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Research Article

Diversity, Abundance, and Pest Potential of *Orthoptera* in Agricultural Crops of a Subtropical Region of Pakistan

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Abstract

Agriculture plays a crucial role in the development of nation's economy. Insect plant interaction is a major component in the trophic food chain and a significant topic in agriculture and entomology. Orthoptera is known to be one of the largest and common insect order in Pakistan. The present study aims to determine the diversity of the order Orthoptera in crop system of district Sialkot, Pakistan. This study was conducted to understand the economic importance of Orthoptera insects and generate a better design for Integrated Pest Management (IPM) in the future. Sampling on the sorghum, rice and maize crops was done for a period of four months from June to September 2022. Insects were collected by using a sweep net and handpicking method. A total of 628 specimens were collected of order Orthoptera belonging to two suborders Caelifera and Ensifera, representing 26 species from three families Acrididae, Pyrgomorphidae and Tettigoniidae. Results suggest that the cropping system of district Sialkot has rich fauna of order Orthoptera and some species could act as serious agricultural pest and can cause huge economic loss to crop production. Eco-friendly Orthoptera management techniques are needed to maintain a sustainable agro-ecosystem to achieve 2nd SDG (Sustainable Development Goals) goal with no hunger.

Keywords: Orthoptera, Diversity, Grasshopper, Crops, Pest.

1. Introduction

Agriculture is one of the most important sectors of Pakistan's economy [1]. It provides 19.2% to the nation's Gross Domestic Product (GDP). Total 38.5% of people are attached to this department in Pakistan [2]. The agroecosystem comprises of the planned diversity includes all the animals and plants which are introduced by the farmers while the unplanned diversity includes weeds, predators and microbes which get colonized by surrounding atmosphere.

Orthoptera is one of the largest orders of insects with approximately 22,500 species [2]. Order *Orthoptera* includes two monophyletic suborders, including Ensifera and Caelifera [3]. Two infraorders of Enisfera (crickets, wetas and katydids) include Gryllidea and Tettigoniidea [4]. They have long and flagellated antennae and a sword-like female ovipositor. They are also termed as long-horned grasshoppers. The suborder Caelifera (grasshoppers and locusts) consists of two infraorders Acrididea and Tridactylidea. They are having short antennae and only two valvular pairs are present in female ovipositor that's why termed as short-horned grasshoppers [5]. Acrididae is one of the most important family in order *orthoptera* because many of its species are destructive agricultural pests which makes them ecologically and economically important insects [6].

Plants are considered the most important primary producers in the ecosystem. Insect plant interaction is a major component in the trophic food chain [7]. It is estimated that insects consume 10-15% of plant biomass each year. therefore, it is important to understand how plant and insect interact, how their interaction evolve over time and how it impacts the overall ecosystem [8]. The damage associated molecular patterns are present in the plants and they have different chemicals to develop resistance against insects [9]. The herbivore associated molecular pattern is also present for the recognition of herbivores. These are known as elicitors. They activate defense mechanisms in the plants when an herbivorous insect attacks the plant. Some herbivores had also evolved the effectors which are introduced in the plants by the insects. These effectors will inhibit the defensive mechanisms of the plants [10].

In 2019, locust (Acrididae) damaged 68,000 km^2 area of Pakistan, which caused 33% of the agricultural yield loss [11]. Different international commissions have been formed to control the migratory locust attacks. The outbreaks of grasshopper and locusts are now controlled more effectively as compared to the past. But the climate change is causing serious pest attacks in some parts of the world. Effective preventive management techniques should be adopted to control the locust attack [12]. It can be done by the better understanding pest distribution, pest biology and its control measures [13]. Geographic information system (GIS) is used to locate the locusts and grasshoppers' habitats and their invasions in different parts of the world so that early control measures can be adopted [14].

The main objective of the current study is to determine the diversity of the order *Orthoptera* across the various cropping systems of district Sialkot, Pakistan. This will provide a better understanding of *orthoptera* biodiversity, which will help in developing advanced and sustainable pest management practices.

2. Materials and Methods

2.1. Study area

The study was conducted in Sialkot, Punjab, Pakistan. 32° 29' 33" north and 74° 31' 52" east are its geographical coordinates. The climatic conditions are hot and humid during summer season, cold in the winters and temperature drops to -2 °C. The land in Sialkot is plain, fertile and annual rainfall is about 1000 mm [15]. The insects were sampled from different agricultural areas of Sialkot. Government College Women University, Sialkot was taken as zero point for the selection of sampling sites. The collection of specimens was done by setting up an area within the 40 km from the zero point for four months from different tehsils of district Sialkot which include Daska, Pasrur, Sambrial and Sialkot.

2.2. Collection of specimens

Insects were collected for the period of four months from crops System of district Sialkot for the determination of diversity of order *Orthoptera* in crops sorghum, rice and maize. The insects were collected by sweep net and handpicking method [16]. Sampling was carried out during morning hours between 8:00 AM and 11:00 AM, when insect activity was comparatively higher. In each selected field, sampling sites were chosen randomly following a diagonal pattern. At every sampling site, 20 sweeps were performed using a standard sweep net, and three replications were maintained per field. For handpicking, ten plants were randomly selected from the central and corner portions of the field, and insects present on leaves, stems, and nearby vegetation were carefully collected manually. Specimens were killed by using Potassium cyanide or distilled water. Then the insects were relaxed and stretched for the purpose of pining of the insects properly at the pronotum. The insects were displayed in insect collection boxes. The naphthalene balls were used in insect box to protect specimen from predators and parasitoids [6].

2.3. Identification of collected specimen

The morphological identification of collected specimen was done up to species level by using identification key (Dichotomous key), literature available online and in Fauna of British India by [17,18].

2.4. Statistical analysis

On crop and month wise diversity Analysis of Variance (ANOVA) was applied by using Minitab 20.4. Level of significance was set at $\alpha < 0.05$. Shannon diversity indices were determined by Past 3.25 software.

3. Results and Discussion

3.1. Diversity and percent relative abundance of order Orthopter

In the present study diversity and abundance of order *Orthoptera* was determined in the crops system of district Sialkot, Pakistan for a period of four months from June to September, 2022. Total 628 specimens belonging to order *Orthoptera* were collected. The collected insect species belonged to two suborders of *Orthoptera* including Caelifera and Ensifera. Total 26 species were collected and identified in current research (Table 1).

The most diverse and relatively abundant suborder in the present study was Caelifera with 22 species and 540 specimens with 85.98% relative abundance. Relatively a smaller number of specimens 88 and four different species were found in suborder Ensifera with 14.01% relative abundance. Total 20 species having 474 specimens belonged to family Acrididae and two species having 66 specimens belonged to family Pyrgomorphidae of suborder Caelifera of order *Orthoptera*. Four species having 88 specimens belonged to family Tettigoniidae of suborder Ensifera of order *Orthoptera* (Figure 1).

The most abundant and diverse subfamily was Oxyinae with six species having 192 specimens followed by Acridinae with five species having 161 specimens. The least abundant subfamily was Melanoplinae with one species having only six specimens followed by Conocephalinae with one species having 20 specimens. The most abundant species were *Oxya japonica* having 63 specimens and *Oxya hyla* with 58 specimens. While the least abundant species were *Sphingonotus Indus* only having five specimens, *Melanoplus bivittatus* and *Chorthippus biguttulus* having six specimens each. In the current research 26 taxonomical species were identified having 628 collected specimens with Shannon diversity index 3.038 (Table 2).

According to the feeding habits of collected Orthopteran species, 23 were herbivores and can gain the status of being a pest. Some herbivorous insect species were further characterized as graminivorous (feeding on grass), forbivorous (feeding on forbs) and monophagous in nature. Two species were scavengers but they also act as herbivoures including *Hexacentrus japonicas* and *Ducetia japonica*. In the collected species only one species was predator in nature *Phaneroptera nana* which preys on European grapewine moth. The insects were identified according to distinct morphological characteristics up to species level (Table 3).

3.2. Crop wise variation of order *Orthoptera* species

The sampling was done from three different crops rice, sorghum and maize. The current study represented high diversity and abundance of Orthopteran species in the selected crops. 268 specimens were collected from sorghum (*Sorghum bicolor*) having the highest diversity and abundance of *Orthoptera* species followed by rice (*Oryza sativa*) from which 231 specimens were collected and relatively less number of specimens were collected in maize crop (*Zea mays*) 129 in number (Figure 2).

Table 1. Diversity and percent relative abundance of order *Orthoptera* from crops system of district Sialkot.

Suborder	Family	Subfamily	Species	No. of specimen
Caelifera	Acrididae	Acridinae	*Acrida cinerea*	3.98(25)
			Acrida exaltata	3.34(21)
			Acrida gigantea	7.8(49)
			Acrida turrita	5.41(34)
			Acrida ungarica	5.1(32)
		Oxyinae	*Oxya chinensis*	7.48(47)
			Oxya fuscovittata	1.43(9)
			Oxya hyla	9.24(58)
			Oxya japonica	10.03(63)
			Oxya nitidula	1.11(7)
			Oxya velox	1.27(8)
		Gomphocerinae	*Chorthippus biguttulus*	0.96(6)
			Dichromorpha viridis	2.55(16)
		Hemiacridinae	*Hieroglyphus banian*	4.46(28)
		Melanoplinae	*Melanoplus bivittatus*	0.96(6)
		Oedipodinae	*Chortophaga viridifasciata*	2.23(14)
			Locusta migratoria	1.59(10)
			Oedaleus infernalis	3.82(24)
			Sphingonotus Indus	0.8(5)
			Trilophidia annulata	1.91(12)
	Pyrgomorphidae	Pyrgomorphinae	*Atractomorpha crenulata*	7.32(46)
			Atractomorpha lata	3.18(20)
Ensifera	Tettigoniidae	Conocephalinae	*Conocephalus melaenus*	3.18(20)
		Hexacentrinae	*Hexacentrus japonicas*	5.1(32)
		Phaneropterinae	*Ducetia japonica*	2.55(16)
			Phaneroptera nana	3.18(20)
			Total	100(628)

Table 2. Shannon diversity index of order *Orthoptera* species from crops system of district Sialkot.

Taxa-S	26
Individuals	628
Dominance_D	0.05612
Simpson-1-D	0.9439
Shannon-H	3.038
Evenness_e^H/S	0.8027

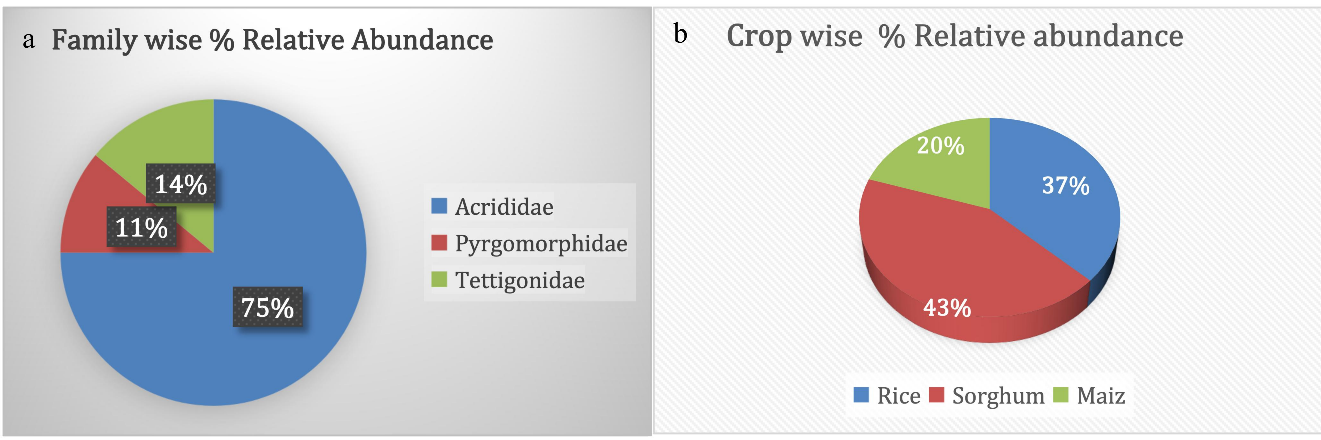


Figure 1. (a) Percent relative abundance of families of *Orthoptera*, (b) Crop wise Percent relative abundance of order *Orthoptera* species.

Table 3. Morphological identification characteristics of collected Orthopteran species.

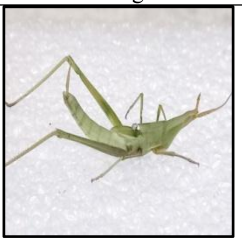
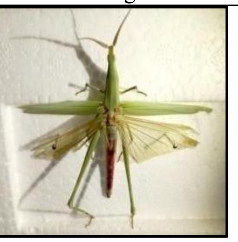
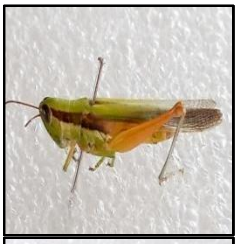
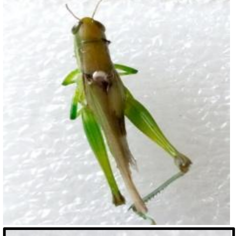
Identification characteristics	Images	Identification characteristics	Images
1. *Acrida cinerea* Common name: Chinese Grasshopper/ Oriental longheaded grasshopper. They are either green or brown in color. Have long conical head.		2. *Acrida exaltata* Long conical head is present and festigium of vertex is long beyond eyes. The head and pronotum are having equal length.	
3. *Acrida gigantea* Common name: Silent slant faced grasshopper Head is slightly longer and can be shorter than pronotum. Pronotum and head have pale pinks bands.		4. *Acrida turrita* Common name: Short-horned grasshopper Head is long and festigium of the vertex is extending in front of the eyes.	
5. *Acrida ungarica* Common name: Cone headed grasshopper/ nosed grasshopper/ Mediterranean slant-faced grasshopper Have conically ascending head.		6. *Oxya chinensis* Common name: Rice grasshopper The lateral sides are having a brown or black color band which runs from the eye to the whole three segments.	
7. Oxya fuscovittata Antennae are filiform. It is slightly longer than head and pronotum.		8. *Oxya hyla* Common name: Rice grasshopper Large head and obtuse fastigium is present. Face is vertical in position.	
9. *Oxya japonica* Common name: Japanese grasshopper The dorsal side of the pronotum and the wings are brown in color.		10. *Oxya nitidula* They are olive green or yellow in color. A brown stripe runs on the pronotum.	
11. Oxya velox Have a black band running from the eye till the base of tegmina. Vertex is having brown lines.		12. *Chorthippus biguttulus* Common name: Bow-winged grasshopper The carinae of pronotum are sub parallel.	
13. Dichromorpha viridis Common name: Short winged green grasshopper Filiform antennae are present and pronotum is flat. Wings are short.		*14. Hieroglyphus banian* Common name: Rice grasshopper The insect and the antennae are green in color. They are having four sulci.	

Table 3 Continued..

15. *Melanoplus bivittatus*

Common name:
Two striped grasshopper/ Yellow striped grasshopper
They have pale yellow stripes from their eye until the wings which helps in identification.

16. *Chortophaga viridifasciata*

Common name:
Green striped grasshopper
Have rigid pronota. Wings are smokey near the tips.

17. *Locusta migratoria*
Common name:
Migratory locust
Ridged and constricted pronotum is present. Length of tegmina is long and brown in color.

18. *Oedaleus infernalis*

Common name:
Band winged grasshopper
The arolium is extremely short. The hindlegs are having yellow and brown colored bands.

19. Sphingonotus Indus
Head is punctured and has coastal ridges. Hindwings are having black bands.

20. *Trilophidia annulata*
Commom name:
Band winged grasshopper
They are brown or grey in color with black markings. Tegmina are grey in color and have two brown bands.

21. *Atractomorpha crenulata*

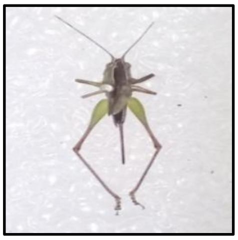
Common name:
Tobacco grasshopper
It has well developed tegmina and green in color. They have short antennae and are having light pink shade.

22. *Atractomorpha lata*

Common name:
Smaller longhead grasshopper
They are identified by their conical head. Distinct lateral carinae is present on pronotum. No membranous area is present near the pronotum.

23. *Conocephalus melaenus*

Common name:
Black-kneed meadow katydid
They are usually small to medium sized less than 17mm. They have no spines on front tibiae's dorsal surface.



24. *Hexacentrus japonicus*

Common name:
Bush cricket
Have broad tegmen which is modified for the purpose of stridulation.

25. *Ducetia japonica*

Common name:
Bush cricket/ White Median-striped katydid
They have long hair like antennae and are monochromatic.

26. *Phaneroptera nana*

Common name:
Mediterranean katydid/ Southern sickle bush cricket
Hindwings are longer than the forewings.

So according to the following statistics rich diversity of *Orthoptera* was present in the crops system of district Sialkot.

One way ANOVA was applied for three different crops from which insects were collected. The level of significance (α value) was set at 0.05 in all the statistical analysis for estimating the significance of the results. The actual level of significance (p value) was 0.006 which is less than α value so it indicates that the results were significant and there was variation in total amount of species collected from different crops. For estimation of difference of mean Tukey test was applied. Maize vs sorghum had the lowest p value giving significant results (Table 4).

Table 4. Multiple Comparison Test for crop wise diversity.

Difference of Levels	Difference of Means±SE	95% CI	T-Value	P-Value
Sorghum vs Rice	1.42±1.68	(-2.59 - 5.44)	0.85	0.675ns
Maize vs Rice	-3.92±1.68	(-7.94 - 0.09)	-2.33	0.057ns
Maize vs Sorghum	-5.35±1.68	(-9.36 - 1.33)	-3.18	0.006**

Table 5. Multiple Comparison Test for Month wise diversity.

Difference of Levels	Difference of Means±SE	95% CI	T-Value	P-Value
July vs June	2.50±1.28	(-0.84 -5.84)	1.96	0.211ns
August vs June	6.19±1.28	(2.85 - 9.53)	4.85	0.001**
September vs June	6.69±1.28	(3.35 - 10.03)	5.24	0.001**
August vs July	3.69±1.28	(0.35 - 7.03)	2.89	0.024*
September vs July	4.19±1.28	(0.85 - 7.53)	3.28	0.008**
September vs August	0.50±1.28	(-2.84 - 3.84)	0.39	0.980ns

Data are expressed as mean ± standard error. P-value for factors are given as (*p>0.05*: ns, *p<0.05*: *, *p<0.01*: **, *p<0.001*: ***)

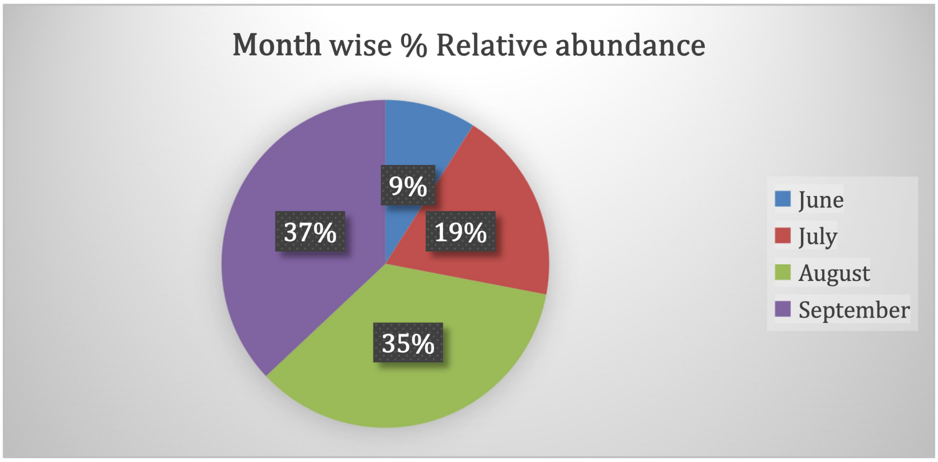


Figure 2. Month wise %relative abundance of order *Orthoptera* species.

3.3. Month wise variation of order *Orthoptera* species

From June to September, increase in the number of diversity and relative abundance was observed. The highest diversity and abundance of *Orthoptera* was determined in the month of September in which 231 specimens were collected during the fortnight visit in the agricultural areas followed by month of August in which 218 specimens were collected which was also very high and 122 specimens were collected in month of July. In June 57 specimens were sampled which was least in all four month (Figure 2).

One way ANOVA was applied on diversity of four month in which insects were collected. The p value was 0.001, indicating variation in total amount of species collected in four month time span. Tukey test for month wise variation represented significant difference in collected specimens of all the compared months except for July vs June and September vs August (Table 5).

4. Discussion

Diversity of order *Orthoptera* in crops System of district Sialkot, Pakistan was reported in this study. Species were collected from different tehsils of district Sialkot including, Sialkot, Sambrial, Pasrur and Daska. A total of 628 specimens were collected belonging to order *Orthoptera* and its two suborders' Caelifera and Ensifera. Sampling was carried out for a period of four months from June to September, 2022.

The most diverse and relatively abundant family was Acrididae with 20 species pertaining to six subfamilies, two species belonged to family Pyrgomorphidae of suborder Caelifera and four species belonged to family Tettigoniidae of suborder Ensifera of order *Orthoptera* [19]. The most abundant and diverse subfamily was Oxyinae 30.57% followed by Acridinae 25.64%, Oedipodinae 10.35% and Gomphocerinae 3.5%. Results are being supported by Ali et al. [6] in which Oxyinae, Acridinae, Oedipodinae and Gomphocerinae subfamilies were also abundant.

The highest diversity and abundance of *Orthoptera* was in the month of September. The results reported are like Mazhar [20], leading to the increase of locust population with the increase in temperature and precipitation. Geppert et al. [21]. Studied the relation between plant communities and temperature in the herbivore group including Orthopteran insects, and recorded the Orthopteran insects to be limited in cold temperature whereas, in abundance with the increase in temperature. Hussain et al. [22] Also stated increase in abundance of Orthopteran species from May to September in croplands of Sialkot, Punjab, Pakistan due to the rainy season. So, it can also be an environmental factor which results in an increase of Orthoptera specimens.

Total 268 specimens were collected from sorghum (42.68%) having the highest diversity and abundance of *Orthoptera* species followed by rice (36.78%) from which 231 specimens were collected and relatively a smaller number of specimens 129 were collected from maize crop (20.54%). Hussain et al. [22] Studied the Orthopteran biodiversity in paddy fields and concluded that high diversity of Orthopterans is present in theses field and can become serious pest of crops which is similar to our findings. According to research done by Hussain et al. [22] high abundance was present in rice fields of Sialkot but according to our research Orthopteran insects are not only major pest of rice but are also abundantly present in sorghum crop. This might be due to vegetation type-or? less use of insecticide in the sorghum crop. Rice crops are sprayed heavily due to its economic importance compared to sorghum crops, which may have allowed the insects to survive and multiply freely, resulting in a higher count of orthopteran insects in sorghum.

The most abundant species was *O. japonica* (10.03%) having 63 specimens in the current study. Oxya common name is rice grasshopper because it usually feeds on rice. So it can become serious pest of rice according to Li et al. [24]. The findings of present study indicate that Orthopteran insects may become serious pests of rice, sorghum and maize if not managed properly. For the effective control of insects integrated pest management (IPM) techniques should be implemented. Regular field monitoring, crop rotation, modern cultivation practices and biological control methods should be encouraged. Recommended insecticidal doses should only be done in case of severe infestation of insects.

5. Conclusion

Total 628 specimens were collected of order *Orthoptera* belonging to two suborders Caelifera and Ensifera for a period of four months, from June to September 2022 and an increase in the number of diversity and relative abundance was observed with each passing month. The sampling was done from three different crops rice, sorghum, and maize. Total 26 species were collected and identified which belonged to three families Acrididae, Pyrgomorphidae and Tettigoniidae. In a nutshell, high diversity and abundance of Orthopteran species is present in district Sialkot which can become serious agricultural pest if not effectively controlled.

Author contributions

Moazama Batool: Conceptualization, Validation, Supervision. Tayyaba Zahoor: Conceptualization, Supervision, Writing-review & editing. Sajida Mushtaq: Conceptualization, Supervision. Wajeeha Tanveer: Investigation, Data curation, Formal analysis, Writing-original draft. Sadia Maalik: Writing -review & editing. Nazia Ehsan: Formal analysis, Validation, Writing-review & editing. All authors have read and agreed to the published version of the manuscript.

Ethical approval

Ethical approval was obtained from GCWUS Ethical Review Board, Ethical letter No.D/REG/EIRB/22/3203).

Conflicts of Interest

All authors declare that they have no conflicts of interest.

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Data availability statement

The data presented in this study are available on request from the corresponding author.

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