Adamawa State University Journal of Scientific Research
Volume 10 Issue 1, 2022; Article no. ADSUJSR 1001004
ISSN: 2705-1900 (Online); ISSN: 2251-0702 (Print)
http://www.adsujsr.com

Performance of Okra (*Abelmoschus esculentus* (L.) Moench) as affected by Nitrogen Fertilizer application rates in Mubi North, Adamawa State, Nigeria

Bake, I. D.[1] and Idris, A. I[2],
1Department of Crop Science Faculty of Agriculture, Adamawa State University, Mubi, Adamawa State nigeria
2Department of Forestry Technology, Federal Polytechnic, Mubi, P.M.B.35, Adamawa State
Contact: ibrahimdaudabake@gmail.com; 08069797877

(Received in January 2021; Accepted in April 2022)

Abstract
The field experiment was conducted to examine the performance of okra (Abelmoschus esculentus (L.) Moench) as affected by nitrogen fertilizer application rates in Mubi North, Adamawa State, Nigeria, grown at the Teaching and Research Farm of Food and Agricultural Organization / Tree Crop Plantation (FAO/TCP), Faculty of Agriculture, Adamawa State University Mubi, during 2018 and 2019 rainy seasons. The experiments were laid out in a Complete Randomized Blocked Design (CRBD) with four (4) treatment levels of nitrogen: 0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1} and 150 kg N ha^{-1}replicated 3 times. Data collected on plant height, number of leaves/plant, stem diameter, days to first fruit setting, fruit length, fruit diameter, number of seeds/fruit, fresh and dried fruit yield/hectare. All the data collected were subjected to analysis of variance using Statistical Analysis System (SAS, 2010) and means that showed significant differences separated by F-test using Duncan Multiple Range Test. The results revealed that, at 9 WAS in 2018, 2019 and their combined effect, nitrogen fertilizer application rates significantly influenced plant height (34.960, 42.165 and 38.563 cm), number of leaves/plant (19.796, 19.680, 19.738), stem diameter (15.244, 14.076, 14.660 mm) recorded the highest values 150 kg N ha^{-1}. On the response of phonological traits and yield components of okra, to nitrogen fertilizer application rates, significant reduction in days to first fruit setting: 60.333 and 59.083 days 2018 and combined in the plots that received 150 kg N ha^{-1}compare with the shortest 58.00 days recorded in 2019 at 100 kg N ha^{-}.^{1} Furthermore, highest values of: 8.584, 9.088, 8.836 cm (fruit length) and 9.731, 9.867, 9.799 cm (fruit diameter), 102.023, 102.484, 102.258 (number of seeds/fruit), 1238.38, 1293.42, 1265.90 kg ha^{-1} (dry fruit yield/hectare) and 615.33, 652.33, 633.83kg ha^{-1} (fresh fruit yield/hectare) were obtained from the plots that received 150 kg N ha^{-i} accordingly. It was concluded that, plants from the plots received 150 kg N ha^{-i} performed significantly higher than the rest of the treatments. The study therefore recommends the application of 150 kg N ha^{-1} at 3 and 6 WAS as suitable dose to okra farmers in Mubi and its environs for optimum fruit yield.

Keywords: Fertilizer, Nitrogen Okra, Performance and Rates.

Introduction

Okra (*Abelmoschus esculentus* (L.) Moench), originated from Ethiopia in Africa, but nowadays widely cultivated throughout the tropics, sub-tropics and warmer parts of the temperate regions of the world (Echo, 2003; Khalid *et al*., 2005; Farinde, *et al*., 2007). It is a flowering plant and a member in *malvaceae* family, a polyploidy crop with chromosome number as: 2 n = 130, as reported by National Research Council (NRC. 2006). Distribution of West African okra is restricted to humid and per humid climates in Africa, between 12^0 N and 12^0 S. It is grown from Guinea to Nigeria in West Africa, Cameroon, Gabon and DR Congo in Central Africa and Uganda, in East Africa (Dhaliwal, 2017). It is one of the priority vegetable crops in Nigeria and ranks above other vegetable crops including cabbage, Amaranthus, and Lettuce (Babatunde *et al.*, 2007). The fruits are consumed immature and can be used in salads, soups and stews fresh or dried, fried or cooked (Gemede *et al*., 2013). Fresh okra fruits are the most important vegetable source of viscous fiber, an important dietary component to lower cholesterol (Arapirtsas, 2008). Seed protein of okra is rich in tryptophan (94 mg/g N) and also contains adequate amounts of sulfur-containing amino acid (189 mg/1 g N) (Chadha, 2002). Okra fruit contain carbohydrate, protein, vitamin A, B, C and K, sodium, calcium as well as magnesium. The vitamin A, Vitamin B_6, calcium and folic acid presence in okra could help in good vision, bone formation, growth and proper circulation of blood, and digestion (FAO, 2004).

Although, okra is a very important vegetable crop with outstanding qualities, but yields obtained from farmers' fields are often very low. Average yield per hectare in Nigeria is 2.10 t / ha, which is less than half of those in other countries like India (10.12 t / ha) and world average (7.65 t / ha). Research identified low soil fertility, weed infestation and the use of low yielding varieties as the major production constraints attributed to low yields of okra in Nigeria (Adeyemi *et al*., 2008; Iyagba *et al*., 2012). Unfortunately, crops and weeds have the same basic nutrient requirements (Foster, 1996) because the same nutrients applied to crops are generally available to weeds as reported by O'Donovan *et al.* (2001). The rate and time of nutrient application therefore, determines the relative competitiveness between crops and weeds. Hence strategies to increase productivity of okra in less fertile soils in order to meet the increasing demands of okra in Nigeria will have to focus on the supply of adequate nutrients for vigorous okra growth and yield (Adeigun *et al*., 2018). It is worthy to note that, empirical data and information on nitrogen fertilizer application rates is still inadequate in the study area. This study therefore, was carried out to examine the performance of okra as affected by nitrogen fertilizer application rates in Mubi North, Adamawa State, Nigeria.

Materials and Methods

The experiment was conducted at the Teaching and Research Farm of Food and Agricultural Organization / Tree Crop Plantation (FAO / TCP), Faculty of Agriculture Department of Crop Science, Adamawa State University. Mubi is situated between Latitude 9^0 26′ and 10^0 10′ N and Longitude 13^0 10′ and 13^0 44′ E at an altitude of 696 m above sea level. The soil is largely of sandy clay loam, sandy loam or loam textured. The annual mean rainfall in Mubi was 900 mm and the minimum temperature of 18 ^{0}C during the harmattan period and 40 ^{0}C maximum in April (Adebayo *et al*. (2020). Muhammad, *et al*., (2017) identified 2 types of seasons, viz; the wet season which lasted from April – October and dry season covered November – March characterized by cold dry dust laden wind especially in January and February.

Prior to sowing in both years, 5 core soil samples were randomly collected from 0 – 30 cm depth using soil auger and were properly mixed to form a composite sample. The composite soil samples were air – dried, grounded, and passed through a 2 mm sieve mesh and subsequently subjected for analysis to determine the soil textural classes, chemical properties and exchangeable bases of soil using standard laboratory procedures. The soil pH was determined by glass electrode pH meter, total nitrogen content was obtained by micro-kjedahl method designed by (Bremner and Mulvaney, 1982), and total Phosphorus was by Bray 1 method (Bray and Kurzt, 1945), while calcium and magnesium were determined by the Atomic Absorption Spectrophotometer (Perkin-Elmer Corp, 1969). Sodium determined using flame emission photometry profound by Doll and Lucas (1973). Determination of organic carbon content was achieved according to Walker- Black wet oxidation method (Walkey and Black, 1934) as shown in Table 1.

The two year experiments were laid out in a Complete Randomized Blocked Design (CRBD) with four treatment levels of nitrogen: 0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1} and 150 kg N ha^{-1} replicated 3 times. The experimental site was cleared and then ploughed with the aid of tractor mounted implement, larger soil clods were further broken down to create fine soil tilth conditions. Then, plots were manually constructed using hand hoe, shovel, rake and other simple farm tools. Total land area of the experimental plots were 32.7 x13.5 (441.45 m^2) with gross plot size of 3 × 2.1 (6.3 m^2) and the net plot size of 2.25 x 1.8 m (4.05 m^2). The experimental field was divided into 3 blocks and each consisted of 16 plots given a total of 48 plots. A path way of 0.5 m between plots and 1 m between blocks to allow easy passage for regular data collection was created. Nitrogen fertilizer was applied to the field in 2 split doses (3 and 6 weeks after seedling emergence) in accordance with the experimental design as follows: 50 kg N ha^{-1}, 100 kg N ha^{-1} and 150 kg N ha^{-1} and the control (0 kg N ha^{-1}).

The okra seeds (variety Yar-kwadam) used for the experiments were obtained from a certified local seed vendor in Mubi main market was treated with Apron Star WS (*Thia-methoxan + difenocanazole*) at 1 sachet (10 g) per 3 kg okra seeds 5 hour prior to planting on the field. Healthy seeds were sown in 10th July, 2018 and 2019 manually by placing the seeds in a moist soil after rainfall at the rate of 2 – 3 seeds / hole using 2 - 3 cm depth and later thinned down to 1 seedling / stand at 2 weeks after sowing. Seeds were sown at the spacing distance of 75 cm x 30 cm inter and intra raw spacing. Weeding was done 3 times at 3 weeks intervals. Karate lambda insecticide (Lambda cyhalothrim) mixed with water was applied 4 times at 5 days intervals to guard against insect pest and also during flowering stage. Fresh okra fruits were harvested at an interval of 3 days and average values recorded. Growth and yield parameters determined includes: plant height, number of leaves/plant, stem diameter, days to 1st fruit settings, fruit length, fruit diameter, number of seeds/fruit, dry and fresh fruit yield/hectare. The data collected were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS, 2010) and means that showed significant differences were separated using Duncan Multiple Range Test (DMRT).

Results and Discussion

Soil analysis:

Physico-chemical properties of soil of the experimental site before cropping are presented in Table 1. The result showed that, the texture of the soil of the study site was sandy-loam, with the pH of 6.41 and 6.62 (2018 and 2019) which is slightly acidic in nature. The organic carbon content (3.70 % and 3.93 %) equally fall under the category of very high in accordance with the rating of Bello *et al*, (2006), who classified soil organic percentages as: < 1.0, 1.0 – 1.71; 1.72 – 3; 3.1 – 4.29 and > 4.3 as very low, low, medium high and very high respectively. The soil of the experimental site is with medium total nitrogen (0.73 % and 0.19 %) content in accordance with the rating of London (1991); who classified soils having total nitrogen of greater than 1.0 % as very low, 0.5 - 1 % high, 0.2 – 0.5 % medium, 0.1 – 0..2 % low and less than 0.1 % as very low in total nitrogen content. Available phosphorus of 6.67 ppm and 6.83 ppm, which is medium soil according to the classification of Bray and Kurzt (1945), they also classified available P < 5 ppm as: very high, high, medium, low and very low accordingly. The experimental site has Carbon exchange capacity (CEC) of 3.25 and 3.44 meg/100, which is very low according to rating of the London (1991) who classified soils having CEC of > 40, 25 – 40, 15 – 25, 5 - 15 < 5 meg/100 g as very high, high, medium, low and very low.

Growth traits

Results for the performance of okra to nitrogen fertilizer application rates on plant height, number of leaves/plant and stem girth in 2018, 2019 cropping seasons and their combined effect are presented in Table 2, 3 and 4. The results indicated that, nitrogen fertilizer applied at the highest rate of 150 kg N ha^{-1} significantly ($P \geq 0.001$) influenced the growth traits of okra at 3, 6 and 9 weeks after sowing. Plant height recorded the highest values of: 8.907, 10.542, 9.734 cm (3 WAS) 19.613, 22.408, 21.010 cm (6 WAS) and 34.960, 42.165, 38.563 cm (9 WAS), number of leaves/plant, 6.267, 8.542, 7.404 (3 WAS), 8.883, 14.948, 11.915 (6 WAS), 19.796, 19.680, 19.738 (9 WAS) and stem girth: 2.753, 2.860, 2.807 (3 WAS), 6.413, 5.988, 6.201 (6 WAS), 15. 244, 14.076, 14.660 mm (9 WAS) while the lowest mean values for these traits recorded by plants from the control plots (0 kg ha^{-1}). The sequence of response showed by growth traits in this study under varying rates of nitrogen fertilizer was in accordance with the earlier findings of Sultana, (2002) who reported that Nitrogen fertilizer level at the rate of 150 kg N ha^{-1} significantly improved growth and yield of okra. Significant increase in okra stem girth with the application of 100 kg N ha^{-1} nitrogen was equally observed (Singh *et al*., 2007). Uddin *et al.* (2014) have earlier reported significantly higher number of leaves/okra plant and other related growth characters at the nitrogen application rates of 120 kg N ha^{-1}.

Table 1: Physico-chemical properties of soil of the experimental site before cropping

S/No.	Parameters	2018	2019
	Physical properties		
a.	**Particle size distribution (%**		
.	Clay	14.2	14.3
	Silt	31.6	33.0
	Sand	54.2	53.7
b.	**Textural Class**	Sandy-loam	Sandy-loam
c.	**Cation exchange capacity**		
	pH (1 – 2 soil: water solution)	6.41	6.62
	Organic carbon (kg^{-1})	3.70	3.93
	Cation exchange capacity (c mol (+) kg^{-1})	3.25	3.44
	Available nitrogen (g N kg^{-1})	0.73	0.19
	Available phosphorus (mg P kg^{-1})	6.67	6.83
	Available potassium (c mol (+) kg^{-1})	0.45	0.46
	Available magnesium (c mol (+) kg^{-1})	0.47	0.48
	Available sodium (c mol (+) kg^{-1})	0.38	0.36
	Available calcium (c mol (+) kg^{-1})	1.93	1.95

Source: laboratory experiment, 2018 and 2019

Table 2: Performance of okra as affect by nitrogen fertilizer application rates on plant height in 2018 and 2019 cropping season

Treatments	3 WAS			6 WAS			9 WAS		
Nitrogen	**2018**	**2019**	**Combined**	**2018**	**2019**	**Combined**	**2018**	**2019**	**Combined**
0 kg N ha^{-1}	8.128^{c}	9.920^{c}	9.024^{d}	15.478^{c}	18.529^{d}	17.003^{d}	28.385^{d}	34.483^{c}	31.434^{d}
50 kg N ha^{-1}	8.478^{b}	10.089^{b}	9.283^{c}	17.216^{b}	19.618^{c}	18.417^{c}	30.942^{c}	37.718^{b}	34.330^{c}
100 kg N ha^{-1}	8.751^{a}	10.417^{a}	9.584^{b}	18.013^{b}	20.625^{b}	19.319^{b}	32.955^{b}	38.803^{b}	35.879^{b}
150 kg N ha^{-1}	8.907^{a}	10.542^{a}	9.724^{a}	19.613^{a}	22.408^{a}	21.010^{a}	34.960^{a}	42.165^{a}	38.563^{a}
SE ±	0.074	0.055	0.046	0.332	0.249	0.208	0.393	0.678	0.392
Level of Sig.	***	***	***	***	***	***	***	***	***

Mean with the same letter (s) in each treatment group are not significantly different at 5 % level of probability using Duncan's Multiple Range Test (DMRT). **Key:** WAS = Week after Sowing, SE = Standard Error, *** = Significant at 0.001 %

Table 3: Performance of okra as affect by nitrogen fertilizer application rates on the number of leaves/ plant in 2018 and 2019 cropping season

Treatments	**3 WAS**			**6 WAS**			**9 WAS**		
Nitrogen	**2018**	**2019**	**Combined**	**2018**	**2019**	**Combined**	**2018**	**2019**	**Combined**
0 kg N ha^{-1}	5.417^{c}	7.650^{c}	6.533^{d}	7.958^{c}	11.247^{c}	9.603^{c}	14.345^{c}	15.569^{c}	14.956^{d}
50 kg N ha^{-1}	5.783^{b}	8.017^{b}	6.900^{c}	8.208^{c}	13.041^{b}	10.625^{b}	16.335^{b}	16.447^{c}	16.391^{c}
100 kg N ha^{-1}	6.067^{a}	8.158^{b}	7.113^{b}	8.567^{b}	14.733^{a}	11.650^{a}	17.818^{b}	18.267^{b}	18.042^{b}
150 kg N ha^{-1}	6.267^{a}	8.542^{a}	7.404^{a}	8.883^{a}	14.948^{a}	11.915^{a}	19.796^{a}	19.680^{a}	19.738^{a}
SE ±	0.091	0.103	0.069	0.092	0.549	0.278	0.551	0.482	0.366
Level of Sig.	***	***	***	***	***	***	***	***	***

Mean with the same letter (s) in each treatment group are not significantly different at 5 % level of probability using Duncan's Multiple Range Test (DMRT). **Key:** WAS = Week after Sowing, SE = Standard Error, *** = Significant at 0.001 %.

Table 4: Performance of okra as affect nitrogen fertilizer application rates on stem girth in 2018 and 2019 cropping season

Treatment	3 WAS			6 WAS			9 WAS		
Nitrogen	2018	2019	combined	2018	2019	Combined	2018	2019	Combined
0 kg N ha^{-1}	2.238^{c}	2.437^{b}	2.337^{c}	5.098^{c}	5.304^{c}	5.201^{d}	12.408^{c}	11.718^{c}	12.063^{d}
50 kg N ha^{-1}	2.460^{b}	2.583^{b}	2.521^{b}	5.662^{b}	5.556^{b}	5.609^{c}	13.309^{b}	12.454^{bc}	12.882^{c}
100 kg N ha^{-1}	2.543^{b}	2.602^{b}	2.573^{b}	5.937^{b}	5.709^{b}	5.823^{b}	14.028^{b}	13.123^{b}	13.575^{b}
150 kg N ha^{-1}	2.753^{a}	2.860^{a}	2.807^{a}	6.413^{a}	5.988^{a}	6.201^{a}	15.244^{a}	14.076^{a}	14.660^{a}
SE ±	0.046	0.082	0.047	0.095	0.065	0.058	0.273	0.303	0.204
Level of Sig.	***	*	***	***	***	***	***	***	***

Mean with the same letter (s) in each treatment group are not significantly different at 5 % level of probability using Duncan's Multiple Range Test (DMRT). **Key:** WAS = Week after Sowing, SE = Standard Error, ** = Significant at 0.01 %, *** = Significant at 0.001 %

Phenological Traits

Variation in the rates of nitrogen fertilizer applied to okra significantly (P ≥ 0.001) influenced days to first fruit setting, fruit length and diameter in 2018, 2019 cropping seasons and combined Table 6. The results indicated that, the shortest: 60.333 (2018) and 59.083 (combined) days to first fruit setting obtained at 150 kg N ha^{-1} but in 2019, the shortest (57.667 days) recorded from the plots that received 100 kg N ha^{-1}. Meanwhile, okra fruit reached the maximum length and diameter of: 8.584, 9.088, 8.836 cm and 9.731, 9.867, 9.799 cm at the highest application rates of 150 kg N ha^{-1} with their minimum values recorded from the control treatment (0 kg N ha^{-1}) accordingly. The observed pattern of significantly progressive increased in fruit length and diameter at the varying rates of nitrogen fertilizer recorded in this study was relatively similar to the previous findings of Mani and Ramanathan (1980); Mjambu *et al.* (1985), and Singh *et al.* (1998) recorded linear increase in fruit length and diameter of okra with the application of nitrogen at the rates of 125 kg N ha^{-1} and 145 kg N ha^{-1}. Sultana (2002) equally reported significant improvement of okra fruit length with nitrogen fertilizer at the rates of 100 kg ha^{-1}.In their previous findings Dwivedi *et al*. (1994) and Ambare *et al.* (2005) recorded maximum number of days to 50 % flowering and first fruit setting in okra plants from the field that received the highest rates of 100 and 150 kg N ha $^{-1}$. In the same vein, Amanga (2014) in his investigation indicated that application of nitrogen at the rate of 46 and 69 kg N ha^{-1} led to the longest days to 50 % flowering and first fruit setting in contrast with the control treatment.

Table 5: Performance of okra as affect by nitrogen fertilizer application rates on some phonological traits in 2018 and 2019 cropping season

Treatment	Days to first fruit setting			Fruit Length (mm)			Fruit Diameter (mm)		
Nitrogen	2018	2019	Combined	2018	2019	combined	2018	2019	Combined
0 kg N ha^{-1}	61.333^{b}	58.750^{a}	60.042^{a}	7.633^{d}	8.129^{d}	7.881^{d}	8.560^{d}	8.996^{c}	8.778^{d}
50 kg N ha^{-1}	61.083^{ab}	61.083^{ab}	59.958^{a}	8.003^{c}	8.418^{c}	8.210^{c}	9.041^{c}	9.318^{b}	9.179^{c}
100 kg N ha^{-1}	60.500^{ab}	57.667^{b}	59.167^{b}	8.298^{b}	8.655^{b}	8.477^{b}	9.392^{b}	9.614^{a}	9.503^{b}
50 kg N ha^{-1}	60.333^{b}	58.00^{b}	59.083^{b}	8.584^{a}	9.088^{a}	8.836^{a}	9.731^{a}	9.867^{a}	9.799^{a}
SE ±	0.306	0.008	0.194	0.091	0.007	0.056	0.089	0.010	0.066
Level of Sig.	*	**	***	***	***	***	***	***	***

Mean with the same letter (s) in each treatment group are not significantly different at 5 % level of probability using Duncan's Multiple Range Test (DMRT). **Key:** SE = Standard Error, *= Significant at 0.05 %, **= Significant at 0.01 %, *** = Significant at 0.001 %

Yield Traits

The same results pattern were observed with regard to the number of seeds/fruit, dry and fresh fruit yield/hectare (Table 6), where the greatest number of: 102.023, 102.484, 102.258 seeds/fruit, dry and fresh fruit yield in the range of 0.780, 0,815, 0.798 kg ha^{-1} and 1.238, 1.293, 1.265 kg ha^{-1} in 2018, 2019 and combined were obtained as the nitrogen level increased to 150 kg ha^{-1}. However, the control treatment (0 kg ha^{-1}) having the lowest means values, remained the least. The highest number of seeds/fruit, dry and fresh fruits yield/ha^{-1} was collected at 150 kg N ha^{-1} while the least was from the control (0 kg N ha^{-1}). This is similar to the earlier studies by Gates (1998) and Chandler (1999) who recorded significant improvement in okra seeds numbers at 150 kg N ha^{-1} while Navdeep and Daljeet (2016) reported significantly higher number of fruits/fruit and yield/ha^{-1} when nitrogen was applied at the rate of 125 kg ha^{-1}. Olasatan (2001); Babatola *et al*. (2002) revealed that, growth and yield of okra fruits depends on available soil nitrogen and also amount of nitrogen applied.

Table 6: Performance of okra as affect by nitrogen application rates on some yield and yield attributed traits in 2018 and 2019 cropping seasons

Treatment	Number of seeds per fruit			Fresh Fruit Yield Per Hectare (kg ha-1)			Dried Fruit Yield Per Hectare (kg ha-1)		
Weeding	2018	2019	Combined	2018	2019	Combined	2018	2019	Combined
0 kg N ha-1	88.932c	92.333c	90.632c	1.032c	1.109c	1.071d	0.464c	0.493d	0.478d
50 kg N ha-1	94.364b	97.038b	95.701b	1.084c	1.163c	1.124c	0.518c	0.535c	0.527c
100 kg N ha-1	97.291b	98.733b	98..012b	1.162b	1.234b	1.198b	0.576b	0.591b	0.583b
150 kg N ha-1	102.023a	102.484a	102.258a	1.238a	1.293a	1.265a	0.615a	0.652a	0.633a
SE ±	1.271	1.094	0.839	23.933	20.000	15.598	14.333	11.117	9.070
Level of Sig.	***	***	***	***	***	***	***	***	***

Mean with the same letter (s) in each treatment group are not significantly different at 5 % level of probability using Duncan's Multiple Range Test (DMRT). **Key:** SE = Standard Error, *** = Significant at 0.001 %

Conclusion

The results of this study showed that, nitrogen fertilizer application rates significantly promoted the growth, phenological and yield traits of okra in 2018, 2019 cropping season and combined. In that, nitrogen applied at the highest rate of 150 kg ha^{-1} recorded plants having the greatest mean values in terms of: plant height, number of leaves/plant, stem girth, days to first fruit setting, fruit length and diameter. Other traits are; number of seeds/fruit, dry and fresh fruit yield/ha^{-1}. Although, the highest values were almost recorded at 150 kg ha^{-1}, the yield obtained at 100 kg ha^{-1}, are comparable to 150 kg ha^{-1}.

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