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Kalar1 and Kalar2, Newly Released Wheat Varieties for Cultivation under Rain-fed Conditions

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ABSTRACT

Improving new varieties plays an important role in increasing the productivity of wheat grain yield worldwide. Garmian region as a semi-arid area is extremely suffering with low wheat yield production as a result of continuing yield potential reduction of the local cultivars over the time. This project was conducted at the Directory of Garmian Agricultural Research to develop new cultivars through four field trials from 2009 to 2013. In the selection phase, 50 lines of Facultative and Winter Wheat Observation Nurseries (16th FAWWON-IR) were screened, and three superior lines (SL1; "CH75479/SARDARIHD74", SL2; "CATBERD/CNO79*2/HEF1", and SL3; "ID800994W/V-EE/5/CA8055/4/ROMTAST/BON/3/DIBO//SU") to the best local check (Aras) for grain yield, thousand grain weight, anthesis date and plant height were selected for testing in three field trials of comparison phase. Averaging over years, the results of this project significantly confirmed that two of the selected lines (SL1 and SL2) performed superior (4.24 and 4.73 t h^{-1}, respectively) to the local check (Aras; 2.83 t h^{-1}) with regards to grain yield production by about 50-60%. This superiority of the selected lines compared to the local check was due to significant longer spike through increasing grain number, and wider flag-leaf area which leads to assimilate more CO_2 to the grain during grain filling duration. Based on these results, the superior genotypes (SL1 and SL2) were then qualified for identification and officially released (Reference Number 192, dated November 21, 2018) as new cultivars namely Kalar1 (SL1) and Kalar2 (SL2) by the National Committee for Recording and Protecting Agricultural Varieties in Iraq for the

climate of Garmian region.

1. INTRODUCTION

One of the most essential crops around the world is winter wheat (*Triticum aestivum* L.) [1] which is considered as a major food crops due to its global contribution by 30% of grain production and 45% of cereal foods [2]. Worldwide, wheat cultivated area is about 216 million hectares with the total grain yield production of about 765 million tons in 2019 (average on-farm yield 3.54 t ha^{-1}) [3]. In Iraq, about 1.5 million hectare of land was cultivated with the total yield production of 4.3 million tons (average on-farm yield 2.87 t ha^{-1}) of wheat grain yield in 2019 [3]. Global wheat demand is increasingly rising at a ratio of about 1.7% each year, and this is expected to be raised by approximately 60% to feed around 10 billion people in the next 40-50 years [4, 5, 6, 7, 8] as global population is still growing [9, 10, 11].

Therefore, developing higher yield potential of wheat varieties under abiotic stress environments is one of the critical challenges besides the expected climate change over the next 30 years [12, 13, 14]. The climate factor significantly influences crop yield production and globally considered as the main contributed factor to yield production difficulties [15, 16, 17]. In developing countries, around 50% of wheat cultivated area is rain-fed conditions area where less than 600 mm of annual rainfall is typically expected [18] which affects about 99 million hectares of wheat cultivated area, and can reduce average grain yield by 17-70% [19]. Under Mediterranean conditions, abiotic factors are most limiting wheat yield potential such as high temperature, irradiance and water stress due to low rainfall together during the most critical growth stages of grain filling and grain formation periods [20, 21]. In such kind of environments, inadequate annual rain-fall (less than 1000 mm), irregular rain-fall distribution (typically occurred in autumn and spring) and heat stress during the grain filling stage can efficiently reduce crop yield performance [22, 23, 24].

Increasing wheat production is estimated by 0.5% per year, which is less than the global wheat demand by above two third [25]. Therefore, new wheat cultivars must be developed with further increasing grain yield per area [26]. From 1980 onwards, wheat breeding achieved an improvement in increasing grain yield production around the world [27, 28, 29, 30]. Wheat provides the food energies of the world's population by 20% of total calories on average [31], and about 32% of the wheat cultivated area are generally semi-arid and face water restriction at different key stages of wheat development [19]. Therefore, the aim of wheat breeding is mainly grain yield improvement and stability of grain production in semi-arid region to preserve food security through developing new adapted and high throughput cultivars [22, 32, 33]. The objective of this cultivar development process research was identifying and developing new cultivars with superiority characteristics to the local check such as grain yield production and related traits under semi-arid climate of Garmian region. A set of Facultative and Winter Wheat Observation Nurseries (16th FAWWON-IR) lines with the best local check were used through conducting four years of field experiments.

2. METHODS AND MATERIALS

2.1. Growing conditions and plant materials

This study was carried out at the Directory of Garmian Agricultural Research in Garmian region, As Sulaymaniyah, Kurdistan region, Iraq located at latitude 34.607 N and longitude

45.306 E at the elevation level of 178 meters under rain-fed conditions. The region is characterized as Hyperthermic temperature regime [22] and semi-arid climate condition [34]. In Figure 1a, the total monthly amount of rainfall for each growing season and long term rainfall for 19 years from (2000 to 2019) is shown in the region. The total amount of rainfall is also shown for each season (2009-10; 323.9 mm), (2010-11; 234.7 mm), (2011-12; 135.1 mm), (2012-13; 394.8 mm) and (LTM, 2000-2019; 318.86 mm). The average monthly temperature and humidity are shown in Figure 1b for the growing season of 2012-13.

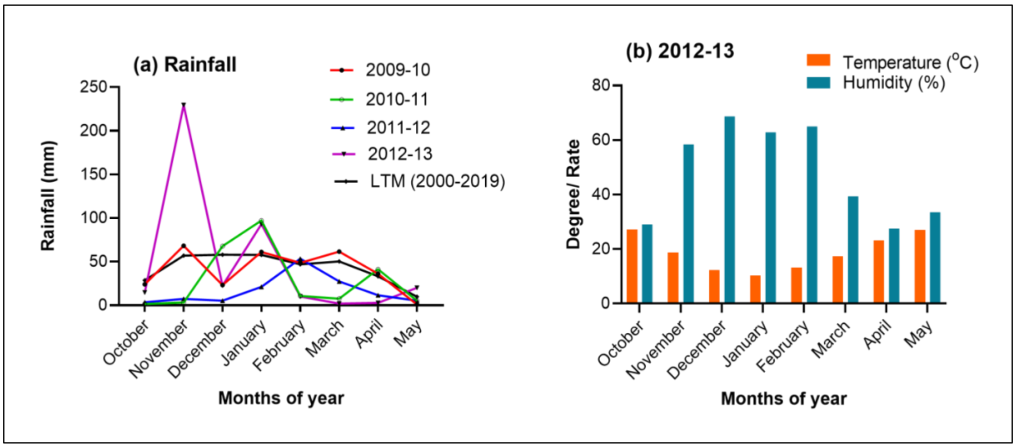

Figure 1. Climatic data of (a) total monthly amount of rainfall for four growing seasons (2009-10, 2010-11, 2011-12 and 2012-13, and Long Term Mean (LTM) 2000-2019), and (b) average monthly temperature and humidity for the growing season of 2012-13 at Kalar, Garmian region. (Data obtained from Directory of Garmian Agricultural Research)

The plant material was comprised of a number of Facultative and Winter Wheat Observation Nurseries (16th FAWWON-IR) lines, which were developed and distributed by the International Winter Wheat Improvement Program in Turkey [35]. At the phase of selection during 2009-2010 growing season, 50 different lines including a local Check (Aras) were sown on 4-6/11/2009 namely "98039G5-103, BOUHOUTH6/4TJB841/1543//YMH/63-122-66-2/3/HYS/CER,H-308, DBDI, ID870303/5/OR7946/HILL/HILL/6/OR7946/HILL/HILL, VORONA/HD2402/5/SMB/HN4//SPN/3/WTS//YMH/HYS/4/NWT/3/TAST/SPRW//TAW12 399.75, KATIA, HYS/YY/63-112-66-4/3/OR87065,H-281/4/FRENCH LINE E81FR, Mv17//Attila/Bcn, PYN/BAU//F6038W12-2, DEYA, QU19-81/TEMU58-82/QUELEN, ID800994.W/VEE/5/CA8055/4/ROMTAST/BON/3/DIBO//SU, TRK/KNR//W175.6.SC3.2, PYN*2/CO725052/PASTOR/6/ZCL/3/PGFN//CNO67/SON64(ES86-8)/4/JUN/5/AFG2/BU-C//KVZ, F98047G14-2INC, F98432G1-2002, MOTAH/BOUHOUTH6, NUWEST/4/D887-74/PEW//3/LNCR//CARSTEN/GIGANT/5/MRS/C114482//YMH/HY-S/3/RONDEZVOUS, CASHUP/5/VPM/MOS-951//HILL/3/SPN/4/SPN, TE3904-313110/FTM-II, MV17/ZM, Ghk"S"/BOW"S"//90ZHONG87/3/SHIR, DOKA, MV11-04, ATTILA/3/AGRI/NAC//MLT, TAST/SPRW//ZAR/5/YUANDONG/3/4PPB8-68/CHRC/3/PYN/TAM101/AMOGO, SERI, CENTINEL, ALPU, F00429GP1, GRK/KAUZ//PYN/BAU, Gascogne/4/Hys/7C//503A-OA/3/No688437, BC97-ROM50W, CO724377/NAC/SERI/3/ERYTHROSPERMUM5678/87, PYN/BAU//YUNA, CUPRA-1/3/KAUZ*2/K134(60)/VEEt, TX01V5314, F00628GP34-1, UNUMLIBUGDAY/3/AGRI/BJY/VEE/4/AGRI/BJY//VEE, CH75479/SARDARI-HD74, BEZOSTAYA, I.Tijereta/KS82142, MV-17//Rsh*2/I0I20, CATBERD/CNO79*2HE1, MV17-04, 338-K1-1/ANB/BUC/3/KIRGIZ, AGRI/BJY/VEE/3/BUL6687.12, QUE$_K$OAINIA, ATTILA/3/AGRI/NAC//MLT". Genotypes were screened for yield and yield components. Therefore, three lines ("CH75479/SARDARI-HD74", referred hereafter as SL1), ("CATBERD/CNO79*2/HEF1", referred hereafter as SL2) and ("ID800994.W/VEE/5/CA-8055/4/ROMTAST/BON/3/DIBO//SU", referred hereafter as SL3) were selected according to grain yield, thousand grain weight, plant height and number of days from sowing to flowering.

This set of three lines and a locally grown cultivar (Aras) were compared in three growing seasons (2010-11, 2011-12 and 2012-13) at the phase of comparison. At the time of seed sowing, 100 kg/hectare of Di-Ammonium Phosphate (DAP) and after 60 days 80 kg/hectare of urea were applied to the experiment fields.

2.2. Traits measurement

In all field trials (2010-11; sown on 22/11/2010, 2011-12; sown on 3/11/2011 and 2012-13; sown on 4/12/2012), all plants in a 4 m^2 in each plot were collected from ground-level after physiological maturity by around seven to ten days. The plant materials were then divided into ears and straw. The ears were hand-threshed and separated to grain and chaff. The grains were dried based on 15% moisture content after drying for 48 hours at 72 °C, and weighed for each plot samples. Regarding thousand grain weight, a sample of five hundred grains was weighed and multiplied by two to obtain the thousand grain weight. Plant height was also measured from the soil surface to the top of the plant ears in each plot on five randomly selected plants using a normal ruler. Plant height in each plot was calculated by taking the average of the plant heights. Flag-leaf area was calculated through collecting ten randomly selected flag-leaves in each experimental unit at flowering time, and the areas of the flag-leaves were then measured using CI-202 LASER AREA METER, made in USA.

2.3. Experimental design and statistical analysis

The seed of the fifty genotypes were sown in a 5 meter raw for each genotype in 2008-09 for the purpose of selection. The three selected lines with local cultivar (Aras) were grown on 12 plots (each on 6 m^2) using randomized complete block design (RCBD) with three replications for three growing seasons (2010-11, 2011-12 and 2012-13). Statistical analysis of variance (ANOVA) and Duncan's test to compare any pair of means were conducted using IBM SPSS statistics software by applying a randomized block design for all trails [36]. GraphPad Prism 8.0.0 software package was used for analyzing and designing the graphs [37].

3. RESULTS

3.1 Selection traits (2009-2010)

In 2009, grain yield was ranged from 0.27 to 4.91 t h^{-1} among genotypes, and selected lines were recorded the highest grain yield of 4.91, 4.36, and 4.22 for SL1, SL2 and SL3, respectively, while the local check (Aras) yielded 2.15 t h^{-1} (Fig 2a). Regarding thousand grain weight, the range was between 18.2 and 40.1 g for all genotypes. However, there was a slight difference between selected lines and the local check and recorded 38 to 40 g (Fig 2b). Plant height was different in a wide range of 30 to 105 cm among genotypes, and 92, 100 and 80 cm were recorded for SL1, SL2 and SL3, respectively, while the local check was 90 cm height (Fig 2c). Number of days from sowing to flowering was also ranged from 139 to 150 days among genotypes; however, selected lines demonstrated the longest period of 150 days (Fig 2d).

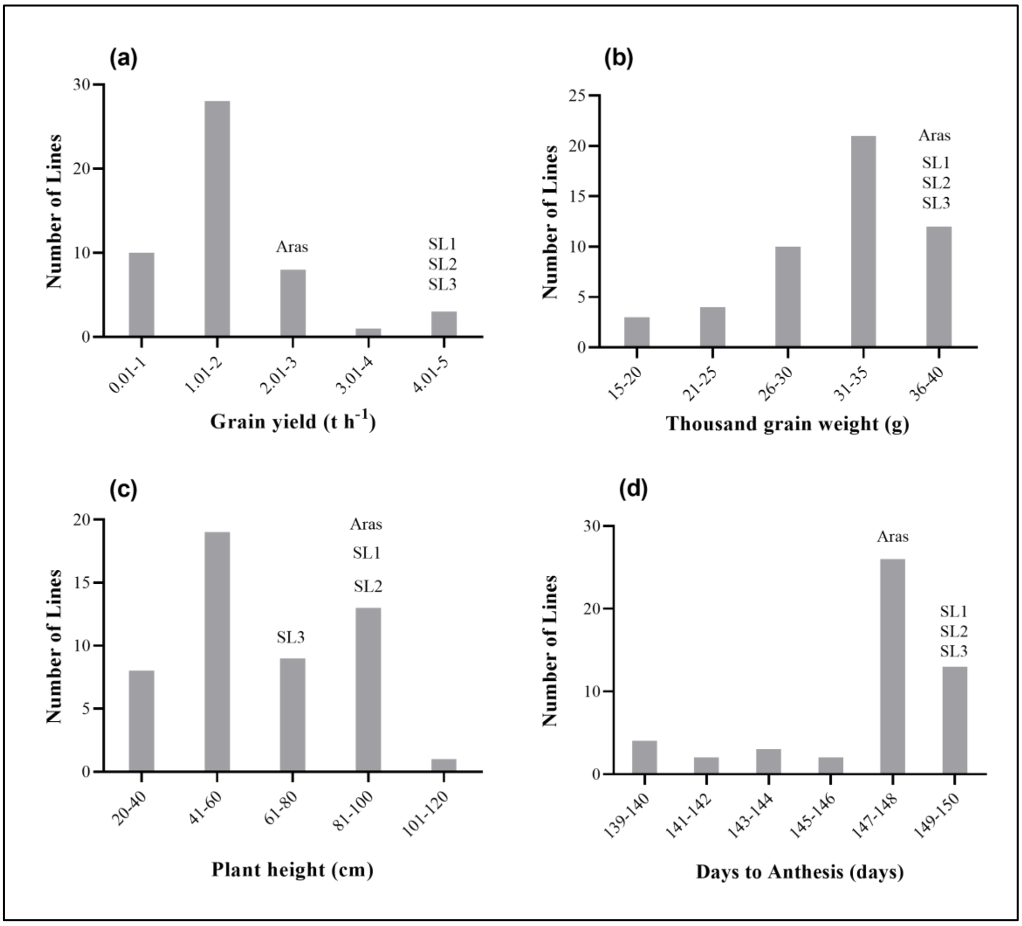

Figure 2. Frequency distribution of 50 lines (including local check) for (a) grain yield (t h^{-1}), (b) thousand grain weight (g), (c) plant height (cm) and (d) days to anthesis (days) in 2009-2010 growing season.

3.2 Evaluation traits (2010-2013)

In 2010, grain yield was ranged from 3.252 (Aras) to 5.634 t ha^{-1} (SL2), and 1.523 (Aras) to 5.084 t ha^{-1} (SL2) in 2011. In 2012, however, a difference between genotypes was not significant. Averaging over years, genotypes differed in the range 2.832 (Aras) to 4.729 t ha^{-1} (SL2) (Table 1). Thousand grain weight was ranged from 29.00 (SL3) to 37.33 g (Aras) in 2011, and from 36.05 (SL3) to 40.52 g (Aras) in 2012. However, the difference was not significant between genotypes in 2010. Averaging across years, genotypes differed in the range 35.35 (SL3) to 39.95 g (Aras) (Table 1). Genotypes were significantly different for plant height in all seasons and cross-year means. The tallest genotype was observed by SL2 in all seasons (90 cm in 2010, 100 cm in 2011, 119 cm in 2012 and 103 cm averaging over years). The local genotype (Aras) showed shortest plant height (75 cm) in 2010 and (87.11 cm) averaging over years. However, SL3 was recorded the shortest plant height in both 2011-12 and 2012-13 growing seasons (78.6 cm and 105 cm, respectively; Table 1).

Table 1: Grain yield (t h^{-1}), thousand grain weight (gm) and plant height (cm) of three selected lines (SL1, SL2 and SL3) and local variety (Aras) in 2010, 2011, 2012 and cross-year mean.

Traits	Years of comparisons	Genotypes				
		SL1	SL2	SL3	Aras	Mean
Grain	2010	4.751 a,b	5.634 a	3.349 b	3.252 b	4.246*

Yield ($t\ h^{-1}$)	**2011**	4.321 a	5.084 a	3.297 a,b	1.523 b	3.556^{*}
	2012	3.640 a	3.470 a	3.724 a	3.721 a	3.639^{ns}
	Cross-year	4.237 a,b	4.729 a	3.457 b,c	2.832 c	3.814^{***}
Thousand Grain Weight (g)	**2010**	41.02 a	43.00 a	41.00 a	42.00 a	41.75^{ns}
	2011	34.33 a	30.67 b	29.00 b	37.33 a	32.83^{**}
	2012	38.81 a	39.61 a	36.05 c	40.52 a	38.75^{**}
	Cross-year	38.05 a,b	37.76 a	35.35 b	39.95 a	37.78^{ns}
Plant Height (cm)	**2010**	85.00 b	90.00 a	85.00 b	75.00 c	83.75^{***}
	2011	96.60 a	100.00 a	78.60 b	79.33 b	88.63^{**}
	2012	111.00 b	119.00 a	105.00 b	107.00 b	110.5^{**}
	Cross-year	97.53 b	103.00 a	89.53 c	87.11 c	94.29^{**}

(a, b and c) Duncan's test letters for the significance difference between any pair of means
Significance levels are (***) P < 0.001, (**) P < 0.01, (*) P < 0.05 and (^{ns}) not significant.

As shown in Table 2, genotypes were significantly different for flag-leaf area in all seasons and cross-year means. In 2010, flag-leaf area was ranged from 29.84 (SL3) to 37.56 cm^2 (SL1), and from 29.97 (Aras) to 34.60 cm^2 (SL2) in 2011. The range was from 29.17 (Aras) to 33.70 cm^2 (SL2) in 2012. Averaging across years, genotypes differed in the range from 30.03 (Aras) to 34.49 cm^2 (SL2). Spike length was ranged from 8.12 (SL3) to 12.84 cm (SL1) in 2010, and from 8.03 (SL3) to 11.00 cm (SL2) in 2011. However, the difference was not significant between genotypes in 2012. Averaging across years, genotypes differed in the range 8.40 (SL3) to 11.73 cm (SL2) (Table 2).

Table 2: Flag-leaf area (cm^2) and spike length (cm) of three selected lines (SL1, SL2 and SL3) and local variety (Aras) in 2010, 2011, 2012 and cross-year mean.

Traits	Years of comparisons	Genotypes				
		SL1	**SL2**	**SL3**	**Aras**	**Mean**
Flag-leaf area (cm^2)	**2010**	37.56 a	35.18 a,b	29.84 b,c	30.97 b	33.39^{*}
	2011	30.63 b	34.60 a	33.03 a	29.97 b	32.06^{**}
	2012	33.20 a	33.70 a	30.20 a,b	29.17 b	31.57^{*}
	Cross-year	33.80 a	34.49 a	31.02 b	30.03 b	32.34^{**}
Spike Length (cm)	**2010**	12.84 a	12.18 a	8.12 b	8.31 b	10.36^{**}
	2011	10.03 a	11.00 a	8.03 b	10.68 a	9.94^{*}
	2012	11.02 a,b	12.00 a	9.03 b	10.57 a,b	10.65^{ns}
	Cross-year	11.30 a	11.73 a	8.40 c	9.85 b	10.32^{***}

(a, b and c) Duncan's test letters for the significance difference between any pair of means
Significance levels are (***) P < 0.001, (**) P < 0.01, (*) P < 0.05 and (ns) not significant.

3.3 Descriptive traits (2010-2013)

Observations in Table 3 were assessed for the three experiments from 2010 to 2013 growing seasons. The highest rate of germination was recorded for SL1 and SL2 (85% and 80%, respectively), while Aras showed the lowest germination rate (60%). Tiller number was also counted and a slight difference was observed between genotypes (roughly 5 tillers for all genotypes except SL1 which was 4 tillers; Table 3). All genotypes had erect spike on panicles with yellow colour and a slight difference in awn length from 7 to 8.5 cm was recorded. There were not leaf rolling and stem lodging for all genotypes (Table 3).

Table 3: Morphological and descriptive traits of three selected lines (SL1, SL2 and SL3) and local variety (Aras) which measured or observed in 2010, 2011, 2012.

Morphological traits	Genotypes			
	SL1	**SL2**	**SL3**	**Aras**
Germination rate	85%	80%	65%	60%
Tiller Number	4	5	5	5
Spike color	Yellow	Yellow	yellow	yellow
Spike position	Erect	Erect	erect	erect
Awn length (cm)	7.5	8.5	7	8.5
Leaf rolling	no	no	no	no
Lodging	no	no	no	no

(no): it refers to (no leaf rolling) or (no stem lodging).

4. DISCUSSION

Identification and selection of superior lines is the most widely method to improve and develop new variety in crop breeding program [14, 38]. In this study, SL1, SL2 and SL3 were selected based on the highest grain yield, thousand grain weight and longest vegetative period between sowing to anthesis date in comparison to the local check (Aras). In addition, plant height was also taken into consideration in this selection process as semi-dwarf cultivars can have higher harvest index through reducing biomass partitioning, while taller genotypes can have more vegetative biomass and potentially more CO_2 assimilates to the grain at grain filling stage [16, 39]. In the comparison phase, the highest grain yield was recorded by SL1 and SL2 averaging over years, and increased grain yield by 50-60% compared to the local cultivar (Aras). Although, SL3 also yielded higher grain yield than Aras, but the difference was not statistically important. However, differences in thousand grain weight were not significant between genotypes. Therefore, this superior performance in grain yield may due to more grains per each spike instead of grain size, as they had significantly longer spikes than the local check cultivar [40]. In addition, SL1 and SL2 had a wider flag-leaf area than the local check cultivar which leads to assimilate more CO_2 to the grain. These might be the key driver for this improvement by these two lines in this grain yield potential. Grain yield increases over time from 1940s to 2010s related to flag-leaf area and high photosynthetic rate have been reported previously [29, 41, 42]. Plant height can have a significant effect on yield through increasing crop biomass and more CO_2 assimilation to grain yield [30]. Although, plant height does not obviously play the role in some cases, but plant height of about 80 cm would achieve the highest grain yield [29, 30, 43]. Both lines (SL1 and SL2) were almost similar in most of morphological properties, no leaf rolling and stem lodging. However, they had the highest germination rate which can lead to increase crop density and better yield potential, and this high germination rate may due to the ability of seed to consume efficiently more nutrient reserves in most of growing conditions [44, 45].

5. CONCLUSION

Improving new varieties of wheat is essential to increase the agricultural productivity in Garmian region which is defined as a semi-arid climate region in Iraq. There is a wide rain-fed agricultural area which is mostly cultivated with field crops such as wheat and barley. Identification of new cultivars which perform superior to checks for mainly grain yield has become a certain necessary. Based on our findings, SL1 (Kalar1) and SL2 (Kalar2) appeared to be qualified for identification during the four years of testing in different trials. Although, further seed quality studies are needed, but grain yield potential of these lines was promising to be identified and released as new cultivars for the researchers, seed growers and farmers.

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