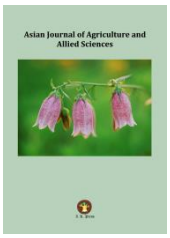

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On Farm Participatory Evaluation and Demonstration of Improved Tomato (*Lycopersicum esculentum* Mill.) Varieties Under Irrigation Condition in South-Eastern Ethiopia

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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

In Ethiopia, tomatoes are one of the most economically important vegetable crops. However, a number of factors, including a lack of improved and adapted tomato varieties, limit their productivity and production. A field study was conducted during the 2020 -2021 cropping season at Arsi areas, Tiyo, and Zuway Dugda districts and aimed to evaluate the performance of released tomato varieties, on-farm demonstrations, and varietal selection based on farmers' preferences. Six released tomato varieties, Chali, Melkashola, Melkasalsa, Eshete, ARP-D2, and Fetan were

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planted on basic plots at farms and replicated at the research station. Data were collected on growth, yield and yield related traits from the mother trials and farmers perception on the demo varietal trials. The analysis of variance revealed that the tested varieties had significant differences (P≤0.05) in yield and yield-related traits. As a result, Gelilema variety had significant marketable yield (55.91 t ha^{-1}) and total yield (65.24 t ha^{-1}), followed by Melkashola variety with marketable yield (47.42 t ha^{-1}) and total yield (59.12 t ha^{-1}). Total fruit yield correlated positively and significantly with marketable yield (0.89), average fruit weight (0.87), number of fruit per cluster (0.65), number of cluster per plant (0.97), and was negatively associated with plant height (-0.05). Farmers' preferred traits, such as higher fruit yield, better disease tolerance, fruit size, shape, transportability, and higher market demand, were used to rank the most preferred varieties at both distinct areas. At Golja kebele, Gelilema was the most preferred and best-performing variety, followed by Melkashola. At Zuway Dugda, Melkashola and Melkasalsa were selected as the first and second choices, respectively. As a result, in order to address the demand of the farming community public agricultural extension and other stakeholders should promote the selected improved tomato varieties from smallholder farmers to large-scale production in the area of study and comparable agro-ecologies.

Keywords: Correlation; farmers' preference; marketable yield; variety.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), a member of the *Solanacaea* family, mostly consumed vegetable crop, both in its fresh and processed form (Massimi, M. 2021). In terms of production, the second most cultivated vegetable crop throughout the world following the potato (Panno, S. 2021), whereas tomato ranks first as a processing crop among all vegetables (OECD. 2017). Tomato is grown as annual or short lived perennial crop sexually propagated through seeds (Jain, S. 2022). It has been globally cultivated in tropical, subtropical and temperature regions due to high yielding potential, wider adaptability and multipurpose usage (Kumar, M. N. 2021; Sirba, H. Y. 2022).

Ethiopia has diverse agro-ecologies that allow the country to produce different crops including tomato in different cropping seasons (Fikre, G. 2022). However, tomato is mostly grown under irrigation conditions in the country due to high disease pressure in the rainy season (Kelley, T. 2014; Gezahegn, F. 2022). The yield and quality of tomato have been described to be under genetic control and hence do vary widely with cultivars (Oko-Ibom, G. O. 2007). In Ethiopia, improved crop varieties and their production packages are developed by researchers mainly in research sites and tested on farmers' fields (verification trial) in very few locations of the potential areas, and variety recommendation is done based on average performance of the varieties without considering genotype by environment interactions and farmers' needs and preferences, and the released varieties are distributed to the growers across the country (Assefa, W. 2014). This top-down approach did not convince the farmers to grow improved varieties particularly in marginal areas. To improve technology generation, dissemination and adoption of improved technologies, different stakeholders have to be part of the breeding process. This can be through participatory variety selection by identification of priority traits, on-farm demonstrations, popularization and re-evaluation of the technologies (Ceccarelli, S. 2007). Commonly, participatory variety selection is employed to characterize farmers' needs and preferences in plant breeding to ensure that new varieties fulfil the needs and expectations of end-users (Steinke, J. 2017; Magaisa, A. 2021). It also assists plant breeders to develop technologies that fit into a specific production niche and the farmers' needs (Ceccarelli, S. 2000). Traditional farmers, employ more diverse and complex selection criteria, revolving around stable crop performance over seasons and they grow a range of genotypes that meet their needs in very complex and heterogeneous environments (Ceccarelli, S. 2007). In addition, it will eliminate a number of unacceptable varieties and speed up the selection and fast-track the dissemination processes (Assefa, T. 2006). Moreover, participatory research complements the formal breeding system (Belay, G. 2006), increases the job efficiency of the researchers (Bellon, M. R. 2001). Research costs can be reduced and adoption rates increased if the farmers are allowed to participate in variety testing and selection (Witcombe, J. R. 2005), and also creates a feeling of ownership for farmer (Weltzien, E. 2003). Hence, participatory variety

selection is seen by several scientists as a way to overcome the limitations of conventional breeding by including the farmer's knowledge, and their selection criteria, into a plant improvement program (Grando, C. S. 2007). Though, suitable varieties those have the yield potential, and productivity need to be tested at high potential area of Arsi Zone, Oromia Region (Geleta, D. Sh. 2023). Accordingly, the study was conducted with the objectives of evaluating the performance, and identify farmer preferred plant traits, high yielding and well adaptable improved tomato varieties through farmer's participation.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted in Tiyo and Zuway Dugda districts of Arsi zone at farmer's field of the potential tomato production, during 2020 and 2021 seasons. Tiyo distinct is located at 6° 59'' to 8° 49'' N latitudes and 38° 41'' to 40° 44'' E longitudes. Zuway Dugda distinct is situated at 7° 44'' to 8° 16'' N latitudes and 38° 50'' to 39° 8'' E longitudes, with major types of soil in Arsi Zone are Nitisols and Vertisols (Geleta, D. Sh. 2023). At on station of Kulumsa Agricultural Research Center (KARC) which is located at 8°00" to 8º02"N and 39°07" to 39°10"E and an altitude of 2210 m a.s.l. in Oromia, Ethiopia. The agro- climatic condition of the area is wet with 811mm mean annual rain fall and it is a uni-modal rainfall pattern with extended rainy season from March to September with altitude ranging from 1980 to 2230 m. However, the peak rainy season is from July to August, with the mean annual maximum (23.1°C) and minimum (9.9°C) temperatures.

2.2 Experimental Materials

The experiment consisted of six released tomato varieties, (Chali, Melkashola, Melkasalsa, Eshete, ARP-D2 and Fetan), which were released by Melkasa Agricultural Research Center for production of both fresh and processing purposes (Ministry of Agriculture. 2013).

2.3 Design and Field Management

The experiment was carried out at three distinct as Mother trial at on station and demo trials at different groups of farmer's field under irrigation. The mother trial was arranged in a Randomized Complete Block Design (RCBD) with three replications. Seedlings of each variety were raised on seed bed with the size of 1m x 2m. Uniform and vigorous seedlings of each variety were selected and transplanted to well-prepared field on plot size of 4mx3m, with 1m and 0.3m spacing between rows and plants respectively (Lemma, D. 2002). Agronomic as well as other management practices were carried out according to the recommendation as weeding, cultivation, irrigation, fertilizer application (100 and 200 kg ha^{-1} Urea and NPS, respectively) and staking were carried out uniformly during the growing season for all plots. Finally multi-disciplinary team of researchers from breeder, pathology and extension were involved to evaluate the performance of the varieties.

2.4 Farmers' Selection and Participatory Evaluation of the Varieties

In this study, two kebeles from Zuway Dugda and one kebele from Tiyo districts were selected purposely based on their accessibility and production potential of tomato. Demo farmer's field were selected from each district which used for participatory varietal selection and to value farmers' preferences during evaluation. Those farmers were selected based on availability of suitable and sufficient land to accommodate the trials, accessibility of irrigation, initiatives to implement the activity, field management and others criteria used to select the hosting farmers.

Table 1. Description of the tomato varieties used for the experiment

Variety name	Year of release	Growth habit	Maturity days	Yield potential (t ha^{-1})		Utilization
				Research field	Farmers field	
Melka shola	1998	Determinate	100-110	45	19.4	Processing
Melka salsa	1998	Determinate	100-120	43	13-17	Processing
Fetan	2005	Determinate	78-80	45.4		Fresh
Chali	2007	Determinate	110-120	30	12	Processing
ARP d2	2012	Determinate	100-120	37.2	13-16	Fresh
Gelilema	2015	Determinate	100-120			

Source: Adapted from Tujuba and Ayana (2020); Fikre et al. (2022); MoA, (2009)

Training was given for the farmers and experts about the overall technologies of tomato crop production, seed bed preparation, efficient use of irrigation water, integrated disease/pest management, stacking, recommended fertilizers and post-harvest handling of tomato crop. For those individuals, leaflets and small manuals on the technologies of tomato were organized and distributed before starting the activity.

Farmers' data collection was conducted through votes during a pre-harvest period when the crop reached maturity to evaluate the performance of the introduced varieties. A total of 45 farmers, having five different groups with nine members were participated in the evaluation of the varieties at both kebeles of Zuway-Dugda distinct. Also at Golja kebele five different group of farmers having eleven members a total of 55 farmers were participated. Before the evaluation of varieties, discussions on tomato crop characters were made with invited participants and the farmer groups by providing their opinion on the preferred attributes to select best tomato variety as: vegetative performance, maturity, number of fruits per plant, fruit size, fruit shape, transportability, market preference and resistance to late blight (Mehadi, S. 2016). The overall perception using these criterion and the parameters analyzed using pair wise and matrix ranking (Boef, W. S. 2007). Information gathered from the discussions, interviews (group discussion) and from the key informants was used to rank for each variety were given, using the mean of the group members value for each varieties on the plot.

2.5 Data Analysis

Data were analyzed using SAS statistical software and the least significant difference (LSD) at 5% was used in separating means. Farmers' preference data were analyzed using pairwise matrix preference ranking method.

3. RESULTS AND DISCUSSION

3.1 Performances of Yield and Yield-Related Traits

The result of the experiment revealed that the presence of significant differences (*P≤0.05*) in yield and yield related traits of the tested tomato varieties.

Days to maturity: The varieties statistically difference in days to maturity, number of fruit per cluster, number of cluster per plant, plant height, average fruit weight, marketable yield and total yield of tomato (Table 2). The Variety Melkashola mature earlier (76.0 days) than other varieties, followed by Chali (82.33 days) and Fetan (82. 45 days) whereas ARP-d2 (83.67) was the late maturing one (Table 2). It is in agreement with the finding of Sirba *et al.* (2022) who reported that days to 50% maturity was highly significantly (P≤ 0.05) influenced by tomato varieties. The early fruit maturity and furthermore the late maturity in tomato is attributed by genotypic character and in the extent influenced by the environmental factors of any particular growing area (Fayaz, O. K. 2007).

Plant height (cm): The pooled mean values of plant height varied between 99.93 cm (Melka shola) and 83.53 cm (Melka salsa) (Table 2). On the other hand Melka salsa was found to be the shortest variety among the six tested varieties. As reported by several authors, heights of tomato plants vary from Varity to variety (Ketema, W. 2021; Girma, N. 2023). Certain genes control and express varietal characteristics, such as height, shortness, and other morphological differences. Similar findings showed that, the highest plant height was recorded by variety Melkashola (79.84cm) next to Eshete (98.73cm) variety, whilst the lowest plant height (55.89cm) was recorded by variety Fetan followed by variety Chali (56.10cm) and Melkasalsa (67.40cm) (Fikre, G. 2022).

Number of fruit per cluster and clusters per plant: There were significant differences (*P≤0.05*) between the varieties in the number of fruit per cluster and the number of clusters per plant. The amount of clusters per plant varied from 9.40 to 15.27, and the mean values of fruit per cluster fell between 3.13 and 5.00 (Table 2). Melkasalsa produced the most clusters per plant, followed by Gelilema, while the Fetan variety produced the least number of clusters. Fruit yield increases with increasing number of clusters per plant, so, a tomato variety with more number of clusters per plant is regarded as high yielding type. According to the report of Pandey *et al*. (2006), one of the most important factors in tomato variety selection is the number of clusters per plant, which also defines the variety's potential productivity and ideal fruit size. These findings closely match those of Sirba *et al.* (Sirba, H. Y. 2022), Fikre *et al.* (2022), who found that 'Fetan' variety showed the lowest fruit number when compared with other varieties.

Table 2. Combined mean performance of tomato varieties at kulumsa on-station as mother trial during 2020 and 2021

Varieties	Days to 50% ripening	Plant height (cm)	Number of fruit per cluster	Number of cluster per plant	Average fruit weight (g)	Marketable yield (t ha^{-1})	Total fruit yield (t ha^{-1})
Melka salsa	83.33^{a}	83.53^{b}	4.47^{ab}	15.27^{a}	67.30^{d}	33.18^{b}	56.15^{ab}
Melka shola	76.00^{b}	99.93^{a}	5.00^{a}	11.47^{ab}	75.70^{b}	47.42^{ab}	59.12^{ab}
Gelilema	83.00^{a}	90.53^{ab}	4.07^{abc}	12.13^{ab}	83.00^{a}	55.91^{a}	65.24^{a}
ARP D2	83.67^{a}	93.13^{ab}	3.47^{bc}	8.33^{b}	70.40^{c}	37.01^{b}	46.11^{bc}
Chali	82.33^{a}	89.73^{ab}	4.00^{abc}	11.80^{ab}	42.70^{e}	32.05^{b}	41.83^{bc}
Fetan	82.45^{a}	84.72^{b}	3.13^{c}	9.40^{b}	45.00^{e}	31.55^{b}	35.74^{c}
Mean	81.796	93.556	4.022	11.400	64.02	39.518	50.697
LSD (5%)	1.746	9.8401	1.15	4.2203	2.5801	15.919	18.647
CV (%)	2.68	5.78	15.52	20.35	3.71	22.143	20.126

Means followed by the same letter or with no superscript letter within a column are not significantly different at 5% level; LSD = least significant difference; and CV = Coefficient of Variation

Average fruit weight (g): There was a significant difference (P≤0.05) in the average fruit weight between the varieties, the variety Gelilema (83.0g) had significantly higher average fruit weight when compared to Melkashola (75.70g) and ARP-D2 (70.40g), which gave a good fruit weight. The minimum average fruit weight (45.80g) was recorded for Chali (58.00g) and Fetan (59.63g). In agreement with the finding Mesfin (2022), Girma *et al*. (2023), Ademe and Melaku (Ademe, M. 2023), reported differences in fruit weight among varieties of tomato, which confirms our findings.

Marketable and total yield (t ha^{-1}): The marketable and total fruit yield results indicated significant variations (P<0.05) among the varieties. Gelilema variety had significant marketable yield (55.91 t ha^{-1}) and total yield (65.24 t ha^{-1}), followed by Melkashola variety with marketable yield (47.42 t ha^{-1}) and total yield (59.12 t ha^{-1}). Similar result also confirmed by Simba *et al*. (2016), reported that the highest total fruit yield was recorded from variety Gelilema, while the lowest total fruit yield obtained from variety ARP-Tomato-d2. On the other hand, Fetan and chali varieties were the least performing. Similar conclusion was reported by different authors, confirming our results as variety Melkashola had the higher yield with wider adaptability and acceptable for both processing and fresh consumption (Shibiru, T. 2016; Bekele, W. 2024). The highest yield variety could be due to having the highest number of clusters and number of fruits per cluster enhancing production of increased marketable fruit yield.

3.2 Correlation among Traits

According to correlation coefficient analysis, marketable fruit yield (0.81), number of fruit per cluster (0.67), number of cluster per plant (0.49), and average fruit weight (0.34) were all positively and significantly correlated with total fruit yield (Table 3). However, there was a negative correlation between plant height and both total fruit yield (-0.05) and average fruit weight (-0.06). Marketable yield had a positive correlation with the number of fruits per cluster (0.57), average fruit weight (0.47), and number of clusters per plant (0.38). This suggests that the marketable fruit yield increases in line with increases in the average fruit weight and the number of fruits per cluster. This outcome is consistent with research by Mesfin (2022), Girma *et al.* (2023), Ademe and Melaku (2023), which found a positive correlation between the marketable yield of the varieties and the number of tomato fruits produced per plant.

3.3 Farmers' Preference

In both districts, most of the farmers' selection criteria were comparable. The results of the study indicated that Gelilema had a higher overall mean of the ranks for each performance indicator at Tiyo (Golja) distinct. Overall, the farmers stated that the Gelilema tomato variety was selected because of its higher yield, comparatively better disease resistance, good vegetative performance, fruit size, fruit shape, transportable, and market demand, despite Melka shola and Melkasalsa following in second and third, respectively (Table 4). This indicates that farmers have good knowledge towards the variety selection because preferred varieties by

farmers confirm the research result at the mother trial, by way of Gelilema variety is a better yielder than other evaluated varieties, followed by Melkashola (Table 2). This result is consistent with that of Girma *et al.* (2023), who found that in the Ataye, Shewarobit area, farmers preferred and recommended the Melkashola variety for production. However, based on their preference criteria mean value, the farmers' preferred variety among the varieties evaluated at Zuway Dugda (Abura and Araxa) district revealed that Melkashola was the most preferred variety at both kebeles, followed by Gelilema and Melkasalsa, respectively (Table 4). Similarly, the best-performing tomato cultivars chosen by farmers and suggested for the Areka and Gofa districts in southern Ethiopia were Melka-salsa and Melka-shola, according to Tewodros and Negasi (Tewodros, M. 2014). Mostly, when selecting tomato varieties across all districts, the ranks and the average farmers' preferred attributes such as market preference, disease tolerance, number of fruits per plant, fruit size and shape, and yield potential were typically given priority (Fig. 1).

Table 3. Correlation of yield and yield related traits of tomato varieties

	NFPC	NCPP	PH	AvWt	MY	TY
NFPC	1.00					
NCPP	0.21228305	1.00				
PH	0.28307802	0.03957	1.00			
AvWt	0.03934304	0.21014	-0.06931	1.00		
MY	0.57748022	0.38801	0.10337	0.47505	1.00	
TY	0.6703378	0.49907	-0.0506	0.33638	0.81319	1.00

NFPC= number of fruit per cluster, NCPP=number of cluster per plant, PH = Plant height, AvWt= average weight MY = Marketable yield, TY=Total yield.

Table 4. Farmers' selection criteria and their average score for the varieties at Tiyo and Zuway-Dugda districts

Distinct		Farmers selection criteria									Total	Mean	Rank
		A	B	C	D	E	F	G	H	I			
Golja	Melkaselsa	4	4	4	4	4	3	3	4	5	35	3.9	3
	Melkashola	4	4	5	5	4	5	5	4	5	41	4.6	2
	Gelilema	5	4	5	5	5	4	5	5	5	43	4.8	1
	ARP D2	4	4	3	3	4	3	4	3	3	31	3.4	5
	Chali	4	4	4	4	4	5	3	3	4	35	3.9	4
	Fetan	3	3	2	3	3	2	2	3	4	25	2.8	6
Abura	Melkaselsa	4	3	4	3	4	4	3	2	3	30	3.3	5
	Melkashola	5	4	5	4	5	4	5	4	5	41	4.6	1
	Gelilema	5	3	5	4	4	5	5	3	5	39	4.3	2
	ARP D2	4	3	4	3	4	3	4	2	4	31	3.4	4
	Chali	4	3	5	4	3	5	5	4	5	38	4.2	3
	Fetan	4	4	3	2	3	4	2	4	4	30	3.3	5
Araxa	Melkaselsa	4	4	4	5	4	4	5	5	5	40	4.4	2
	Melkashola	5	4	4	5	5	4	5	4	5	41	4.6	1
	Gelilema	5	3	4	4	5	4	5	4	5	39	4.3	3
	ARP D2	3	3	4	3	4	3	4	4	4	32	3.6	5
	Chali	3	3	4	4	3	4	4	4	4	33	3.7	4
	Fetan	4	4	3	3	3	4	4	2	4	31	3.4	6

Scoring scale: 1= very poor, 2= poor, 3= good, 4= very good, 5= excellent/highly preferable; A= Vegetative perform, B= Early maturity, C= No. of fruit per plant, D= Fruit size, E= Fruit shape. F=Transportability, G= Marketability, H= Disease tolerance, I= Yield performance

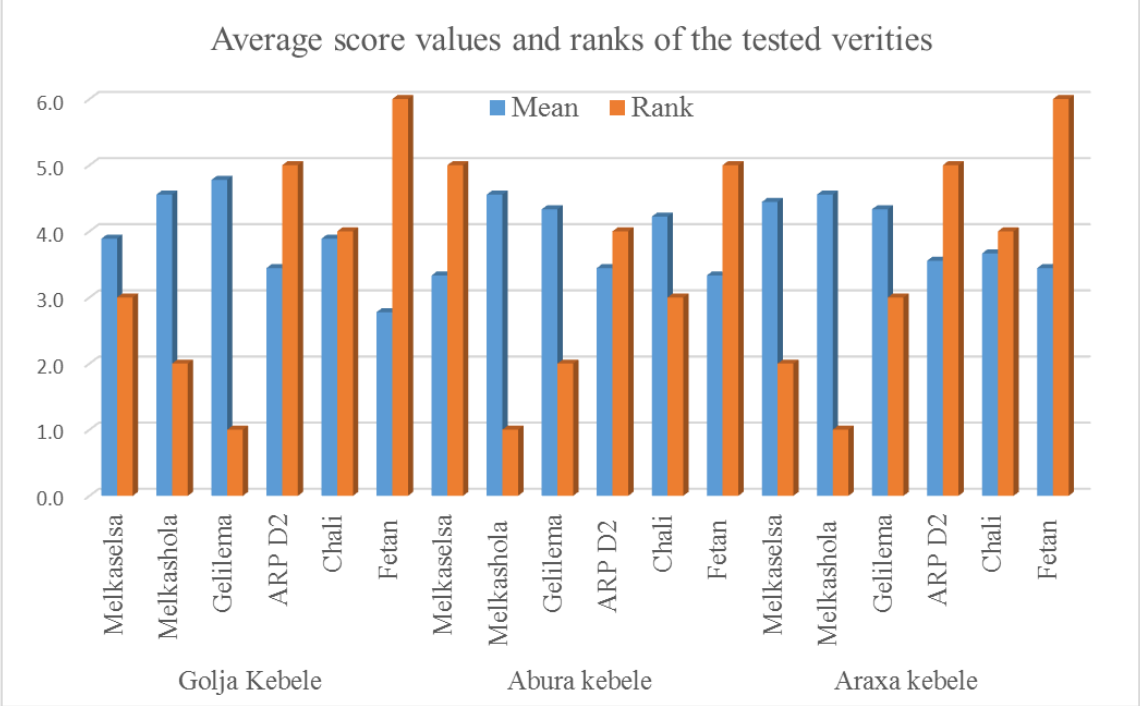

Fig. 1. Histogram of the average score values and ranks of the tested verities in all locations

Fig. 2. Field photo during demonstration and evaluation of tomato varieties at different sites

4. CONCLUSION

Among the evaluated improved varieties, variety Gelilema produced the highest total fruit yield, followed by Melkashola, positively the highest score of overall preference attributes rank by farmers. The varieties that farmers preferred at both distinct levels were ranked according to their preferred traits, which were utilized for evaluation and selection. Gelilema, Melkashola, and Melkasalsa were the three best-performing and chosen varieties, and they were selected as

the first, second, and third options, respectively. As a result, farmers' preference of Gelilema and Melkashola were higher yielding and the first rank preferred tomato varieties by farmers in both Tiyo and Zuway-dugda districts, respectively. Thus, Gelilema Melkashola and Melkasalsa varieties were identified and recommended as the best tomato varieties in the study area under irrigation based on both the farmers' evaluation criteria and the research findings. Therefore, public agricultural extension and other stakeholders should popularize the selected improved tomato varieties with its associated agronomic practices to smallholder farmer's at large scale production in the similar agro-ecology.

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 this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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