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Influence of Bulb Weight at Planting and Drought Stress on Growth and Development of onion (*Allium cepa* L.) in the Northern Region of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author IKA designed the study, supervised data collection and wrote the first draft of the manuscript. Authors GO performed the statistical analysis while HT read through the work and edited it after it had been drafted by IKA. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To determine the effects of drought and bulb weight at planting on growth and development of onion in the Northern Region of Ghana.
Study Design: Levels of bulb weights at planting and watering regimes were factorially combined and replicated three times in randomised complete block design.
Place and Duration of Study: The study was conducted at the plant house of the University for Development Studies, Nyankpala in the Northern Region of Ghana from the 15th of July to 30th October, 2012 and repeated during the same period and in the same manner in year 2013.
Methodology: Three onion bulb weights namely large bulb (44.3g), medium bulb (26.1g) and small bulb (16.7g) were planted in pots, each of capacity 0.01m^3, and subjected to three levels of watering regimes: watering weekly throughout the experimental period, from the time of planting up to three weeks after planting, and from the time of planting up to five weeks after planting. The study was conducted using randomised complete block design with three replications. Growth parameters, plant vigour and bulb yield at harvest were collected for statistical analysis.

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Results: Drought stress did not significantly affect vegetative growth and bulb yield of onion but it played a crucial role in influencing plant vigour. Bulb weight at planting, however, influenced plant vigour, vegetative growth and bulb yield at harvest. In general, as the weight of the planted bulb increased, growth and yield parameters also increased in proportion to the weight of the planted bulb.

Conclusion: Onion growers in the Northern Region of Ghana should use large bulb weight (44.3g) at the time of planting in order to get optimum growth and bulb yield at harvest. Growers should also have access to irrigation facilities to supply water on their farms during the time of drought to maintain the vigour of plants especially when the crop is produced by planting small or medium bulbs.

Keywords: Onion; bulb weight at planting; drought stress; growth and development; plant vigour.

1. INTRODUCTION

In West Africa, the cultivation of onion (*Allium cepa* L.) is concentrated in Burkina Faso, Northern Nigeria, Niger, Senegal and Northern Ghana. In Ghana, however, the crop is grown commercially in the Northern and Upper Regions especially in areas around Bawku, Bolgatanga and the Kusasi districts. Other production areas are Ashiama, Dawhenya, Akatsi, Nsawam, Prestea, Koforidua, Kwahu, Mankessim and the Berekum districts [1].

The use of onion bulb as planting material is preferred by most onion growers as compared to onion seeds during planting. This is because bulbs are easier to use as compared to seeds. Planted bulbs also sprout and mature earlier than seeds. In addition, bulbs produce true-to-type plants. But majority of onion farmers in the Northern Region of Ghana do not have good knowledge about the right bulb weight to be used at the time of planting in order to get maximum growth and bulb yields at harvest. Selection of optimum onion bulb weight for planting is thus important, and onion growers must address this concern at the time of planting. Ashrafuzzaman et al. [2] reported that in bulbous crops, bulb weight affects plant height, number of leaves, length of scape, effective fruit per umbel, percentage of fruit set and seed yield. It is known that large mother bulb has a high food and water supply as compared to a smaller bulb and therefore plants produced from the former are characterised by more vigorous growth and higher yields than those of the latter [3].

Onion is shallow rooted and sensitive to water stress. The crop requires regular watering throughout its growth for best production. In bulbous crop production, drought stress may decrease growth and bulb yield at harvest [4]. Kadayifci et al. [5] stated that water deficits should be avoided especially during the period of bulb formation in order to obtain high bulb yield at harvest. Studies in the United States have also indicated that onion plants stressed prior to bulb formation recorded reduced bulb weights that were not acceptable as market grades. Those plants stressed after bulb formation were also prone to re-growth problems which resulted into serious storage problems [6]. The time of water stress in onion therefore determines the degree of yield and grade loss. Singh and Alderfer [7] observed that soil water stress at any growth stage leads to reduction in marketable yield at varying levels. Scientists and growers should have a good knowledge about the response of onion to drought stress in the Northern Region of Ghana. This knowledge is important as it will increase the understanding of the mechanisms of drought tolerance in the crop. In fact, breeders may also use this knowledge to develop cultivars with improved tolerance to drought. Similarly, a good knowledge about the right weight of bulb used for planting in the area will not only increase the yield but improve the quality of onion produced. This study was therefore conducted to determine the influence of drought and bulb weight at planting on growth and development of onion in the study area.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

Variations in the conditions of the plant house with respect to temperature and relative humidity during the period of experimentation were as shown in Table 1. Climatic conditions in the study area are also shown in Table 2.

2.2 Experimental Design and Planting

The study was conducted at the plant house of the University for Development Studies, Nyankpala in the Northern Region of Ghana. Field experiments began in the rainy seasons (July–October) of year 2012, and were repeated in the same manner and duration for year 2013. The experiments consisted of two factors namely: onion bulb weight and water regime. The first factor of onion bulb weight consisted of 44.3g, 26.1g and 16.7g representing the large, medium and small bulbs, respectively. The second factor of water regime involved watering plants throughout the experimental period, watering plants from the time of planting up to five weeks after planting (WAP), and watering plants from the time of planting up to three weeks after planting. These were subjected to nine treatments: T1, T2, T3, T4, T5, T6, T7, T8 and T9, where T1 refers to large onions watered throughout; T2 large onions watered up to 5 WAP; T3 large onions watered up 3 WAP; T4 medium onions watered throughout; T5 medium onions watered up to 5 WAP; T6 medium onions watered up 3 WAP; T7 small onions watered throughout; T8 small onions watered up 5 WAP and T9 small onions watered up 3 WAP. These treatment combinations were arranged on the plant house benches and replicated three times in a randomized complete block design. In all, three blocks, each having a dimension of 1.5 m x 1.0 m were used. The blocks were separated from each other by a distance of 0.5 m. Pots, (0.01 m^3 capacity) were filled with Nyankpala soil series (Plinthic Acrisol) and watered prior to planting of the bulbs. Four bulbs from each group of bulb weights from 'Bawku red,' the most popular onion cultivar in the area were planted. The bulbs were placed upright and planted at a depth of 2 cm from the soil surface. During watering, an amount of 1 litre (1000 mls) of water was applied to the plants in each pot per week as per each watering regime.

2.3 Cultural Practices

Pest and disease control were not carried out as they were not observed during experimentation but weeds were manually controlled by hand pulling at 4 weeks after planting. In general, the plants were watered according to their watering regimes as explained under section 2.2. The bulbs were harvested between the 10^{th} and 11^{th} week after planting.

2.4 Data Collection and Analysis

Data were collected on leaf length, number of leaves, numbers of tillers and bulb fresh weight at harvest. Plant vigour was also scored based on physical appearance and health of the plant stand. Considerations were given to the general plant performance and plant weakness resulting from water stress. Characteristics such as leaf greenness, plant growth rate, wilting or drooping of leaves were of paramount importance during scoring. In general, plants were scored on a scale of 1–5, where 1= very weak plant, 2 = weak plant, 3 = moderately weak plant, 4 = healthy plant and 5 = very healthy plant. The vigour score data were transformed using the formula $\log_{10}(x+1)$ where x = raw vigour score values of the plants and 1 = transformation constant. Means of data collected in the two years were computed prior to entering them into the spread sheet for analysis of variance (ANOVA) using Genstat statistical software. The least significant difference (LSD) was used to separate the treatment means at P=0.05.

3. RESULTS

3.1 Climatic and Plant House Conditions

The daily maximum and minimum temperatures and relative humidity of the plant house recorded during the experimental periods between the hours of 12.00 and 14.00 show that the maximum and minimum temperatures did not vary so much in the plant house. October was the hottest month whilst September was the coldest. Relative humidity values also ranged from 60–86% (Table 1). Meteorological data in monthly averages over a period of 5 years from 2009 to 2013 [8] in the study area indicates that the lowest average minimum temperature of 20.0°C occurs in November whilst the highest average temperature of 38.0°C is experienced in March. The highest rainfall is recorded in September (232 mm) whilst December – January are the driest months of the year (3 mm of rainfall). The relative humidity values follow closely that of rainfall with September recording the highest whilst December – January have the least (Table 2).

Table 1. Changes in weather conditions of the Plant house during the experimental period

Climatic parameter	July	Aug	Sep	Oct
Av. Max. temp. (°C)	33	34	32	35
Av. Min. temp. (°C)	24	24	23	26
Av. Rel. humid. (%)	76	81	86	60

3.2 Number of Tillers

For tiller production, a highly significant variation (P<0.01) existed among bulb sizes but no significant (P>0.05) differences were observed among the three watering regimes. The interaction between bulb size and watering regime was also significant (P<0.05). The single effects of bulb size indicate that there was no significant difference between the small (mean of 5.22) and medium bulb (mean of 6.44), but significant difference existed between the small and the large bulb or the medium and the large bulb. Plants from the large bulb produced the highest tiller number while those from the small bulb recorded the lowest. In all, the highest number of tillers was produced by plants of the large bulb that were subjected to water stress at three weeks after planting (Table 3).

Table 2. Variations in climatic conditions in the study area

Climatic parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Av. Max. temp.(°C)	35	37	38	37	35	32	31	31	30	33	36	34
Av. Min. temp. (°C)	22	22	23	24	24	22	22	23	22	21	20	21
Av. Rainfall (mm)	3	10	52	78	112	154	169	201	232	77	11	3
Av. Rel. humid.(%)	44	45	62	65	68	74	78	84	87	61	49	45

ata source: CSIR – SARI, Nyankpala, Tamale, Ghana

Table 3. Variations in tiller number of the three bulb sizes

Bulb size	Watering regimes			Mean
	Watered throughout	Watered up to three weeks after planting	Watered up to five weeks after planting	
Small bulb	5.67	4.67	5.33	5.22
Medium bulb	8.00	5.33	6.00	6.44
Large bulb	10.33	12.00	11.00	11.11
Mean	8.00	7.33	7.44	

LSD (0.05): Bulb size = 2.16; Watering regimes = 2.16; Bulb size × Watering regime = 3.73

3.3 Bulb Yield at Harvest

Bulb fresh weight at harvest differed significantly (P<0.05) among bulb sizes but no significant (P>0.05) variations were observed among the watering regimes. The interaction between bulb size and watering regime was also significant. Plants from the large bulb produced the highest bulb fresh weight at harvest while those from the small bulb recorded the least. The highest bulb fresh weight was obtained when plants of the large bulb were subjected to water stress at three weeks after planting (Table 4).

Table 4. Variations in bulb fresh weight of the three bulb sizes at harvest (g)

Bulb size	Watering regimes			Mean
	Watered throughout	Watered up to three weeks after planting	Watered up to five weeks after planting	
Small bulb	6.78	5.78	6.44	6.33
Medium bulb	9.11	6.44	7.11	7.55
Large bulb	11.44	13.11	12.11	12.22
Mean	9.11	8.44	8.55	

LSD (0.05): Bulb size = 1.12; Watering regimes = 1.26; Bulb size × Watering regime = 2.54

3.4 Leaf Length

In general, leaf growth of plants was particularly high from 2 to 4 WAP (weeks after planting) after which it slowed down (Fig. 1). The distribution of leaf growth did not, however, follow a definite pattern.

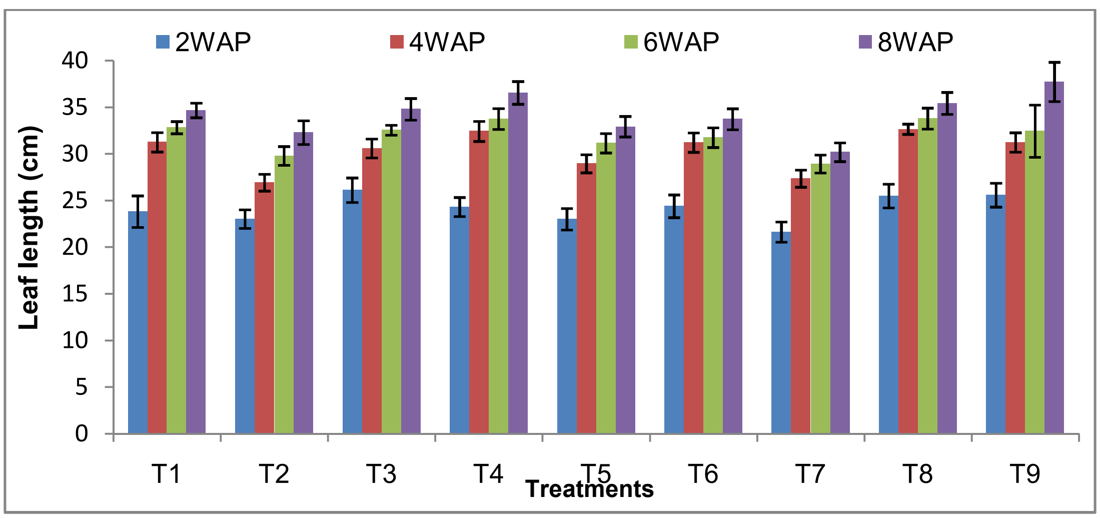

Fig. 1. Variations in leaf length of onion from the various treatment combinations

3.5 Leaf Number

Leaf production varied significantly (P < 0.05) among the various bulb sizes. Plants obtained from the large bulbs consistently and significantly recorded the highest leaf number, followed by those from the medium bulbs, while those obtained from the small bulbs gave the lowest values (Fig 2). However, number of leaves produced did not follow a particular trend among the various drought regimes within any bulb weight group.

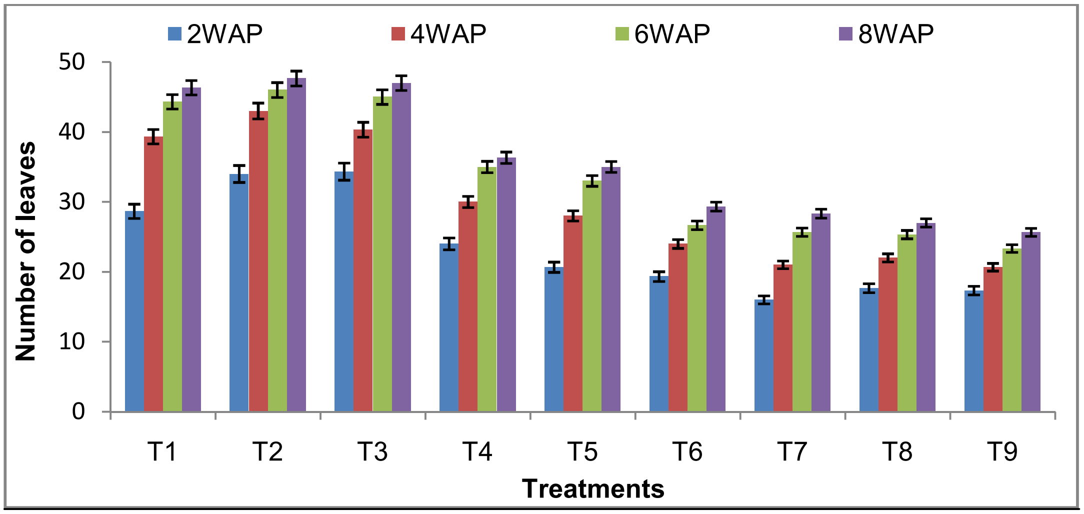

Fig. 2. Variations in leaf number of onion from the various treatment combinations

3.6 Vigour Score

In general, values for vigour rating increased from 2 to 4 WAP, or in some cases from 2 to 6 WAP. In all treatment combinations, the parameter decreased from 6 to 8 WAP. In the case of plants produced from large bulbs watered up to 3 WAP (T3), however, there was an increase in vigour from 6 to 8 WAP (Fig. 3). For this parameter, no significant (P>0.05) difference existed among the two factors at 2 and 4 WAP, but from 6 to 8 WAP, the parameter varied significantly (P<0.05) among watering regimes and bulb weights (Table 5).

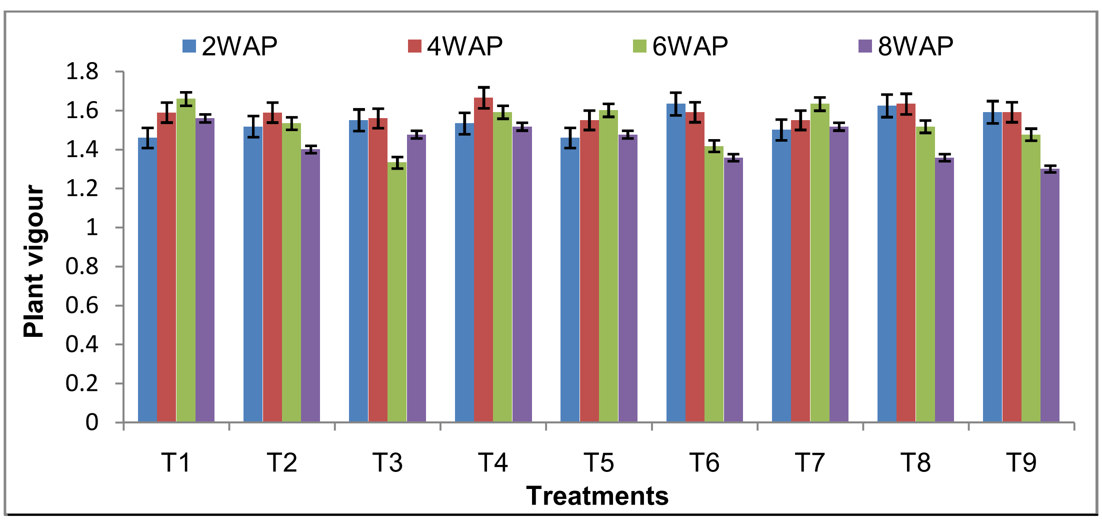

Fig. 3. Variations in plant vigour of onion from the various treatment combinations

Table. 5. Analysis of variance of vigour scores

Sources of variation	Degree of freedom	Sum of squares	Mean square.	Variance ratio	F prob.
Two weeks after planting					
Rep stratum	2	0.0133	0.0066	0.3200	
Bulb sizes	2	0.0180	0.0090	0.4300	0.65 NS
Watering regimes	2	0.0406	0.0203	0.9800	0.39 NS
Bulb size * watering regime	4	0.0426	0.0106	0.5100	0.72 NS
Residual	16	0.3319	0.0207		
Total	26	0.4464			
Four weeks after planting					
Rep stratum	2	0.0110	0.0055	0.5800	
Bulb sizes	2	0.0015	0.0011	0.1100	0.89 NS
Watering regimes	2	0.0015	0.0008	0.0800	0.92 NS
Bulb size * watering regime	4	0.0317	0.0079	0.8400	0.52 NS
Residual	16	0.1519	0.0094		
Total	26	0.1984			
Six weeks after planting					
Rep stratum	2	0.0106	0.0053	0.3400	
Bulb sizes	2	0.0003	0.0001	0.0100	0.99 NS
Watering regimes	2	0.1607	0.0803	5.1500	0.02 *
Bulb size * watering regime	4	0.0254	0.0063	0.4100	0.80 NS
Residual	16	0.2494	0.0156		
Total	26	0.4464			
Eight weeks after planting					
Rep stratum	2	0.0212	0.0106	1.5300	
Bulb sizes	2	0.0351	0.0175	2.5100	0.01*
Watering regimes	2	0.1170	0.0585	8.3800	0.01 *
Bulb size * watering regime	4	0;0378	0.0095	1.3600	0.29 NS
Residual	16	0.1116	0.0070		
Total	26	0.3228			

NS = Not significant (P > 0.05), = Significant (P < 0.05)*

4. DISCUSSION

Bulb weight used for planting is very important in the selection of planting materials for bulb production. In the present study, bulb weight influenced vegetative growth and bulb yield of onion at harvest. In general, as the weight of the planted bulb increased, leaf numbers, tiller numbers and fresh weight of bulbs at harvest also increased. The observation made here agrees with the results reported by [9]. According to these authors, higher vegetative growth and yield occurred when large bulbs were used as planting materials while small bulb weights recorded low growth. The increase in number of leaves was also directly related to the number of tillers produced. De Munk and Schipper [10] also worked on Irish bulb and reported that weight was an important indicator for flowering in that species. In onion, as in other bulbous crops, vegetative growth is observed mainly as increase in tiller and leaf production. The observed increase in growth or number of leaves and tillers in the present study could be explained using the concept of source-sink relationship. Leaves and tillers are important sink organs that depend on the reserves stored in the bulb for growth and development. The increase in leaves and tillers in this study was proportional to the size of the planted bulb. In fact, the observed increase in vegetative growth of plants produced from the large bulb also led to high bulb yield as compared to those from the medium and the small bulbs. According to [11], in vegetatively propagated plants, large planting materials are characterized by higher and more conspicuous reduction in weight during sprouting than small bulbs, and the higher the reduction in weight during sprouting, the higher the vegetative growth and yield at harvest. A large bulb does not only have a large food supply but also high water content [3], and all these enhanced good vegetative growth, high plant vigour and high bulb yield at harvest. The results presented in this study also confirm the findings of an earlier work [12] on ornamental geophytes. In that study, it was observed that reserved carbohydrates played a crucial role in the growth and development of bulbs.

The main effects of watering regimes in the present study on tiller production indicated that there was no significant difference; however, the interaction between bulb size and watering regimes was significant. According to Pelter et al. [13], onions are more sensitive to water stress during bulb elongation than they do in the vegetative stage. It has also been established [14] that the most critical growth period of onions to water stress is the bulb formation and development stage. The effect of water stress alone not being significant on tiller production of onion, among other factors, may be attributed to the duration of the stress period. Either the duration of drought might not have been long enough to adversely affect the parameters measured on the crop, or that the variety of onion used in this study was genetically tolerant to drought stress. Reducing irrigation by 25% had little effects on onion growth whereas large irrigation reductions resulted in large yield drops [15]. Results from the present study have revealed that, in general, increase in plant vigour was associated with large bulb weight at planting. This finding is in conformity with the observation that plants obtained from a large mother bulb recorded vigorous plant growth [3]. In the present study, plants produced from the large bulb significantly increased in vigour while those from the small or medium bulbs did not especially from 6 to 8 weeks after planting. In fact, when plants were subjected to water stress at 3 weeks after planting, the plants obtained from the large bulb significantly increased in vigour. Subjecting plants to drought stress at 3 weeks after planting implies that these plants had a longer period of drought stress than those stressed at five weeks after planting. Thus when plants were stressed for this longer period (watered up to 3 weeks after planting), only plants obtained from the large bulbs were vigorously growing and this might explain why plants from this category had higher tiller numbers. The relatively high growth rate that characterized these plants and probably coupled with high photosynthetic ability of these plants might have led to high dry matter accumulation in the bulb resulting in their higher bulb fresh weight at harvest as compared to those from the other treatment combinations. The higher plant vigour associated with plants produced from large bulbs probably was as a result of their higher storage reserves and water content as compared with those of small or medium bulbs. The low vigour rating which characterized plants from the small or medium bulbs during water stress is an indication that application of water to onion especially when they are planted from small or medium bulbs would be important in maintaining vigour for increased bulb yield and quality at harvest. The relatively higher vegetative growth of plants obtained from the large bulb is also an indication that in bulbous crops, plants produced from large bulbs mature quickly to reach senescence earlier [16] than those obtained from medium and small bulbs.

5. CONCLUSION

In onion production, the bulb weight used for propagation is very important in the selection of planting materials for bulb production. Bulb weight influenced vegetative growth, plant vigour and bulb yield of onion at harvest in this study. In fact, as the weight of the planted bulb increased, growth and yield parameters also increased. However, drought stress did not significantly affect these parameters probably because the duration of drought was not long enough to adversely affect the parameters measured, or perhaps the variety of onion used was tolerant of drought. Onion farmers in the Northern Region of Ghana who grow ‘Bawku red' cultivar should use large (44.3g) bulb size for planting in order to achieve good growth, development, and high bulb yield at harvest. Farmers should also have access to irrigation facilities to supply water on their farms during the time of drought to maintain the optimum plant vigour particularly if small or medium bulbs are used as planting materials for propagation.

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COMPETING INTERESTS

Authors declare that there are no competing interests.

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