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Influence of Liming and Phosphorus Application on Growth of Soybean in Acidic Soil of Chandauli, Uttar Pradesh, India

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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

The objective of this research is to solve problem due to acidity and phosphorus deficiency in soybean crop grown in acidic soils. As acidic soils have an abundance of exchangeable forms of aluminum and hydrogen and a low supply of basic cations, they limit the productive potential of

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crops. The retention of phosphorus (P) is usually high in acidic soils. At the study area, soil acidity is well-known for limiting the productivity of crop. This study was conducted to determine the influence of liming and phosphorus application on growth of Soybean in acidic soil of Chandauli district. Factorial combinations of four levels of lime (0, 25, 50 and 100% of lime requirement) and four sources of phosphorus (No phosphorus, triple super phosphate, Mussoorie rock phosphate and phosphate rich organic manure) were laid out in completely randomized design with three replications. The results revealed that lime x phosphorus interaction were significant for plant height and relative chlorophyll content SPAD. Findings shows that lime @100% significantly increased the plant height and SPAD values of soybean plant and remained at par with lime @50%. Similarly, application of phosphorus source PROM significantly increased the plant height and SPAD value and remained at par with TSP. Combined application of lime @100% + PROM significantly increased the growth of soybean crop. It remained at par with lime @100% + TSP, lime @50% + PROM, lime @50% + TSP, indicating saving of 50% lime and PROM can be considered as a sustainable alternative that contributes to both phosphorus availability and soil health. The results of the study verified that application of lime and phosphorus sources improved growth and growth related traits of soybean crop.

Keywords: Lime; Triple super phosphate; Mussoorie rock phosphate; PROM; SPAD; Soybean.

1. INTRODUCTION

Soybean holds a significant position in the global oilseed farming landscape because of its exceptional yield, financial benefits, and essential role in preserving soil fertility. The crop is also well recognized as the most significant seed legume in the world, producing 25% of the vegetable oil produced worldwide, around two thirds of the protein concentrate used in animal feed, and a valuable component of fish and poultry formulas. Its high and inexpensive source of protein (40–42%) and oil content (18–20%) having unsaturated fatty acids (85%–85%), of which 55% are polyunsaturated fatty acids (PUFA), and 0.3% are flavones. For animal feeds and the majority of manufactured meals, fat-free soybean meal serves as the main and most affordable source of protein [1]. It is grown on 12.14 million hectares in India, yielding 12.98 million tonnes of output with a productivity of 1069 kg ha^{-1} [2]. It is grown on 17 thousand hectares in Uttar Pradesh, where it yields 8.9 thousand tons of product and 521 kg ha^{-1} of productivity annually [2].

One of the most important macronutrients for crops, phosphorus (P) is involved in numerous fundamental life activities, including photosynthesis and energy transformation [3]. Achieving optimal crop yield requires sufficient soil P [4]. Phosphorus is the most crucial mineral nutrient for pulse crops. Similar to nitrogen, phosphorus is a necessary mineral, yet Indian soils have low to moderate levels of phosphorus accessible. Roughly 30% of the phosphorus given to crops is really used by the crops; the remaining phosphorus is transformed into insoluble phosphorus [5]. Alternative P sources, such as organic sources and rock phosphates, can be employed to lower the yield cost [6].

Liming is the most popular management technique for neutralizing acid soil and the issues brought on by soil acidification. It is also the best way to maintain a pH that is appropriate for a range of crop growth, enhanced nitrogen fixation, and the availability of vital nutrients (Ca, P, and Mo) [7]. It is believed that using lime in the development of legumes improves the pH, base saturation, Ca, Mg, and P availability of the soil. Liming raises the pH of soil solutions by hydrolyzing additional carbonate (CO_3^{2-}) to produce hydroxide ions (OH^-). By decreasing their positive surface charge, this significantly reduces Al oxide activity and weakens P retention [8]. Liming decreases the ability of oxide surfaces to retain P and therefore enhances P availability because it also tends to exchange anionic P species from oxide surfaces for added OH^- [9]. Low P availability in acidic soils as a result of Al and Fe phosphate precipitation is one of the main issues. For every pH unit drop, their solubility products drastically decrease by up to a factor of 100. In acidic soils, organic matter is used to increase the availability of phosphorus [10].

Liming and phosphorus supplementation are crucial for optimizing soybean growth in acidic soils. Together, liming and phosphorus supplementation create an ideal environment for robust soybean growth and increased yields. With the aim of determining their potential to ameliorate soil acidity and promote optimal soybean development, a pot experiment was conducted to assess the effects of lime and phosphorus applications on acidic soil properties and soybean growth.

2. MATERIALS AND METHODS

2.1 Experimental Setup

A pot culture experiment was conducted in the *kharif* 2021 with soybean in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Bulk acidic soil sample was collected from Chandauli district of Uttar Pradesh. In all treatments we added N at 20 kg ha^{-1} and potash at 40 kg ha^{-1} so that there may not be any unwanted restricting factors for plant growth apart from phosphorus and pH. All treatments were replicated three times, and soils were placed in 10 kg pots. The lime requirement of soil to raise pH to 6.5 was 4.8 t ha^{-1}. Each treatment was replicated for three times. Finally, five plants were kept in the pot and with the help of a meter scale; plant height of lentil was measured at 30, 60 and 90 days after sowing (DAS).

2.2 Treatment Details

Liming and Phosphorus sources each at four levels viz. 0, 25%, 50% and 100% of lime requirement (LR) and No Phosphorus, Triple super phosphate (TSP), Mussorrie rock phosphate (MRP) and Phosphate rich organic manure (PROM) respectively were tested in 16 combinations with RDF. The experiment was laid out in completely randomized design with three replications. Calcium carbonate was used as liming material.

2.3 Statistical Analysis

Recorded data were statistically analysed by applying the analysis of variance technique [11]. The critical difference (5% level of probability) was computed for comparing treatment mean in cases where the effect came out to be significant by F-test.

3. RESULTS AND DISCUSSION

3.1 Influence of Liming and Phosphorus Application on Plant Height of Soybean

The results of the growth of soybean in term of plant height as influenced by lime and phosphorus sources are presented in Table 2. Application of liming and phosphorus has significant effect on plant height at 30 days after sowing (DAS), 60 DAS and at harvest. A perusal of data indicated that liming and phosphorus application gave significantly higher plant height than control. At 30 DAS, among lime levels highest plant height was observed with Lime@100% (L_3) which remains statistically at par with liming @50% (L_2). Among phosphorus sources maximum plant height of 79.03 cm was observed with PROM which remained statistically at par with TSP. The combined application of L_3P_3 produced 18.7% more plant height than the L_3 singly and 8.71% as compared to application of PROM without lime. Graphical representation of interaction effect of lime and phosphorus sources is shown in Fig. 1. At 60 DAS, there was significant increase in plant height with increase

Table 1. Details of treatment

Treatments	Notation	Treatment details
T_1	$L_0 P_0$	Control
T_2	$L_0 P_1$	Control + Triple Super Phosphate (60 kg P_2O_5 ha^{-1})
T_3	$L_0 P_2$	Control + Mussoorie Rock Phosphate (60 kg P_2O_5 ha^{-1})
T_4	$L_0 P_3$	Control + PROM (60 kg P_2O_5 ha^{-1})
T_5	$L_1 P_0$	¼ of LR (25%)
T_6	$L_1 P_1$	¼ of LR (25%) + Triple Super Phosphate (60 kg P_2O_5 ha^{-1})
T_7	$L_1 P_2$	¼ of LR (25%) + Mussoorie Rock Phosphate (60 kg P_2O_5 ha^{-1})
T_8	$L_1 P_3$	¼ of LR (25%) + PROM (60 kg P_2O_5 ha^{-1})
T_9	$L_2 P_0$	½ of LR (50%)
T_{10}	$L_2 P_1$	½ of LR (50%) + Triple Super Phosphate (60 kg P_2O_5 ha^{-1})
T_{11}	$L_2 P_2$	½ of LR (50%) + Mussoorie Rock Phosphate (60 kg P_2O_5 ha^{-1})
T_{12}	$L_2 P_3$	½ of LR (50%) + PROM (60 kg P_2O_5 ha^{-1})
T_{13}	$L_3 P_0$	LR (100%)
T_{14}	L_3P_1	LR (100%) + Triple Super Phosphate (60 kg P_2O_5 ha^{-1})
T_{15}	$L_3 P_2$	LR (100%) + Mussoorie Rock Phosphate (60 kg P_2O_5 ha^{-1})
T_{16}	$L_3 P_3$	LR (100%) + PROM (60 kg P_2O_5 ha^{-1})

Table 2. Effect of liming and phosphorus application on growth parameter of soybean

Treatments	Plant height 30 DAS	Plant height 60 DAS	Plant height harvest	Number of branches 30 DAS	Number of branches 60 DAS	Number of branches harvest	Chlorophyll content SPAD 30 DAS	Chlorophyll content SPAD 60 DAS
Liming Levels								
L_0 (No Lime)	71.13c	98.09c	103.09c	1.23	2.20	3.00	32.27c	36.41c
L_1 (25% Lime)	73.37b	100.59b	105.84b	1.28	2.32	3.12	33.04b	37.17b
L_2 (50% Lime)	75.13ab	102.84a	108.23a	1.37	2.38	3.18	33.77a	37.97a
L_3 (100% Lime)	75.89a	104.50a	109.38a	1.33	2.35	3.15	33.96a	38.09a
Sem±	**0.77**	**0.77**	**0.82**	**0.04**	**0.05**	**0.05**	**0.23**	**0.26**
CD	**2.22**	**2.22**	**2.36**	**NS**	**NS**	**NS**	**0.67**	**0.76**
Phosphorus Sources								
P_0 (No Phosphorus)	66.24c	95.86c	99.38c	1.23	2.22	3.02	31.56c	35.72c
P_1 (TSP)	77.11a	104.36a	110.09a	1.38	2.38	3.18	34.13a	38.16a
P_2 (MRP)	73.12b	99.41b	104.77b	1.25	2.27	3.07	33.04b	37.36b
P_3 (PROM)	79.03a	106.40a	112.30a	1.35	2.38	3.18	34.31a	38.40a
Sem±	**0.77**	**0.77**	**0.82**	**0.04**	**0.05**	**0.05**	**0.23**	**0.26**
CD	**2.22**	**2.22**	**2.36**	**NS**	**NS**	**NS**	**0.67**	**0.76**

in liming levels. Application of lime@100% significantly increased the plant height and remained statistically at par with lime@50%. Highest plant height was observed with PROM (P_3) among phosphorus sources. The combined application of lime@100% + PROM (L_3P_3) resulted in highest plant height which remained statistically at par with lime@100% + TSP, Lime@50% + TSP and lime@50% + PROM. At harvest, highest plant height was observed with treatment combination lime@100% + PROM (L_3P_3). It was 15.68% higher than the plant height observed with the lime@100% (L_3) without phosphorus and 9.6% higher plant height was observed with the PROM (P_3).

The results were supported by Noor et al*,* [12] and they said that by the combine use of compost, poultry manure, farmyard manure, and humic acid maximum plant height was obtained. Addition of poultry manure and phosphatic fertilizers the growth and development of plants can be improved due to sufficient nutrient availability [13]. Zehraeni and Uygur, [10] showed that 100% LR ratio of liming notably decreased phosphorus adsorption, which indicate better availability of phosphorus for the plant in soil and better plant growth.

3.2 Influence of Liming and Phosphorus Application on Number of Branches of Soybean

Results indicates that with increasing levels of lime number of branches increases up to lime@50% and then slightly decreases for lime@100%. But the change in number of branches for the liming and phosphorus application was found not significant for 30 DAS, 60 DAS and for harvest.

3.3 Influence of Liming and Phosphorus Application on Relative Chlorophyll Content SPAD of Soybean

A perusal of the data from Table 3 shows the influence of lime and phosphorus application on relative chlorophyll content in soybean leaves at 30 and 60 days after sowing. A significant variation in relative chlorophyll content in 30 DAS was observed with application of lime and phosphorus. Among liming levels highest chlorophyll content 33.96 was observed with Lime@100% (L_3) which was statistically at par with lime@50% (L_2). Among phosphorus sources highest chlorophyll content 34.31 was observed with application of PROM (P_3). Combined application of lime@100% + PROM (L_3P_3) recorded highest chlorophyll content 35.37 at 30 DAS and remained at par with lime@100% + TSP, Lime@50% + TSP and lime@50% + PROM. At 60 DAS there was increase in SPAD value in all treatments. Treatment Lime@100% (L_3) recorded the highest SPAD value being statistically at par with Lime@50% (L_2). In phosphorus sources PROM (P_3) was found to have highest SPAD value 38.40 and it remained statistically at par with TSP (P_1). Treatment combination lime@100% + PROM (L_3P_3) recorded 4.57% higher relative chlorophyll content SPAD over control at 60 DAS.

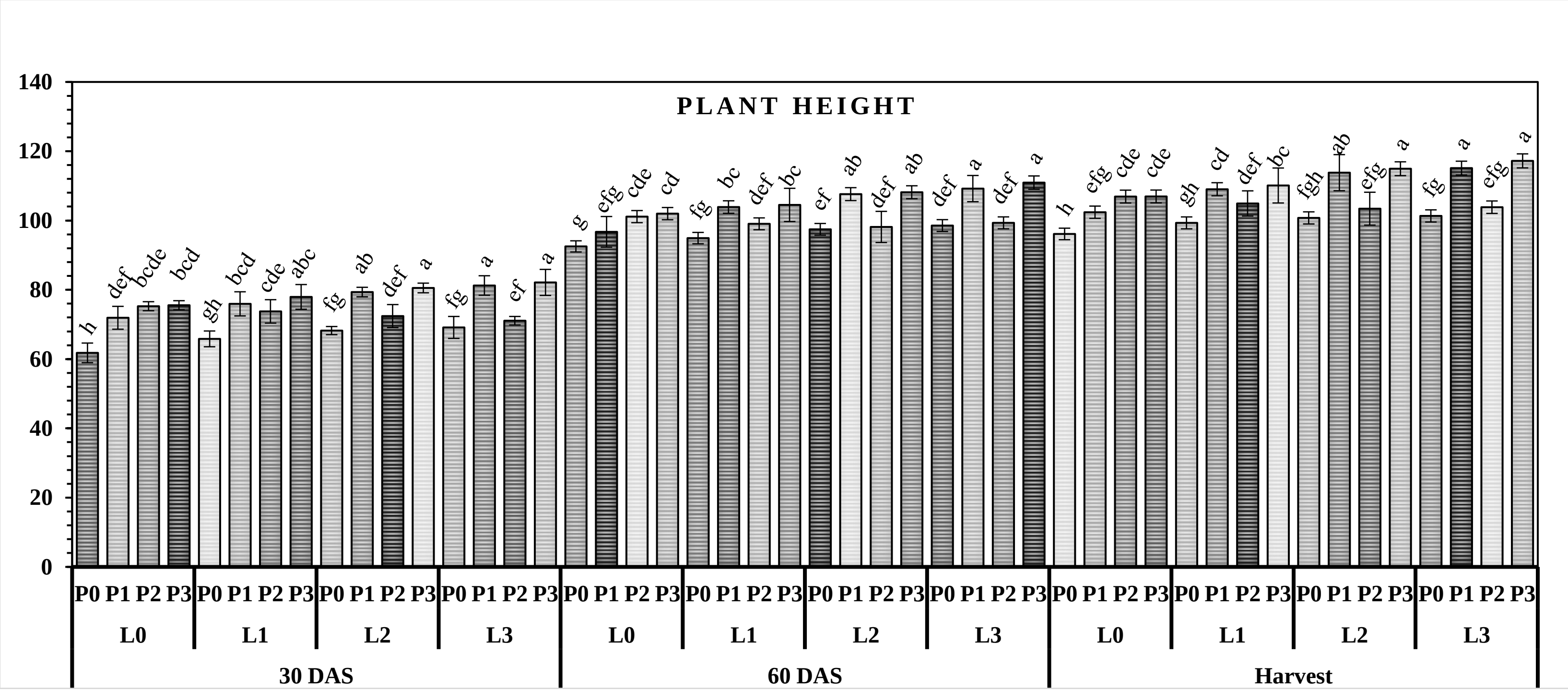

Fig. 1. Interaction effect of of liming and phosphorus application on plant height of soybean at 30 DAS, 60 DAS and harvest

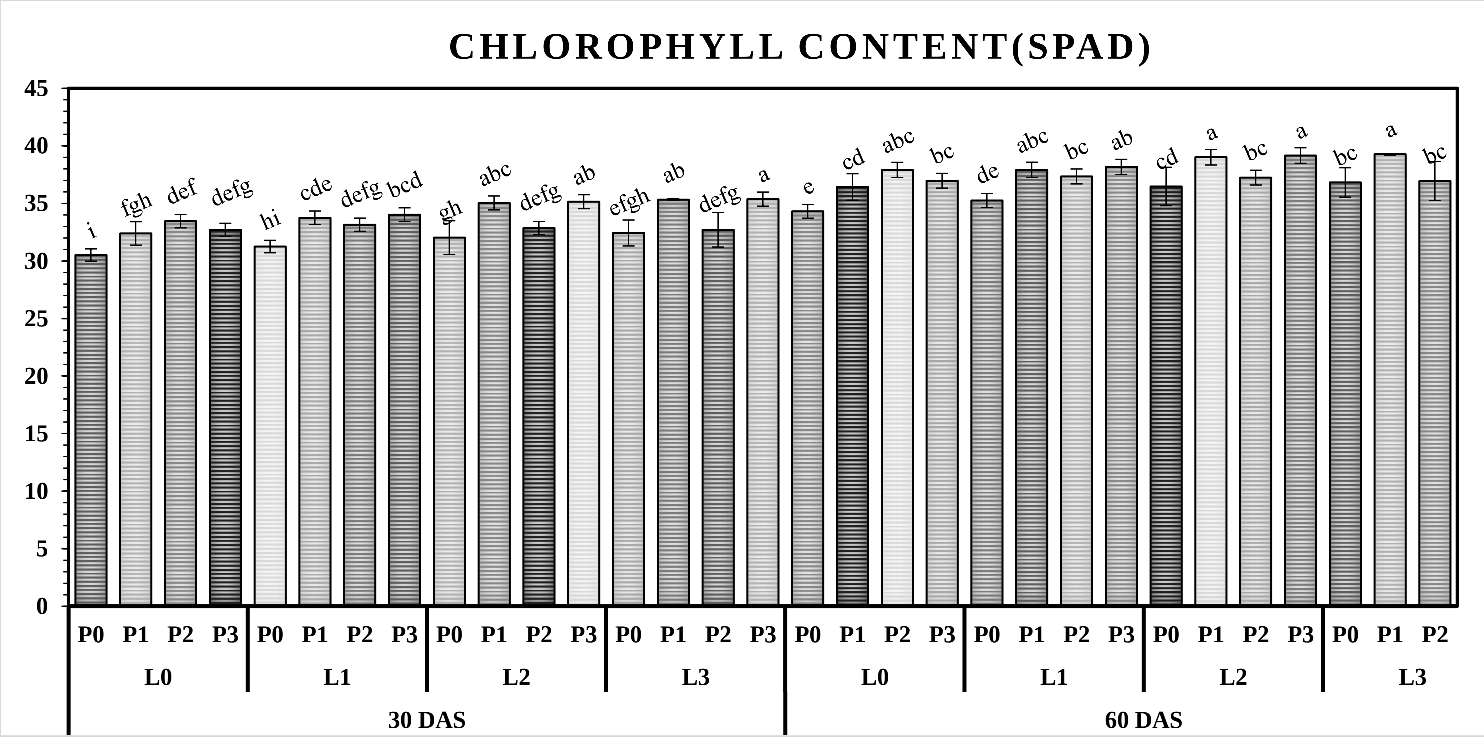

Fig. 2. Interaction effect of of liming and phosphorus application on chlorophyll content (SPAD) of soybean at 30 DAS and 60 DAS

Table 3. Interaction effect of liming and phosphorus application on growth parameter of soybean

Treat-ments	Plant height 30 DAS	Plant height 60 DAS	Plant height harvest	Number of branches 30 DAS	Number of branches 60 DAS	Number of branches harvest	Chlorophyll content SPAD 30 DAS	Chlorophyll content SPAD 60 DAS
L_0 Po	61.79h	92.53g	96.12h	1.20	2.13	2.93	30.52i	34.31e
$L_0 P_1$	71.92def	96.72efg	102.39efg	1.27	2.20	3.00	32.39fgh	36.43cd
$L_0 P_2$	75.25bcde	101.12cde	106.91cde	1.20	2.20	3.00	33.45def	37.91abc
$L_0 P_3$	75.54bcd	101.98cd	106.94cde	1.27	2.27	3.07	32.71defg	36.97bc
$L_1 P_0$	65.82gh	94.92fg	99.31gh	1.20	2.20	3.00	31.25hi	35.25de
$L_1 P_1$	75.94bcd	103.89bc	109.02cd	1.33	2.40	3.20	33.75cde	37.92abc
$L_1 P_2$	73.76cde	99.04def	104.92def	1.20	2.27	3.07	33.15defg	37.34bc
$L_1 P_3$	77.94abc	104.50bc	110.11bc	1.40	2.40	3.20	34.02bcd	38.17ab
$L_2 P_0$	68.22fg	97.45ef	100.75fgh	1.27	2.27	3.07	32.03gh	36.47cd
$L_2 P_1$	79.34ab	107.62ab	113.81ab	1.47	2.47	3.27	35.04abc	39.01a
$L_2 P_2$	72.41def	98.14def	103.42efg	1.33	2.33	3.13	32.86defg	37.24bc
$L_2 P_3$	80.53a	108.16ab	114.95a	1.40	2.47	3.27	35.15ab	39.16a
$L_3 P_0$	69.13fg	98.54def	101.32fg	1.27	2.27	3.07	32.43efgh	36.82bc
L_3P_1	81.24a	109.21a	115.13a	1.47	2.47	3.27	35.33ab	39.27a
$L_3 P_2$	71.07ef	99.32def	103.84efg	1.27	2.27	3.07	32.71defg	36.94bc
$L_3 P_3$	82.12a	110.94a	117.21a	1.33	2.40	3.20	35.37a	39.31a
Sem±	**1.54**	**1.54**	**1.64**	**0.09**	**0.10**	**0.10**	**0.47**	**0.53**
CD	**4.43**	**4.44**	**4.72**	**NS**	**NS**	**NS**	**1.34**	**1.51**

The SPAD value is an important biochemical indicator for identifying the plant's development and yield parameter [14], where a higher value may indicate the higher yield of crops [15] and also a higher photosynthetic rate [16]. In acid soils after liming there is enrichment of essential nutrients that may result in significant increase in the SPAD value, It may eventually show appropriate plant development, growth rate, and chlorophyll content [16,17]. Applying organic amendments considerably changed the plant's relative chlorophyll content (SPAD) in comparison to the control treatment [18].

4. CONCLUSION

Based on the present investigation, it can be concluded that both liming and phosphorus sources have decisive role in growth of Soybean in acid soils of Chandauli. Results indicated that application of liming and phosphorus sources have significantly affected the plant height and relative chlorophyll content of the plant. Based on these results, application of lime @ 50% + PROM would be beneficial in terms of growth of Soybean. The results suggest that for acidic soils, liming combined with PROM is the most effective strategy for optimizing soybean production. However, in soils where organic matter is a concern, PROM can be considered as a sustainable alternative that contributes to both phosphorus availability and soil health. Overall, the research emphasizes the importance of selecting the right phosphorus source in conjunction with soil amendments like lime to achieve optimal crop performance. Future research could explore the long-term effects of these treatments on soil health and crop yield, and investigate the economic feasibility of using PROM compared to other phosphorus sources.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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