

Full Length Research Paper

The effect of multi-component fertilizer and lime application on yield of common bean in Western Kenya

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Soil acidity and micronutrient deficiency is a major constraint affecting common bean production in Western Kenya. Farmers in the region have access to the two fertilizers *Mavuno* and *Sympal* fortified with different micronutrients and recommended for legumes; however, the performance of beans in the region remains low. A field experiment was, therefore, conducted in two sites in Nandi county, western Kenya, to determine the effect of using customized micronutrient fertilizer with lime on common bean yield. A factorial experiment was set up in a randomized complete block design consisting of three fertilizer types and lime treatments applied at two levels (0 and recommended rate). The fertilizer treatments were *Mavuno* (0 and 185 kg ha⁻¹), *Sympal* (0 and 125 kg ha⁻¹), Diammonium phosphate (0 and 62.5 kg ha⁻¹) and lime (0 and 1.6 or 2.0 tons ha⁻¹ depending on the lime requirement for the site). The experiment was run for two seasons, 2019 long and short rain seasons. Data were collected on nutrient uptake, crop growth and yield. The application of *Mavuno* fertilizer with lime significantly increased grain yield by 42, 30 and 27 % compared with control, *Sympal* and DAP, respectively. The application of *Sympal* and DAP did not have a significant effect on bean grain yield. *Mavuno* fertilizer with lime performed better in improving bean yield compared to the standard practice (DAP) and *Sympal* fertilizer. These results demonstrate the importance of using *Mavuno* fertilizer containing micronutrients Mo and B in combination with lime in improving legume production in Western Kenya.

Key words: Common bean, customized fertilizer, lime, macronutrient, micronutrients, soil acidity.

INTRODUCTION

Low soil fertility in sub-Saharan Africa is a major constraint limiting agricultural production, mainly caused by low inherent soil fertility, low use of fertilizers, soil acidity and continuous cropping without adequate nutrient replenishment (Henao and Baanante, 2006). Crop growth and productivity depend on nutrient availability which is primarily influenced by soil pH and organic matter

concentration (Chianu et al., 2012; Kundu et al., 2017).

Low soil pH causes poor plant growth resulting from aluminium (Al³⁺) and magnesium (Mn²⁺) toxicity and deficiency of essential nutrients such as phosphorous (P), calcium (Ca) and magnesium (Mg). Therefore amendments, such as lime application, that improve soil pH and enhance nutrient availability and crop growth is

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required. Unfortunately, most smallholder farmers in Western Kenya rarely use lime due to limited awareness, lack of appropriate recommendation rates, inadequate studies done in the region and unknown agricultural lime quality (Athanasie et al., 2013).

Fertilizer use is a cornerstone in improving crop production and maintaining soil nutrient status (Chianu et al., 2012). Most farmers in sub-Saharan Africa focus mainly on alleviating deficiency of macronutrients nitrogen (N), P and potassium (K). However, there are indications of deficiencies of both secondary and micronutrients limiting crop production in sub-Saharan Africa, particularly under continuous cropping without nutrient replenishment (Vanlauwe et al., 2015; Njoroge et al., 2017). Therefore, management of soil fertility through balanced crop nutrition that takes into account both macro and micronutrients is essential towards increasing crop yield, hence enhancing food security (Kihara et al., 2016).

Soils in Western Kenya can be classified into responsive and non-responsive based on the application of NPK fertilizer; the highly weathered and nutrient-depleted soils classified as *Acrisols* and *Ferralsols* fall into the non-responsive class (Keino et al., 2015; Kihara et al., 2016). Therefore, to address this, the fertilizer industry in Kenya has come up with crop-specific fertilizer formulations which include *Mavuno* horticulture for peas and beans, and *Sympal* for legumes. The use of these fertilizers has, however, not resulted in the expected benefits to farmers in South Nandi Region of Western Kenya probably because they do not address the issue of soil acidity. Both fertilizers supply macro and micronutrients and are thought to improve common bean yield in non-responsive and acidic soils. The objective of this study is to determine the effect of customized fertilizers (*Mavuno* and *Sympal*) when applied alone or in combination with lime in common bean production in non-responsive soils of Western Kenya.

MATERIALS AND METHODS

Study sites

Field experiments were carried out at two sites, Kapkerer (0°0'N, 34°48' E, 1530 masl) and Kiptaruswo (0°2'N, 34°55' E, 1582 masl) located in Nandi County, Western Kenya. The area has an average annual rainfall of between 1200 -1700 mm, and annual maximum and minimum temperature of 29 and 12 °C. The rainfall pattern is bimodal with long rainy season from March to August (average of 700-780 mm) and short rainy season from September to January (average of 630-780 mm). The predominant soils in the area are well-drained, moderately deep to deep, strong brown, friable to firm *humic acrisol*. The main crops grown in the area are maize, beans, kales, cabbage, sweet potatoes, cassava and sugarcane (Jaetzold et al., 2010).

Experimental design and treatments

The experiment was carried out on one farm per site and laid out in

4 × 2 factorial in randomized complete block design, with three replicates. The treatments were; *Mavuno*[®] fertilizer at two levels (0 and 185 kg ha⁻¹), *Sympal*[®] fertilizer at two levels (0 and 125 kg ha⁻¹), the commonly applied Diammonium Phosphate fertilizer at two levels (0 and 62.5 kg ha⁻¹ – Positive control) and lime (0 and 1.6 t ha⁻¹ in Kapkerer site and 0, 2 t ha⁻¹ in Kiptaruswo site; 0 rate – negative control). The fertilizers were applied at the recommended rates for legume production while the lime application for each site was based on a pre-determined lime requirement rate. *Mavuno* fertilizer is a customized fertilizer for legumes and has the formulation NPK 15:10:18 plus sulphur (S), Ca, magnesium (Mg), iron (Fe), copper (Cu), boron (B) and molybdenum (Mo), while *Sympal*, also customized fertilizer for legumes, has a formulation NPK 0:23:15 plus 10% Ca, 4% S, 1% Mg and 0.1% zinc (Zn). Biofix rhizobium inoculant was used specifically for the *Sympal* fertilizer which does not supply nitrogen at the recommended rate.

Agronomic practices

The land was prepared manually using hand hoe to produce fine seedbed. Lime (CaCO₃) was finely ground and broadcasted and incorporated in the soil using hand hoe during planting. The fertilizer treatments were applied using the surface banding method. Seed inoculation was applied for all the treatments with *Sympal* fertilizer. Common bean, *KK13* variety, was sown at a rate of one seed per hill in a plot measuring 3 m × 2 m and at a spacing of 50 cm × 10 cm. Standard cultural practice, such as weeding was done twice by hand cultivation using hoe after emergence and before flowering, and pests and diseases control was done by application of *duduthrin* and *ridomil*; it was carried out uniformly in all plots.

Data collection and analysis

Soil samples (0-20 cm depth) were collected at the beginning of the study at the two study sites for chemical characterization. The soil samples were air-dried and sieved through 2 mm sieve and analyzed for soil pH, lime requirement, available P, exchangeable K, Ca, Mg, B and Zn. Soil pH was determined using a glass electrode pH meter at the soil to water ratio of 1:2.5, while the lime requirement was determined using incubation method. Available P was extracted using Mehlich 3 solution, and P concentration determined calorimetrically by the ammonium vanadate method using UV-VIS spectrophotometer at a wavelength of 430 nm (Okalebo et al., 2002). Exchangeable K, Ca, Mg, B and Zn were determined using Morgan method; the soils were extracted with EDTA solution and the concentration of K, Ca, Mg, B and Zn in the filtrate was determined using ICP-AES (Jones, 2001).

Six plant samples were randomly selected per plot by detaching the two uppermost fully developed leaves at 50% flowering. The samples were placed in brown paper bags and oven-dried at a temperature of 65°C for 48 h. The samples were ground in an electric miller to pass through less 1mm sieve, ashed in a muffle furnace at a temperature of 500°C and then dissolved in a mixed acid (hydrochloric acid and nitric acid) and hydrogen peroxide solution. A sample was taken from solution and analyzed for P, Ca and Mg using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP – AES) (Kalra, 1997).

Aboveground biomass was determined at 50% flowering stage by randomly selecting six common bean plants per plot and cutting them at ground level. The plant materials were then placed in brown paper bags and oven-dried at 65°C for 48 h after which dry weight was determined. The biomass was expressed on a dry weight basis in t per hectare.

Belowground biomass was determined at 50% flowering by randomly selecting and carefully excavating six bean plants per

plot. The roots were washed with a stream of tap water to remove the attached soil. The root samples were detached and placed in brown paper bags, oven-dried at 65°C for 48 h after which dry weight was determined. The biomass was expressed on a dry weight basis in kg per hectare. After attaining physiological maturity, the pods in the three middle rows were harvested, dried, threshed and winnowed to obtain the grain yield in each plot. The grain moisture was determined using an electric moisture meter and used to adjust the grain yield to tons/ha at 12% moisture content (Verhulst et al., 2013). The nutrient uptake, above and belowground biomass, and grain yield data were subjected to analysis of variance (ANOVA) using general linear model and difference in means determined using the Least Significant Difference Test at $p < 0.05$ using SAS statistical package (Version 9.2).

RESULTS AND DISCUSSION

Chemical properties of the study site

Selected soil chemical properties for the two sites are as given in Table 1. The soil pH for Kapkerer farm was 5.53, which falls under moderately acidic soil, while for Kiptaruswo farm, the pH was 4.49, categorized as strongly acidic (Kanyanjua et al., 2002). Available P for Kaptaruswo and Kapkerer was 50 and 48 ppm, respectively, which was medium (31 - 50 ppm) in both sites (Jones, 2001). Total K concentrations in Kapkerer and Kiptaruswo were 826 and 1170 ppm respectively, which was high at both sites (>300 ppm). The Ca concentration in Kapkerer site was 1250 ppm which was medium in the range of 1000 - 1600 ppm; while for Kiptaruswo site it was 1640 ppm which fell under the high level in the range of 1600 - 2400 ppm; Mg concentration in Kapkerer site was 30 ppm which falls under low (20 - 40 ppm); while for Kiptaruswo site it was 373 ppm which falls under high level (> 30 ppm) (Okalebo et al., 2002).

Effect of customized fertilizer on Ca, Mg and P crop uptake

Application of *Mavuno* and *Sympal* fertilizers significantly increased Ca and Mg uptake over positive and negative control by between 2 - 13% at $p < 0.01$ (Table 2). An increase in Ca and Mg uptake may be attributed to the availability of Ca and Mg in *Mavuno* and *Sympal* fertilizers. A study done by Wamalwa et al. (2019) on acidic soil of western Kenya reported that application of blended NPK + Ca + Mg fertilizer significantly increased Ca uptake in finger millet due to the availability of Ca in the fertilizer. The application of *Mavuno* and *Sympal* fertilizer did not have a significant effect on P uptake at $p < 0.05$ (Table 2).

Effect of customized fertilizer on the above- and belowground biomass

The application of *Mavuno* significantly increased

aboveground biomass over positive and negative control at $p < 0.001$ by between 18 - 20% respectively (Table 2). However, the application of *Sympal* fertilizer significantly decreased aboveground biomass over positive and negative control at $p < 0.05$ by between 8 - 4% respectively (Table 2). The decrease in aboveground biomass with *Sympal* application may be attributed to nitrogen deficiency, mostly if biofix inoculation did not result in adequate nitrogen fixation. The application of *Sympal* fertilizer significantly increased belowground biomass over positive and negative control at $p < 0.05$ by between 5 - 10% respectively (Table 2). However, the application of *Mavuno* fertilizer did not have a significant effect on the belowground biomass at $p < 0.05$ (Table 2).

Effect of customized fertilizer on crop yield

The application of *Mavuno* fertilizer significantly increased yields over control for both negative and positive control by about 21% at $p < 0.01$ (Table 2). On the other hand, application of *Sympal* fertilizer significantly decreased yield over control at $p < 0.05$ (Table 2). A decrease in yields may be attributed to nitrogen deficiency, mostly if biofix did not result in adequate nitrogen fixation due to soil acidity.

Interaction effect of customized fertilizer with lime on Ca, Mg and P uptake

Application of *Mavuno* and *Sympal* fertilizers with lime did not have a significant effect on Ca and Mg uptake at $p < 0.05$ (Table 3). The application of *Sympal* fertilizer with lime did not have a significant effect on P uptake at ($p < 0.05$) (Table 3). However, the results for *Mavuno* application with lime showed a significant increase in P uptake over the positive and negative controls at $p < 0.05$ by 2.2% (Figure 1a). Increase in P uptake with *Mavuno* and lime application may be attributed to improved soil pH due to availability of Ca in both lime and *Mavuno* fertilizer and Mg in the fertilizer which improves soil pH by counteracting toxicity, which in turn enhances the availability of P for plant uptake, unlike *Sympal* fertilizer. Application of lime improves the rhizosphere pH and the action of nitrogen-fixing bacteria increasing the availability of inorganic P for plant uptake further enhanced by P in the fertilizer (Barasa et al., 2013; Rengel and Marschner, 2005).

Interaction effect of customized fertilizer with lime on above and belowground biomass

Application of *Mavuno* and *Sympal* fertilizers with lime significantly increased the aboveground biomass over positive and negative controls by 31 and 28% respectively, at $p < 0.001$ (Figures 1b and 1c). An

Table 1. Some selected chemical properties of soils at the two experimental sites.

Parameter	Site	
	Kapkerer	Kiptaruswo
Soil type	<i>Humic Acrisol</i>	<i>Humic Acrisol</i>
pH	5.53	4.49
Available P (ppm)	50	48
K (ppm)	826	1170
Ca (ppm)	1250	1640
Mg (ppm)	30	373
Mn (ppm)	108	213
Zn (ppm)	27	37
Cu (ppm)	17	17
Fe (ppm)	107	107
Al (ppm)	576	541
Total B (ppm)	31	31

Table 2. Main effects of lime, Mavuno, DAP and Sympal fertilizers on Ca, Mg and P crop uptake, aboveground and belowground biomass, and crop yield.

Treatment	Soil pH	Ca uptake (%)	Mg uptake (%)	P uptake (%)	ABG (t/ha)	BGB (t/ha)	Yield (t/ha)
L1	6.14 ^a	1.93 ^a	0.48 ^a	0.453 ^a	1.90 ^a	0.20 ^a	1.34 ^a
L0	4.90 ^b	1.85 ^b	0.44 ^b	0.446 ^b	1.51 ^b	0.17 ^b	0.94 ^b
M1	5.66 ^a	1.94 ^a	0.48 ^a	0.453 ^a	2.04 ^a	0.19 ^a	1.35 ^a
M0	5.48 ^b	1.87 ^b	0.46 ^b	0.448 ^a	1.59 ^b	0.19 ^a	1.07 ^b
D1	5.45 ^a	1.89 ^a	0.47 ^a	0.453 ^a	1.67 ^a	0.19 ^a	1.08 ^a
D0	5.55 ^a	1.89 ^a	0.46 ^a	0.448 ^a	1.71 ^a	0.19 ^a	1.16 ^a
S1	5.54 ^a	1.95 ^a	0.48 ^a	0.446 ^a	1.60 ^b	0.20 ^a	1.03 ^b
S0	5.51 ^a	1.70 ^b	0.46 ^b	0.451 ^a	1.74 ^a	0.18 ^b	1.08 ^a
CV %	3.01	2.98	3.14	1.64	3.44	6.85	7.65
LSD	0.17	0.05	0.01	0.006	0.1	0.01	0.1

Means with the same letter within a column are not significantly different at ($p < 0.05$) using the Least Significant Difference (LSD) test

Key: L1 = Lime applied at recommended rate of 1.6 t/ha, L0 = lime not applied, M1 = *Mavuno* fertilizer applied at recommended rate of 185 kg/ha, M0 = *Mavuno* fertilizer not applied, D1 = DAP applied at 62.5 kg/ha (Positive control), D0 = DAP not applied, S1 = *Sympal* fertilizer applied at recommended rate of 125 kg/ha S0 = *Sympal* fertilizer not applied, ABG = Aboveground biomass, BGB = Belowground biomass.

Table 3. Effect of fertilizer and lime on above and belowground biomass, P, Ca and Mg uptake, and crop yield.

Treatment	pH	ABG (t/ha)	BGB (t/ha)	P uptake (%)	Ca uptake (ppm)	Mg uptake (ppm)	Yield (t/ha)
Mavuno	0.137*	0.875***	0.0005 ^{ns}	0.0002 ^{ns}	0.022**	0.002**	0.017**
DAP	0.0001 ^{ns}	0.088 ^{ns}	0.0010 ^{ns}	0.0001 ^{ns}	0.056 ^{ns}	0.002 ^{ns}	0.004 ^{ns}
Sympal	0.03 ^{ns}	0.031*	0.0016*	0.0001 ^{ns}	0.314**	0.003**	0.022*
Lime	3.26***	0.516***	0.004**	0.00001**	0.048**	0.007**	0.147*
Mavuno*Lime	0.426**	0.208***	0.003**	0.006*	0.004 ^{ns}	0.00008 ^{ns}	0.044*
DAP*Lime	0.005 ^{ns}	0.106 ^{ns}	0.001 ^{ns}	0.004 ^{ns}	0.0077 ^{ns}	0.004 ^{ns}	0.0037 ^{ns}
Sympal*Lime	0.01 ^{ns}	0.106***	0.001**	0.0003 ^{ns}	0.003 ^{ns}	0.0003 ^{ns}	0.0003 ^{ns}
CV%	3.012	3.44	6.85	1.65	2.98	3.14	7.65

ABG- Aboveground biomass, BGB- Belowground ground biomass, *- significant at 0.05 level, **- significant at 0.01 level, ***- significant at 0.001 level ^{ns}- not significant.

increase in the aboveground biomass may be attributed to the availability of both macro and micronutrients

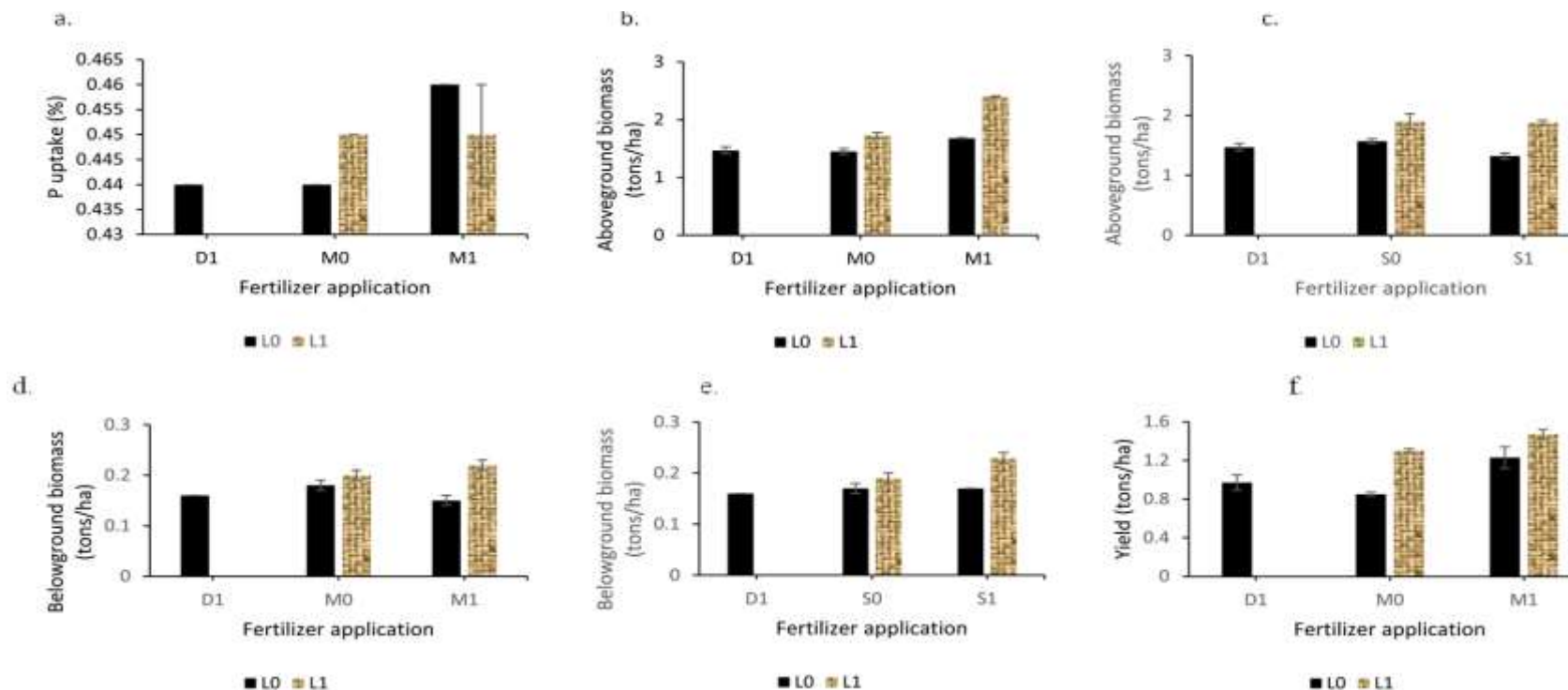


Figure 1. Interaction effect of Mavuno fertilizer with lime on P uptake (a), aboveground biomass (b), belowground biomass (d) and yield (f), and interaction of Sympal fertilizer with lime on aboveground biomass (c) and belowground biomass (e). D1 – Positive control (DAP applied at farmers rate of 62.5 kg ha^{-1}), L0 – Lime not applied, L1 – Lime applied at recommended rate, S0 – *Sympal* fertilizer not applied, S1 – *Sympal* fertilizer applied at recommended rate of 125 kg ha^{-1} , M0- *Mavuno* fertilizer not.

contained in the customized fertilizer further enhanced by improved soil pH with lime application. A study done by Arega and Zenebe (2019) in slightly acidic soils of Ethiopia reported that the application of blended fertilizer NPK + S + B significantly increased the aboveground biomass of common bean due to integration of nutrients in the blended fertilizer. Application of *Mavuno* and *Sympal* fertilizers with lime significantly increased the belowground biomass over positive and negative controls by 29 and 22%, respectively, at $p < 0.01$ (Figure 1d and e).

The effects on belowground biomass were similar to those of the interaction of customized fertilizer with lime on aboveground biomass in both direction and magnitude and may be attributed to the same factors as in aboveground biomass.

Interaction effect of customized fertilizer with lime on yield

The application of *Mavuno* fertilizer with lime significantly increased yield over positive and

negative control by 34 and 42%, respectively, at $p < 0.05$ (Figure 1f). However, the application of *Sympal* fertilizer with lime was not significant at ($p < 0.05$) (Table 3). An increase in yield following application of *Mavuno* and lime may be attributed to improved soil pH and supply of essential nutrients NPK + Ca + Mg + S + B + Mo + Fe + Cu through *Mavuno* fertilizer, unlike *Sympal* fertilizer which has Zn but lacks B, Mo, Fe and Cu micronutrients. A study done by Keino et al. (2015) working on acidic *acrisols* and *ferralsols* in Western Kenya reported that the combined

application of lime and customized fertilizer significantly increased soybean (*Glycine max* L.) yield.

Conclusion

Singular application of lime and *Mavuno* fertilizer significantly increased nutrient uptake (Ca, Mg and P), growth and yield of common bean. This may be attributed to the amelioration of soil acidity by both *Mavuno* and lime, and enhanced supply of deficient micronutrients in *Mavuno* fertilizer. Conversely, the singular application of *Sympal* fertilizer tended to decrease yield and was therefore not suitable for use in the region. The fertilizer does not supply nitrogen, but it depends on inoculum to fix nitrogen, and this could be the reason why nodulation of the bean crop was poor; it could also be as a result of soil acidity. There is a need, therefore for the formulation of site-specific fertilizer towards the improvement of common bean production. The application of *Mavuno* fertilizer with lime significantly improved common bean growth and yield compared with *Sympal* fertilizer with lime which did not have a significant effect on yield. Therefore, to improve common bean production in acidic *acrisols* of Western Kenya application of *Mavuno* fertilizer with lime is recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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