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Evaluation of Agronomic Performance of Green Gram Accessions Grown under Reduced Light Intensity in the Arid and Semi-Arid Areas of Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. All the authors designed the study. Under the guidance of authors SMG, CMO and PWM, author MKM wrote the protocol, managed literature searches, carried out the research work, collected and analyzed the data and wrote the first draft of the manuscript. The other authors SMG, CMO and PWM guided the research work, reviewed and corrected the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Green gram (*Vigna radiata* (L.) is the hardiest of all pulses and is well adapted to Arid and Semi-Arid Areas (ASALs). However, the high light intensities, temperatures and erratic rainfall experienced in these areas lead to high evapo-transpiration rates leaving very little water available for plant use, thus negatively affecting growth and yield parameters. This study was conducted to evaluate the effect of reduced light intensity on agronomic performance of four high yielding green gram accessions (GBK-022494A, GBK-022501A, GBK-022502A and Nylon-1). The study was carried out at Kiboko in Makueni County, Kenya during the 2012 short and 2013 long rain seasons. A Shade net used in this study reduces light intensity by 35 percent. The experiment was laid out in

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a split-plot arrangement with three replications. The main plot treatment was shading at two levels; shaded and non-shaded while the 4 accessions formed the sub-plots. Data on plant height, days to flowering, days to maturity, pods per plant, seeds per pod, weight of 100 seeds and seed yield was collected. Results indicated that during the short rain season, accessions had significant ($P \leq .01$) differences in the number of pods per plant, seed weight and plant height. Accession GBK-022501A was the tallest (55.1 cm) while Nylon-1 was the shortest (44.4 cm); Nylon-1 had the least (12.4 g) seed yield while GBK-022501A had the highest (17.2 g) seed yield. Shading created significant ($P<.05$) differences in seeds obtained per pod where production under shade gave an average of 9 seeds per pod compared to each 8 seeds in the open sunlight condition during the short rain seasons. During 2013 rain season, shade had significant ($P<.05$) effect on plant height and pod length. Under shade net plant height was 54.7 cm while under control, open sunshine condition it was 50 cm. Pod length under shade was 7.7 cm while under control, it was 7.4 cm. Generally, agronomic performance of green gram was improved by shading during the short rains unlike the long rains where growing in the open sunshine condition led to more robust growth and yield. It is therefore recommended that growers incorporate shading in their green gram production during periods of high light intensity.

Keywords: Arid and Semi-Arid areas; green grams; long rain season; accessions; reduced light intensity; shade net.

1. INTRODUCTION

Green gram also known as mung bean originated from India dating back to 1,500 – 1,000 B.C [1,2]. Its cultivation has spread to various parts of the world. It has become a major pulse crop outside Asia, USA and many tropical African countries including Kenya where it is grown in the eastern part of the country. Green gram is used in very many ways such as whole grain mixed with maize to form a main meal, soups, porridge, split to form dhal, sprouted and eaten either raw or cooked; its immature pods and young leaves eaten as vegetables. The remnants (plant, pod shells) can be fed to livestock. Green gram is also grown for fodder, green manure as well as cover crop [3]. Green gram is considered to be the hardiest of all pulse crops [3] and can do well in a wide range of altitudes from 0-1600 meters above sea level (ASL), tolerating high temperatures ranging from 20-40°C, and the optimum being 28 - 30°C. Green gram requires an average annual rainfall of 600-1000 mm, but it can grow well with less [4]. Green gram production data from 2006 to 2010 (Table 1), indicated that the area under crop ranged from 82,784 to 147,352 hectares with a production of between 26,715 to 61,953 metric tonnes registering a yield ranging from 0.29 to 0.7 tonnes per hectare (tons/ha) [5]. This yield was quite low compared to the expected (1.2-1.5 tons/ha) according to reports from Ministry of Agriculture [6].

Green gram is an important pulse crop in the ASAL areas of Kenya. The crop is drought tolerant and able to yield under the adverse conditions of the ASALs [7]. The crop is grown both as food and cash crop and it is capable of Nitrogen fixation in the roots thereby improving soil fertility [8].

Green gram can be grown on a wide range of altitudes from 0 to 1600 m above sea level, and under warm climatic conditions of 28°C to 30°C. It is drought tolerant requiring a little amount of rainfall of about 650 mm per annum. Kenya's economy depends on agriculture and with only 20% of the land area lying in high and medium potential and it is not enough to produce adequate food for the population. Therefore, this calls for production of food crops in the Arid and Semi-Arid Lands (ASALs), areas characterized with high temperatures, low and erratic rainfall. Hence the need to grow crops like

Table 1. Green gram production in Kenya between 2006 and 2010

Year	2006	2007	2008	2009	2010
Area (Ha)	102882	82784	91452	112997	147352
Production (Ton)	43399	61953	26715	42333	61248
yield (Tons/Ha)	0.421833	0.748369	0.29212	0.374638	0.415658

green gram which are suitable in such areas. Green gram (*Vigna radiata* L.) is the hardiest of all pulses and is well adapted to ASALs. However, the high light intensities, high temperatures and erratic rainfall experienced in these areas lead to high evapo-transpiration rates leaving less water available to plant, which may negatively affect the growth and yield parameters. The amount of light intensity in these areas is high and causes high evapo-transpiration and there is need to manage it [9].

Light is one of the ecological factors exerting the greatest effect on germination, seedling emergence and development [10,11]. Shading reduces air and soil temperature [12,13] thus reducing water loss through evaporation and transpiration from plants and this may lead to better agronomic performance of crops in ASALs. According to [9], irrespective of its source, shade reduces Irradiant.[11]indicated that 3 major physiological responses to shade have been observed including; a reduction in the respiration rate, an increase in the shoot to root partitioning photosynthates and an increase in the specific leaf area with a relatively low leaf mass ratio. Further, [11] indicated that in areas where water and nutrients are limited, there is increasing evidence that substantial improvements in herbage yield and forage nutrient quality can be obtained when C4 grasses are grown under tree shade in tropical and subtropical grasslands. According to[14]the most consistent benefit from shade is better soil moisture, leading to a higher soil organic matter breakdown and, therefore, more Nitrogen (N) is available in the soil. Therefore, it is important to introduce shade to a crop in order to achieve good agronomic performance.

There is dearth of information on the effect of reduced light intensity on agronomic performance of pulses. According to [12] reducing the light intensity by 30% did not affect the yield of snap bean and that light reduction tended to decrease pod size, plant biomass, and leaf greenness, while leaf area and chlorophyll contents were increased with increased shading. Also incidences of powdery mildew occurred late in the season and were linearly increased by reduced light. The objective of this study was to evaluate the agronomic performance of green gram accessions under reduced light intensity in the Arid and Semi-Arid Areas of Kenya.

2. MATERIALS AND METHODS

2.1 Site Description

The study was carried out in Kiboko sub-station of KARI Katumani (Kiboko) in Makueni County during the 2012 short and 2013 long rain seasons. Kiboko is situated about 3° 15'S; 37° 50'E and 975 m above sea level. It is located half a km off the road to the right, approximately 159 km South East of Nairobi along the Nairobi-Mombasa Highway. The turnoff at Kiboko Market is about 15 km before Makindu town. The center receives bimodal rainfall with an annual average of 386.4mm. The 2012 short rain season was between the months of March - May with an average of 295.3 mm and long rain season occurs between October and December with annual average of 91.1 mm [15]. Monthly average temperature range from 26.9°C to 30.8°C and an evaporation of 2000 mm. Kiboko is in agro-ecological zone 5 and is a representative of a typical ASAL in Kenya. It is endowed with ferric luvisols [16].

2.2Green Gram Genotypes

Four green gram genotypes; GBK-022494A, GBK-022502A, GBK-022501A and Nylon-1 were used in this study. The genotypes were identified from data on seed yield obtained from two different sites [Kiboko and Machakos ATC (MKS ATC)] during the 2011 short rain and 2012 long rain seasons, whereby the best (in terms of seed yield) overall across sites, the best in each of the sites and the best commercial genotype were selected as indicated on Table 2.

Table 2. Green gram accessions and their source

Accession	Seed yield (gm)	Yield per ha (ton ha^{-1})	Remarks
GBK-022494A	55.6	7.4	Best overall
GBK-022502A	45.2	6.0	Best in Kiboko
GBK-022501A	35.4	5.8	Best in MKS ATC
Nylon-1	43.8	4.7	Commercial variety

2.3 Preliminary Trial on the Appropriate Shade Net for the Study

Before embarking on this experiment, a preliminary trial was conducted to establish the appropriate shade net which reduced the amount of light striking the plant canopy without interfering with the Photosynthetically Active Radiation (PAR). Shade nets that reduced the amount of light intensity striking the plant canopy by 35%, 45% and 50% were evaluated. The shade net reducing the amount of light by 35% was found not to interfere with PAR, and hence was selected and used for the present investigation.

2.4 Experimental Layout and Treatments

The experiment was laid in a Split-plot design with three replications. The main plot was shade with two levels; shaded and un-shaded, with accessions as the sub-plot. The 4 accessions were then planted under the shade net (shade) which reduced the amount of light intensity by 35%. The 4 accessions were also planted under direct light intensity (control) and replicated three times. Diammonium Phosphate (DAP) fertilizer was used during planting at a rate of 100 kg/ha [17]. Sucking pests were controlled by use of Lambdacyhalothrin 17.5 g/l while Mefenoxam at a rate 1 kg per ha and Difenoconazole 250 g/l at rate of 1litre per ha were used to control powdery mildew and rust respectively [18].

2.5 Data Collection

Five plants were randomly selected and tagged in each plot. From these plants data for various traits was collected as follows; Number of days to flowering was achieved by counting as the number of days from planting to the date when the first flower opened. Plant height was measured as the height (cm) between the soil surface and the tip of the central shoot of mature plants. Number of pods per plant was obtained by counting pods on the plant at maturity. Number of seeds per pod was obtained by randomly selecting 10% of the pods per plant, splitting the pods, followed by counting the number of seeds per pod, summing them up, and then dividing by the number of pods involved. Number of days to maturity was gotten by counting the number of days from planting to the date when seventy five percent of the pods per plant were dry. Weight of 100 seeds was obtained through threshing all the pods from each plant and winnowed after which, 100 seed were randomly selected and weighed. Seed yield was obtained by extrapolating the weight of 100 seed weight through the following process; i) the number of seeds per plant was obtained by multiplying the number of seeds per pod by the number of pods per plant ii) The weight of one seed was obtained by dividing 100 seeds weight by 100 (iii) multiplying i& ii above.

2.6 Data Analysis

The data collected for each season were subjected to analysis of variance (ANOVA) using GenStat Ver. 12 statistical software [19] and where significant differences were noted, means were subjected to mean separation using Least Significant Difference (LSD).

3. RESULTS

3.1 Rainfall

During the 2013 long rain season, Kiboko received higher (320 mm) amount of rainfall as compared 140 mm received in 2012 short rain season (Table 3).

3.2 Plant Height

The green gram accessions differed significantly ($P \leq 0.05$) in their plant heights with shading having no effect on their heights during the 2012 short rains (Table 4). Although accession GBK-022501A had the highest (55.1 cm) plant height, it was not statistically taller than GBK-022502A (52.5 cm) and GBK-022494A (49.0 cm). Nylon-1 (check) had the shortest (44.4 cm) plant height during the 2012 short rain season (Table 6). During the 2013 long rain season, shading had significant ($P<0.05$) effect on height of different accessions (Table 4). Generally, plants were taller (54.7 cm) when grown under shade net compared to control, open sunlight conditions (49.9 cm) during the 2013 long rain season (Table 6).

3.3 Days to Flowering

The number of days to flowering was not significantly influenced by the accessions or shade treatments for both 2012 short and 2013 long rain seasons at Kiboko (Table 4).

Table 3. Weather records for 2012 short and 2013 long rains for Kiboko

2012 short rains (only months which rains are indicated)					2013 long rains (only months which rains are indicated)				
Month	Week of the year	Rainfall/ week (mm)	Mean daily Temp(^{o}C)	RH (%)	Month	Week of the year	Rainfall/ week (mm)	Mean daily Temp(^{o}C)	RH (%)
Nov	44	11.0	26.3	87.0	March	11	0.0	26.9	85.6
	45	9.9	25.4	81.0		12	8.3	25.7	88.6
	46	0.0	26.0	82.9		13	47.5	26.3	84.7
	47	0.0	26.6	89.0	April	14	24.6	26.1	91.1
	48	17	25.2	87.7		15	169	25.4	94.3
Dec	49	3.5	25.4	91.0		16	33.8	25.9	90.6
	50	9.5	24.6	90.4		17	0.8	25.1	92.2
	51	33.1	23.3	92.1	May	18	23.5	23.2	91.6
	52	30.0	23.7	91.9		19	12.5	22.7	96.1
Jan.	1	1.5	23.7	90.3		20	0.0	23.6	85.9
2013	2	6.0	25.0	92.4		21	0.0	21.1	92.1
	3	0.0	23.9	92.3		22	0.0	22.2	87.9
	4	0.0	24.2	87.6	June	23	0.0	22.6	86.6
	5	20.5	25.0	80.7		24	0.0	20.5	90.9
Feb.	6	0.0	24.3	87.4		25	0.0	21.1	93.6
	7	0.0	25.9	80.4		26	0.0	20.4	93.2
	8	0.0	26.4	78.4					
	9	0.0	25.7	77.4					

Mean temperature for the 2 seasons = 24.4^{0}C, Mean RH% for the 2 seasons=88.5

3.4 Day to Maturity

The number of days to maturity was not significantly influenced by shade or accession during the 2012 short rain and the 2013 long rain seasons (Table 4).

3.5 Pod Length

The pod length showed significant ($P≤0.05$) differences under the shade treatments while accessions had no effect on pod length during the 2013 long rain season (Table 4). The average pod length under the shade net was longer (7.7 cm) than that in control, open sunlight condition (7.4 cm) as indicated in Table 6. The number of pods per plant was not significantly influenced by the accessions or shade treatments during 2013 long rains (Table 4).There were no significant differences in pod length due to genotype or shading during the 2012 short rain season.

3.6 Number of Pods per Plant

Accessions had significant ($P≤0.01$) effect on number of pods per plant while shade had no effect on number of pods per plant during the 2012 short rain season (Table 4). Accession GBK-022501A had the highest (40) number of pods per plant although this was not significantly different from GBK-022494A with 34 pods per plant. Nylon-1 had the least (25) number of pods per plant which was not significantly differently from GBK-022502A which had 29 pods per plant (Table 7). The number of pods per plant was not significantly influenced by either the accessions or shade treatments during the 2013 long rain season (Table 4).

3.7 Number of Seeds per Pod

Shade had significant ($P≤0.05$) effect on the number of seeds per pod while accessions had no effect on the number of seeds per pod during the 2012 short rain season (Table 4). Number of seeds per pod was higher (9 seeds) under the net while in control, open sunlight conditions the number of seeds per pod was 8 during the 2012 short rain season (Table 5). The number of seeds per pod was not significantly influenced by the accessions or shade treatments during the 2013 long rain season (Table 4).

3.8 100 Seed Weight

The 100 seed weight of the green gram accessions were not significantly influenced by the shade treatments for both the 2012 short rain season and the 2013 long rain seasons (Table 4).

Table 4. Mean squares of various parameters of green gram genotypes measured at Kiboko during 2012 short and 2013 long rain seasons

	Plant Height	Days to Flowering	No. of days to maturity	Pod Length	No. of pods per plant (cm)	No. of seeds per pod (No)	100-Seed Weight (g)	Seed Yield
Kiboko 2012 short rains								
Shade	4.12ns	3.082ns	0.1350ns	0.0033ns	40.56ns	2.160*	0.096ns	1.222ns
Accession	128.61*	2.113ns	2.353ns	0.0625ns	236.73**	0.044ns	1.512ns	29.123**
Shade.Accession	6.03ns	1.308ns	0.717ns	0.040ns	82.06ns	0.436ns	0.183ns	11.537ns
Kiboko 2013 long rains								
Shade	136.64*	9.209ns	124.517ns	0.5360*	25.83ns	3.501ns	0.510ns	4.50ns
Accession	73.07ns	4.304ns	8.954ns	0.145ns	67.55ns	1.074ns	0.178ns	24.35ns
Shade.accession	15.56ns	0.725ns	4.222ns	0.169ns	49.98ns	0.029ns	0.207ns	17.07ns

*ns=Not significant, *=5% significance level, **=1% significance level, cm=centimeters, No.=number, g=grams*

Table 5. Summary of mean values of all the traits under shade treatment at Kiboko during 2012 short rain season

Shade	Plant height (cm)	No. of days to flowering	No. of days to maturity	Pod length (cm)	No. of pods per plant	No. of seeds per pod	100 seeds weight (g)	Seed yield (g)
Net	49.9	39.82	69.13	7.56	31.1	9	5.17	13.97
Control	50.7	39.1	68.98	7.583	33.7	8.4	5.29	14.42
Mean	50.3	39.46	69.06	7.572	32.4	8.7	5.23	14.19
LSD(P≤0.05)	2.69	4.016	3.542	0.0827	31.01	0.472	0.496	15.827
CV%	1.5	2.9	1.5	0.3	27.3	6.2	2.7	31.7

cm=centimeters, g=grams, No.=number

Table 6. Summary of mean values of all the traits under shade treatment at Kiboko during 2013 long Rains

Shade	Plant height(cm)	No. of days to flowering	No. of days to maturity	Pod length (cm)	No. of pods per plant	No. of seeds per pod	100 seeds weight(g)	Seed yield(g)
Net	54.7	38.56	66.79	7.744	25.4	10.11	5.37	14.16
control	49.95	37.32	62.23	7.445	27.5	9.35	5.66	15.02
Mean	52.3	37.94	64.51	7.594	26.4	9.73	5.52	14.59
LSD(P≤0.05)	3.03	3.497	5.945	0.2235	2.77	1.73	0.824	4.999
CV%	1.6	2.6	2.6	0.8	3	5.1	4.2	9.8

cm=centimeters, No=number, g=grams

Table 7. Summary of mean values of the accession's traits at Kiboko during 2012 short rain season]]

Accessions	Plant height (cm)	No. of days to flowering	No. of days to maturity	Pod length (cm)	No. of pods per plant	No. of seeds per pod	100 seeds weight (g)	Seed yield (g)
GBK-022494A	49	39.67	68.53	7.587	34	8.67	5	14.45
GBK-022501A	55.1	39.5	68.57	7.63	40.3	8.73	4.85	17.21
GBK-022502A	52.5	40.03	69.83	7.647	29.4	8.8	5.09	12.67
Nylon-1	44.4	38.63	69.3	7.423	25.8	8.6	5.97	12.44
Mean	50.3	39.46	69.06	7.572	32.4	8.7	5.23	14.19
LSD(P≤0.05)	2.606	2.606	1,171	0.2135	7.37	0.668	1.095	7.242.
CV%	5.1	2.7	1.4	0.4	10.4	6.2	10.5	3.5

cm=centimeters, No.=number, g=gram

3.9 Seed Yield

Accessions had significant (P<0.01) effect on seed yield while shade had no effect on seed yield during the 2012 short rain season (Table 4). Accession GBK-022501A had the heavier (17.2 g) seed yield while Nylon-1 had the least (12.4 g) seed yield although it was not significantly different from GBK-022502A (12.7 g) and GBK-022494A which had a seed yield of 14.5 g (Table 7). However, neither accession nor shade had significant influence on the seed yield during the 2013 long rain season (Table 4).

4. DISCUSSION

Generally the mean values of the parameters measured were found to be higher under the reduced light intensity (shade net) as compared to those under direct intensity (control) during the 2012 rain season in both sites. However, during the 2013 long rains all the measured parameters had generally lower mean values recorded under shade net as compared to those measured in control and open sunlight treatment conditions. The range (of value) of the parameters were picked from both 2012 short and 2013 long rain seasons both under shade net and in control, open sunlight conditions. For instance, range for plant height under shade net was that obtained under net during the 2012 short and 2013 long rain seasons

The accessions had a range of 49.9-54.7 cm plant height under shade net and a range of 49.9 – 50.7 cm in control, open sunlight conditions. These results corroborate with the findings of [20,21] at Kerala Agricultural University, [22] and [23] at Bangladesh, [24] at Kyushu University, Japan, [25] at Phetchaburi, Thailand; [26] at Egypt and [27] at Japan; [28] in Thailand, which showed that plants grown under reduced light intensity had a higher plant height as compared to those under direct sunlight. Higher plant height under the shade could be due to a reduction in the rate of evaporation of the water from the soil providing cooler root zone leading to enhanced root development which probably led to higher plant height and also due to photosynthesis rate which may be proportional to chlorophyll content only at low light intensity.

The accessions took a range of 38-39 days to flower under shade net and a range of 37 and 39 days in control, open sunlight conditions. Light is an indispensable resource for plant growth because the light energy supplied from the sun is the basic factor that regulates growth rate, organ development or structure, function and behavior. Therefore the increase in the days to flowering under the shade net could probably be due to the reduced light which reduced metabolic activities within the plant resulting in slow development. The results were in line with those reported by [29] who reported that long exposure to shade diminishes reproductive potential by directly decreasing initiation of flowering of soybean.

The accessions took a range of 66 and 69 days to mature under shade net and a range 62 – 68 days in control, open sunlight conditions. The days to maturity under the shade net treatment were more because the reduced irradiance intensity led to low photosynthetic apparatus activity for carbon assimilation and photochemical systems in the leaf thereby slowing the rate of growth. The results were comparable to those reported by [12] who indicated that reducing light intensity delayed maturity of snap beans.

The accessions had a range of 7.6 – 7.7 cm pod length under shade net and 7.4 – 7.6 cm in control, open sunlight conditions. The resistance to low light intensity or shading might have been an important factor for the green gram accession in terms of pod length where they were the longest as compared to the control, open sunlight conditions. Shaded plants generally had a higher specific leaf area, because the leaves were characterized by having larger layer (and more densely packed) of palisade cells. This may have caused the increase in the number of chlorophylls, by which the photosynthetic rate per unit leaf area increased at low light intensity. The results were in line with those by [12] who indicated that reduced light intensity reduced pod size.

The accessions had a range of 25 and 31 pods per plant under shade net and a range of 27-33 pods per plant in control, open sunlight conditions. The difference in the number of pods per plant within the same shade could be due to genetic variation of the different accessions while the variation in the average number of pods per plant due to shades (shade net and control) could be brought about by the observed darker green color of the leaves as a sign of high chlorophyll content which is responsible for better production in plants thus leading to the variations. These results were in line with those reported by [22,27,28,29,30,31] who reported that low light reduced number of pods per plant.

The accessions had an average of between 9 and 10 seeds per pod under shade net and a range of 8 - 9 seeds per pod in control, open sunlight conditions. The less solar energy supply by shading might have had no impact on the formation of seeds in the accessions thereby resulting in almost the same productivity compared to the control. These results were in line with [32] who reported that light reduction had no effect on the number of seeds per pod. The results were however contrary to those reported by [22,27,28,30] who reported that reducing light intensity led to reduced number seeds per pod.

The accessions had a range of 5.2 – 5.4 g 100 seed weight under shade net and a range of 5.3 – 5.7 g in control, open sunlight conditions. These results are in line with [22,30] who reported that shading reduced seed weight; [24], who indicated that shading treatment reduced total weight of all the cultivars involved. [25], who stated that shading, reduced dry weight. The results were contrary to those by [28] who reported that light reduction had no effect on seed weight. The no effect on 100 seeds weight could have been brought about by the genetic make-up of the accessions.

The accessions had a range of 13.9 – 14.2 g seed yield under shade net and a range of 14.4 - 15.0 g in control, open sunlight conditions. The leaves of the accessions under shade net had a darker green color probably a sign of high chlorophyll content. Chlorophyll plays a key role in determining the light absorption efficiency within a leaf. The chlorophyll content of plants is dependent on their genetic makeup which in effect results in difference in seed yields. The reduced light intensity probably allowed increased absorption of photosynthetically active radiation and thus enhancing the assimilation efficiency. The results are in line with [21] who reported that maximum grain yield of rice was realized under open direct sunshine; [12,20,22,27, 28,32] who reported that shading reduced seed yield.

5. CONCLUSION

Therefore, it can be concluded that the green gram accessions perform well under shade,in Arid and Semi-Arid areas at a reduced light intensity of (35%).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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