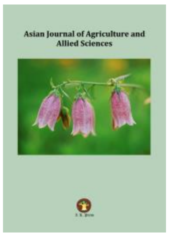

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Evaluation of Potato (*Solanum tuberosum* L.) Varieties for Growth and Yield Components at Bekoji South Eastern Part of Ethiopia

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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

Potato is one of the most important and strategic crops, which enhance food security and economic benefits to the world and countries such as Ethiopia. Ethiopia has suitable conditions for the production of potatoes. A field experiment was conducted in the South Eastern highlands of Ethiopia to evaluate the performance of potato varieties for tuber yield and yield related traits and to select best-performed variety in yield and yield related traits. The experiment was laid out in an alpha lattice design with two replications during 2019 main cropping season at Bekoji sub-station of Kulumsa Agricultural Research Center. The results of analysis of variance (ANOVA) showed the presence of highly significant (P<0.01) differences among varieties over all traits studied. The variety Gera produced the maximum total tuber yield of 51.1 t ha^{-1} and a marketable tuber yield of

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50 t ha^{-1}. Conversely, Moti produced the minimum total tuber yield of 14 t ha-1 and marketable tuber yield of 11.6 t ha^{-1}. For most tuber quality traits, viz., tuber specific gravity and dry matter content, varieties Moti and Belete were the maximum producers, respectively. Thus, it could be concluded that from the current study the best performed variety will be used to increase yield of potato by demonstration of variety in the study area.

Keywords: Agronomic traits; growth traits; potato; released varieties.

1. INTRODUCTION

Originating in South America, the potato (*Solanum tuberosum* L.) belongs to the nightshade or Solanaceae family (CIP. Potato Facts and Figures, 2017). After rice and wheat, it is the third most important food crop in terms of global consumption (Salim and Akte 2023). The amount of potatoes produced worldwide increased from 270 million tonnes in 1961 to 370 million tonnes in 2019. The primary cause of the output increase is a consistent increase in the yield potential of potato cultivars, since the area harvested for potato production decreased from 22.14 million hectares to 17.34 million hectares during the same period (FAOSTAT 2020). It is a major tuber crop that is extensively grown in the humid tropics and is used as a source of carbohydrates by many people in the tropical and subtropical regions (Bilate and Mulualem 2016).

Potatoes are farmed in more than 164 countries and are used almost daily by over a billion people, either in their raw or processed form. It is known in Ethiopia and was discovered by German botanist Schimper in 1858. It can be found on many African continents. Among root crops, it is one of the most important food crops in both developed and developing countries (Asfaw et al., 2017). The highlands of Ethiopia include around 70% of the country's arable land, which is ideal for growing potatoes (Tsegaw, 2005). A basic item, potatoes are important for improving livelihoods and ensuring food security in Ethiopia (Abebe Chindi 2019). Potatoes are the main cash crop and food crop in Ethiopia, especially in the high and moderate elevation regions; according to Yazie et al. (2017), they are also among the most grown vegetables in the country. A major staple crop in the Eastern and Central Africa sub-region, potatoes are becoming increasingly important due to growing urbanization and the consumption of processed potato products like crisps and French fries (chips) (Agerie et al., 2019). This is in contrast to the global average of 20.11 t ha-1 and other African countries like South Africa (37.3 t ha-1), Algeria (31.2 t ha−1), and Egypt (29.2 t ha-1). During the primary wet season alone, over 1.12 million families grew it on more than 78,000 hectares of land. More over 65% of this produce is consumed domestically, while about 20% is sold for profit (ESS. Ethiopia Agricultural Sample Survey 2022/2023). For every unit of land, time, and unfavorable conditions, potatoes provide more nutrient-dense (carbohydrates, proteins, minerals, dietary fiber, and a small amount of fat) food than other food crops (Gumul et al., 2011). With an average dry matter composition of 20% and a high percentage (60–80%) of dry matter composed of starches, potato tubers are rich in carbohydrates (Lutaladio and Castaldi 2009).

In addition to being high in carbs, potatoes also include phenolic acids, ascorbic acid, and carotenoids, which are all good for your health (Ezekiel et al., 2013). The main causes of Ethiopia's potato production challenges are the lack of improved varieties and germplasm for diverse agro-ecologies, the lack of formal seed system (mostly informal seed system), diseases and insect pests (late blight, bacterial wilt, viruses, and PTM), poor agronomic (spacing, fertility, ridging) and irrigation practices, limited capacity (human power, facility, and infrastructure), and the lack of quality and healthy seed tuber/planting material. A crucial factor is choosing the right variety for the area, as well as taking numerous steps to produce potatoes that are high-quality and high-yielding. These days, a lot of variety breeding research is done to find the potato variations that have the best quality, yield, and adaptation. The resulting varieties are then dispersed throughout different locations. The objective of this study was to choose potato cultivars that were very adaptable and performed exceptionally well in terms of yield and quality for high-altitude of Bekoji and the adjacent areas.

2. MATERIALS AND METHODS

2.1 Description of the Study Site and Experimental Materials

The experiment was carried out under rain fed conditions at Bekoji sub-station of Kulumsa Agricultural Research Center during the 2019 cropping season. The physiochemical characteristics of the soils at the Bekoji sub-station were as follows: pH of the soil was 5.23, the total nitrogen content (%) was 0.21, the accessible phosphorous contents (parties per million) was 9.72, the cation exchange capacity was 23.72, and the organic matter content (%) was 1.89. The experiment was conducted using twenty (20) improved varieties (Table 1).

2.2 Treatments and Experimental Design

Two replications and an Alpha lattice design were used for the experiment. The 9 m2 experimental plot was planted with four rows that were 0.75 m apart and 0.30 m apart from one another. Plots and blocks were separated by 1 m and 1.5 m, respectively.

2.3 Experimental Procedures

A tractor was used to harrow, disk plough, and level the ground. Rigging was then carried out by hand. 242 kgha-1 of NPS and 165 kgha-1 of urea were used as fertilizers. Every other required cultural custom was applied consistently to every plot.

2.4 Data Collected and Measurement

2.4.1 Data collected a plot basis

Days to First Emergence (days): The number of days from the date of planting to the day when the first flower bud opens in a plot.

Days to 50% Flowering (days): The number of days from the date of planting to when about 50% of the plants produced flowers.

Days to Maturity (days): The number of days from the date of planting to maturity.

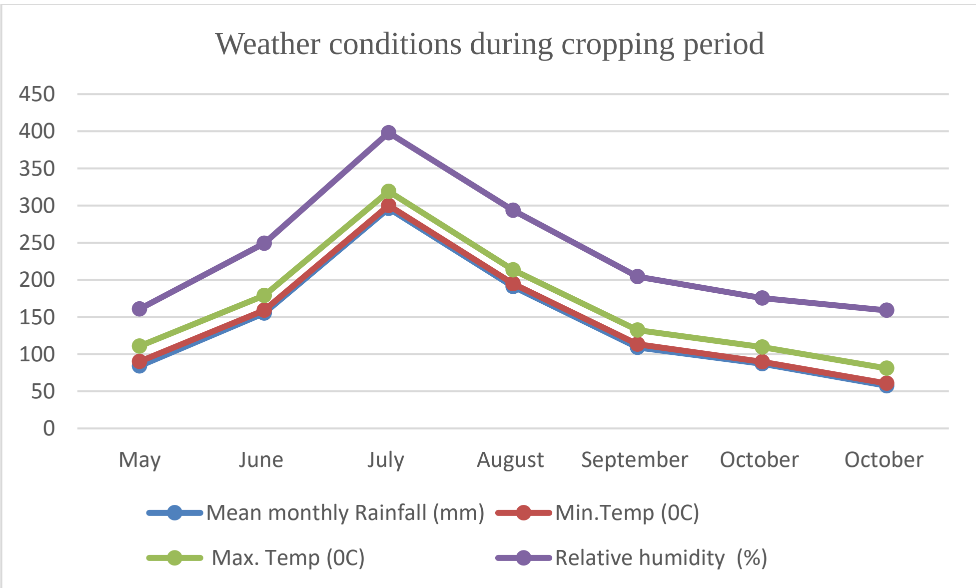
2.4.2 Data collected on plant

Number of Main Stem/Hill: The average number of stems from 10 hills per plot at 50% flowering was used to capture data on this attribute. Main stems were defined as stems that had grown directly from the mother tuber and functioned as a separate plant above the soil.

Plant Height (cm): Using a measuring tape, the height of five samples was recorded from ground level to the tip of the plant. The mean was then calculated.

Average Tuber Weight (g): Was divided by the corresponding total number of tubers to calculate the average tuber weight (g).

Marketable Tuber Yield (tha^{-1}): Weighing all the tubers that were free of flaws, disease, cracks, and other physiological abnormalities and that were not underweight per net plot area allowed us to compute the marketable tuber yield (tha-1), which was then converted into tons per hectare.



Graph 1. Maximum and Minimum temperature, rainfall, and relative humidity of at Bekoji experimental site

Source: Kulumsa Agricultural Research Center, Bekoji Meteorology station, 2019

Unmarketable Tuber Yield (tha^{-1}): Weighing every tuber from each plot that wasn't marketable and converting it to tons per hectare was how the unmarketable tuber yield (tha-1) was determined.

Total Tuber Yield (tha^{-1}): The weights of marketable and unmarketable tubers from the net plot area were added up, and the result was converted to tons per hectare, or total tuber yield (tha-1).

Specific Gravity: This was computed using the following formula after 5 kg of tubers were weighed in the air and subsequently in water (Gould, 1995):

$$Specific\ gravity = \frac{Weight\ in\ air}{weight\ in\ air - weight\ in\ water} \quad \ldots\ldots\ldots\ldots 1$$

Tuber Dry Matter Content (%): Five tubers were diced into 1-2 cm tiny cubes to assess the dry matter content (%). Two sub-samples of 200 g each were then dried in two paper bags in an oven set at 80˚C for 72 hours until a steady weight was achieved. Next, using the formula below, the percentage of dry matter content for each variety was determined as recommended by CIP (2007):

$$Dry\ matter\ content(\%) = \frac{dry\ weight(g)}{fresh\ weight} * 100 \qquad 2$$

2.5 Statistical Data Analysis

All data were subjected to separate analysis of variance (ANOVA) using SAS software version 9.4 (SAS Institute 2010) according to model described in (Gomez and Gomez 1984).

Table 1. Experimental materials

S/No	Variety	Accession code	Year of Release	Breeding Center	Recommended altitude (meter above sea level)
1	Belete	CIP-393371.58	2009	HARC	1600-2800
2	Gudanie	CIP-386423.13	2006	HARC	1600-2800
3	Dagim	CIP-396004.337	2013	ADRC	2000-2800
4	Jalene	CIP-384321.19	2002	HARC	1600-2800
5	Shenkola	KP- 90134.5	2005	AwARC	1700-2700
6	Zengena	CIP-380479.6	2001	AwARC	2000-2800
7	Guassa	CIP-384321.9	2002	ADRC	2000-2800
8	Gera	KP-90134.2	2003	ShARC	2700-3200
9	Mara chere	CIP 389701-3	2003	AwARC	1700-2700
10	Harro	C1P384321.30	2015	BARC	1700-2700
11	Zemen	AL-105	2001	HU	1700-2000
12	Bubu	CIP-384321.3	2011	HU	1700-2000
13	Bedessa	AL-114	2001	HU	2400-3350
14	Gorebella	CIP-382173.12	2002	ShARC	1700-2400
15	Awash	CIP-378501.3	1991	HARC	1500-2000
16	Siquare	-	-	Local cultivar	Mostly grown in Amhara
17	Challa	CIP 387412-2	2005	HU	1700-2000
18	Menagesha	CIP-374080.5	1993	HARC	Above 2400
19	Ararsa	(C1P384321.30	2006	SARC	2400-3350
20	Moti	KP-90147-41	2012	SARC	2400-3350

*Source: (MANR (2016) *HU=Haramaya University, HARC=Holetta Agricultural Research Centre, AwARC= Awassa Agricultural Research Centre, ShARC= Sheno Agricultural Research Centre, ADARC= Adet Agricultural Research Centre, BARC=Bako Agricultural Research Centre, SARC=Sinana Agricultural Research Centre*

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

All traits had extremely significant ($p<0.01$) differences between the types, according to the analysis of variance (ANOVA) results (Table 2).

According to Lemma et al. (2020), the analysis of variance (ANOVA) results revealed that all of the types' differences were very significant (p<0.01). For traits like plant height, tuber diameter, tuber weight/plant, and tuber yield per hectare, the combined mean analysis of variance showed significant (p<0.01) differences among potato varieties; however, no significant differences were found for tuber length or number, according to Damtew et al. (2022). The analysis of variance revealed that there were extremely significant (p<0.01) variations between potato cultivars in terms of plant height, number of main stems per hill, number of tubers per hill, tuber yield per hill, and overall tuber yield, according to Tufan and Öztürk (2024).

3.2 Performance of Varieties for Phenology and Growth Traits

The majority of agronomic (morphological) and growth parameters showed significant heterogeneity across potato cultivars (Table 3). The potato varieties varied from 110.5 days (Siquare) to 123.5 days (Belete) to reach physiological maturity, whereas the Mara Chera and Ararsa took 60.5 days to reach 50% flowering and 85.5 days, respectively (Table 3). The cultivars Zenegena and Dagim had the highest and lowest plant heights, respectively, based on the analysis of variance (107.0 cm and 45.7 cm) (Table 3). Dagim had a significantly different number from other types, although the minimum plant height was the same as that of Awash, Mara chera, and Moti. Variety also had a substantial impact on the number of stems per plant (Table 3). As a result, the Ararsa variety outperformed all other types statistically, producing the highest number of stems per plant (6.0). The variety Awash had the lowest stem number per plant (2.1), which was statistically distinct from all other varieties except Gudanie, Mara chera, Moti, Bedessa, Gorebella, and Zemen.

The Guassa variety was the tallest (108.27 cm), statistically comparable to the Belete variety (103.87 cm), while the Dagim variety was the shortest (79.00 cm), according to Damtew et al. (2022). According to Damtew et al. (2022), the Gudane variety had the highest average stem number (6.93), which was statistically comparable to the Jalene variety (6.72), followed by the Belete variety (5.45), and the Dagim variety (3.22). The average plant height of potato types ranged from 43.3 to 86.6 cm, according to (Tufan and Öztürk 2024). According to Tufan and Öztürk (2024), cultivar had a major impact on the number of stems per hill. The quantity of branches and leaves that contribute to photosynthetic activity is correlated with the number of stems. The ultimate tuber yield may be positively impacted by increased photosynthesis and the synthesis and accumulation of carbohydrates, which can be ensured by increased absorption of solar radiation (Fantaw et al., 2019). The inherent genetic variance in the number of eyeballs on the tubers could be the cause of this. The number of shoots or eyes on tubers and, consequently, the number of main stems are influenced by genetic variations among potato cultivars (Getie et al., 2018).

3.3 Performance of Varieties for Yield Components and Yield

The average tuber weight of the varieties under study varied significantly, according to the results of the pooled analysis of variance. The Gera variety (120.0) and Moti variety (20.0) had the highest and lowest average tuber weights (g/tuber), respectively, according to the analysis of variance. Gera was statistically distinct from other kinds, although it had a non-statistical difference value from variety Belete, Gudanie, Jalene, Shenkola, Guassa, Bubu, Gorebella, Challa, and Menagesha. Additionally, Moti's average tuber weight from the Awash, Siquare, Bedessa, Zemen, Horro, and Dagim types was not statistically significant (Table 3).

The results of the analysis of variance showed that the varieties under study had highly significant differences in total tuber yield. According to Table 3, the farmers' Moti produced the lowest overall tuber yield (14.0 t ha-1), while the Gera variety produced the highest (51.3 t ha-1). The Belete (5.6 t ha-1) and Dagim (0.24 t ha-1) types yielded the highest and lowest amounts of unmarketable tubers, respectively.

Alegria (4497.5 kg da-1), Kaya (4441.0 kg da-1), Marabel (4277.0 kg da-1), and the indigenous variety Petek (5251.5 kg da-1) produced the most tubers, according to Tufan and Öztürk (2024). According to Damtew et al. (2022), the Dagim variety had the lowest tuber yield (20.41 tha-1), while the Belete variety produced the greatest (35.37 tha-1), followed by the Burka variety (31.73 tha-1). The existence of genetic variations utilized in the production of these varieties may be the cause of the highly significant disparities in tuber yield amongst

Table 2. Mean squares from pooled analysis of variances for twelve traits of 20 potato varieties in 2019

Source Variation	Mean Square											
	DF	DE	DF	DM	PH	STN	ATW	MY^t	UMY^t	TY^t	SPG	DMC
Group	1	62.5*	96.1	112.23	75.9	8.65*	0.001	61.94	9.77	120.92	0.007	2.55
Block(group)	8	2.75	24.66	353.67	35.61	0.65	0.0002	34.45	1.2	32.74	0.034	3.32
Treatment	19	29.21**	49.61	329.26	354.26**	2.48*	0.001*	185.68*	5.8*	210.82*	0.03	14.79*
Error	11	4.32	32.98	221.26	32.2	1.01	0.004	46.35	3.32	53.79	0.02	5.74
CV		7.9	7.32	13	7.61	27.13	28.65	30.64	64.1	29.26	12.62	9.91
R^2		94.33	77.7	80.23	96.46	87.78	85.13	90.91	79.82	90.89	75.91	85.54

Where DE, days to emergence, DF, days flowering, DM, days maturity, STN, stem number, STH, stem height, MT, marketable tuber(t/ha), UnM, unmarketable tuber yield(q/ha), TY, total yield(t/ha), SG, specific gravity and DM, dry matter content (%)

Table 3. Mean performances of 20 potato varieties for phenology and growth traits, tuber yield and yield related traits, and quality related traits evaluated at Bekoji in 2019

Trt	DE	DF	DM	PH(cm)	STN	ATw	MY(tha^{-1})	Umy(tha^{-1})	TY(tha^{-1})	SG	DMC
Belete	22.00g-i	82.00a	123.5a	89.00b	4.3a-f	0.09a-c	33.778b	6.4a	40.2a	1.11a	29.72a
Gudanie	26.0d-g	77.00a	127.0a	69.75e-g	2.5ef	0.07a-g	9.78f-h	3.91a-d	13.70ef	1.11b	27.33ab
Dagim	28.5b-e	74.5a	111.00b	45.70i	3.70b-f	0.021c-h	3.33gh	0.24d	3.58f	1.56a	18.83ef
Jalene	22.5g-i	75.5a	117.0a	87.5bc	5.4a-c	0.09a-d	28.89b-d	3.4a-d	32.33b-d	1.1b	26.70a-c
Shenkola	23.5f-i	79.00a	117.5a	93.5b	5.9ab	0.10ab	30.89bc	3.90a-d	34.78bc	1.1b	26.78ab
Zengena	19.0i	83.5a	116.0a	107.00a	5.0a-d	0.06b-g	30.89bc	5.23ab	36.12a-c	1.1b	23.60b-e
Guassa	20hi	79.5a	122.5a	82.5b-d	4.6a-e	0.077a-f	26.44c-e	2.9a-d	29.34b-e	1.1b	22.63b-e
Gera	24.0e-h	75.5a	116.0a	89.00b	5.7a-c	0.12a	50.0a	1.33b-d	51.3a	1.1b	24.11b-c
Mara chere	29.0a-d	60.5b	113.0a	58.00g-i	2.4ef	0.05c-g	23.56c-f	4.1a-d	27.63b-e	1.11b	21.5b-e
Harro	25.0d-g	80.50a	119.0a	70.50d-f	3.5c-f	0.06c-h	24.44c-f	2.67a-d	27.1b-e	1.1b	25.90a-d
Zemen	32ab	81.00a	122.0a	76.0c-e	2.4ef	0.05c-h	18.00c-g	2.11b-d	20.11c-e	1.11b	23.54b-e
Bubu	25.5d-g	81.5a	122.5a	85.5bc	3.1d-f	0.08a-e	30.44bc	3.63a-d	34.1bc	1.11b	24.76a-d
Bedessa	31.00a-c	80.00a	117.5a	76.00c-e	2.6ef	0.04e-h	22.67c-f	4.68a-c	27.34b-e	1.1b	24.2b-c
Gorebella	31.0a-c	80.0a	109.0a	60.00f-h	2.8d-f	0.07a-f	14.9d-h	0.44d	15.33ef	1.1b	23.86b-e
Awash	31.5ab	75a	111.0a	57.5g-i	2.1f	0.04f-h	12.11eh	2.67a-d	14.78ef	1.1b	21.1d-f
Siquare	28.00b-f	77.5a	110.5a	64.00e-h	3.7b-f	0.04gh	15.11d-h	2.11b-d	17.22d-f	1.1b	23.60b-e
Challa	27.5b-f	83.00a	115.0a	64.5e-h	2.90d-f	0.07a-g	21.11c-f	0.91dc	22.02c-e	1.11b	25.36a-d
Menagesha	26.5c-g	82.00a	115.0a	72.00d-f	3.00d-f	0.07a-g	24.44c-f	0.8dc	25.24b-e	1.11b	25.27a-d

Trt	DE	DF	DM	PH(cm)	STN	ATw	MY(tha^{-1})	Umy(tha^{-1})	TY(tha^{-1})	SG	DMC
Ararsa	20i	85.5a	114.0a	87.5bc	6.0a	0.06c-g	22.56c-f	5.2ab	27.72b-e	1.11b	27.6ab
Moti	33.5a	80.00a	122.5a	54.00gi	2.30ef	0.02h	11.6h	2.4d	14f	1.27ab	17.13f
Mean	26.3	78.5	114.38	74.47	3.69	0.065	22.22	2.85	25.1	1.13	24.17
LSD	4.57	12.64	3.34	12.48	2.21	0.041	14.99	4.01	16.14	0.32	5.27
CV	7.9	7.32	13	7.61	27.13	28.65	30.64	64.1	29.26	12.63	9.91

Where DE, days to emergence, DF, days flowering, DM, days maturity, STN, stem number, STH, stem height, AT(w), Average tuber weight, MT, marketable tuber(qt/ha), UnM, unmarketable tuber yield(t/ha), TY, total yield(t/ha), SG, specific gravity and DM, dry matter content (%)

potato types. According to Lemma et al. (2020), there were notable differences amongst potato cultivars in terms of tuber and tuber-related characteristics.

3.4 Performance of Varieties for Tuber Quality Related Traits

There were no appreciable variations in potato specific gravity between the types under study (Table 3). The pooled analysis of variance revealed that Gera had the lowest tuber specific gravity (1.1), while Moti had the highest (1.27), which was significantly different from all other potato varieties. Additionally, the specific gravity value of the Gera variety was not substantially different from that of any other variety (Table 3). Variety also has a major impact on the dry matter content of tubers. The Moti variety (17.13) had the lowest dry matter percentage among the types examined, while the Belete variety (29.72) had the highest percentage, followed by Ararsa (27.6).

The dry matter composition of Moti and Belete was statistically different from that of every other variety. According to Lemma et al. (2020), Menagesha had the lowest tuber specific gravity (1.057), while Belete had the highest (1.102), which was statistically distinct from all other potato types. According to Lemma et al. (2020), the Menagesha variety (15.708) had the lowest dry matter percentage, while the Belete variety (25.417) had the highest percentage, followed by Challa (23.625). According to Damtew et al. (2022), the Belete variety had the highest tuber dry matter content (26.52), which was statistically comparable to the Burka variety (25.85). Gudane (23.35) and Dagim varieties had the lowest (21.18) dry matter contents.

4. CONCLUSION

According to the current study, there are notable variations in tuber yield and yield components amongst potato cultivars. This implied that there was a greater likelihood that these types would be used in the crossover program to enhance tuber production and other significant agronomic or quality attributes. Ultimately, it may be said that yield and potato characteristics were significantly impacted by varietal differences. Therefore, in order to find viable varieties that perform better under a variety of the nation's agro-ecological locations and the ideal parental variety for the crossing program, the national potato research program should include varietal evaluation of potatoes.

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 the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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