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Efficiency of botanical pesticides against some pests infesting hydroponic cucumber, cultivated under greenhouse conditions

Muhammad Shoaib Saleem*, Tuba Sharf Batool, Muhammad Faheem Akbar, Saboohi Raza and Saleem Shahzad

Abstract

Greenhouse cultivation of vegetables, especially cucumber in hydroponic/soilless culture, has been developed in different parts of the world. There is an expanding interest in hydroponics because they can produce fresh food closer to urban areas. The objective of this study was to evaluate the efficiency of the biopesticides: matrine (extract from *Sophora flavescens*), spintoram (derived from soil bacterium *Saccharopolyspora spinosa*), azadirachtin (neem extract), and *Annona squamosa* (custard apple extract) against the cotton aphid (*Aphis gossypii* Glov.) and the two-spotted spider mite, (*Tetranychus urticae* Koch.). A drip-irrigation hydroponics system (DIHS) was designed and used for this study. Fourteen-day-old seedlings of cucumber plants were shifted in DIHS, and nutrient requirements were maintained during the period of experiment. Randomized complete block design (RCBD) was used for this experiment with 3 replicates and with 5 treatments. Data were collected 24 h pre-treatment and 1, 3, 7, and 14 days post-treatment. Results revealed that the custard apple extract showed the highest efficiency (80 and 76%) reduction against the aphid and the mite, respectively, followed by matrine (legend) and neem extract (73%), and spintoram (radiant) (69%) in case of the aphid, while it was followed by matrine (legend) (75%), spintoram (radiant), (66%), and neem extract (56%) in the case of the mite.

Keywords: Biopesticides, Cucumber, Greenhouse, Hydroponics, Aphids, Two-spotted spider mite

Introduction

Cucumber (*Cucumis sativus* L.) is one of the global horticultural crops (Eifediyi and Remison 2010). For obtaining ample amount of yield and better quality in protected cultivation systems, greenhouse conditions and hydroponics are considered effective (Preciado Rangel et al. 2011). In greenhouses, the two-spotted spider mite (*Tetranychus urticae* Koch) is one of the most polyphagous and serious pests (Attia et al. 2013). As well, the cotton aphid (*Aphis gossypii* Glov.) is also a cosmopolitan insect pest that infests more than 569 plant species under 103 families (Tazerouni et al. 2016).

In recent years, plant extracts and botanical pesticides have showed great importance in agricultural fields due to their cheap and low expenses, with no residual effects, environmentally friendly, and highly toxic against major pests such as thrips, aphids, jassids, whitefly, and mites (Stumpf and Nauen 2001). The extract of *Annona squamosa* L. (family Annonaceae), commonly known as Sita phal, and the sweetsop and custard apple have shown potentials for pest control across a large array of insect pests. Laboratory and field experiments proved that custard apple extract effectively managed different field crop pests and stored grain pests (Misra 2000). Synthetic pesticides have many drawbacks as they are persistence, develop resistance in pests, and affect non-target organisms such as natural enemies. Contrary to the chemical pesticides, biopesticides are eco-friendly as the non-target organisms and human beings are less affected (Begum et al. 2013). Alkaloid matrine is the active ingredient obtained from the dry roots of *Sophora flavescens* Ait, which is richly found in the roots of few species from the genus *Sophora* (Mao and Henderson 2007). It has high toxicity against various insect pests and used for the management of leafhoppers, mites, aphids, and caterpillars and bacterial and fungal diseases (Marcic et

* Correspondence: shoaibsaleeemkhan@gmail.com
Department of Agriculture and Agribusiness Management, University of Karachi, Main University Road, Karachi, Karachi City, Sindh 75270, Pakistan

al. 2012). Moreover, it is also used for the management of stored commodities pests (Liu et al. 2007).

Neem oils and extracts are considered as the best option for the insect pest management program in vegetables because they are safe for beneficial organisms, target-specific, and compatible for biological control agents (Tang et al. 2002). Spintoram is a reduced risk insecticide from a novel class of chemicals spinosyns (Srivastaba et al. 2008).

The present study demonstrates the efficiency of 4 products of bioinsecticides. Matrine, spintoram, neem, and custard apple extracts against *Tetranychus urticae* Koch and *Aphis gossypii* Glov. on hydroponic cucumber cultivation under greenhouse conditions.

Materials and methods

Nursery preparation and drip irrigation hydroponics system (DIHS) design

Experiments were conducted at the Zain Advanced Growing Research Facility (ZAGF), Department of Agriculture and Agribusiness Management, University of Karachi, during the year 2018. Leeza (F1 hybrid) cucumber variety was used as a host for the tested pest. Cucumber nursery was prepared in sterilized coco peat seedling trays. After 20 days of germination, the seedlings were transplanted into DHIS. The system was designed, using 15-ft polyvinyl chloride (PVC) pipe of 6-in. diameter, and 2-in. holes were done in pipes. Hole to hole distance in each pipe was 6 in., while pipe to pipe distance was 18 in. There was an inlet and outlet at the opposite ends of the PVC pipe. Two inches of hydroponic net cup was used in this study. Cucumber seedlings were shifted in each cup with coco peat in net cups. A tank with a capacity of 30 l was connected to the system. A submersible pump with motor was connected to the inlet of PVC pipe and the outlet was connected to the tank. Half-inch drip irrigation pipe with emitters were installed on the PVC pipes. Nutrients were prepared according to Hoagland's nutrient recipe Hoagland and Arnon (1950).

Custard apple (*Annona squamosa* L.) seed extraction

During 2018, fresh fruits of custard apple were procured from the local market of Karachi, and seeds were removed from them after washing with tap water. Seeds were left to dry in shade and smashed in an electric grinder. Thereafter, powdered seeds were mixed with methyl alcohol (70%) in the ratio of 1:3 (*w*/*v*), i.e., 100 g seed powder and 300 ml methyl alcohol. The mixture of seed and alcohol was agitated well every 8 h for 6 times. The supernatant of the solution was filtered by using Whatman's filter paper after 48 h. The amount of solution thus was obtained about 200 ml. Volume of filtered supernatant was adjusted to 400 ml by adding 200 ml methyl alcohol additionally. After completing extraction, the mixture was brought for condensation through evaporation in an evaporating chamber. After evaporation, 100-ml volume was considered as 100% seed extract, which was used as biopesticides for further study (Arain 2017).

Experimental design and biopesticides application

Experiments were arranged in a randomized complete block design (RCBD) by Sokal and Rohlf (1981), with 3 replicates for each biopesticide. Each comprising 5 treatments including control. Plants were monitored for mite and aphid infestation, and application of biopesticides was carried out, when the population of the pests reached the economic threshold level (ETL), i.e., 5–10 for mites per leaf (Walgenbach 2015) and 5–7 aphids per leaf (Afshari et al. 2009). Biopesticides were prepared according to the recommended dose mentioned on the label, i.e., matrine at 6.17 g a.i./ha, spintoram at 296.4 g a.i./ha, azadirachtin at 1.58 g a.i./ha, and custard apple at 247 g a.i./ha. Spray was done using a handheld sprayer at dusk time. Population density of the mite and aphid was recorded on 10 selected plants at each treatment. Three leaves/plants were selected from top, middle, and bottom (Kaushik et al. 1990), and pests were carefully counted on under side of the leaves. Collected data were expressed as mean populations at each plot. Pre-treatment counts were taken 1 day before treatments, while the post-treatment counts were undertaken after one, 3, 7, and 14 days of spray.

Statistical analysis

Obtained data were compiled in two manners: as a change in percent population density and efficacy percentage relative to the untreated (control) plots. The change in population density was calculated as follows:

Change in Population Density (CPD%) = $[(Xi - X0)/X0] \times 100$

where $X0$ is the mean number of live insects before treatment, Xi is the mean number of live insects at the assessment after treatment. Positive values in the table indicate an increase.

The reduction percentage was calculated by Henderson-Tilton's formula (Henderson and Tilton 1955) according to the following equation:

$$\%\text{reduction in population} = 100 \times 1 - \left(\frac{T_a \times C_b}{T_b \times C_a}\right)$$

where:

T_a = number of insects after treatment

T_b = number of insects before treatment

C_a = number of insects in control plots after treatment

C_b = number of insects in control plots before treatment

The collected data were subjected to statistical analysis through SPSS version 16.0. The mean differences between various treatments were tested by using Tukey's HSD test at 5% significance level.

Results and discussion

The biopesticides applied at the recommended dose significantly reduced the mean number of live insect and showed high efficacy in controlling *Tetranychus urticae* and *Aphis gossypii*.

Efficiency of the biopesticides against *Aphis gossypii*

One day post-treatment (Table 1), spintoram showed a maximum reduction in *A. gossypii* population by (59%), with the efficacy of 46%, followed by azadirachtin, custard apple, and matrine that reduced the population (49, 38, and 18.3%) with the efficacy of 46, 31, and 39%, respectively. Three days post-treatments, maximum reduction was recorded by the custard apple (95%) with the efficacy of 95%, matrine and azadirachtin showed 83 and 79% population reduction with 87 and 81% efficacy, respectively, followed by spintoram (46%) reduction with 49% efficacy. Seven days post-treatments, custard apple showed the highest population reduction (97%) with the efficacy of 98%, azadirachtin and spintoram showed 82 and 85% reduction with 28 and 81% efficacy, respectively, followed by matrine (84%) reduction with 69% efficacy. Meanwhile, after 14 days of treatment, spintoram showed the highest population reduction (94%) with the efficacy of 99%, matrine and custard apple showed 94 and 91% reduction with 97 and 93% efficacy, respectively, followed by azadirachtin (86%) reduction with 86% efficacy against *A. gossypii*.

An overall performance of all the pesticides (Table 1 and Fig. 1) represents that the custard apple extract was the highly effective one against the aphid, followed by azadirachtin, matrine, and spintoram (80, 73, 73, and 69%), respectively.

Efficiency of the biopesticides against *Tetranychus urticae*

One day post-treatments (Table 2), matrine showed the maximum reduction of *T. urticae* population by 60%, with the efficacy of 76%, followed by azadirachtin, spintoram, and custard apple (16, 3, and 1%) with the efficacy of 47, 41, and 33%, respectively. Three days post-treatments, the maximum reduction was recorded in custard apple (82%) with the efficacy of 91%, azadirachtin and matrine showed 54 and 19% reduction with 79 and 62% efficiency, respectively, followed by spintoram (5%) reduction with 53% efficiency. Seven days post-treatments, custard apple showed the highest population reduction (90%) with the efficacy of 89%, spintoram and matrine showed 75 and 72% reduction with 78 and 69% efficacy, respectively, followed by azadirachtin (26%) reduction with 31% efficacy. Meanwhile, after 14 days of treatments, matrine showed the highest population reduction (91%) with the efficacy of 88%, spintoram and custard apple showed 91 and 92% reduction with 86 and 85% efficacy, respectively, followed by azadirachtin (51%) reduction and 31% efficacy.

An overall performance of all the biopesticides (Table 2 and Fig. 2) represents that custard apple extract was highly effective against the mite, followed by matrine, spintoram, and azadirachtin (76, 75, 66 and 56%), respectively.

Figure 3 shows the comparative efficacy data of all treatments. Eventually, it endorses the performance of biopesticides by an overall effect in the treatments against *T. urticae* and *A. gossypii* that ranked as custard apple extract, azadirachtin, matrine, and spintoram.

Biopesticides differ in their mode of actions. According to the US Environmental Protection Agency (EPA), biorational insecticides exhibit minimum risk to the environment, break down quickly, have minimum residue, and are safe for applicant, and a comparatively small quantity is required for booming control of target organisms (Sadeghi et al. 2009). The findings of the present study revealed that custard apple had the topmost effect over the 2 pests: *T. urticae* and *A. gossypii*.

Table 1 Population densities of *Aphis gossypii* (*N*) on hydroponic cucumber and effectiveness of biopesticides

Treatments	Before spray	After 24 h			After 72 h			After 168 h			After 336 h		
		N	CPD (%)	EF (%)	*N*	CPD (%)	EF (%)	*N*	CPD (%)	EF (%)	*N*	CPD (%)	EF (%)
Matrine	23.6[a]	19.3[ab]	− 18.3	39	4.0[a]	− 83.0	87	3.6[a]	− 84.5	69	1.3[a]	− 94.3	97
Spintoram	35.6[a]	14.3[a]	− 59.8	46	19.0[ab]	− 46.7	49	5.0[a]	− 85.9	81	2.0[a]	− 94.3	99
Azadirachtin	81.3[a]	41.0[ab]	− 49.5	46	17.0[ab]	− 79.0	81	14.0[a]	− 82.7	82	10.6[a]	− 86.8	86
Custard apple	74.3[a]	45.6b	− 38.5	31	3.6[a]	− 95.0	95	2.0[a]	− 97.3	98	6.3[a]	− 91.4	93
Control	27.6[a]	31.6[ab]	15.8		39.3[b]	43.9		32.0[b]	17.0		33.3[b]	21.9	
Significance level	$F = 2.10$; df = 4; $P \geq 0.05$	$F = 4.43$; df = 4; $P \leq 0.05$			$F = 4.38$; df = 4; $P \leq 0.05$			$F = 13.8$; df = 4; $P \leq 0.01$			$F = 30.8$; df = 4; $P \leq 0.01$		

The mean number of aphids/leaf (30 leaves per plot); within a column, the means pursued by the same letter are not significantly different (Tukey's HSD test, $\alpha = 0.05$)

CPD (%) change in population density, *EF* (%) percent efficacy (Henderson-Tilton formula)

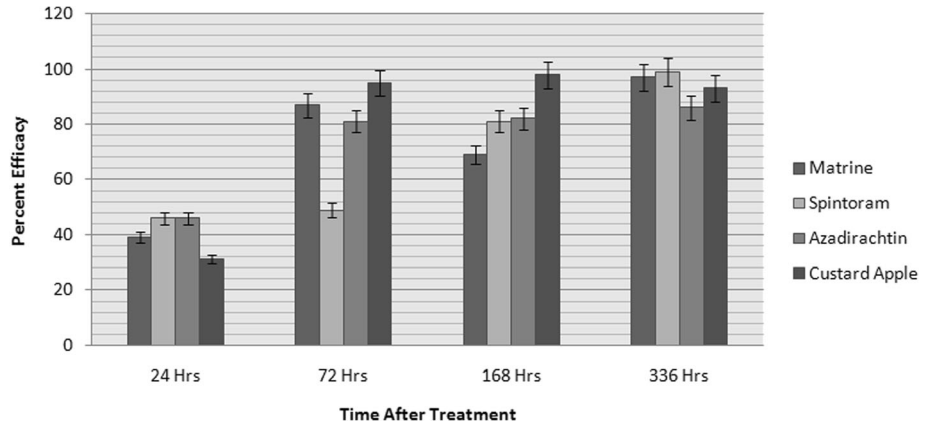

Fig. 1 Comparative efficacy of biopesticides against *Tetranychus urticae* Koch and *Aphis gossypii*.

It is reported that the seed of *A. squamosa* has insecticidal and causative properties. Previous studies showed that crude oils from seeds of *A. squamosa* significantly reduced leaf damage caused by *Spodoptera litura* when applied at 2.5% concentrations (Babu et al. 1998). The population of *Callosobruchus maculatus* was also reduced when extracts of fresh seeds of *A. squamosa* were applied with acetone (Dharmasena et al. 2001). In this study, seed extract was prepared in absolute alcohol, which was highly effective against *T. urticae* (76%) and *A. gossypii* on 80% on hydroponics cucumber crop under greenhouse conditions (Table 2). Sonkamble et al. (2000) found that the seed extract at 1.5% concentration had the maximum mortality against *Helicoverpa armigera* (43.33%) and 36.66% percent mortality at 1% concentration against *S. litura*. It is reported that *A. squamosa* seed extract had repellent and anti-oviposition properties against *Ceratitis capitata* (Epino and Chang 1993). Topical application of *A. squamosa* seed extract showed a substantial decline of all 5th instar larvae of *Dysdercus koenigii*, which rise in fresh free amino acid under laboratory conditions (Reddy et al. 1993).

In the present study, biopesticide derived from *S. flavescens (*Ait.) matrine showed high effectiveness in comparison to spintoram. The findings of this study is supported by many previous studies, which indicated that matrine is very effective for the management of sucking insect pest. In Brazil, it succeeded to reduce the infestation with *Planococcus citri* and *Eutetranychus banksi*, in a commercial citrus farm (Zanardi et al. 2015). In another study, results showed that the most efficient treatment was matrine (2 l/ha) against diamondback moth, *Plutella xylostella*. Matrine, when applied at the rate of 2 l/ha and 1.5 l/ha, showed similar efficacy until 15 days of post-treatment. However, matrine (2 l/ha) found much better when assessed 20 days post-treatment. Overall, after 20 days of pesticide application matrine (2 l/ha) showed the highest efficacy (89.9%), followed by matrine 1.5 l/ha (Karimzadeh 2014). Additionally, it is also reported that matrine can be

Table 2 Population densities of *Tetranychus urticae* (*N*) on hydroponic cucumber and effectiveness of biopesticides

Treatments	Before spray	After 24 h			After 72 h			After 168 h			After 336 h		
		N	CPD (%)	EF (%)	*N*	CPD (%)	EF (%)	*N*	CPD (%)	EF (%)	*N*	CPD (%)	EF (%)
Matrine	28.6^{a}	11.3^{a}	− 60.4	76	23.0^{a}	− 19.7	62	8.0^{a}	− 72.0	69	2.3^{a}	− 91.8	88
Spintoram	26.3^{a}	25.3^{a}	− 3.7	41	27.6^{ab}	5.0	53	6.3^{a}	− 75.9	78	2.3^{a}	− 91.1	86
Azadirachtin	30.0^{a}	25.0^{a}	− 16.6	47	13.6^{a}	− 54.4	79	22.0^{b}	− 26.6	31	14.6^{b}	− 51.1	31
Custard apple	33.3^{a}	33.3^{a}	− 1.0	33	6.0^{a}	− 82.0	91	3.3^{a}	− 90.0	89	2.6^{a}	− 92.0	85
Control	40.3^{a}	67.6^{b}	67.7		88.3^{b}	119		45.6^{c}	13.2		55.0^{c}	36.3	
Significance level	$F = 0.61$; df = 4; $P \geq 0.05$	$F = 19.6$; df = 4; $P \leq 0.01$			$F = 5.52$; df = 4; $P \leq 0.01$			$F = 95.9$; df = 4; $P \leq 0.01$			$F = 12.5$; df = 4; $P \leq 0.01$		

The mean number (*N*) of mites/leaf (30 leaves per plot); within a column, the means pursued by the same letter are not significantly different (Tukey's HSD test, $\alpha = 0.05$)

CPD (%) change in population density, *EF* (%) percent efficacy (Henderson-Tilton formula)

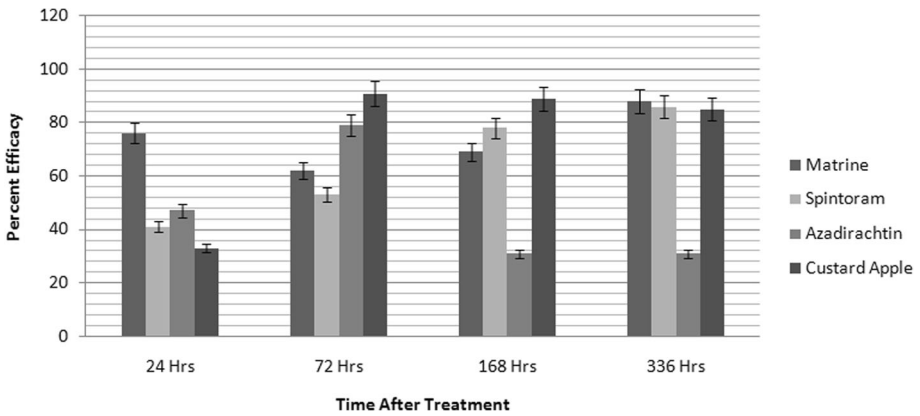

Fig. 2 The percent mortality of *Aphis gossypii* at different days after spraying in the greenhouse

useful to control spider mites without causing any phytotoxic problems, which is one of the very serious issue associated with the use of botanical pesticides in citrus seedlings (Cloyd et al. 2009).

Neem-based products (azadirachtin) which are commercially available in the market have varied pest control properties, disturbing insect growth stages, fertility, and anti-feeding activity, in addition to their direct toxicity and oviposition restrain changes (Naqvi 1996). Obtained findings indicated that azadirachtin had a moderate efficacy (69 and 56%) against *A. gossypii* and *T. urticae*, respectively, on hydroponic cucumber, which is probably due to its mode of action and which is different from synthetic compounds. For example, the efficacy of different neem-based formulations and synthetic compounds against cabbage butterfly (*Pieris brassicae)* has been studied. The results indicated that all synthetic compounds had 100% efficacy after 72 h treatment, which was higher than neem-based compounds. It is found that neem oil formulation was effective for the management of aphid population than the treatment with neem oil or control plants. Similarly, numerous other neem-based products showed effectiveness of *Myzus persicae* on several host plants (Akbar et al. 2010). The neem extract was extremely effective to control jassid, whitefly, aphid, and mites on brinjal (Ali et al. 2017).

Spintoram is a relatively newer biopesticide and has shown good efficacy against *T. urticae* and *A. gossypii* on on hydroponic cucumber crop under greenhouse conditions. The findings of the present study are similar to the study conducted by El Kady et al. (2007) as all doses of spintoram caused reduction of infestations of different stages of *T. urticae.* The maximum reduction was observed in egg treatment (100%) after 13 and 19 days. For adult, 96.7% reduction was recorded after 5 days and 87.5% mortality was observed in immature stages after 11 days at dose 1 ml solution/liter water. Wang et al. (2016) reported that spintoram also reduced the developmental time of *T. urticae* from egg to adult when treated with LC_{10} and LC_{20}. Spintoram also hinders the egg duration, mean generation time, and larval duration of insect whether adult females or eggs were poisoned. Due to some broad spectrum activity of spinosyns, it is reported that they are effective against many insects from different orders like Diptera, Homoptera, Isoptera, Thysanoptera, Orthoptera, and Coleoptera (Salgado 1998). Mahmoud

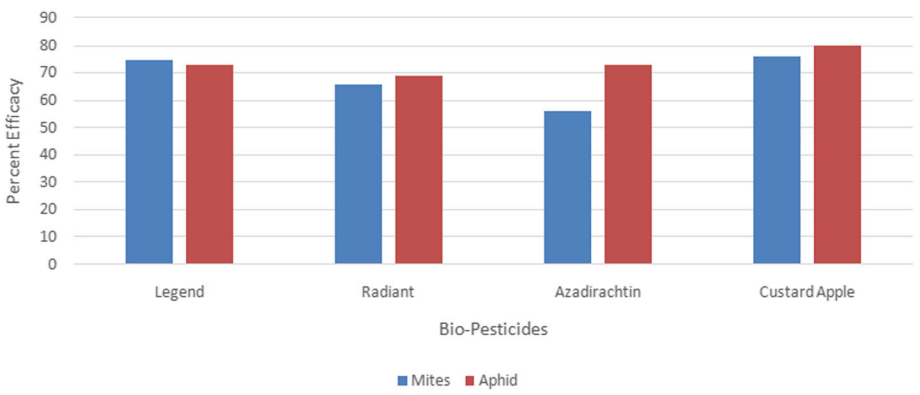

Fig. 3 The percent mortality of *Tetranychus urticae* at different days after spraying in the greenhouse

and Osman (2007) reported that Spinosad showed the maximum mortality against the populations of *Thrips tabaci* on onion crop till 21 days after treatment.

Conclusion

In conclusion, according to the findings of the present research, custard apple extract and matrine showed excellent results against *Tetranychus urticae* and *Aphis gossypii* on hydroponics cucumber under greenhouse conditions. However, neem extract was very effective against aphids as compare to mites. Increasing market trend and awareness of pesticide residue-free vegetables, consumeable after the harvest, efforts to slow down or underrate pest resistance to synthetic pesticides (Fournier and Brodeur 2000) and balanced insecticidal activities (Baldwin 2008), the bio rational insecticide of the plant origin could be suggested for the management of *Tetranychus urticae* on hydroponics cucumber under greenhouse plantings in an IPM program.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contribution

MSS conducted the experiment, data collection, and data analysis, wrote the results and discussion, and collected references and literature. TSB conducted the experiment, data collection, and data analysis, wrote the abstract and introduction, and collected references and literature. MFA conceived the idea and conducted the overall management of the article. SR reviewed the manuscript and contributed to the data analysis. SS reviewed the manuscript. All authors read and approved the final manuscript.

Authors' information

1. Muhammad Shoaib Saleem Ph.D Scholar, Visiting Lecturer
2. Tuba Sharf Batool Ph.D Scholar, Teaching Associate
3. Muhammad Faheem Akbar Ph.D, Assistant Professor
4. Saboohi Raza Ph.D, Associate Professor/Chairperson
5. Saleem Shahzad Ph.D, Professor

Ethics approval and consent to participate

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Competing interests

The authors declare that they have no competing interests.

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