

Sensitivity of Okra Growth Indices to Various Moisture Conditions

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Abstract: This study evaluates the effects of flooding conditions on two Okra cultivars (Ibadan local and Jokoso) at Abeokuta, Nigeria. The flooding conditions vary from continuous Flooding (FLD), Wetting after three Days (W3D), Wetting after five Days (W5D), Wetting after seven Days (W7D), and Wetting after ten Days (W10D). The agronomic parameters (leaf width, leaf length, plant height, numbers of leaves, and leaf area) and yield data (weight, fruit diameter, fruit length) were subjected to analysis of variance and treatment means separated using the Least significant difference. Okra growth and fruit yield were significantly ($p < 0.05$) affected by moisture conditions; FLD produced significantly ($p < 0.05$) the tallest plant at 7 WAP in Ibadan Local and Jokoso with 34.0 and 42.2 m respectively while W10D gave the shortest plant height of 24.5 and 20.5 cm for Ibadan Local and Jokoso respectively. Several leaves at 7 WAP followed a similar trend as plant height with FLD producing significantly more leaves in Ibadan Local and Jokoso with 5.0 and 9.0 leaves respectively while W10D produced the lowest number of leaves of 2.67 and 2.33 leaves for Ibadan and Jokoso respectively. Okra Leaf Area was highest in FLD at 7WAP in Ibadan Local and Jokoso with 224.2 and 249.7 cm², respectively and W10D produced 144.0 and 78.8 cm² for Ibadan Local and Jokoso respectively. Moisture conditions significantly ($p < 0.05$) affected fruit yield characters with FLD recorded the highest fruit weight of 13.97 and 0.87g for Ibadan Local and Jokoso, respectively, while W7D recorded 0.78 g for Ibadan Local and 0.00 g for Jokoso. Also, FLD recorded the highest fruit diameter in Jokoso with 6.43 and 2.63 cm for Ibadan Local while W7D recorded 2.23 cm for Ibadan Local and 0.0 cm for Jokoso. The trend for Fruit length was similar with FLD producing the longest fruits in Ibadan Local with 5.51 and 4.67 cm for Jokoso while W5D produced 4.62 cm in Ibadan Local and 3.00 cm in Jokoso. It could be concluded from the study that flood conditions such as continuous flooding, wetting after three days, and wetting after five days were suitable for the growth and fruit yield of okra cultivars; Ibadan Local and Jokoso in the study area while wetting after seven days and wetting after ten days appeared detrimental to these cultivars.

Keywords: Okra, Growth Indices, Flooding, Sensitivity

Introduction

Crops are watered periodically during the growing season, either by natural rainfall or by irrigation. In the intervals of each watering, soil moisture stress sometimes becomes severe and limits plant growth and development (Khalil, 2004). This is particularly true in rain-fed agriculture where the amount of rainfall is insufficient for the plant to complete growth and also under irrigated agriculture where the amount of available water is limited.

Many studies have indicated that even a brief water shortage is likely to interfere with the normal function of vital processes of plants, thereby influencing their vigor and productivity. The timing of water stress during crop growth and development is an important factor in determining the magnitude of the effect of stress, (Khatana *et al.*, 2018).

Generally, annual crops are particularly sensitive to stress at a critical stage of development, (Guimarães *et al.*, 2015). Salter and Williams (1967) suggested that most of

the determinate crops are sensitive to water stress especially at the time of floral initiation and during flowering and, to a lesser extent, during fruit and seed development. In indeterminate and perennial crops, in which vegetative growth and reproductive processes overlap, the situation is not very clear, (Khatana *et al.*, 2018). Due to the economic importance of Okra in food security, it is crucial to understand how drought conditions potentially affect okra yield under climate change and to explore appropriate adaptation measures to maintain or increase okra production. Previous studies indicate that irrigation is the most efficient adaptation measure to mitigate the negative effects caused by drought in crop production (Li *et al.*, 2005; Olesen *et al.*, 2011; Rui-Peng *et al.*, 2012).

Although okra is usually grown as an annual plant, it is a perennial plant. In this crop, after short vegetative development, reproductive growth including flower opening and fruit development and vegetative growth occur concurrently. In such crops, the relationship between the stage of plant growth and the effect of water deficit is not clearly understood yet. This experiment was conducted to analyze the responses of two okra cultivars to various flood conditions in a forest-savanna transition zone of Nigeria.

Materials and Methods

Experimental Site Descriptions

The experiment was conducted in a screen house at the Federal University of Agriculture, Abeokuta (FUNAAB) behind the College of Environmental Resources Management (COLERM), located between Latitude 7°2' 23" N and Longitude 3°4' 03" E. The study area is characterized by a tropical climate with distinct wet and dry seasons. The wet season is associated relatively with the prevalence of the moist maritime southerly monsoon from the Atlantic Ocean and the dry season by the continental North Easterly harmattan winds from the Sahara Desert. The area is located within a region characterized by a bimodal rainfall pattern (April to July being the wettest months, followed by August to October). The annual rainfall ranges between 1400 and 1500 mm in Abeokuta and its environs. Isolated and scanty rains usually start in mid-March and steadily increase to reach the peak values in July followed by a short break in August. The dry season is normally from October to March and is often characterized by hot days.

Experimental Procedure

The experimental crop used was two Okra varieties (Ibadan Local and Jokoso) obtained from National Horticultural Research Institute (NIHORT), Ibadan. Topsoil at 0-30 cm, collected from the FADAMA wetlands of the Federal University of Agriculture, Abeokuta Nigeria, (2021 planting season) was sieved to fine particles using a 200 mm Sieve before being filled into plastic pots. Eighteen (18) plastic pots were used;

they were perforated at the bottom before use to enable free drainage of water. 3 kg of sieved soils were measured to into each plastic pot. The plastic pots containing soil were watered to saturation and left for a day, after which seeds of two (2) okra varieties (Ibadan Local and Jokoso) were planted in each plastic pot arranged in the split-plot (cultivar and flood conditions as the main and sub-plot respectively) with three replicates. The experiment was 5 × 2 factors, consisting of five flooding conditions and two varieties of okra. The flooding conditions were continuous Flooding (FLD), Wetting after three Days (W3D), Wetting after five Days (W5D), Wetting after seven Days (W7D), and Wetting after ten Days (W10D) while the two varieties used were Ibadan Local and Jokoso. Three weeks after planting the plants were thinned to one per pot and weeded manually. Herbicide was applied in the screen house for the protection against pests and diseases.

Data Collection and Analysis

The data set for several leaves, plant height, leaf area, and fruit yield characters were subjected to Analyses of Variance (ANOVA) using SAS software package 9.1 (SAS Institute, 2003). Comparisons among the combination of the treatment were carried out at a 0.05% probability level and treatment means were separated using Least Significance Difference (LSD).

Results and Discussion

As shown in Fig. 1 below, the screen house was hottest at 6 weeks after planting with temperature, Relative humidity, and light intensity of 37°C, 65%, and 5760 lux respectively while it was coldest at 1 and 9 weeks after planting having 30°C, 80% and 2070 lux respectively for temperature, relative humidity, and light intensity. The trends of micro-climatic conditions within the screen house follow the typical one of the rainfall-savanna transition zone of Nigeria (Olaniran and Babatolu, 1987).

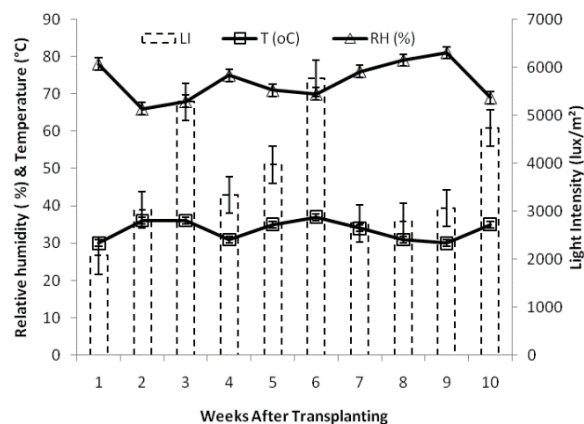


Fig. 1: Trends of Micro-climatic conditions in the screen house during the growth of Okra Cultivars in Abeokuta

Plant Height (Ibadan Local)

The plant height of the Ibadan Local was significantly different on all sample occasions (Table 1). The plant height at 3WAP ranged from 15.63 cm in W10D, followed by 17.23 cm in W3D, then by 17.37 cm in W5D, followed by 17.90 cm in W7D while the highest plant was obtained in FLD with 19.17 cm. Equally the plant height at 5WAP ranged from 21.03 cm in W10D followed by 22.47 cm in W7D, followed by 23.93 cm in W5D, and 25.67 cm in W3D while the highest value was obtained in FLD with 27.97 cm. Also, the plant height at 7WAP ranged from 24.47 cm in W10D, followed by 25.20 cm in W7D, followed by 28.87 cm in W5D, and 34.03 cm in FLD while the highest value was obtained in W3D with 35.63 cm (Table 1).

Plant Height (Jokoso)

The plant height of Jokoso was statistically significant on all sampled occasions (Table 1). The plant height at 3WAP ranged from 11.00 cm in W10D, followed by 14.00 cm in W7D, then 14.83 cm in W3D while the tallest plant with 16.33 cm was obtained in FLD. A similar pattern was observed at 7WAP when the plant height was from 19.00 cm in W10D, to 32.83 cm in W5D while the tallest plant with 42.17 cm was obtained in FLD (Table 1).

Leaf Area of Okra (Ibadan local)

The leaf area of the okra varieties was significantly different on all sample occasions (Table 2). The leaf area of the Ibadan Local at 3WAP increased from 38.67 cm² in W10D, followed by 57.69 cm² in W7D, then 60.83 cm² in W5D, and 74.87 cm² in FLD while the highest value was obtained in W3D with 76.64 cm². Also, the leaf area of the okra variety at 7WAP ranged from 144.05 cm² in W10D, followed by 181.95 cm² in W5D, followed by 182.22 cm² in W7D, and 224.23 cm² in FLD while the highest value was obtained in W3D with 298.51 cm² (Table 2).

Leaf Area of Okra (Jokoso)

Leaf area of Jokoso at 3WAP increased from 21.25 cm² in W10D, then 35.34 cm² in W7D and 40.30 cm² in W5D while the largest area of 42.92 cm² was obtained in FLD (Table 2). The leaf area recorded at 5WAP was in the order, of 170.48 cm² in FLD followed by 160.42 cm² in W5D, then 147.50 cm² in W7D, and 135.45 cm² in W3D while the least value of 106.23 cm² was obtained in W10D. Again, at 7WAP it ranged from 78.83 cm² in W10D, then 140.33 cm² in W3D and 183.33 cm² in W5D while the largest value of 249.75 cm² in FLD (Table 2). The result implies that the leaf area of Jokoso and Ibadan local was not influenced by

moisture stress of fewer than 7 days, this may be due to the nature of okra plants to survive under moderate water supply, this agrees with Lawlor and Leach (1985) and Sasani, *et al.*, (2004) who opined that a decrease in leaf area is majorly a common effect of drought.

Number of Leaves of Okra (Ibadan Local)

The number of leaves of the okra variety was significantly different on all sample occasions (Table 3). The number of leaves of Ibadan Local at 3WAP in FLD, W3D, and W5D are the same with 6.00 leaves while the number of leaves in W5D and W7D was 5.00. Equally the number of leaves at 5WAP ranged from 4.67 leaves in W10D and W7D, followed by 8.00 leaves in W5D and W3D while the highest value of 8.67 leaves was obtained in FLD. Also, the number of leaves at 7WAP ranged from 2.67 leaves in W10D and W7D, followed by 3.67 leaves in W5D, while the highest value was obtained in FLD and W3D with 5.00 leaves (Table 3).

Number of Leaves Okra (Jokoso)

The number of leaves of Jokoso at 3WAP was 4.67 leaves in FLD and W7D, 4.33 leaves in W5D, 4.00 leaves in W10D while W3D had 3.67 leaves (Table 3). The observations at 5WAP show that FLD had the highest number of leaves with 6.67 leaves, followed by W5D with 6.33 leaves, then W10D with 6.00 leaves while the lowest value of 5.67 leaves was obtained in W3D and W7D. At 7WAP, FLD again had the highest number of leaves with 9.00 leaves, followed by W5D and W7D with 7.00 leaves, then W3D with 6.33 leaves while the least value of 2.33 leaves was recorded in W10D (Table 3). Generally, several leaves of both varieties showed high resilience to moisture stress conditions of wetting intervals of three, five, and seven days (i.e., W3D, W5D, and W7D).

Soil Temperature with Ibadan Local

Soil temperature differed considerably at various stages of crop growth (Table 4). The soil temperature trend for Ibadan local at 3WAP to W7D had 32.33°C, followed by 31.53°C in W10D, then 30.93°C in W3D, and 30.80°C in FLD while the least temperature of 30.67°C was obtained in W5D. Also, at 5WAP the highest temperature of 37.90°C was obtained in W7D followed by 37.87°C in W10D, then 34.40°C in W3D, and 34.27°C in W5D while the least temperature of 33.27°C was recorded FLD. Equally, at 7WAP the highest temperature of 31.27°C was obtained in W10D followed by 30.43°C in W7D, then 28.03°C in FLD, and 28.00°C in W3D while the least temperature of 27.87°C was obtained in W5D (Table 4).

Table 1: Effect of flood conditions on the plant height of Ibadan local and Jokoso in Abeokuta

Ibadan local						
Flood conditions	3WAP	4WAP	5WAP	6WAP	7WAP	
FLD	19.17±1.89	21.00±2.00	27.97±2.66	31.67±2.51	34.03±1.27	
W3D	17.23±0.91	19.17±2.02	25.67±1.27	32.87±1.51	35.63±1.01	
W5D	17.37±0.32	17.00±3.12	23.93±1.00	29.67±1.59	28.87±1.16	
W7D	17.90±1.47	17.60±2.51	22.47±1.96	24.33±2.76	25.20±0.95	
W10D	15.63±1.50	14.33±1.89	21.03±4.13	23.30±2.46	24.47±2.29	
LSD	2.43**	4.28**	4.49**	4.05**	2.59**	
Jokoso						
Flood conditions	3WAP	4WAP	5WAP	6WAP	7WAP	8WAP
FLD	16.33±4.04	20.67±6.43	29.00±9.64	36.67±12.42	42.17±12.77	47.50±11.76
W3D	14.83±4.54	19.83±5.01	25.67±7.23	31.67±7.23	39.17±6.79	40.50±8.26
W5D	14.50±5.68	18.33±5.78	23.67±5.5	25.83±5.39	32.83±6.79	35.50±5.07
W7D	14.00±1.32	17.67±2.52	21.50±2.29	24.33±1.53	30.50±5.89	32.67±9.17
W10D	11.00±1.50	13.17±1.04	16.00±2.00	17.83±2.25	19.00±3.00	20.50±3.78
LSD	6.96**	8.42**	11.06**	12.69**	14.07**	14.71**

LSD: Least Significant Difference WAP: Weeks After Planting
 FLD: Flooding of the plant every Day. W3D: Irrigating every three Days
 W5D: Irrigating every five Days. W7D: Irrigating every seven Days
 W10D: Irrigating every ten Days. **: Significant at 0.05

Table 2: Effect of flood conditions on the leaf area of Ibadan local and jokoso in Abeokuta

Ibadan local						
Flood conditions	3WAP	4WAP	5WAP	6WAP	7WAP	
FLD	74.87±11.58	187.33±26.820	220.98±27.59	213.39±30.50	224.23±25.44	
W3D	76.64±5.33	211.17±89.140	262.67±137.19	295.03±168.52	298.51±158.34	
W5D	60.83±20.29	167.10±102.84	210.23±102.01	240.43±115.81	181.95±11.17	
W7D	57.69±19.31	87.31±1.2200	120.03±3.56	144.33±18.50	182.22±3238	
W10D	38.67±13.40	94.02±51.320	102.40±50.18	136.24±50.66	144.05±49.33	
LSD	27.31**	120.34**	146.72**	173.83**	139.32**	
Jokoso						
Flood conditions	3WAP	4WAP	5WAP	6WAP	7WAP	8WAP
FLD	42.92±24.56	112.20±57.61	170.48±34.17	220.75±91.97	249.75±127.11	245.08±149.91
W3D	35.42±21.88	71.38±33.56	135.45±20.27	147.42±15.04	140.33±18.58	150.00±16.70
W5D	40.30±27.52	61.70±36.44	160.42±44.71	185.92±50.38	183.33±44.17	193.60±57.76
W7D	35.34±8.07	93.32±46.88	147.50±15.77	176.42±15.44	199.50±36.65	190.50±39.32
W10D	21.25±5.81	41.76±5.630	106.23±46.44	94.25±94.25	78.83±13.60	121.50±14.31
LSD	35.82**	72.78**	62.93**	87.16**	115.01**	135.75**

Table 3: Effect of flood conditions on the number of leaves of Ibadan local and Jokoso in Abeokuta

Ibadan local						
Flood conditions	3WAP	4WAP	5WAP	6WAP	7WAP	
FLD	6.00±0.00	7.67±0.58	8.67±0.58	5.00±1.00	5.00±1.73	
W3D	6.00±0.00	7.33±0.58	8.00±2.00	6.00±1.73	5.00±2.00	
W5D	6.00±0.00	7.67±1.15	8.00±2.00	4.33±0.58	3.67±0.58	
W7D	5.00±0.00	6.33±1.15	4.67±0.58	3.33±0.58	2.67±0.58	
W10D	5.00±1.00	6.67±0.58	4.67±0.58	3.00±1.00	2.67±0.58	
LSD	0.81**	1.56**	2.44**	1.94**	2.30**	
Jokoso						
Flood conditions	3WAP	4WAP	5WAP	6WAP	7WAP	8WAP
FLD	4.67±0.58	6.67±0.58	6.67±0.58	8.33±1.53	9.00±3.61	9.33±4.93
W3D	3.67±0.58	5.33±1.52	5.67±0.58	7.00±0.00	6.33±1.53	6.33±1.15
W5D	4.33±0.58	5.00±0	6.33±0.58	5.33±0.58	7.00±3.00	8.67±3.79
W7D	4.67±0.58	6.67±0.58	5.67±1.53	5.67±1.53	7.00±3.61	6.00±4.36
W10D	4.00±0.00	5.33±0.58	6.00±0	4.00±0	2.33±0.58	3.00±1.00
LSD	0.94**	1.49**	1.49**	1.82**	4.99**	6.30**

Table 4: Effect of flood conditions on the soil temperature trends under okra cultivars in Abeokuta

Ibadan local						
Flooding conditions	3WAP	4WAP	5WAP	WAP6	7WAP	
FLD	30.80±0.70	30.63±2.15	33.77±1.04	32.17±0.38	28.03±0.21	
W3D	30.93±1.03	29.27±0.67	34.40±1.15	32.03±0.23	28.00±0.36	
W5D	30.67±0.15	29.13±0.57	34.27±0.21	32.77±0.75	27.87±0.90	
W7D	32.33±0.68	30.33±0.15	37.90±1.40	33.27±0.47	30.43±0.55	
W10D	31.53±0.23	31.17±0.61	37.87±0.21	34.33±0.67	31.27±0.29	
LSD	1.17**	1.95**	1.72**	0.97**	0.95**	
Jokoso						
Flooding conditions	3WAP	4WAP	5WAP	6WAP	7WAP	8WAP
FLD	31.37±0.90	28.37±0.23	30.27±0.50	29.47±0.35	26.17±0.06	27.43±0.40
W3D	30.47±0.58	27.93±0.28	30.63±1.10	29.77±0.57	26.53±0.15	27.53±0.40
W5D	30.57±0.89	27.93±0.12	31.07±0.76	30.00±0.34	26.77±0.15	27.47±0.45
W7D	30.93±0.42	27.5±0.06	30.80±0.50	30.43±0.21	26.87±0.40	28.60±0.26
W10D	31.17±0.35	29.73±0.51	34.30±1.04	31.07±0.15	27.23±0.38	29.63±0.40
LSD	1.18**	0.53**	1.49**	0.65**	0.49**	0.71**

Table 5: Effect of flood Conditions on okra Cultivars fruit diameters, fruit lengths, fruit weight, and number of fruit

Flood conditions	Ibadan local				Jokoso			
	FRW	FRD	FRL	FRN	FRW	FRD	FRL	FRN
FLD	0.87±1.50	2.63±4.56	5.51±9.54	0.67±1.15	13.97±12.23	6.43±5.81	4.67±4.16	0.67±0.57
W3D	1.00±1.73	2.68±4.65	8.64±14.96	0.67±1.15	4.94±8.56	3.34±5.78	1.83±3.18	0.33±0.58
W5D	0.85±1.47	2.25±3.90	4.62±8.00	0.67±1.15	7.67±13.27	2.83±4.91	3.00±5.19	0.67±1.15
W7D	0.78±1.34	2.23±3.87	3.81±6.60	0.67±1.15	0.00	0.00	0.00	0.00
W10D	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00	0.00	0.00	0.00
LSD 0.05	2.47**	6.93**	16.72**	1.88**	7.772**	6.002**	16.253**	1.151**

FRW: Fruit Weight (g), FRD: Diameter (cm), FRL: Fruit Diameter (cm), FRN: Number of fruits

Soil Temperature with Jokoso

The soil temperature trend for Jokoso at 3WAP shows that FLD had 31.37°C, followed by 31.17°C in W10D, then 30.93°C in W7D, and 30.57°C in W5D while the least temperature of 30.47°C was obtained in W3D (Table 4). Also, at 5WAP the highest temperature of 34.30°C was obtained in W10D followed by 31.07°C in W5D, then 30.80°C in W7D, and 30.63°C in W3D while the least temperature of 30.27°C was recorded FLD. Equally, at 7WAP the highest temperature of 27.23°C was obtained in W10D followed by 26.87°C in W7D, then 26.77°C in W5D, and 26.53°C in W3D while the least temperature of 26.17°C was obtained in FLD (Table 4). The range of soil temperature observed fell within the optimum soil temperature required for optimum crop production in southwest, Nigeria (Makinde *et al.*, 2019). For instance, Okra needs soil temperature above 20°C for normal growth and development, Lamont (1999), El-Kader *et al.* (2010) and Akande *et al.* (2004).

Yield Characteris of Ibadan Local and Jokoso

There was a significant difference in fruit diameter, fruit length, and several fruits in all samples of the fruit harvested (Table 5). The fruit weight of Ibadan Local ranged between 0.87 g in FLD and 0.78 g in W7D while for the Jokoso cultivar it ranged between 13.97 g in FLD

and 0.00g in W7D. The fruit diameter of the cultivar Ibadan Local ranged between 2.63 cm in FLD and 2.23 cm in W7D while for the Jokoso cultivar it ranged between 6.43 cm in FLD and 0.00 cm in W7D. The fruit length of Ibadan Local ranged between 5.51 cm in FLD and 4.62 cm in W5D while for the Jokoso cultivar it ranged between 4.67 cm in FLD and 3.00 cm in W5D. The mean number of fruits for both cultivars; Ibadan Local and Jokoso was 0.67 fruits across all moisture conditions that produce yield. Ibadan local was able to produce yield under W7D while Jokoso was unable to produce yield under both W7D and W10D (Table 5).

A similar result was obtained by Gunawardhana and de Silva (2011) and Boland *et al.* (2000), that the number of fruits/plants was lowest when okra was subjected to water stress conditions. They noted that even at the highest temperature and water stress conditions, the number of fruits/plants was higher compared to other treatments. It shows that the combined effect of temperature and water has a less negative effect on several fruits/plants in okra when compared to individual water stress treatments.

The results of this study suggest that using these two okra cultivars (Ibadan Local and Jokoso) as a crop in water-limited environments may enable farmers of these regions to use deficit irrigation, preventing short-term decreases in gas exchange and plant growth when the soil dries and improving irrigation efficiency, which is similar to the observation of Owusu-Sekyere and Annan, (2010).

Conclusion

Jokoso cultivar showed high sensitivity to Flooding (FLD), Wetting after three Days (W3D), and Wetting after five Days (W5D) while moisture conditions from Wetting after seven Days (W7D) appeared detrimental to its growth and fruit yield quality. Also, the results have shown that a reduced level of water in the plant has an increasingly negative effect on the early growth, development, yield, and plant survival depending on the magnitude of excess or deficit of the water. Wetting after three Days (W3D) was shown to give maximum performance for Ibadan Local while Flooding (FLD) gave a maximum performance for the Jokoso cultivar. The study recommends further study using different genotypes in field experiments.

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Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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