



Investigation on the Biology of *Helicoverpa armigera* (Hubner) on Chickpea under Laboratory Condition

Sachin Kumar Yadav ^{a++*}, D. R. Singh ^{a#},
Ram Singh Umrao ^{a†}, Vishal Yadav ^{b++}, Gaurav Yadav ^{c++}
and Abhishek Pati Tiwari ^{c++}

^a Department of Entomology, CSAUA&T Kanpur (UP) – 208002, India.

^b Department of Vegetable Science, CSAUA&T Kanpur (UP) – 208002, India.

^c Department of Seed Science and Technology, CSAUA&T Kanpur (UP) – 208002, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2024/v27i5826

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/114667>

Original Research Article

Received: 02/02/2024

Accepted: 06/04/2024

Published: 22/04/2024

ABSTRACT

The *Helicoverpa armigera* (Hubner) is a polyphagous pest that is found throughout the world. Due to its damaging nature, it causes quantitative as well as qualitative loss and finally overall economic loss in agricultural crop production. So, the present investigation was done by rearing of *H. armigera* on chickpeas under laboratory conditions. The study revealed that this pest has four distinct stages i.e., egg, larva, pupa, and adult for completing its life cycle. The total life cycle of males and females were completed in 49-50 days and 52.30-53.00 days, respectively. The whole life period was divided as the incubation period takes 4-5 days, larval stage was completed in

⁺⁺ Ph.D. Research Scholar;

[#] Professor;

[†] Assistant Professor;

*Corresponding author: E-mail: sachincsak@gmail.com;

20.00-20.50 days by passing through six instars under laboratory conditions at a temperature of $27\pm 1^{\circ}\text{C}$ with $70\pm 5\%$ relative humidity in 12 hours of light. The last larval instar did not molt and it contracted into a grub-like pre-pupal stage which lasted for 2-3 days and a pupal period of 13-14 days. The adult period of male and female insects was completed in 8.50-9.00 and 12.00-12.50 days, respectively. The female moths had a pre-oviposition period of 3-4 days that included a sexual maturity period. The oviposition and post-oviposition periods recorded were 5-6 days and 2 days, respectively. A single female produced on average 992.50-1085 eggs throughout her entire life span. The average hatching percentage of eggs recorded on 63.00-67.50 percent.

Keywords: *Helicoverpa armigera*; biology; chickpea; fecundity.

1. INTRODUCTION

Helicoverpa armigera (Hubner) commonly known as the cotton bollworm or chickpea pod borer, is a polyphagous pest belongs order lepidoptera family noctuidae. *Helicoverpa armigera* are typically dull light brown in color with a wing expanse of 30-45 mm. Fore wings of the moth are with a series of irregular, a pale band near the margin. Hind wings are pale with a dark broad outer margin with a pale patch in it. Lifecycle of *H. armigera* take 4-6 weeks from egg to adult in summer and 8-12 weeks in spring or autumn. The lifecycle stages are egg, larva, pupa and adult. The female moths lay eggs on tender parts of the plant, a single moth can lay up to 500-890 eggs. The freshly laid eggs are yellowish-white in colour. The apical area of egg is smooth and the rest of the surface sculptured in the form of longitudinal ribs. Larva had six distinct instars in chickpea" [1]. Thus, it causes significant damage to various crops due to having a wide and large diverse range of host plant in major agricultural crops, including chickpea.

"In India Chickpea (*Cicer arietinum* L.) is an important legume pulse crop (family: *Fabaceae*) and also known as the king of pulses, Ceci bean, Bengal gram, Garbanzo bean, Chana and Sanagalu bean. This is a rich source of protein among the food crops grown in India so it is also known as poor man's meat. India is the largest producer and consumer of pulses which constitute about 27 percent of the Indian diet. It is the most important pulse crop in the world, cultivated in an area of 13.84 million hectares with a production of 13.65 million tonnes. In India chickpea, is grown in an area of 9.85 million hectares with a production of 11.99 million tonnes. In India, Rajasthan is the largest chickpea-growing state with an area of 2.46 million hectares with a production of 2.66 million tonnes followed by Maharashtra and MP. Uttar Pradesh is the 4th largest producer with an area

of 0.62 million hectares with production of 0.85 million tonnes" [2]. "Chickpea pods in raw form are consumed as both whole fried or boiled and salted. It is made into split pulse (Chana dal) which is cooked and eaten and as flour (Besan) out of which a variety of dishes like snacks and sweets are made. Fresh green leaves and grains are used as vegetables (Chhole). It is being used increasingly as a substitute for animal protein. The straw of chickpea is an excellent source of fodder for cattle besides both husk and bits of the 'Dal' serve as valuable cattle feed. Chickpea seed contains 18.22 percent protein, 16-62 percent total carbohydrate, 47 percent starch, 5 percent fat, 6 percent crude fibre, 6 percent soluble sugar, and 3 percent ash" [3]. "Although pulses have been consumed for thousands of years for their nutritional qualities" [4].

Understanding the reproductive biology of *Helicoverpa armigera* on chickpea is equally imperative. Studies delve into aspects such as mating behavior, fecundity, fertility, and oviposition preferences of adult moths reared on chickpea plants in laboratory conditions. Observations of egg-laying patterns and the number of eggs laid per female provide insights into the reproductive potential and population dynamics of this pest species. In laboratory settings, researchers conduct comprehensive studies to elucidate the various aspects of *Helicoverpa armigera* life cycle, behavior, and interactions with chickpea plants. These studies typically encompass several key elements that shed light on the dynamics of this pest species.

2. MATERIALS AND METHODS

The present study entitled "Investigation on the biology of *Helicoverpa armigera* (Hubner) on chickpea under laboratory condition" was carried out at the Department of Entomology C. S. Azad University of Agriculture and Technology, Kanpur during rabi season 2021-22 and 2022-23. The culture of *Helicoverpa armigera* was reared in the laboratory of the Department of Entomology at a

constant temperature of $27\pm 1^{\circ}\text{C}$, and $70\pm 5\%$ relative humidity and 12 hours of light. A pure culture of *Helicoverpa armigera* was developed by collecting its larvae from the field and their rearing in the laboratory to get sufficient adult emergence, which were held in glass jars of 20x15 cm size and offered 10 percent glucose solution in cotton swabs as food to them. Folded papers were kept in the jar to serve as a substrate for resting and egg laying.

"The eggs were laid singly on marking cloth. These eggs as well as pupae were treated along with the cloth in sodium hypochloride solution to prevent the viral infection in culture, the larvae on hatching, were transferred to a glass vial (10x2.5 cm) containing approximately 10g of artificial diet as described by Sri et al. [5]. They were fed on the artificial diet, having chickpea flour (100g), agar-agar (12.8g), yeast (30.0g) methyl-parahydroxy benzoate (2.0g), sorbic acid (1.0g), ascorbic acid (3.2g), Wesson salt mix (7.2g), streptomycin sulfate(40g), vitamin supplement (2.0ml), choline chloride (10% 7.2ml), formaldehyde (40% 1.0ml), carbendazim (0.500g), water (720ml) and covered with black cloth on attaining the second instar (1.5 to 2 cm long) the larvae were transferred to individual vials (7.5x2.5 cm) to avoid cannibalism. As soon as pupation takes place inside the vials, it was separated 2-3 days after pupation to avoid damage" Armes et al. [6].

3. RESULTS AND DISCUSSION

The freshly laid eggs were hemispherical with a flat base and yellowish white and changed to deep yellow after a day and then changed to dark or grey-black a day before hatching. The average incubation period was recorded as 5.00 ± 1.41 and 4.00 ± 1.41 days during 2021-22 and 2022-23 (Tables 1&2). The average hatching percentage of eggs was recorded at 63.00 ± 7.07 and 67.50 ± 7.78 percent in respective years (Tables 3&4). These findings are following the results of earlier workers, Baikar and Naik [7], Chaitanya et al. [8], Chakravarty et al. [9], Choudhury et al. [10], Nunes et al. [11] and Sharma et al. [12].

The larva passed through six instars. Freshly emerged first instar larvae were translucent and yellowish white with black heads, while, the second instar larva was yellowish green in color with black thoracic legs. The full-grown larva was brownish or pale green-brown lateral strips and a

distinct dorsal stripe and it was long and ventrally flattened but convex dorsally. The average larval period of first, second, third, fourth, fifth, and sixth instar larvae were 3.50 ± 0.71 , 2.50 ± 0.71 , 2.50 ± 0.71 , 3.50 ± 0.71 , 4.00 ± 1.41 and 4.50 ± 2.12 , at respective days during 2021-22 (Table 1). During 2022-23, the average larval period of first, second, third, fourth, fifth, and sixth instar larvae were 2.50 ± 0.71 , 3.00 ± 1.41 , 2.50 ± 0.71 , 3.50 ± 0.71 , 4.00 ± 1.41 and 4.50 ± 2.12 , at respective days. (Table 2). The total larval development period was on an average of 20.50 ± 6.36 and 20.00 ± 7.07 days during 1st and 2nd year (Tables 1&2). The present findings are also supported by Baikar and Naik [7], Chakravarty et al. [9], Deepa and Srivastava [13], Jaykumar et al. [14], Nunes et al. [11] and Sharma et al. [12].

In this stage, the full-grown larva becomes sluggish, wrinkled, and suspended feeding and movement. The average of the pre-pupal stage was 2.00 ± 1.41 and 3.00 ± 1.41 days, respectively during 1st and 2nd year (Tables 1&2). In agreement with our findings, Acharya et al. [15], Baikar and Naik [7], Chaitanya et al. [8], Chakravarty et al. [9], Nunes et al. [11], Sharma et al. [12] and Singh and Yadav [16].

Freshly formed pupa was light green and yellowish in color but later on turned into dark brown before emergence of moth. The pupa was object type, broadly rounded anteriorly and tapered posteriorly. The average duration pupal stage was 13.00 ± 4.24 and 14.00 ± 2.83 days in respective year (Tables 1&2). In support of our findings, Acharya et al. [15], Baikar and Naik [7], Chaitanya et al. [8], Chakravarty et al. [9], Nunes et al. [11] and Sharma et al. [12] also found.

The adult moth was a brownish color, forewing was pale brown with a series of dots on the margins and a black kidney-shaped mark on the underside of each forewing. Hind wings were lighter in color with dark patch at the apical end. The female moth was slightly bigger than the male moth and was identified by the presence of a tuft of hair on the tip of the abdomen. The average time duration male stage was 8.50 ± 2.12 and 9.00 ± 1.41 days and female stage was 12.00 ± 2.83 and 12.50 ± 3.54 days, respectively during 1st and 2nd year (Tables 1&2). The present findings are also supported by Baikar and Naik [7], Chakravarty et al. [9], Nunes et al. [11], and Sharma et al. [12].

Table 1. Period of various stages of gram pod borer, *Helicoverpa armigera* (Hubner) reared on chickpeas in laboratory condition during Rabi 2021-22

Sl. No.	Stage	Period (days)		
		Min.	Max.	Av. ± S.D.
1	Incubation period	4	6	5.00±1.41
2	Larval period			
	I instar	3	4	3.50±0.71
	II instar	2	3	2.50±0.71
	III instar	2	3	2.50±0.71
	IV instar	3	4	3.50±0.71
	V instar	3	5	4.00±1.41
	VI instar	3	6	4.50±2.12
	Total larval period	16	25	20.50±6.36
3	Prepupa period	1	3	2.00±1.41
	Pupal period	10	16	13.00±4.24
4	Adult period			
	Male	7	10	8.50±2.12
	Female	10	14	12.00±2.83
5	Total life period			
	Male	38	60	49.00±15.56
	Female	41	64	52.50±16.26

Table 2. Period of various stages of gram pod borer, *Helicoverpa armigera* (Hubner) reared on chickpea in laboratory condition during Rabi 2022-23

Sl. No.	Stage	Period (days)		
		Min.	Max.	Av. ± S.D.
1	Incubation Period	3	5	4.00±1.41
2	Larva Period			
	I instar	2	3	2.50±0.71
	II instar	2	4	3.00±1.41
	III instar	2	3	2.50±0.71
	IV instar	3	4	3.50±0.71
	V instar	3	5	4.00±1.41
	VI instar	3	6	4.50±2.12
	Total larval period	15	25	20.00±7.07
3	Prepupa period	2	4	3.00±1.41
	Pupal period	12	16	14.00±2.83
4	Adult period			
	Male	8	10	9.00±1.41
	Female	10	15	12.50±3.54
5	Total life period			
	Male	40	60	50.00±14.14
	Female	42	65	53.50±16.26

Table 3. Pre-oviposition, oviposition, post-oviposition, fecundity and hatching percentage of gram pod borer, *Helicoverpa armigera* in laboratory condition during Rabi 2021-22

Sl. No.	Stage	Period (days)		
		Min.	Max.	Av. ± S.D.
1	Pre- oviposition period (days)	2	4	3.00±1.41
2	Oviposition period (days)	5	7	6.00±1.41
3	Post-Oviposition period (days)	1	3	2.00±1.41
4	Fecundity	635	1350	992.50±505.58
5	Hatching percentage	58	68	63.00±7.07

Table 4. Pre-oviposition, oviposition, post-oviposition, fecundity and hatching percentage of gram pod borer, *Helicoverpa armigera* in laboratory condition during Rabi 2022-23

Sl. No.	Stage	Period (days)		
		Min.	Max.	Av. \pm S.D.
1	Pre- oviposition period (days)	3	5	4.00 \pm 1.41
2	Oviposition	4	6	5.00 \pm 1.41
3	Post-Oviposition	1	3	2.00 \pm 1.41
4	Fecundity	650	1520	1085 \pm 615.18
5	Hatching percentage	62	73	67.50 \pm 7.78

Pre-oviposition, oviposition and post-oviposition periods: The average number of eggs laid by a female of *Helicoverpa armigera* was 992.50 \pm 505.58 and 1085.00 \pm 615.18 respectively both years. The average pre-oviposition period was noticed as 3.00 \pm 1.41 and 4.00 \pm 1.41 days respectively both years. The average oviposition and post-oviposition periods were 6.00 \pm 1.41 and 2.00 \pm 1.41 days during the first and during the second year, 5.00 \pm 1.41 and 2.00 \pm 1.41 days, respectively. The average hatching percentage of eggs was 63.00 \pm 7.07 and 67.50 \pm 7.78 days during 1st & 2nd year (Tables 3&4) Ali et al. [1], Gadhiya et al. [17] and Patel et al. [18].

The total life period (egg to death of adult) of *Helicoverpa armigera* an average of 49.00 \pm 15.56 and 50.00 \pm 14.14 days in males and females was 52.50 \pm 16.26 and 53.50 \pm 16.26 days in during 1st and 2nd year (Tables 1&2), indicating that *Helicoverpa armigera* females have longer average life than the males Deepa and Srivastava [13], Choudhury et al. [10] and Parmar [19].

The present findings also supported by Bhatt and Patel [20] studied "the biology of *Helicoverpa armigera* at room temperature from December 1998 to February 1999. There were six larval instars and the larval period was 20.60 \pm 1.78 days while the pupal period was 16.21 \pm 1.40 days. The average longevity of males was 9.15 \pm 0.90 days, whereas that of females was 11.40 \pm 0.91 days. The duration of total life span (egg to death of adult) for males was 50.9 \pm 4.89 days while for females, it was 53.90 \pm 5.41 days. The average number of eggs laid by females was 990.70 \pm 127.40. The hatching percentage of eggs was 90.89 \pm 5.23. The pre-oviposition, oviposition, and post-oviposition periods were 2.85 \pm 0.65, 7.5 \pm 0.86, and 1.10 \pm 0.54 days, respectively". Khandwe and Gujrati [21] reported "the biology of the pod borer, *Helicoverpa armigera*, on pigeon peas was studied in the laboratory. The female moth laid eggs on buds, flowers, and leaves of pigeon

peas, in small batches of 1 to 10. The average incubation, larval, pre-pupal, and pupal period lasted for 3.93+ or -0.85, 18.06+ or -0.77, 2.26+ or -0.44 and 16.66+ or -1.24 days, respectively. The average adult longevity was 10.8+ or -1.46 days for males and 13.4+ or -1.08 days for females. The average life cycle lasted for 40.51+ or -3.30 days". Hossain et al. [22],[23,24] "the pre-oviposition, oviposition, and post-oviposition periods were 2.25+ or -0.19, 3.45+ or -0.23 and 1.15+ or -0.08 days, respectively. Females laid 680-1620 eggs singly or 2-6 eggs in a cluster at night during 3.45 days of oviposition period. The hatching percentage of eggs was 85.77+ or -5.19. The incubation period of the egg ranged from 2-4 days. The larva passed through six instars and the durations of 1st, 2nd, 3rd, 4th, 5th, and 6th instar larvae were 2-4, 2-4, 2-3, 1-3, 1-3, and 1-2 days, respectively. The length and breadth of full-grown larvae ranged 25.0-36.0 mm and 4.0-5.5 mm, respectively. A period of 10-15 and 9-14 days were required to complete larval and pupal stages, respectively. The longevity of males and females ranged 3-5 and 4-9 days, respectively. The male and female completed their life span (egg to death of adult) between 28-33 days and 29-36 days, respectively".

4. CONCLUSION

The average incubation period of an egg was recorded as 5.00 \pm 1.41 and 4.00 \pm 1.41 days during 1st and 2nd years. The average larval period of first, second, third, fourth, fifth, and sixth instar larvae were 3.50 \pm 0.71, 2.50 \pm 0.71, 2.50 \pm 0.71, 3.50 \pm 0.71, 4.00 \pm 1.41 and 4.50 \pm 2.12, at respective days during 1st year. During 2nd year the average larval period of first, second, third, fourth, fifth, and sixth instar larvae were 2.50 \pm 0.71, 3.00 \pm 1.41, 2.50 \pm 0.71, 3.50 \pm 0.71, 4.00 \pm 1.41 and 4.50 \pm 2.12, at respective days. The total larval development period was on an average of 20.50 \pm 6.36 and 20.00 \pm 7.07 days in during 1st and 2nd years. The average of the pre-pupal stage was 2.00 \pm 1.41 and 3.00 \pm 1.41 days,

respectively during 1st and 2nd year. The average duration pupal stage was 13.00±4.24 and 14.00±2.83 days at respective year. The average time duration male stage was 8.50±2.12 and 9.00±1.41 days and female stage was 12.00±2.83 and 12.50±3.54 days, respectively during 1st and 2nd year. The average number of eggs laid by a female of *Helicoverpa armigera* was 992.50±505.58 and 1085.00±615.18 respectively both years. The average pre-oviposition period was noticed 3.00±1.41 and 4.00±1.41 day respectively both years. The average oviposition and post-oviposition periods were 6.00±1.41 and 2.00±1.41 days during first year. During second year 5.00±1.41 and 2.00±1.41 days, respectively. The average hatching percentage of eggs was 63.00±7.07 and 67.50±7.78 percent respectively both years. The total life period (egg to death of adult) of *Helicoverpa armigera* on an average of 49.00±15.56 and 50.00±14.14 days in males and females was 52.50±16.26 and 53.50±16.26 days in during 1st and 2nd year. Clearly indicating that *Helicoverpa armigera* females have longer average life that the males.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ali A, Choudhury RA, Ahmad Z, Rahman F, Khan FR, Ahmad SK. Some biological characteristics of *Helicoverpa armigera* on chickpea. Tunisian Journal of Plant Protection. 2009;4:99-106.
2. Anonymous. Directorate of Economics & Statistics, Department of Agriculture & Farmers Welfare (DAC&FW), Govt. of India; Agriculture statistics at a glance. 2021;42-43.
3. Jukanti AK, Gaur PM, Gowda CLL, Chibbar RN. Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.). British Journal of Nutrition. 2012;108S11-S26.
4. Kerem Z, Yadun LS, Gopher A, Weinberg P, Abbo S. Chickpea domestication in the neolithic Levant through the nutritional perspective. Journal of Archaeological Science. 2007;34:1289-1293.
5. Sri IA, VR Rao, PR Sekhar, Chalam MSV. Taxonomic studies on different lepidopteran caterpillars on cotton, chilli and pulses. Ann. Pl. Protec. Sci. 2010; 18:104-107.
6. Armes NJ, Jadhav DR, Bond GS, King ABS. Insecticide resistance in *Helicoverpa armigera* in southern India. Pesticide Sci. 1992;34:355-364.
7. Baikar AA, Naik KV. Biology of fruit borer, *Helicoverpa armigera* (Hubner) on chilli under laboratory conditions. Plant Archives. 2016;16(2):761-769.
8. Chaitanya T, Sreedevi K, Krishna TM, Prasanthi L. Biology and population dynamics of *Helicoverpa armigera* (Hubner) in *Cajanus cajan* (L.) Millsp. Ann. Pl. Protec. Sci. 2014;22:287-290.
9. Chakravarty S, Srivastava CP, Keval R. Biology of *Helicoverpa armigera* (Hubner) on chickpea based artificial diet under laboratory conditions. Annals of Plant Protection Sciences. 2018;26(2):265-269.
10. Choudhury RA, Rizvi PQ, Ali A, Ahmad SK. Age specific life table of *Helicoverpa armigera* on *Cicer arietinum* under natural condition. Ann. Pl. Protec. Sci. 2013;21:57-61.
11. Nunes MLS, Figueiredo LL, Andrade RDS, Rezende JM, Czepak C, Albernaz-Godinho KC. Biology of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) rearing on artificial or natural diet in laboratory. Journal of Entomology. 2017;14(4):168-175.
12. Sharma VG, Kumar S, Srinivas G. Biology of *Helicoverpa armigera* (Hubner) on tomato in South Gujarat. Journal of Entomology and Zoology Studies. 2019; 7(5):532-537.
13. Deepa M, Srivastava CP. Biological characteristics of *Helicoverpa armigera*. Ann. Pl. Protec. Sci. 2010;18:370-372.
14. Jaykumar P, Jat MC, Singh A, Monga D. Life table studies of *Helicoverpa armigera* on cotton. Ann Pl. Protec. Sci. 2005;13:467-468.
15. Acharya MF, Vyas HJ, Gedia MV, Patel PV. Life table intrinsic rate of *Helicoverpa armigera* on cotton. Ann. Pl. Protec. Sci. 2007;15:338-341.
16. Singh SK, Yadav DK. Life table and biotic potential of *Helicoverpa armigera* on chickpea. Ann. Pl. Protec. Sci. 2009;17:90-93.
17. Ghadiya HA, Borad PK, Bhut JB. Bionomics and evaluation of different bio pesticides against *Helicoverpa armigera* (Hubner) Hardwick infesting groundnut. The Bioscan. 2014;9(1):183-187.

18. Patel RS, Patel KA, Patil KS, Toke NR. Biology of *Helicoverpa armigera* Hub. on rose in laboratory condition. Pest Management in Hort. Ecosystems. 2011; 17(2):144-148.
19. Parmar KD. Bio-ecology and management of *Helicoverpa armigera* (Hubner) Hardwick infesting okra. M.Sc. (Agri.) Thesis submitted to Anand Agricultural University, Anand; 2006.
20. Bhatt NJ, Patel RK. Biology of chickpea pod borer, *Helicoverpa armigera*. Indian Journal of Entomology. 2001;63(3):255-259.
21. Khandwe N, Gujrati JP. Biology of pod borer *Helicoverpa armigera* (Hubner) on Arhar. Bhartiya Krishi Anusandhan Patrika. 2002;17(2/3):126-131.
22. Hossain MA, Haque MA, Prodhan MZH. Biological, studies of pod borer, *Helicoverpa armigera* (Hubner) in chickpea. Annals of Bangladesh Agriculture. 2007;11(2):95-105.
23. Kumar P, Mishra DN, Singh DV, Kumar S, Shanker R, Patel A. Biology of pod borer, *Helicoverpa armigera* (Hubner) on Chickpea Leaves and pods under Laboratory conditions. Biological Forum – An International Journal. 2022;14(3):603-607.
24. Singh B, Kumar A, Gupta GP. Effect of natural host plants on biological parameters of *Helicoverpa armigera* (Hubner). Ann. Pl. Protec Sci. 2022;17: 279-282.

© Copyright (2024): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/114667>