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Advance and Registration of a New Bread Wheat Variety Shaki (ETBW9089) for Mid to High Altitude Wheat Producing Areas of Ethiopia

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ABSTRACT

Ethiopia is one of the highest wheat-producing countries in Africa. With 5.5 metric tons of wheat production in 2020, the country ranks 24th in the World and 2nd in Africa. Although the potential for wheat production in the area, production is reduced by fungal wheat rusts. During the epidemic year, wheat rust causes damage to the crop and results in a high reduction in wheat production. The national wheat research program objectively works in developing and releasing bread wheat variety with wheat rust disease resistance, high grain yield, and good wheat quality. In Bread Wheat National Variety Trial for Optimum Area Set I (BWNVTOASETI), Twenty -three advanced elite bread wheat lines and two checks: one local check and one standard check; as a whole, twenty-five genotypes were tested across six locations in 2018 and 2019 for two years by the national wheat research program. The Trial was conducted in square lattice design with three replication at all locations. The experimental unit was a plot of six rows with 2.5m in length by 1.2 m in width. The analysis of variance ANOVA is done to determine the effects of genotypes, environment, and their interaction on grain yield. Yield mean separation computed to differentiate the potential among the genotype. Compared to the yield of the checks, ETBW9089 and ETBW174464 were significantly different at ($p<0.001$) from the checks: Wane and Lemu. ETBW9089 has better disease resistance and grain yield. Therefore, the program was decided and proposed as a candidate variety for the 2020 cropping season. The NVRC accepted the recommendation From TC and released ETBW9089 as a new variety for mid to highland wheat-producing areas. The success of the wheat breeding program in Ethiopia mainly depends on the sustainably avail new technology and deliver more alternative bread wheat varieties for the farmers with a good quality foundation seed.

Key words: Wheat, BWNVTOASETI, ANOVA, genotypes

1. INTRODUCTION

Wheat is one of the substantial crops on the earth adopted and used by human Bing. It is under species of cereal grasses of the genus *Triticum* and family *Poaceae* [1]. More than 1000 species are known. And common wheat (*Triticum aestivum)* is the most widely grown. Bread wheat covers about 95% of world wheat production among cultivated wheat species [2].

Ethiopia is one of the highest wheat-producing countries in Africa. With 5.5 metric tons of wheat production in 2020, the country ranks 24th in the World and 2nd in Africa [3]. It is a staple food for millions of people and a source of income for the millions of farmers in the country. Wheat is produced in almost all parts of the region by smallholder farmers from low lands of afar depression to the highlands of Arsi and Bale.

Following the high birth rate and population growth in Ethiopia, the demand for wheat and its product increases nowadays. It plays a big role in the market. It has about 1-2 billion USD financial value in the market price of Ethiopia annually [6]. Hence, it is one of the strategy crops set for food security. The government gives high priority to wheat farming and puts more areas under irrigation for wheat production. In addition, the government supplies inputs and encourages private investors to participate in the wheat business.

Following the expansion and strengthen of wheat research at national and regional level, the progress of productivity is an indicator for wheat self-sufficient. It is projected from 1.8 t/ha in 2013 to 2.97 t/ha in 2019 [5]. But, reduced to 2.76 in the 2021 cropping season due to desert locust [8].

Although the potential for wheat production in the area, productivity is mainly reduced by fungal wheat rusts. During the epidemic year, wheat rust causes damage to the crop and results in a high reduction in wheat production.

Stem rust and yellow are the two biotic constraints in wheat production. Under high disease pressure, stem rust causes about 100% yield losses on susceptible varieties. Yield loss recorded more than 90% on variety Kubsa on unsprayed plots due to yellow rust at Bekoji and Meraro. Additionally, on variety Lemu, greater than 50% grain yield was observed at Meraro [4]. That is why, in wheat technology development, wheat rust resistance is the main trait which is why the national variety releasing committee set an evaluation character for wheat.

Yellow rust/striperust is caused by Puccinia striiformis f. sp. Tritici. It can be occurs throughout growth period of the plant. It causes high yield loss if the infection takes place at early stages of the plant growth. Small, yellow-orange pustules arranged in rows (stripes) on the leaves of wheat are the symptoms. Stripe rust needs a green host (wheat, perennial grassy weeds) to survive. A cool, humid weather favors the development of the disease.

Stem rust is caused by Puccinia graminis f. sp. Tritici. Usually it occurs at late of the plant growth. Large orange to red oval shaped pustules on stems, leaves, and leaf sheaths of infected plants are the symptoms of this disease. On susceptible bread wheat verities it can cause severe damage; there is a possibility to lose the whole crop. Warmer weather condition favors the disease.

More than a hundred bread wheat varieties have been released in Ethiopia since wheat research in the late 1960s [9] by research centers and universities. Due to the wheat rust outbreak, most of the varieties are out of production. The national wheat research program objectively works in developing and releasing bread wheat variety with wheat rust disease resistance, high grain yield, and satisfactory wheat quality.

2. MATERIAL AND METHOD

2.1. Evaluation of elite genotypes

2.1.1. The study material and Description of Experimental sites

The national Wheat research program set two trials as Bread wheat National Variety Trial for optimum areas in 2018. Those were, Bread Wheat National Variety Trial for Optimum Area Set I (BWNVTOASETI) and Bread Wheat National Variety trial for Optimum Area Set II (BWNVTOASETII). In Set I Twenty -three advanced elite bread wheat lines and two checks: one local check and one standard check; as a whole, twenty-five genotypes were tested across six locations in 2018 and 2019 for two years by the national wheat research program.

The trial was conducted all across Ethiopia at six locations; Adet, 11°17′N 37°43′E latitude and longitude with an Altitude of 2240 meters a.s.l. Sinan is 7°07′N 40°10′E latitude and longitude with an Altitude of 2240 meters a.s.l. Kulumsa, 8°02′N 39°10′E latitude, and longitude with an Altitude of 2200 m.a.s.l. Bokoji t has a latitude and longitude of 7°35′N 39°10′E with an elevation of 2810 m; Asasa has a latitude and longitude of 07°06′N 39°12′E with an Altitude of 2367 meters above sea level.; Arsirobe has a latitude and longitude of 09°36′N 39°08′E with an Altitude of 2435 meters above sea level.

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2.1.2. Experimental Methodology

The Trial was conducted in square lattice design with three replication at all locations. The experimental unit was a plot of six rows with 2.5m in length by 1.2 m in width. Area of the experimental unit was 3m2. The distance between rows was 20cm; distance between plots was 1m, and between reps was 1.5m. Fertilizers were applied per recommendation for the areas by the program; 121kg/ha NPS and 200kg/ha Ureas. The urea was applied two times: first at planting and the second at the seedling stage as a top dressing.

2.1.3. Data collection and Analysis

2.1.3.1. Grain Yield and Yield components

Date of heading, Date of maturity, and plant height taken on time on the field by the team. Thousand kernel weight, Hectoliter weight, and grain yield were taken after harvest in the laboratory by the member. The grain yield harvested from $3m^2$ weighed in gram per plot then, converted to ton per hectare. The analysis of variance ANOVA computed to determine the effects of genotypes, environment, and their interaction on grain yield. Grain mean separation was done to differentiate the potential among the genotype.

2.1.3.2. Wheat Rust Diseases

The two major wheat rust diseases: Stem rust and Stripe rust, scored two times on the field. The first score was taken 8-10 days after the first symptom. The second score (final score) was scored 3-4 weeks after the first score.

The design has three replication, and every genotype is repeated three times in each experiment at each location. That means a single genotype had three scores in a single trial. Then, the maximum score from the three scores uses to evaluate and select promising genotypes. For scoring yellow rust and stem rust modified cobb scale was used [10,11].

The modified cobb scale is a combination of numbers and letters, where the number stands for the severity of the disease, and the letter stands for the reaction of the host [12].

Severity =percentage of rust infection on the plant

The present used for scoring wheat rust severity are:
1= trace, 5%, 10%, and multiple of 5 up to 100%

Reaction = field response/ host response
The letters used to score the rust reaction are:
0= no visible infection on the plant
R= resistance: visible chlorosis or necrosis with the absence of uredia
MR= moderately resistance: small uredia are present and surrounded by either chlorotic or necrotic area
M= Intermediate: variable sized uredia are present some with chlorotic, necrosis, or both
MS= moderately susceptible: Medium size uredia are present and possible surrounded by chlorotic areas
S= Susceptible: Large uredia present, generally with little or no chlorosis and no necrosis

2.2. Evaluation of Candidates

2.2.1. Materials and Experimental locations

Bread wheat candidate varieties ETBW9089 and ETBW9606 were selected from National Variety Trial Set I and Set II I in 2019 by KARC. Two checks: Standard check Lemu and Local check Hidasse selected from widely grown wheat varieties in the area. As a whole, four entries were set for a Variety Verification Trial (VVT) in 2020. The trial had no design and replication. At each location, three testing sites were selected ahead of planting. Two of these were on a farmers' farm and one on a research station. Sites were with a minimum of 5KM apart.

Table 1: Information on Altitude, Soil, rainfall and temperature of tested location in 2020

Location	Altitude (m)	Representing agro-ecology	Soil type	Rain fall	Temperature	
					max	min
Kulumsa	2200	Mid altitude	Clay soil (luisols)	820mm	22.8	10.5
Arsi robe	2420	Water logged	Heavy clay soil	890mm	22.1	6

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		vertisoil	(verisiol)			
Sagure	2568	Water logged vertisoil	Heavy verti soils	546.9	21	12
Bokoji	2780	High land/high rainfall	Clay soil (nitosols)	1020mm	18.6	7.9

2.2.2. Registration of ETBW9089 (Shaki)

Kulumsa Agricultural Research Center submitted a proposal to the Ethiopian Ministry of Agriculture (MoA). The proposal was for registration and release as of their two elite bread wheat promising lines: ETBW9089 and ETBW9606 for mid to high lands. The proposal submitted to MoA contains application letter and two years national variety trial (NVT) of the candidate varieties. A minimum of three years for two years or a minimum of six years.

The ministry of Agriculture accepted the proposal and assigned a Technical Committee (TC) for field performance evaluation of the candidates. The TC moved to the field and evaluated the trial for agronomic performance, disease resistance, farmers' preference, and breeders' interest. Spike length, number of seeds per spike, seed color and size, number of tiller per plant, Plant height, maturity, yellow rust, and stem rust were traits taken by the TC.

The TC gathered the farmers from the surroundings and let them evaluate the candidates compared to the checks. The farmers gave ranks among the candidates and the reason for their selection. In addition, the TC took the breeders' view on their candidates relative to the checks. Finally, the TC reported their assessment over the candidate to NVRC and recommends or rejects the candidate for release based on their valuation.

3. RESULT AND DISCUSSION

3.1. Result and Discussion of Elite genotypes

Variation among the genotypes is one of the necessities that every crop research looking for in his breeding population to accomplish a fruitful selection. The probability of getting promising genotypes largely depends on the variation among genotypes. Also, very important to identify the source of variation using ANOVA [12]. Variation due to the genetic makeup of the genotype is the tool for selection. The higher genetic variation among the genotypes means the higher probability of getting potential candidate varieties [13, 14].

Results from the analysis of variance (ANOVA) revealed that (table 2) existence of very high significance differences among the genotypes at (P<0.001) for date of heading (DTH), date of maturity (DMA), Plant height (PHT), thousand kernel weight (TKW), Hectoliter weight (HLW), and grain yield (GYLD).

Environment, which is accumulative of location and year, has very high significant differences at (P<0.001) for all parameters in the study. Also, the Genotype by environment (GXE) interaction showed very high significant differences at (P<0.001) for all parameters. It showed that the traits of interests are largely governed by Genotype, environment, and interaction.

Table 2. Genotype (G), environment (E), and GXE means squares for yield and yield components of twenty five bread wheat genotypes tested at optimum areas.

Source of variation	DF	DHE	DMA	PHT	TKW	HLW	GYLD
Rep	2	25.2ns	33.5ns	21.2ns	5.3 ns	17.7 ns	0.02ns
Genotype	24	226.4***	130.1***	559.6***	406.7***	25.2***	3.69***
year	1	5684.2***	4518.1***	5618.9***	3435.2***	9084.4***	131.97***
Loc	5	7648.9***	4147.0***	5372.6***	808.9***	14848.8***	536.52***
Environment(E)(Loc: Year)	5	2430.0***	16713.3***	2550.0***	2285.2***	8044.1***	39.86***
Genotype: Year(GXE)	120	27.8***	26.9***	27.3ns	32.5***	8.2***	0.85***
Pooled error	582	15.9	24.5	24.4	12.5	2.4	0.53

DF= Degree of freedom; DHE=Date of Heading; DMA= Date of Maturity; PHT= Plant Height; TKW= Thousand kernel weight; HLW=Hectoliter Weight; GYLD= Grain Yield

Lemu and Wane are a bread wheat variety released in 2016 in Ethiopia for mid to high lands of the country. In this study, the two released bread wheat varieties were used as checks. Grain yield mean separation of the genotypes was used to distinguish the

significance of the grain yield differences among the genotypes. Compared to the yield of the checks, ETBW9089 and ETBW174464 were significantly different at ($p<0.001$) from the checks: Wane and Lemu (Table 3). ETBW9086, ETBW9304, ETBW9094, ETBW9102, ETBW9315, ETBW174460, ETBW174461, ETBW174462, and ETBW174463 were significantly different at ($p<0.001$) from a variety Lemu only (Table 3).

Table 3 Mean grain yield, Least significant difference, and coefficient of variation of twenty-five advanced bread wheat genotypes across six locations in Ethiopia.

Entry	Genotype	Adet	Arsi robe	Asasa	Bokoji	Kulumsa	Sinana	Mean
1	WANE	3.23	3.9	7.1	3.52	7.58	1.93	4.54
2	ETBW 9185	3.17	4.47	5.52	4.72	7.5	2.62	4.67
3	ETBW 9193	3.52	4.57	5.98	4.03	7.52	2.02	4.61
4	ETBW 9086	3.25	4.53	5.95	4.75	7.57	2.15	4.70
5	ETBW 9087	3.07	4.54	5.17	4.5	7.75	2.27	4.55
6	ETBW 9089	3.55	3.17	6.97	5.93	8.53	2.8	5.16
7	ETBW 9109	3.37	3.5	5.72	3.82	7.17	2.3	4.31
8	ETBW 9284	3.7	3.1	5.96	2.8	7.67	2.27	4.25
9	ETBW 9299	3.25	3.72	5.03	4.75	7.42	2.13	4.38
10	ETBW 9304	3.47	3.97	6.75	5.47	7.6	2.18	4.91
11	ETBW 9313	3.08	2.47	6.05	1.83	7.12	1.67	3.70
12	ETBW 9094	2.97	3.95	6.72	4.77	7.77	2.28	4.74
13	ETBW 9066	3.35	3.55	5.4	3.9	6.58	2.37	4.19
14	ETBW 9102	3.75	4	5.97	5.63	7.67	2.35	4.90
15	ETBW 9315	3.78	4.68	6.28	4.48	6.88	2.23	4.72
16	ETBW174459	3.38	4.73	5.95	3.22	7.9	2.5	4.61
17	ETBW174460	3.53	4.43	5.78	4.83	7.9	2.22	4.78
18	ETBW174461	3.18	3.95	6.22	5.47	7.8	2	4.77
19	ETBW174462	3.18	4.17	6.33	4.83	7.65	2.27	4.74
20	ETBW174463	3.4	4.18	6.37	4.35	8.02	2.45	4.80
21	ETBW174464	3.73	4.4	7.52	5.22	7.88	2.48	5.21
22	ETBW174465	2.97	3.53	4.74	3.4	6.85	2.33	3.97
23	ETBW174466	3.45	3.52	6.22	4.05	7.37	1.9	4.42
24	ETBW174467	3.53	2.73	6.32	4.3	7.05	1.78	4.29
25	LEMU	3.28	2.73	5.57	3.58	7.07	2.42	4.11
	Mean							4.57
	LSD(0.05)							0.56
	CV							22.31

*ETBW +number: n ETBW=Ethiopian bread wheat; and the number is a unique accession number given for individual genotypes by the national wheat research program

Table 4 Stem rust and Yellow rust score of twenty five advanced genotypes evaluated across six locations for two consecutive years

Entry	Geno	KU18		KU29		BK18		BK19	AR18	AR19	AA19	SN19	
		YR	SR	YR	SR	YR	SR	YR	YR	YR	YR	YR	SR
1	WANE	1MR	1MS	5MR	30S	20MS	0	10MS	15M	30S	5MS	1MS	0
2	ETBW 9185	5MR	5M	10S	30S	5MR	0	1S	1MR	1M	5M	0	20MS
3	ETBW 9193	1MS	20M	5M	20M	50M	1MS	5S	30M	5MS	1M	5M	15MS
4	ETBW 9086	5MS	5M	5M	40S	10MR	1MR	1MS	1M	1MS	1M	1MR	20MS
5	ETBW 9087	5M	50M	10M	20M	5MR	1MS	1MS	1MR	0	1MR	1MS	10S
6	ETBW 9089	1MR	1M	5MS	20M	10M	0	10S	5M	5MS	1M	1MS	10S
7	ETBW 9109	10M	1MR	40S	40S	15m	0	30S	5M	40S	10S	30M	1S
8	ETBW 9284	5M	50S	50S	10M	30M	0	50S	30M	50S	1MR	20M	20S

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9	ETBW 9299	5MR	20S	5M	20M	20M	1MS	1MS	5M	25M	0	1MS	25S
10	ETBW 9304	5M	50S	10MS	20S	15M	5MS	25MS	5M	20M	1MS	5M	50S
11	ETBW 9313	1M	70S	50S	30S	50M	5M	70S	20M	50S	5MS	40S	80S
12	ETBW 9094	1M	80S	1MS	20M	15M	5M	5M	5M	5MS	1MR	5M	40S
13	ETBW 9066	0	30M	10M	30S	20M	0	50S	20M	20M	1MS	5M	30S
14	ETBW 9102	1MR	40M	5M	40SS	5M	30M	1MS	1MR	20M	10M	1MS	50S
15	ETBW 9315	10M	50S	40S	40S	20M	0	5MS	10M	10M	5M	5MS	60S
16	BW174459	5M	40M	15M	30S	25M	1MS	50S	15M	10MS	5MS	10MS	20S
17	BW174460	1MR	1MR	1MR	40S	5MR	0	1MS	1M	30S	5MS	10S	5MS
18	BW174461	1MR	1MR	5M	50S	5MR	0	0	1MR	40S	0	20S	1MS
19	BW174462	5MR	1MR	10MS	30S	10M	0	1MS	1M	5M	1M	10S	1MS
20	BW174463	5M	10M	5M	30S	30M	0	5MS	5M	10M	1M	10M	10S
21	BW174464	1MR	1MR	10S	50S	1MS	0	1MR	1MR	5S	10MS	1M	1MR
22	BW174465	1M	1MR	20M	50S	1MR	0	1MS	1S	1MS	10M	1MR	5S
23	BW174466	20M	50S	60S	30S	50M	1MS	50S	60S	50S	5MS	40S	70S
24	BW174467	10M	1MR	50S	30S	70S	0	1S	40M	20MS	5M	60S	0
25	LEMU	5MR	1MR	30S	40S	80S	0	40MS	5M	35S	5M	50M	1MR

YR=Yellow rust; SR=stem rust; R=resistance; MR=moderately resistance=intermediate; MS=moderately susceptible; S=Susceptible KU18=Kulumsa in 2018; KU19=Kulumsa in 2019; BK18=Bekoji in 2018; BK19=Bekoji in 2019; AR18=Arsirobe; AR19=Arsirobe in 2019; AA19=Asasa in 2019; SN19=Sinana in 2019

In some years, the occurrence of wheat rust disease across locations varies. In some places, it occurred with high inoculum. That is, significantly high on the experimental plot. It enables breeders to select resistance genotypes. Whereas, in some, the incidence is very low; trace or zero score on the entire experiment [16]. In this case difficult to evaluate the genotypes and better not to use the score for evaluation. The rust diseases occurred with little/no pressure at some locations in this study. Due to this, the data is not included in table 4 for evaluation of the genotypes.

Usually, the program gives chances for those genotypes that have score less than the 30S for yellow rust and stem rust during selection. Sometimes tolerate 30 severities if the reaction is MS, MR, and R. Of twenty-five genotypes in the study: ETBW9089 has the maximum 20M for stem rust at Kulumsa in 2019 and ETBW9299 has the maximum 25S for stem at Sinana in 2019 .Thus, they have better resistance to the two wheat rusts among tested materials and selected as better for the two wheat rusts (Table 4).

ETBW9299 is resistant to wheat rust disease but is inferior in grain yield to the checks. Also, Grain Yield is as important as disease resistance. Because of this, ETBW9299 is not recommended for candidate variety for release and registration. ETBW9089 has better disease resistance and grain yield (Table 2 &4). Therefore, the program was decided and proposed as a candidate variety for the 2020 cropping season.

Development of resistance varieties is the best management option to reduce the damage caused by wheat rusts. Identifying the resistance gens available in wheat and introgression to existing population through crossing is mandatory for any wheat breeding program.

3.2. Result and Discussion of Candidate Varieties

Due to high wheat rust pressure in the region, a recently released bread wheat variety loses its resistance within a few years and becomes out of the market [7]. Bread wheat Varieties: Hidasse and Ogolcho, widely adopted and popular varieties since their time of release in 2012, are now become highly susceptible to stem rust and yellow rust; because of this, they are on the way to being out of production. Additionally, varieties like Wane, Kingbird, Kakaba, and Huluka are losing their potential for disease and grain yield due to the rust disease pressure encountered since their release. They are losing the performance that has at the time of release.

Unlike other crops produced in the country, on wheat, new rust races occur frequently and break the resistance genes found in varieties under production. As a result, wheat production is threatened by diseases. It affects the economy of the farmers. Therefore, approaching farmers with many new alternative bread wheat varieties is crucial that the wheat breeding community need to give attention.

The Technical Committee (TC) evaluated the performance of candidate varieties in the field and research station. Their evaluation was on disease resistance and agronomic performance. Also, they assessed farmer interest in the candidate varieties and breeders' thoughts on their materials.

Yellow and stem rust, the number of seeds per spike, spike length, tillering capacity, Lodging percentage, stand percentage, and plant height were parameters taken by the TC on the field.

Based on-field performance, farmer's selection, and the two year data no the candidate from National Variety Trial (NVT), the TC decided to release candidate variety ETBW9089 as a new bread wheat variety and submitted their recommendation for NVRC.

The TC presented their validation at a meeting held in Adissababa at the Ministry of Agriculture in June 2021 to NVRC. The NVRC accepted the recommendation and released ETBW9089 as a new variety for mid to highland wheat-producing areas.

National Wheat Research program of Ethiopia, Kulumsa Agricultural Research Center KARC proposed the newly released variety. Therefore, the center has responsibility for maintenance and naming. The staff gathered and named Shaki after one of the test sites where the genotype, ETBW 9089 showed the best performance.

Some morphological features of bread wheat variety Shaki

Shaki, bread wheat variety has Vigor growth at seedling stage with moderate tillering capacity; has deep green color, head is long >10cm. In sufficient moisture or adequate rainfall the head bends at early heading stage unlike most other wheat varieties. Most wheat varieties bend after the plant dries (close to harvest). Medium ear density at early spikelet setting but later if the environment is favor the seed become vigor and look likes dense. The grain has amber color with ovoid shape. The ear or head is naturally slightly color at maturity [15].

Fig 1. Shaki, Bread wheat variety released in 2021

4. CONCLUSION

The success of any crop breeding program is measured by, the potential of the technology that they deliver to the farming community. Likewise, the success of the wheat breeding program in Ethiopia mainly depends on the sustainably avail new technology and deliver more alternative bread wheat varieties for the farmers with a good quality foundation seed. To get the real potential of the lines and select and release widely adapted varieties for the farmers, identifying the potential location for the trial is vital. Testing genotypes across many locations for years helps to see the interaction between the genotypes and the environment

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(GxE). The GXE interaction helps to pick a stable and widely adapted genotype which later after release enables to use at many different agro-ecologies. ETBW9089, Shaki ranked 1st at Bokji, Kulumsa, and Adet; 3rd at Asasa (Table 2). This shows that the variety has wider adaptability. Therefore, it is recommended for the farmers to grow from the mid to highlands of the country.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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