Registration of a Climate-Resilient Bread wheat variety "Melka" for the ~~h~~Highlands of Ethiopia

Abstract

Developing countries face a critical food production challenge due to rising populations, food scarcity, malnutrition, and environmental degradation. To address this, innovative solutions and improved crop varieties must tailored to diverse conditions and socioeconomic realities. Ethiopia's wheat production faces challenges ~~like~~ not only yellow and stem rust, but also Septoria and fusarium head scab diseases necessitating continuous research for new varieties with high yield potential and adaptability. The "Melka" variety, a high-yielding, disease-resistant bread wheat variety, is being developing under multiple evaluation stages before officially released, registered, and commercialized. "Melka" is a new variety, was introduced from CIMMTY, and has a pedigree name: MANKU/3/MUU/FRNCLN//FRANCOLIN #1 and selection history CMSS13B00894S-099M-099Y-28M-0WGY. "Melka" is a bread wheat variety aimed at highland areas with good agronomic characteristics and late-maturing type. "Melka", a recently released variety, exhibits a significant yield advantage over standard check, with an overall mean of 30.54% Boru, and local check, with an overall mean of 58.10% Danda'a. "Melka" has a better thousand-kernel weight (39.90 g) than standard check Boru (37.6 g), and local check Danda'a (32.70 g) and 71.7 hl /kg. Likewise, the "Melka" variety had bold seeds than checks. It possessed a 6.12% and 10.33 % HLW advantage over the Boru and Danda'a varieties respectively. Beyond its exceptional yield, this variety's distinctive feature lies in its enriched nutritional profile, particularly its high content of iron (Fe) 35.5 ppm (parts per million) and zinc (Zn) 38.1 ppm(parts per million), which surpasses that of other available varieties. The recently released ~~'~~"Melka"~~'~~ wheat variety is stable and adaptable for Ethiopian highland agro ecologies. It exceeded a standard check~~s~~ in grain yield and is more resistant to stem yellow and leaf rust than other varieties.

Keywords: Check, Disease resistance, high yielding, Production, Yield advantage,

1. Introductions

Wheat (*Triticum aestivum* L.), is a self-pollinating annual plant, it is in the true grass family, *Gramineae*, extensively grown as a staple food source in the world [17] and this cereal is naturally polyploidy and domestically grown worldwide and plays an important role in agriculture [14, 12, 11]. It is one of the most important crops among the prime cereals at the global level [23]. Globally, it is an economic crop for food, feed, seed, and industrial uses. Wheat is a vital food source for Africa's food and nutrition security, providing 70-90% of calories and 66-90% of protein in developing countries [3]. Wheat is a major source of energy, starch, protein, vitamins, minerals, dietary fiber, and phytochemicals [15, 20]. Wheat is a strategic and important cereal crop for a significant proportion of the world's population. It accounts for over half of global food calories and is a primary nutrition source for 36% of the world's population, grown in 70% of farmed areas [11]. Wheat is a strategic, economic, industrial, commercial, political, and food security commodity in Ethiopia [2)]. Thus, the demand for wheat has been increasing in the country [7, 22, and 1].

Wheat is primarily produced in Ethiopia's highlands and mid-altitudes [1], with major areas in the Oromia region, Amhara region, Southern Nations Nationalities & Peoples Region, Tigray region, Benishangul Gumuz region, and Afar region [4]. Genotype evaluation is crucial for ensuring stable genotype performance and selecting high yielding, consistently performing varieties in diverse environments. However, genotypes respond differently to climatic and soil conditions, leading to complex selection of crop varieties and Genotype-environment interaction (GEI) in variety development. Multi-environment trials (METs) are essential for evaluating genotypes and selecting superior ones for high yield, stability, and other important traits, as they help breeders select high-yielding, stable varieties [18].

Wheat production in Ethiopia, influenced by various biotic and abiotic factors and socio-economic challenges [8]. Biological constraints include wheat rust diseases [5, 21], poor agronomic practices, marginal agricultural land use, drought stress [9, 19], and low soil fertility, high temperatures, and erratic rainfall patterns wheat [10, 13] impacting wheat breeding goals and varietal choices. Farmers may perceive these constraints differently, affecting their farming practices.

Despite efforts to develop high-yielding and disease-resistant wheat varieties, their agronomic life span is short. The development of wheat genotypes for disease resistance, adaptability, and high yield is ongoing through research institutes and universities. However, most cultivars are out of production due to their susceptibility to rust disease. Developing high-yielding, stable, and rust-resistant genotypes is crucial for wheat varieties development strategy. Evaluation across locations forms the basis for breeding. Current commercial bread wheat varieties in highland areas are susceptible to yellow rust, Septoria and fusarium diseases making a new ~~rust~~ resistant variety a crucial solution for resource-poor farmers. Therefore, the objective of the present study is to evaluate the performance of the recently released bread wheat variety "Melka", which aims to fill the variety out of production and exploit its wheat production capacity for end-users.

2. Materials and Methods

"Melka" selected from the 9thHPAN trials acquired from CIMMYT in Mexico for the 2018 cropping season. The "Melka" variety was included in observation nursery trials in 2019 and promoted to the next breeding stage (preliminary yield trials) in 2020 based on its yield potential and rust resistance. Twenty-eight advanced bread wheat genotypes and two standard checks were tested under national variety trials for two consecutive years 2021 to 2022 at Kulumsa, Bekoji, Arsi-Robe, Sinana, Holetta, Debra Markos, Kofale, Chafe Donsa, Enawari, and Gonder. Evaluating materials were sow and harvested from mid-June to mid-July and November to December, respectively. The advanced genotypes selected or screened from observation nurseries and preliminary variety trials in the preceding years. The genotypes arranged in a row-column experiment design, with a plot size of six rows of 2.5 m by 1.2 m (3 m^2) long and 0.2 m inter-row spacing. Every plot planted at a seed rate of 150 kg ha^{-1}. Except for the genetic and other environmental variations, other agronomic management practices applied uniformly to each plot. Fertilizer was applied at the recommended rate, 182 kg/ ha NPS and 100 kg/ha urea's. Finally, data were collected for days to heading (days), days to maturity (days), plant height (cm), thousand seed weight (g), hector-liter weight (hl/kg), and grain yield (t/ha); and diseases data (stem rust, leaf rust, yellow rust, and septoria). For agronomic traits for multiple environments combined and analyses had carried out; while for quality parameters samples analyzed from each genotype. According to the seed proclamation, no 782/2013 variety release and registration, application were submitted before May 30, 2023, along with data that show the performance of the variety so as to justify the potential of the candidate variety. The application had sent to the secretariat office (Plant Variety Release, Protection, and Seed Quality Control Directorate (PVRSQC)). The submitted application and its performance at the verification trial were evaluated by the technical committee along their recommendation has to be provided to the national variety release committee (NVRC)

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who are responsible for the final decision on whether to release a variety. Finally, based on the results for agronomic performance; disease resistance, and quality parameters genotypes “Melka” had selected and verified on farmer’s fields along with two st. checks Shaki and Lemu in 2023. At physiological maturity stage, the National Variety Release Committee had evaluated with the farmers and proposed to release a candidate variety “Melka” for official registration in the country as a commercial variety.

3. ~~RESULT~~ Result ~~SUMMARY~~ Summary

3.1.Varietal Evaluations, Agronomic characteristics and Yield Performance

The “Melka” bread wheat variety, a high yielding, disease-resistant, had evaluated in several stage before officially released, registered, and commercialized. “Melka” is a newly released variety, was introduced from CIMMTY with a pedigree name MANKU/3/MUU/FRNCLN//FRANCOLIN #1 and selection history CMSS13B00894S-099M-099Y-28M-0WGY. “Melka” is a bread wheat variety well suited for cultivation in highland areas. Its late-maturing characteristics and strong agronomic traits make it a promising choice for farmers in these regions. It outperformed other varieties in observation and preliminary yield trials, leading to its advancement to a national variety trial for further testing across various locations over the years. The bread wheat national variety trial, involving 12 advanced genotypes, found that “Melka” consistently outperformed other tested genotypes over two years. Verified at 10 locations in 2023, “Melka” demonstrated superior overall agronomic performances over the standard check Shaki and local check Lemu, indicating its potential for official release.

The study revealed significant variations in grain yield among bread wheat genotypes across test environments, suggesting that effective genotype selection may be possible. The average yield across the genotypes was 3.5 t/ha, with “Melka” yielding 4.7 t/ha **(Table 2).** The new variety “Melka” has a high positive yield advantage over the standard check Boru, and ~~d~~Danda’a at all environments (**Table 1b).** It outperformed the standard check Boru and Danda’a in terms of yield by 30.5% and 58.1 %, respectively. The recently released '“Melka”' wheat variety is stable and adaptable for Ethiopian highland agro~~-~~ecologies. It had the short projection from the AEC x-axis indicating the highest mean yield and stability across test environments, because of which it was comparatively closer to the concentric circle. Therefore, it selected as the most stable genotypes across the testing environment compared to the other test genotypes **(Figure 1).** It exceeded standard checks in grain yield and is more resistant to stem yellow and leaf rust than other varieties. This offers new hope for resource-poor farmers in stem ~~rust-prone~~ and yellow rust-prone areas, proving the genotypes' broad adaptability. Beyond its exceptional yield, this variety's distinctive feature lies in its enriched nutritional profile, particularly its high content of iron (Fe) 35.5 (parts per million(ppm) and zinc (Zn) 38.1 parts per million(ppm), which surpasses that of other available varieties (**Table 1a**).

Table 1a. Agronomic and morphological characteristics of new bread wheat variety "Melka"

SN	Description	
1	Variety name	Melka (EBW182767)
	Pedigree	MANKU/3/MUU/FRNCLN//FRANCOLIN #1
2	**Environment**	
	Adaption area	Mid to highland agro-ecologies
	Altitude (masl)	2200 - 2700
	Rainfall (mm)	700-1200
	Seed rate (kg/ha)	125-150
	Planting date	Mid-June to early July
	Fertilizer:	
	NPS (kg/ha)	182
	Urea (kg/ha)	100
3	**Agronomic and morphological characteristics**	
	Days to heading	72
	Days to maturity	122
	Plant height (cm)	93.7
	Growth habit	Erect
	Ear shape	Tapering
	1000 seed weight (g)	39.9
	Seed color	White
	Crop pest reaction	Resistant to stem and yellow rusts
4	**Grain Quality characteristics:**	
	Hectoliter weight (kg/hl)	71.7
	Fe (ppm)	33.5
	Zn (ppm)	38.1
5	**Grain Yield (t/ha)**	
	Research field:	5.0 – 7.6
	Farmers field:	4.0 – 7.0
6	Year of release	2024
7	Breeder / maintainer	Kulumsa Agricultural research Center

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Table 1b. Relative yield advantages of the candidate varieties over the standard checks

SN	Environment	Melka	GYLD adv. to Boru	GYLD adv. to Danda'a
1	KF20BWOL	3.5	52.17	0
2	KU20BWOL	4	21.21	2.56
3	KU20BWPL	4.5	15.38	87.5
4	RA20BWPL	2.4	26.32	41.18
5	SN20BWPL	2	81.82	53.85
6	DM21BWNL	5	2.04	25
7	HL21BWNL	3.8	46.15	111.11
8	RA21BWNL	4	25	25
9	SN21BWNL	4.3	43.33	34.38
10	BE21BWNL	4.3	79.17	230.77
11	BE21BWPL	4.2	75	133.33
12	KF21BWPL	4.2	121.05	162.5
13	BE22BWNL	5.2	40.54	67.74
14	KF22BWNL	6.6	407.69	407.69
15	RA22BWNL	6.7	26.42	67.5
16	CD22BWNL	5.5	1.85	10
17	DM22BWNL	5.9	1.72	20.41
18	EW22BWNL	7.6	2.7	15.15
19	GD22BWNL	5.3	1.92	51.43
20	HL22BWNL	4.4	15.79	109.52
21	KU22BWNL	6.2	12.73	121.43
	Overall mean	4.7	30.54	58.1

20BWPLRA, 21BWNLRA and 22BWNLRA = Arsi Robe, 20BWOLKU, 20BWPLKU and 22BWNLKU= Kulumsa, 21BWNLHL, 22BWNLHL= Holetta, 22BWNLGD= Gonder, 2BWNLEW=Enawari, 22BWNLCD= Chafe Donsa, 21BWNLBE, 22BWNLBE= Bekoji, 20BWOLKF, 21BWPLKF = Kofale, 20BWPLSN = Sinana

Table 2. Mean grain yield (t/ha) performance of 10 genotypes and 2 checks tested from 2020 to 2022 cropping seasons																						
SN	**Genotype**	**KF20BWOL**	**KU20BWOL**	**KU20BWPL**	**RA20BWPL**	**SN20BWPL**	**DM21BWNL**	**HL21BWNL**	**RA21BWNL**	**SN21BWNL**	**BE21BWNL**	**BE21BWPL**	**KF21BWPL**	**BE22BWNL**	**KF22BWNL**	**RA22BWNL**	**CD22BWNL**	**DM22BWNL**	**EW22BWNL**	**GD22BWNL**	**HL22BWNL**	**KU22BWNL**	**Mean**
1	EBW192345	2.3	2.9	4	2.6	3.2	4.4	3.3	4.2	5.4	4.7	4.4	5.2	4.4	6.9	6.7	5.2	4.6	7.1	5.2	3.1	5.9	4.6
2	**Melka**	**3.5**	**4**	**4.5**	**2.4**	**2**	**5**	**3.8**	**4**	**4.3**	**4.3**	**4.2**	**4.2**	**5.2**	**6.6**	**6.7**	**5.5**	**5.9**	**7.6**	**5.3**	**4.4**	**6.2**	**4.7**
3	EBW192022	1.5	2.5	2.7	2.1	1.6	4	2.4	3.5	4	2.9	3.3	3.3	3.3	1.6	4.6	5.2	4.2	6.6	4.3	2.2	3.9	3.3
4	EBW192387	2.2	2.9	2.8	2	2.3	3.6	1.7	3.5	4.2	2.4	2.5	2.9	3	2.3	5.1	5	3.5	6.5	4.3	1.8	4.1	3.3
5	EBW182981	2.7	3.2	3.6	2.1	3	3.9	2	3.7	4.3	2.3	2	2.2	2.8	2.6	5.5	4.8	3.4	6.8	4.5	2.1	4.7	3.4
6	EBW192874	1.5	2.6	3.9	2.1	1.5	4.9	2.6	3.3	3.4	2.5	2.4	2	3.6	1.6	5.1	5.3	5	7.2	5.2	3.3	5.2	3.5
7	**Boru**	**2.3**	**3.3**	**3.9**	**1.9**	**1.1**	**4.9**	**2.6**	**3.2**	**3**	**2.4**	**2.4**	**1.9**	**3.7**	**1.3**	**5.3**	**5.4**	**5.8**	**7.4**	**5.2**	**3.8**	**5.5**	**3.6**
8	EBW192873	0.5	1.8	3.8	2.4	1.7	4.4	2.3	3.4	3.7	2.4	2.2	2	3	1.7	5.3	5.2	3.6	6.9	5.2	2.5	5.1	3.3
9	EBW192140	2.3	3.2	4	2	2.4	4.8	2.4	3.3	3.7	2.3	2	1.8	3.2	2	5.1	5	4.6	7.3	5	3.2	5.4	3.6
10	EBW183001	0.8	2.3	3.7	1.3	3	5	2.5	2.5	3.5	2.8	2.4	2.3	3.6	1.7	3.1	4.7	5	6.5	5.3	3.7	5.5	3.4
11	EBW182999	1.9	2.9	3.4	1.3	3.4	4.5	2.2	2.8	3.8	2.4	2.1	2.2	3.1	1.7	3.2	4.5	4.5	6.4	4.7	3	4.9	3.3
12	**Danda'a**	**3.5**	**3.9**	**2.4**	**1.7**	**1.3**	**4**	**1.8**	**3.2**	**3.2**	**1.3**	**1.8**	**1.6**	**3.1**	**1.3**	**4**	**5**	**4.9**	**6.6**	**3.5**	**2.1**	**2.8**	**3.0**
Mean		2.2	3.1	3	1.5	1.7	4.4	2.3	3.3	3.8	2.5	2.2	2.3	3.7	3.2	5.2	5.2	4.7	7	4.9	3	5	3.5
Genetic Variance		0.8	0.4	0.9	0.3	1	0.5	1.3	0.4	0.8	1.2	1.1	1.7	0.8	4	1	0.1	1	0.2	0.3	0.8	0.9	0.9
Error Variance		0.9	0.5	0.2	0.2	0.1	0.4	0.2	0.5	0.3	0.1	0.1	0.8	0.4	0.3	0.2	0.5	0.5	0.3	0.5	0.2	0.4	0.4

20BWPLRA= Robe Arsi 2020; 21BWNLRA= Robe Arsi 2021; and 22BWNLRA = Robe Arsi 2022; 20BWOLKU=Kulumsa 2020; 20BWPLKU=Kulumsa 2021; and 22BWNLKU= Kulumsa 2022; 21BWNLHL=Holetta 2021; 22BWNLHL= Holetta 2022, 22BWNLGD= Gonder 2022; 22BWNLEW=Enawari 2022; 22BWNLCD= Chef dosa 2022, 21BWNLBE= Bekoji 2021; 22BWNLBE= Bekoji 2022; 20BWOLKF=Kofale 2020; 21BWPLKF = Kofale 2021; 20BWPLSN = Sinana 2020.

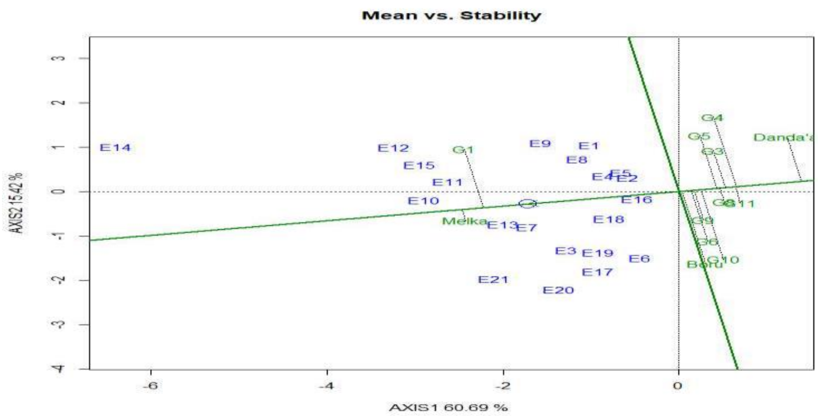

Figure 1: *GGE biplot analysis of the polygon view of the environments and genotypes for the PC1 and PC2*

E1= KF20BWOL, E2= KU20BWOL, E3= KU20BWPL, E4= RA20BWPL, E5= SN20BWPL, E6= DM21BWNL, E7= HL21BWNL, E8= RA21BWNL, E9= SN21BWNL, E10= BE21BWNL, E11= BE21BWPL, E12= KF21BWPL, E13= BE22BWNL, E14= KF22BWNL, E15= RA22BWNL, E16=CD22BWNL, E17= DM22BWNL, E18= EW22BWNL, E19= GD22BWNL, E20= HL22BWNL, E21= KU22BWNL

3.2. Mean performance of yield related agronomic traits

The wheat germplasm distributed globally by CIMMYT is the primary source of cultivars for developing countries and a highly valuable source of improved crossing parents for breeding programs and developing wide adaptability with high-yielding, resistance to disease, and high-quality traits worldwide. “Melka” was adapted high land-agro ecologies of Ethiopia. In an attempt to develop “Melka”, higher yield, and resistance to major bread wheat diseases were important traits of consideration. “Melka” took 72.2 days for heading and 122.3 days for maturing (**Table 3).** Concerning day to flowering, the number of days to flowering was later than the local check Danda’a by 3.2 days and by 1.6 days than the standard check Boru. “Melka” took 122.3 days to mature. The number of days to maturing was similar to the standard check Boru but later than the local check Danda’a by 3.3 days (**Table 3).** The “Melka” is comparatively taller than the standard varieties of Boru and local check Danda’a. However, “Melka” has better thousand kernel weight (39.90 g) than standard check Boru (37.6 g), and local check Danda’a (32.70 g) and 71.7 hl kg^{-1} **(Table 3).** Likewise, the “Melka” variety had bold seeds than checks. It possessed a 6.12% and 10.33 % HLW advantage over the Boru and Danda’a variety at the time of release, respectively.

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Table 3. Mean performance of some important agronomic traits of 10 genotypes and 2 checks tested from 2020 to 2022 trial seasons

SN	Genotype	DTH (days)	DTM (days)	HLW (kg/hl)	PHT (cm)	TKW(g)
1	EBW192345	69.3	121.3	69.1	84.2	39.9
2	**"Melka"**	**72.2**	122.3	**71.7**	**93.7**	**39.9**
3	EBW192022	73.1	118.7	67.9	84.1	34.4
4	EBW192387	72.1	116.7	66.6	86.3	33.3
5	EBW182981	68.2	116.0	70.0	87.5	32.9
6	EBW192874	67.1	120.7	68.9	82.5	36.7
7	Boru	70.6	122.3	67.3	92.1	37.6
8	EBW192873	67.5	116.0	67.5	85.7	35.7
9	EBW192140	70.6	120.7	70.5	86.2	37.8
10	EBW183001	65.0	115.7	70.3	82.5	34.9
11	EBW182999	66.4	116.3	70.9	84.7	36.1
12	Danda'a	75.4	119.0	64.3	98.9	32.7
	Mean	**69.8**	**118.8**	**68.7**	**87.4**	**36.0**
	SEM (+/-)	**3.1**	**2.6**	**2.1**	**5.0**	**2.5**

Abbreviations: DTH = Day to heading, DTM = Days to maturity, HLW = Hectoliter weight, PHT = Plant height and TKW=Thousand kernel weight

3.3.Disease Resistance

Resistance and susceptibility are relative terms they represent a continuum on a scale. Breeders want resistance that is easy to select, minimizes yield loss, and is durable. Rust diseases of wheat are among the most important production constraints in all wheat-growing regions globally. Stem rust caused by *Puccinia graminis* f. sp. *tritici* (Pgt) and stripe rust caused by *P. striiformis* f. sp. *tritici* (Pst) can cause up to 100% yield loss on susceptible cultivars [6]. The disease is largely distribute in wheat-growing countries around the globe and considered as one of the most important diseases associated with the crop [16]. The recently developed bread wheat varieties are comparable to the Danda'a and Boru in terms of leaf rust disease and are only moderately better resistant to stem rust and yellow rust. The highland's current commercial bread wheat cultivars are susceptible to yellow rust. The newly released bread wheat variety with the local name "Melka" showed a high level of yellow rust resistance with resistance and a moderately resistant response to stem rust in the face of severe stripe rust disease pressure (**Table 4).** Therefore, the development of new rust-resistant varieties will provide an excellent chance for producers of wheat in areas with limited resources.

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Table 4: Disease summary for newly released variety and checks			
Diseases/insects and other hazard	**"Melka"**	**Boru (St. Check)**	**Danda'a (~~St.~~ Local Check)**
Stem rust (%+ reaction)	10MRMS	40MS	50MS
Yellow rust (%+reaction)	5RMR-5MR	30MSS	40MRMS
Leaf rust (%+ reaction)	0	0	0
Septoria (0-9)	2	5	5

3.4.Variety maintenance

The goal of seed maintenance is to create new breeder seed lots with the same genetic makeup. Once the variety had released to the public, it is the breeder's responsibility to preserve it. In ear-rows, wheat plants that represent the variety will grown under careful supervision. Row plots, or small plots, are where plants from particular rows will collected and grown. Consequently, it is the responsibility of the wheat breeder at the Kulumsa Agriculture Research Institute to maintain the variety.

4. Conclusion

To address the challenges of population growth, food shortages, malnutrition, and resource destruction in developing countries, it is crucial to intensify crop production through innovations and better crop varieties adapted to varying agro ecological conditions and socioeconomic setups. A successful variety should produce high yields in favorable environments while maintaining acceptable yields under less favorable conditions. "Melka", a best-yielding bread wheat variety, demonstrated stable grain yield performance, and resistance to major wheat ~~rust~~ diseases, and officially released for highland wheat-growing areas of Ethiopia in 2024. Beyond its exceptional yield, this variety's distinctive feature lies in its enriched nutritional profile, particularly its high content of iron (Fe) 35.5 ppm and zinc (Zn) 38.1 ppm, which surpasses that of other available varieties. Farmers preferred this variety for its superior performance, white grain color, and high-quality bread.

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