1992) and Eigenbrode et al. (2002), where they reported that smells of plants around the external area perform a key role for aphids in host plant resistance.

Khan et al. (2009), reported that some inhibitory compounds present naturally in different crops, significantly affect the feeding level of insect pests. The different levels of *M. persicae* infestation on different potato cultivars during the antixenosis test could be due to the presence of natural inhibitory compounds in the potato plant. Earlier studies (Frei et al., 2003; Alvarez et al., 2006) have observed similar results using different potatoes cultivar Kardal depends upon the developmental stage of plant leaves.

In the present study the cultivars have shown range of response to *M. persicae* infestation. Differential resistance of potato cultivars against *M. persicae* has previously been reported by (Chen et al., 2015a, b; LeRoux et al., 2008). Our results are in agreement with the findings of LeRoux et al. (2004) who suggested that S. *polyadenium* and *S. tarijense* were highly resistant compared to Desiree against *M. euphorbiae and M. persicae.* Another similar finding was obtained in laboratory conditions by LeRoux et al., 2007, 2008, which reported that *S. stoloniferum* was highly resistant compared to Desiree against *M. persicae,* but susceptible to *M. euphorbiae.* On the other hand, some cultivars of potato crop such as Sahiwal Red, FD- 70, were more susceptible to *M. persicae* than Desiree. Our results match with those of Pelletier and Clark (2004) who revealed that *S. pinnatisectum* was more resistant to *M. euphorbiae* under laboratory conditions. The variations found maybe due to environmental changes in some potato

(Gianfagna et al., 1992; Nihoul, 1993).

Sarpo Mira has shown lesser and delayed attraction for *M. persicae* on account of some deterrent factors such as presence of inhibitory compounds or glandular trichomes plant leaves different volatile compounds. Our results coincides with Mottaghinia et al. (2010) who observed least numbers of aphids on cultivar Cosmos showing antixenotic characters to *M. persicae*. The susceptibility of potato cultivars to *M. persicae* infestation in this study was more possibly due to the lack of those morphological or bio-chemical characteristics present in the resistant cultivars of potato. Previous studies (Alvarez et al., 2006; Thomson et al., 2010; Mottaghinia et al., 2010) have also shown similar results where potato cultivars lacking resistant characteristics were susceptible to the attack of aphids. Numerous morphological characters of plants like roughness of the leaves epidermic tissues may effect the host plant acceptable quality for *M. persicae* (Dixon, 1998; Alvarez et al., 2007). Potato plants bear greater number of trichomes at younger growth stages than at later older growth stages. The resistance potential of a potato cultivar *S. polyadenium* at early growth stage was observed better than its later vegetative growth stage (Alvarez et al., 2006).

Pelletier and Clark (2004) and Le Roux et al. (2007) have also reported varied response of potato genotypes against different species of aphids. For example, potato accessions *S. stoloniferum* was observed more resistant than the *S. tuberosum* against *M. persicae* while *S. stoloniferum* was reported susceptible to *M. euphorbiae*. *M. persicae* resistance in potato cultivars is highly desirable and most effective when used in combination with other control strategies such as biological control and use of insecticides.

Author's Contribution

Zafrullah Khan: Principal author, concieved the idea of the study, planned and conducted the research and collected and analysed the data.
Shah Alam Khan: Supervised the study and guided thoughout the project, proofread the manuscript.

References

Abbas, M.F., S. Hameed, and C.A. Rauf. 2014. Presence of new strain of potato virus y in Pakistan. Int. J. Agric. Biology. 16(5): 941-945.

Alvarez, A.E., E. Garzo, M. Verbek, B. Vosman, Dicke and W.F. Tjallingii. 2007. Infection of potato plants with potato leafroll virus change attraction and feeding behavior of Myzus persicae. Entomol. Exp. Appl. 125: 135-144. https://doi.org/10.1111/j.1570-7458.2007.00607.x

Alvarez, A.E., W.F. Tjallingii, E. Garzo, V. Vleeshouwers, M. Dicke and B. Vosman. 2006. Location of resistance factorsin the leaves of potato and wild tuber-bearing Solanum species to the aphid Myzus persicae. Entomol. Exp. Appl. 121: 145-157. https://doi.org/10.1111/j.1570-8703.2006.00464.x

Basky, Z. 2002. The relationship between aphid dynamics and two prominent potato viruses (PVY and PLRV) in seed potatoes in Hungary. Crop Prot. 21(9): 823-827. https://doi.org/10.1016/S0261-2194(02)00045-5

Bass, C., A.M. Puinean, C.T. Zimmer, I. Denholm, L.M. Field, S.P. Foster and M.S. Williamson. 2014. The evolution of insecticide resistance in the peach potato aphid, *Myzus persicae*. Insect Biochem. Mol. Biol. 51: 41-51

Bertoft, E. 2017. Understanding starch structure: Recent progress. Agronomy. 7(3): 56.

Birt, D.F., T. Boylston, S. Hendrich, J.L. Jane, J. Hollis, L. Li, J. McClelland, S. Moore, G.J. Phillips, M. Rowling, K. Schalinske, M.P. Scott and E.M. Whitley. 2013. Resistant starch: promise for improving human health. Adv. Nutr. 4(6): 587-601. https://doi.org/10.3945/an.113.004325

Blackman, R.L. and V.F. Eastop. 1984. Aphids on the worlds crop: an identification and information guide. Wiley, New York.

Carlo, C. and B. Batyr. 2008. Aphids infesting potato crop in the highlands of Uzbekistan. Potato J. 35(3/4): 134-140.

Chen, Y.H., R. Gols and B. Benrey. 2015a. Crop domestication and its impact on naturally selected trophic interactions. Ann. Rev. Entomol. 60: 35–58. https://doi.org/10.1146/annurev-ento-010814-020601

Chen, Y.H., R. Gols, C.A. Stratton, K.A. Brevik and B. Benrey. 2015b. Complex tritrophic interactions in response to crop domestication: predictions from the wild. Entomol. Exp. Appl.157: 40–59. https://doi.org/10.1111/eea.12344

Dixon, A.F.G. 1998. Aphid ecology, an optimization

approach. Chapman and hall, London, United Kingdom.

Eigenbrode, S.D., H. Ding, P. Shiel and P.H. Berger. 2002. Volatiles from potato plants infected with potato leafroll virus attract and arrest the virus vector, Myzus persicae (Homoptera: Aphididae). Proc. R. Soc. Ser. B 269: 455-460.

Flinn, M., C.M. Smith, J.C. Reese and B.S. Gill. 2001. Categories of resistance to greenbug (Homoptera: Aphididae) biotype I in Aegilopstauschiigermplasm. J. Econ. Entomol. 94: 558-563. https://doi.org/10.1603/0022-0493-94.2.558

Foster, S.P., I. Denholm and A.L. Devonshire. 2000. The ups and downs of insecticide resistance in peach-potato aphids (Myzus persicae) in the UK. Crop Prot. 19: 873-879. https://doi.org/10.1016/S0261-2194(00)00115-0

Fréchette, B., M. Bejan, E. Lucas, P. Giordanengo and C. Vincent. 2010. Resistance of wild Solanum accessions to aphids and other potato pests in Quebec field conditions. J. Insect Sci.10 (1): 161.

Frei, A, H. Gu, J.M. Bueno, C. Cardona and S. Dorn. 2003. Antixenosis and antibiosis of common beans to thrips palmi Karny (Thysanoptera: Thripidae). J. Econ. Entomol. 93: 1577-1584. https://doi.org/10.1603/0022-0493-96.5.1577

Gianfagna, T.J., C.D. Carter and J.N. Sacalis. 1992. Temperature and photoperiod influence trichome density and sesquiterpene content of Lycopersicon hirsutum f. hirsutum. Plant Physiol. 100: 1403- 1405. https://doi.org/10.1104/pp.100.3.1403

Higgins, J.A. 2004. Resistant starch: metabolic effects and potential health benefits. J. AOAC Int. 87(3): 761–8.

Khan, M.A., A.U.R. Saljoqi, N. Hussain and S. Sattar. 2011. Response of Myzus persicae (Sulzer) to imidacloprid and thiamethoxam on susceptible and resistant potato varieties. Sarhad J. Agric. 27(2): 263-270.

Khan, S.A., M. Murugan, S. Starkey, A. Manley and C.M. Smith. 2009. Inheritance and categories of resistance in wheat to Russian wheat aphid (Hemiptera: Aphididae) biotype 1 and biotype 2. J. Econ. Ent. 102: 1654-1662. https://doi.org/10.1603/029.102.0433

Le Roux, V., J. Saguez, C. Vincent and P. Giordanengo. 2004. Rapid method to screen resistance of potato plants against *Myzus persicae* (Homoptera: Aphididae) in the laboratory. J. Econ. Entomol. 97(6): 2079-2082. https://doi.org/10.1093/jee/97.6.2079

Le Roux, V., E.D.M. Campan, F. Dubois, C. Vincent and P. Giordanengo. 2007. Screening for resistance against Myzus persicae and Macrosiphum euphorbiae among wild Solanum. Ann.Appl.Boil. 151(1):83-88. https://doi.org/10.1111/j.1744-7348.2007.00155.x

Le Roux, V., S. Dugravot, E. Campan, F. Dubois, C. Vincent and P. Giordanengo. 2008. Wild solanum resistance to aphids: Antixenosis or antibiosis? J. Econ. Entomol. 101(2): 584-591. https://doi.org/10.1093/jee/101.2.584

Martinez-Torres, D., S.P. Foster, L.M. Field, A.L. Devonshire and M.S. Williamson. 1999. A sodium channel point mutation is associated with resistance to DDT and pyrethroid insecticides in the peach potato aphid, Myzus persicae (Sulzer) (Hemiptera: Aphididae). Insect Mol. Biol. 8: 1-8. https://doi.org/10.1046/j.1365-2583.1999.83121.x

Meng, J., C. Zhang, X. Chen, Y. Cao and S. Shang. 2014. Differential protein expression in the susceptible and resistant Myzus persicae (Sulzer) to imidacloprid. Pestic. Biochem. Physiol. 115: 1-8. https://doi.org/10.1016/j.pestbp.2014.09.002

Mottaghinia, L., J. Razmjou, G. Nouri-Ganbalani and H. Rafiee-Dastjerdi. 2010. Antibiosis and antixenosis of six commonly produced potato cultivars to the green peach aphid, *Myzus persicae* Sulzer (Hemiptera: Aphididae). Neotrop. Entomol. 40(3): 380-386.

Mottaghinia, L., J. Razmjou, G. Nouri-Ganbalani and H. Rafiee-Dastjerdi. 2011. Antibiosis and antixenosis of six commonly produced potato cultivars to the green peach aphid, Myzus persicae Sulzer (Hemiptera: Aphididae). Neotrop. Entomol. 40(3): 380-386.

Niaz, T. and M. Ayub. 2007. Population pattern of Myzus persicae on potato crop at Faisalabad. J. Agric. Res. 45: 305-310.

Nihoul, R. 1993. Do light intensity, temperature and photoperiod affect the entrapment of mites on glandular hairs of cultivated tomatoes? Exp. Appl. Acarol. 17: 709-718. https://doi.org/10.1007/BF00058510

Pelletier, Y. and C. Clark. 2004. Use of reciprocal grafts to elucidate mode of resistance to

COLorado potato beetle (Leptinotarsa decemlineata (Say) and potato aphid (Macrosiphum euphorbiae (Thomas) in six wild Solanum species. Am. J. Potato Res. 81: 341-346. https://doi.org/10.1007/BF02870180

Pickett, J.A., L.J. Wadhams, C.M. Woodcock and J. Hardie. 1992. The chemical ecology of aphids. Annu. Rev. Entomol. 37: 67-90. https://doi.org/10.1146/annurev.en.37.010192.000435

Robert, Y., J.A. Trefor, Woodford and D.G. Ducray-Bourdin. 2000. Some epidemiological approaches to the control of aphid-borne virus diseases in seed potato crops in northern Eur. Virus Res. 71: 33-47. https://doi.org/10.1016/S0168-1702(00)00186-6

Sabbaghan, K. and E. Soleymannejadian. 2007. Seasonal population fluctuation of Myzus persicae (Hom., Aphididae) and its parasitoid Aphidius matricariae (Hymenoptera: Braconidae) on potato in Behbahan and Yassuj regions. Sci. J. Agric. 29: 153-162.

Spooner, D.M., R.G. van der Berg, A. Rodríguez, J. Bamberg, R.J. Hijmans and S.I. Lara Cabrera. 2004. Wild potatoes (*Solanum* section *Petota*, Solanaceae) of North and Central America. Syst. Bot. Monogr. 68. https://doi.org/10.2307/25027915

Thomson, L.J., S. Macfadyen and A.A. Hoffmann. 2010. Predicting the effects of climate change on natural enemies of agricultural pests. Biol Control. 52: 296-306. https://doi.org/10.1016/j.biocontrol.2009.01.022

Weaver, C. and E.T. Marr. 2013. White vegetables: a forgotten source of nutrients: Purdue roundtable executive summary. Adv. Nutr. 1; 4 (3): 318S-26S.

Wikman, J., A. Blennow, and E. Bertoft. 2013. Effect of amylose deposition on potato tuber starch granule architecture and dynamics as studied by lintnerization. Biopolymers, 99(1): 73-83.

Woolfe, J.A. 1987. The potato in the human diet. New York: Cambridge Univ. Press. 1987. pp.10. https://doi.org/10.1017/CBO9780511753435

Zafar, M., M.K.A. Khan and A. Ullah. 2015. Efficacy of cypermethrin, bifenthrin and azadirechtin against crop infesting aphid species of Lipaphis erysimi (katenbach) and Myzus persicae (sulzer) on cauliflower and potato plants. J. Zool. 30 (1): 007-009.