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Zinc Induced Resistant against Yellow Stem Borer (*Scirpophaga incertulas*, Walker) in Rice

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Authors' contributions

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

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ABSTRACT

To confirm the zinc induced resistant against yellow stem borer, a field experiments were conducted during *kharif* 2022 and 2023 at N. M. College of Agriculture, Navsari Agricultural University, Navsari Gujarat (India). In experiment total eight treatments are given first four are soil application of zinc and next four are foliar application, Overall performance of the zinc treatments over two *kharif* seasons highlighting efficacy of zinc treatments in keeping the YSB damage in control both at vegetative and heading (reproductive) stages of the rice crop confirmed the superiority of treatment T_2 ($ZnSO_4$ @ 50 g/ha), T_4 (Zn- EDTA @ 25 kg/ha) and T_8 (foliar application of Biosynthesis Zinc nanoparticle @ 100 ppm). At vegetative stage, treatments T_2, T_4 and T_8 recorded numerically the lowest mean borer damage of 6.45, 7.60 and 8.60 per cent DH attributing in 55.61, 47.69 and 40.81 per cent decline in borer damage over control, respectively. While, at the heading stage, similar

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treatments T_2, T_4 and T_8 recorded numerically the lowest mean borer damage of 7.01, 8.28 and 9.69 per cent DH attributing in 62.63, 55.86 and 48.35 per cent decline in borer damage over control, respectively. YSB damage was significantly and negatively correlated at vegetative (r = -0.64**) and heading stage (r = -0.67**) with zinc content.

Keywords: Zinc induced resistance; rice; yellow stem borer; zinc sources.

1. INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Gramineae. Rice is India's prominent crop and is the premier staple food for 65 percent India's population and contributes 20-25 percent of the agricultural GDP [1]. India is the first in terms of area (43.79 mha) and second in production (168.50 million tonnes) of rice, next only to China. with an average productivity of 2494 to 3850 kg/ha below the average world average productivity of 4600 kg/ha [2]. In India, rice is grown in almost all the states among them, west Bengal and Uttar Pradesh have the highest rice production. Among the states, Gujarat ranked 16th with respect to rice production, contributing only 1.7% to country's total rice production in 2014 (Ministry of Agriculture and Farmer's Welfare, 2016). In Gujarat, rice is grown in an area of 0.86 million hectares covering the South and Middle Gujarat with a production of 2.84 million tonnes and productivity of 3.31 t/ha in the year 2017-18 [3]. The variations in climatic zones among these areas seem to have direct impact on production and productivity of rice in the state, which are also affected by different types of stress.

Biotic stress is a major contributor towards low crop productivity and financial loss to the farmers attributing to 27.9% by insect pests [4]. Nearly 300 species of insect pests are attacking rice crop at various crop growth stages and among them only 23 species cause notable damage [5]. Amongst the major pests, the rice stem borer complex is the most abundant borer complex supposedly cause the major part of destruction in rice crop throughout the world [6] leading to an average loss of 30% in yield [7]. This rice borer complex comprises of yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) is the most destructive pest that attacks rice plant from seedling to maturity in almost all ecosystem in both *kharif* and rabi seasons [8] causing a yield loss of about 10-60 per cent throughout the Indian sub-continent.

Farmers are more accepting of insecticidal applications for pest management due to their fast and efficient management of insect pests but excessive and irrational dependency on chemical control of insect pests has led to secondary pest outbreak, development of pesticide resistance, resurgence, environmental pollution and harmful residue in feed, directly or indirectly affecting our health. In this context, host plant resistance (HPR) in rice is a useful and alternate strategy that can be applied to control insect pests and minimize the yield losses, keep agricultural system eco-friendly and ensuring long-term soil and environmental sustenance [9]. Induced resistance through chemical elicitor such as fertilizers having silicon, zinc, manganese, and others are possible [10].

Zinc is an essential micronutrient plays a pivotal role in modulating plant defense responses against various stressors as it serves as a cofactor for all 6 classes of enzymes (oxidoreductases, transferases, hydrolases, lyases, isomerase and ligases). Zinc (Zn) emerges as a promising candidate for enhancing rice's resistance against insect herbivores, including the yellow stem borer [11]. Moreover, fifty per cent Indian soils are deficient in zinc [12] and numbers of Zn sources *viz*. $ZnSO_4$, ZnO, Zn-EDTA have been used to eliminate zinc deficiency [13]. Malandrakis et al. [14] suggested foliar application of several Zn based nano patrticles (NPs) alternatives against synthetic chemicals because of their high effectiveness at low doses in controlling infestation of insect pests and are eco-friendly. In view of above background, an attempt has been made to confirm the zinc induced resistant against yellow stem borer.

2. MATERIALS AND METHODS

To confirm the zinc induced resistant against yellow stem borer in rice, a field experiments were conducted during *kharif* 2022 and 2023 at N. M. College of Agriculture, Navsari Agricultural University, Navsari Gujarat (India). Field experiments were conducted in medium black clayey soil, slightly saline reaction with a pH (7.35), EC (0.38 dS/m) and deficient in available-Zn (0.345 ppm). Total nine treatments were tried *viz.*T_1: $ZnSO_4$ @ 25 kg/ha , T_2: $ZnSO_4$ @ 50 kg/ha, T_3: Zn-EDTA @ 12.5 kg/ha, T_4: Zn-EDTA @ 25 kg/ha, T_5: foliar application of $ZnSO_4$ @1%, T_6: Foliar application of Zn- EDTA @1% , T_7: foliar application of zinc nanoparticle @ 100 ppm, T_8: foliar application of biosynthesis Zinc nanoparticle @ 100 ppm and T_9: Control (Water spray only) to explore the mechanism of Zn induced resistance against the YSB, *S. incertulas* The selected field was subjected to rice-fallow cropping system each year and hence, suitably trial was super imposed in the two consecutive years for getting cumulative effect of the treatments. The experiments were laid in CRD, Large plot Techniques with three replications. Rice (*var*. GR 11) was fertilized with recommended dose of NPK while, zinc fertilization were made as per treatments. Foliar application of $ZnSO_4$ and Zn-EDTA, zinc nano particle and biosynthesized Zinc nano particle as per treatments was sprayed at tillering and grain filling stage of rice. The crop was raised following all recommended agronomic practices for rice. YSB damage at the vegetative (30 and 50 DAT) and heading stage (70 DAT) was calculated from the mean data of per cent dead heart (DH) at vegetative and white ear heads (WEH) at heading stage as follows:

$$\text{Percent dead hearts (\% DH)}$$

$$= \frac{\text{Total number of dead hearts x 100}}{\text{Total number of tillers}}$$

$$\text{Percent white ear heads (\% WEH)}$$

$$= \frac{\text{Total number of white heads x 100}}{\text{Total number of panicles bearing tillers}}$$

3. RESULTS AND DISCUSSION

***Kharif* 2022:** Significant effect of applied Zn through different sources was observed on damage by YSB (Table 1), right from early tillering stage (30 DAT). Significantly lower per cent of DH was recorded in treatmentT_2 (5.46, % DH) receiving $ZnSO_4$ @ 50 kg/ha through basal soil application and was on par with the treatments T_4 (6.47% DH) receiving Zn- EDTA @ 25 kg/ha through basal soil application and T_8 (7.18% DH) receiving foliar application of Biosynthesis Zinc nanoparticle @ 100 ppm while, treatment T_8 remained on par with treatments T_1 (7.52% DH) receiving $ZnSO_4$ @ 25 kg/ha through basal soil application), T_3 (8.14% DH) receiving Zn-EDTA @ 12.5 kg/ha through basal soil application and T_7 (9.10% DH) receiving foliar application of Zinc nanoparticle @ 100 ppm. Remaining zinc treatments T_5 and T_6 found less effective in controlling YSB damage.

The data on DH at 50 DAT revealed that treatment T_2 recorded significantly lower damage (8.85% DH) and was at par with treatments T_4 (10.53% DH) and T_8 (11.84 % DH) while, treatment T_8 stood on par with treatments T_1 (12.71% DH), T_3 (13.51 % DH) and T_7 (15.20% DH). Treatments T_5 and T_6 were found least efficient in controlling YSB damage.

Overall performance of the treatments during the vegetative stage as depicted in the mean column also exhibited the superiority of treatments T_2, T_4, T_8, T_1 and T_3 with numerically mean borer damage of 7.15, 8.50, 9.51, 10.11 and 10.82 per cent DH attributing in 54.19, 45.55, 39.08, 35.23 and 30.68 per cent decline in borer damage over control.

YSB damage at the heading stage is considered to be more critical, which contributes maximum to determining the crop yield. The performance of treatment T_2 in arresting the borer damage at the heading stage was superior and remained on par with treatment T_4 with a record of 8.70 and 10.60 per cent WEH resulting in 61.10 and 52.61 per cent decline in borer damage over control. Further, treatment T_4 was only at par with treatment T_8 having 11.94 % WEH and resulting in 46.62% decline in borer damage over control. While, remaining zinc treatments *viz.*T_1, T_3, T_5, T_6 and T_7 miserably failed to contain the borer damage.

***Kharif,* 2023:** Zinc applied through different sources generated significant and promising effect in minimizing YSB destructive effect in field *kharif* rice 2023 (Table 2) right from early tillering stage (30 DAT). Significantly lowest per cent DH was noticed in treatment T_2 (4.54 % DH) and was on par with only treatment T_4 (5.31% DH) while, treatment T_4 remained was at par with treatment T_8 (6.24 % DH) only. Amongst the remaining zinc treatments, treatment T_1, T_3, T_5 and T_7 found less effective as compare to treatments T_2, T_4 and T_8.

At 50 DAT, the data on YSB damage revealed that treatment T_2 ($ZnSO_4$ @ 50 kg/ha) recorded significantly lower damage (6.96% DH) and was at par with treatments T_4 (8.08% DH) and T_8 (9.14% DH). While, treatment T_8 stood on par with all remaining zinc treatments except T_6.

Overall performance of the treatments during the vegetative stage as depicted in the mean column exhibited the superiority of treatments T_2, T_4 and T_8 with numerically the lowest mean borer damage of 5.75, 6.69 and 7.69 per cent DH attributing in 57.18, 50.18 and 42.74 per cent decline in borer damage over control. Treatments T_1, T_3, T_7, T_5 and T_6 failed to contain the borer damage.

At the heading stage, treatment T_2 ($ZnSO_4$ @ 50 kg/ha) produced significantly the lowest YSB damage (5.68% WEH) resulting in 64.84% decline in borer damage over control. Next better treatment was T_4 (8.13% WEH) showing 60.68% decline in borer damage over control and stood on par with treatments T_8 (9.34% WEH), T_1 (8.82% WEH) T_3 (9.59% WEH) and T_7 (10.61% WEH) having 50.92, 41.82, 36.74 and 30.01 per cent decline in borer damage over control, respectively. Remaining zinc treatments *viz.* T_5 and T_6 failed to hold the borer damage.

Pooled: Pooled data revealed the overall performance of the treatments over two *kharif* seasons highlighting efficacy of zinc treatments in keeping the YSB damage in control both at vegetative and heading (reproductive) stages of the rice crop (Table 3). The pooled data confirmed the superiority of treatment T_2 ($ZnSO_4$ @ 50 kg/ha) as it registered minimum damage (5.00% DH) at early vegetative stage (30 DAT) and 7.90% DH damage at late vegetative stage (50 DAT). Next better treatments were T_4 and T_8 which also registered lower damage 5.89 and 6.71 per cent DH at early vegetative stage (30 DAT) and 9.30 and 10.48 per cent DH at late vegetative stage (50 DAT), respectively and stood on par among themselves. While, remaining zinc treatments *viz.* T_1, T_3, T_7, T_5 and T_6 were found less effective in arresting YSB damage.

Overall performance of the treatments during the vegetative stage as depicted in the mean column exhibited the superiority of treatments T_2, T_4 and T_8 with numerically the lowest mean borer damage of 6.45, 7.60 and 8.60 per cent DH attributing in 55.61, 47.69 and 40.81 per cent decline in borer damage over control, respectively. While, remaining zinc treatments *viz* T_1, T_3, T_7, T_5 and T_6 found less effective in arresting YSB damage.

At the heading stage the treatment T_2 noted minimum damage (7.01% WEH) having 62.63% decline in borer damage. Next better treatments were T_4 (8.28 % WEH) and T_8 (9.69 % WEH) resulting in 55.86 and 48.35 per cent decline in borer damage respectively. While, remaining zinc treatments *viz* T_1, T_3, T_5, T_6 and T_7 failed to hold the borer damage in rice.

Zinc induced resistant against YSB might be due to antibiosis effect of applied zinc on rice plant. Zn being an essential element plays a key role as a structural constituent, triggers the synthesis of defensive compounds which act as chemical shields against herbivores, Zn content is directly involved in plant defense mechanism enhancing rice's resistance against insect herbivores [15,16]. Panda [17] and Amsagowri et al. [18] reported the antagonistic indirect effect of zinc against yellow stem borer due to induced antibiosis effect of zinc and developing of hard *pseudostem.* Sardar et al. [19] confirmed the superiority of soil application of $ZnSO_4$ @ 10 kg/ha over chelated zinc (Zn- EDTA) and 0.5% foliar application of zinc alone. Malandrakis et al. [14] suggested foliar application of several Zn based nano particles (NPs) alternatives against synthetic chemicals because of their high effectiveness at low doses in controlling infestation of insect pests and are eco-friendly. Further, in present investigation, higher doses of either $ZnSO_4$ @ 50 kg/ha (T_2) or Zn- EDTA @ 25.0 kg/ha (T_4) found more effective than recommended doses of $ZnSO_4$ or Zn-EDTA for rice might be due to present rice variety was grown in Zn deficient field (0.395 ppm) hence application of zinc at higher rate might provides balanced nutrition to rice [19].

Zinc content: Zinc content from whole rice plant was chemically analyzed at vegetative, heading and at harvest and results are depicted in Table 4. Significantly higher Zn content was noticed in treatment T_2 at all stages *i.e.* vegetative (119.00ppm), heading (117.30 ppm) and at harvest stage (107.33 ppm) in field rice and was statistically on par with all remaining zinc treatments except, T_6 and T_7 at vegetative and harvest stages and T_5, T_6, T_7 and T_8 at heading stage. Results are in agreement with Dwivedi and Srivastva [20] who noticed that the application of 25 kg $ZnSO_4$/ha significantly increased 70.9% and 50.7 % zinc concentration in grain and straw of rice, respectively and Ahmed et al. [21] registered maximum increase of 66% Zn concentration in rice leaves and 127% increase in rice grain content over control with application of 15.0 kg Zn/ha through $ZnSO_4$.

Table 1. Effect of different zinc sources on damage caused by yellow stem borer in rice field (*kharif*-2022)

No.	Treatments	Damage at vegetative stage (DH%)				Damage at heading stage(%WEH)	
		30 DAT	**50 DAT**	**Mean**	**Decrease over control (%)**	**Heading stage**	**Decrease over control (%)**
T_1	Zinc Sulphate @ 25 kg/ha	7.52 (2.83)	12.71 (3.62)	10.11 (3.22)	35.23	15.23 (3.96)	31.78
T_2	Zinc Sulphate @ 50 kg/ha	5.46 (2.43)	8.85 (3.05)	7.15 (2.74)	54.19	8.70 (3.02)	61.10
T_3	Zinc EDTA @ 12.5 kg/ha	8.14 (2.94)	13.51 (3.74)	10.82 (3.33)	30.68	16.20 (4.08)	27.58
T_4	Zinc EDTA @ 25 kg/ha	6.47 (2.63)	10.53 (3.31)	8.50 (2.97)	45.55	10.60 (3.33)	52.61
T_5	Foliar application of Zinc Sulphate @ 1%	9.34 (3.14)	16.22 (4.08)	12.78 (3.61)	18.13	19.08 (4.41)	14.70
T_6	Foliar application of Zinc EDTA @ 1%	9.84 (3.21)	16.56 (4.13)	13.20 (3.66)	15.43	19.80 (4.50)	11.49
T_7	Foliar application of Zinc nanoparticle (100 ppm)	9.10 (3.10)	15.20 (3.96)	12.15 (3.53)	22.23	18.00 (4.30)	19.53
T_8	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	7.18 (2.76)	11.84 (3.51)	9.51 (3.13)	39.08	11.94 (3.52)	46.62
T_9	Control (Water spray)	12.20 (3.56)	19.04 (4.42)	15.62 (3.98)	0.00	22.37 (4.77)	0.00
	Mean	**8.36 (2.96)**	**13.38 (3.56)**	**11.09 (3.35)**	**-**	**15.77 (3.99)**	-
	S.E.m ±	0.12	0.15	-	-	0.17	-
	C.D.$_{0.05}$	0.34	0.46	-	-	0.49	-
	CV (%)	6.77	7.08	-	-	7.19	-

Table 2. Effect of different zinc sources on damage caused by yellow stem borer in rice field (*kharif*- 2023)

No.	Treatments	Damage at vegetative stage (DH%)				Damage at heading stage(%WEH)	
		30 DAT	**50 DAT**	**Mean**	**Decrease over control (%)**	**Heading stage**	**Decrease over control (%)**
T_1	Zinc Sulphate @ 25 kg/ha	7.35 (2.80)	9.49 (3.15)	8.42 (2.97)	37.30	8.82 (3.05)	41.82
T_2	Zinc Sulphate @ 50 kg/ha	4.54 (2.23)	6.96 (2.72)	5.75 (2.48)	57.18	5.33 (2.41)	64.84
T_3	Zinc EDTA @ 12.5 kg/ha	8.16 (2.94)	10.53 (3.31)	9.34 (3.13)	30.45	9.59 (3.17)	36.74
T_4	Zinc EDTA @ 25 kg/ha	5.31 (2.39)	8.08 (2.93)	6.69 (2.66)	50.18	5.96 (2.54)	60.68
T_5	Foliar application of Zinc Sulphate @ 1%	9.32 (3.13)	11.38 (3.44)	10.35 (3.29)	22.93	11.52 (3.47)	24.01
T_6	Foliar application of Zinc EDTA @ 1%	9.97 (3.23)	12.27 (3.57)	11.12 (3.40)	16.46	12.40 (3.58)	18.20
T_7	Foliar application of Zinc nanoparticle (100 ppm)	8.23 (2.95)	11.08 (3.40)	9.66 (3.18)	28.07	10.61 (3.33)	29.15
T_8	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	6.24 (2.59)	9.14 (3.10)	7.69 (2.85)	42.74	7.44 (2.81)	50.92
T_9	Control (Water spray)	11.42 (3.45)	15.43 (3.99)	13.43 (3.72)	0.00	15.16 (3.95)	0.00
	Mean	**7.84 (2.86)**	**10.48 (3.29)**	**9.16 (3.03)**	**-**	**9.65 (3.14)**	-
	S.E.m ±	0.12	0.15	-	-	0.17	-
	$C.D._{0.05}$	0.34	0.46	-	-	0.49	-
	CV (%)	6.77	7.08	-	-	7.19	-

Table 3. Pooled effect of different zinc sources on damage caused by yellow stem borer in rice field over seasons

No.	Treatments	Damage at vegetative stage (DH%)				Damage at heading stage(%WEH)	
		30 DAT	**50 DAT**	**Mean**	**Decrease over control (%)**	**Heading stage**	**Decrease over control (%)**
T_1	Zinc Sulphate @ 25 kg/ha	7.43 (2.81)	11.09 (3.38)	9.26 (3.12)	36.27	12.02 (3.51)	35.93
T_2	Zinc Sulphate @ 50 kg/ha	5.00 (2.32)	7.90 (2.88)	6.45 (2.63)	55.61	7.01 (2.71)	62.63
T_3	Zinc EDTA @ 12.5 kg/ha	8.14 (2.93)	12.01 (3.52)	10.08 (3.25)	30.63	12.89 (3.63)	31.29
T_4	Zinc EDTA @ 25 kg/ha	5.89 (2.51)	9.30 (3.12)	7.60 (2.84)	47.69	8.28 (2.93)	55.86
T_5	Foliar application of Zinc Sulphate @ 1%	8.66 (3.13)	13.80 (3.76)	11.23 (3.42)	22.71	15.30 (3.94)	18.44
T_6	Foliar application of Zinc EDTA @ 1%	9.33 (3.22)	14.41 (3.84)	11.87 (3.51)	18.31	16.09 (3.04)	14.23
T_7	Foliar application of Zinc nanoparticle (100 ppm)	8.66 (3.02)	13.14 (3.68)	10.90 (3.37)	24.98	14.30 (3.81)	23.77
T_8	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	6.71 (2.67)	10.48 (3.30)	8.60 (3.01)	40.81	9.69 (3.16)	48.35
T_9	Control (Water spray)	11.81 (3.50)	17.24 (4.20)	14.53 (3.87)	0.00	18.76 (4.36)	0.00
	Mean	**7.95 (2.90)**	**12.15 (3.52)**	**10.06 (3.22)**	**-**	**12.70 (3.45)**	-
	S.E.m ±	0.06	0.07	-	-	0.69	-
	$C.D._{0.05}$	0.18	0.22	-	-	2.07	-
		$C.D._{0.05}$	**$C.D._{0.05}$**	**$C.D._{0.05}$**	-	**$C.D._{0.05}$**	-
	Y	NS	NS	-	-	NS	-
	YxT	NS	NS	-	-	NS	-
	CV (%)	5.59	5.48	-	-	7.60	

Table 4. Effect of different zinc sources on Zn content at different growth stages of field rice (*Var. GR 11*)

No.	Treatments	Zn content (ppm)		
		Vegetative stage	**Heading stage**	**At harvest**
T_1	Zinc Sulphate @ 25 kg/ha	114.00	112.00	101.00
T_2	Zinc Sulphate @ 50 kg/ha	119.00	117.30	107.33
T_3	Zinc EDTA @ 12.5 kg/ha	112.67	110.00	100.67
T_4	Zinc EDTA @ 25 kg/ha	117.00	114.66	109.00
T_5	Foliar application of Zinc Sulphate @ 1%	107.33	105.33	96.63
T_6	Foliar application of Zinc EDTA @ 1%	103.00	101.67	98.00
T_7	Foliar application of Zinc nanoparticle (100 ppm)	105.58	103.43	97.00
T_8	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	107.60	106.25	99.67
T_9	Control (Water spray)	80.69	77.28	79.33
	Mean	**107.44**	**105.38**	**98.74**
	S.E.m ±	4.01	3.32	3.64
	$C.D._{0.05}$	11.92	9.87	10.83
	CV (%)	6.47	5.47	6.39

Table 5. Correlation between Zn content and YSB infestation at vegetative and heading stage

Correlation study parameters	Correlation coefficient (r)
Zn content Vs YSB damage at vegetative stage (DH)	-0.64**
Zn content Vs YSB damage at heading stage (WEH)	-0.67**

Significance level: 0.381 (0.05), 0.487 (0.1)

Correlation: YSB damage was significantly and negatively correlated at vegetative (r = -0.64**) and heading stage (r = -0.67**) with zinc content (Table 5). Significant and negative correlation between Zn content and YSB damage was computed at vegetative and heading stages might be due to reason that high Zn concentration in plant tissues is potentially toxic to all insect pests [22,23].

4. CONCLUSION

Application of zinc at higher rates ($ZnSO_4$ @ 50 kg/ha, Zn-EDTA @ 25 kg/ha) and foliar application of bio-synthesized zinc NPs were found to be the most promising in enhancing the induction of resistance in rice plants against its most notorious pest, *S. incertulas* and promote Zn accumilation content. $ZnSO_4$ in particular could be considered as a potential source of Zn as it is cheap and easily available in the nearby locality. Thus, the present study emphasizes on use of this zinc source for the management of rice pests in general and yellow stem borer in particular.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text to image generation have been used during writing or editing manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interest exist.

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