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GROWTH AND YIELD RESPONSES OF OPEN POLLINATED MAIZE (*Zea mays*) TO TYPES AND RATES OF ORGANIC FERTILISERS IN RAINFOREST TRANSITORY AGROECOLOGY OF NIGERIA

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ABSTRACT

Sustainable maize (*Zea mays*) production in resource challenged regions of the world is achievable among others through optimal utilisation of organic fertilisers at varying rates. Field trials were conducted in Abeokuta (Latitude 7°10' N and Longitude 3°15' E) in the late cropping season of 2010 and 2011. Three commercially available organic fertilisers [(Gateway 1 (GF1), Gateway 2 (GF2) and Sunshine (SF)], at three rates (0, 10 and 20 t ha^{-1}) and three replicates were used on improved open-pollinated maize variety (Swam 1 yellow). The experiment was laid out in a randomised completely blocked design. GF1 had significantly (P < 0.05) the highest effect on growth parameters (Plant height, stem girth, leaf area and leaf area Index), with SF the least. A significant depression was observed in most growth parameters at increasing application rates of organic fertiliser, a converse pattern was observed on 1000 grain weight (GW), harvest index and cob length. A significantly higher (P < 0.05) vegetative growth, cob weight and grain yield was observed in 2010 than 2011, while 2011 had longer cobs and more 1000 GW than 2010. GF1 was recommended in Rainforest transitory zone of Nigeria at higher application rates though mediated by environmental factors.

Keywords: Open-pollinated maize, Organic fertiliser, Rainforest transitory zone, Sustainable

INTRODUCTION

Maize (*Zea mays*) occupies a significant portion of food value chain for both man and animal. It is commonly cultivated in most part of the world, Africa inclusive (Iken and Amusa, 2004). Its sustainable production in resource challenged regions of the world; environmental and economic could be ensured through integrated nutrient management as well as utilisation of open-pollinated maize varieties.

Application rates and right source of fertilisers is a significant component of integrated nutrient management practises (Shilpashree *et al.,* 2012). Organic fertiliser sources had been advocated recently in most part of the world as a viable alternative to inorganic fertiliser because of their accessibility, slow releasing property and positive effect on the environment compared to the conventional inorganic fertilisers (Bengtsson *et al.,* 2005). Applied at the right rate, crops are most likely to benefit from the application of organic fertilisers.

Akpako and Yiljep, 2001 opined that most farmers in resource challenged countries of the world could not afford hybrid seeds because of the cost of procurement where available and accessibility. Therefore, they have resulted into the use of open-pollinated maize varieties, which could prove economically sustainable in the long run. The use of commercially available organic fertiliser sources at the right rate in combination with open-pollinated maize varieties could be a veritable management practise for sustainable maize production for resource challenged farmers. Hence, the objectives of this study was to examine the effect of types and rates of commercially available organic fertilisers on vegetative and reproductive growth parameters of open-pollinated maize variety in the rainforest transitory zone of Nigeria.

MATERIALS AND METHODS

Experimental location and site characterisation

Field trials were carried out on a lowland field located at Gateway Fertilizer Plant, Eleweran, Abeokuta (Latitude 7^{o}10' N and Longitude 3^{o}15' E). These trials were established on the 6th and 11th of September in 2010 and 2011 respectively. The experiment was rainfed with the possibility of crop growth being sustained by residual moisture in the lowland. In both years, the experimental location was characterized by bimodal rainfall pattern, with the peaks observed in July, September (2010) and October (2011). Absence of precipitation was observed in December of both years and January (2011) (Fig.1). Both years experienced a relatively stable pattern of temperature, with higher temperature at the beginning of the year, with a depression in July and thereafter a rise again towards the end of the year (Fig.2). Both years had their pH close to neutral. The textural class of soil for both years was similar (sandy loam). Similarity in calcium and sodium content was observed for both years except potassium, which was more in 2010 than 2011 in absolute values. Percentage base saturation in both years was observed to be similar. Similar pattern was observed on organic carbon content and total nitrogen in both years (Table 1).

Experimental design and treatment

The experiment was a 3 × 3 × 2 factorial combination; comprising three organic fertiliser types (Gateway 1, Gateway 2 and Sunshine) applied at three different rates (0, 10 and 20 t ha^{-1}), in 2010 and 2011 late cropping season, in randomised complete block design (RCBD), with three replicates. The plot size was 5 m × 3 m. Net plot area was 4.5 m^{2}. Gateway 1consisted of cow dung, cassava peel and OBD+ (Osho Bio-Degrader) to enhance decomposition and mineralization; Gateway 2 was made from poultry waste, cow dung, wood ash and OBD+; while Sunshine was made from poultry manure. By chemical composition nitrogen content in Gateway 1 and Gateway 2 were similar, but the least (3.5 g N kg^{-1}) was observed in Sunshine. Similar pattern was observed in K content in all the organic fertilisers. Conversely, P content in Gateway 2 and sunshine were similar, while the least P content (0.02 %) was observed in Gateway 1.

Table 1: Soil Physico-chemical properties of the experimental site

Parameter	Year 2010	2011	methods
pH	6.6	6.5	pH meter (Mclean, 1982)
Sand (%)	75.2	74.6	
Clay (%)	6.0	6.8	
Silt (%)	18.8	18.6	
Textural class	Sandy loam	Sandy loam	Hydrometer method (Bouyoucus, 1962)
Total Nitrogen (g kg-1)	1.2	0.92	Modified micro Kjeldahl digestion technique (Jackson, 1962)
Organic carbon (g kg-1)	0.93	0.92	Wet-oxidation method (Walkey and Black method modified by Allison, 1965
Mehlich P (mg kg -1)	56.4	39.63	Mehlich, 1984
K+ (cmol kg-1)	0.96	0.5	Extracted with normal ammonium acetate, pH 7, extract determined by flame photometry
Ca2+ (cmol kg-1)	5.43	5.2	Atomic Absorption Spectrophotometer
Na+ (cmol kg-1)	1.4	1.40	Extracted with normal ammonium acetate, pH 7, extract determined by flame photometry
Base saturation (%)	99.53	98.6	

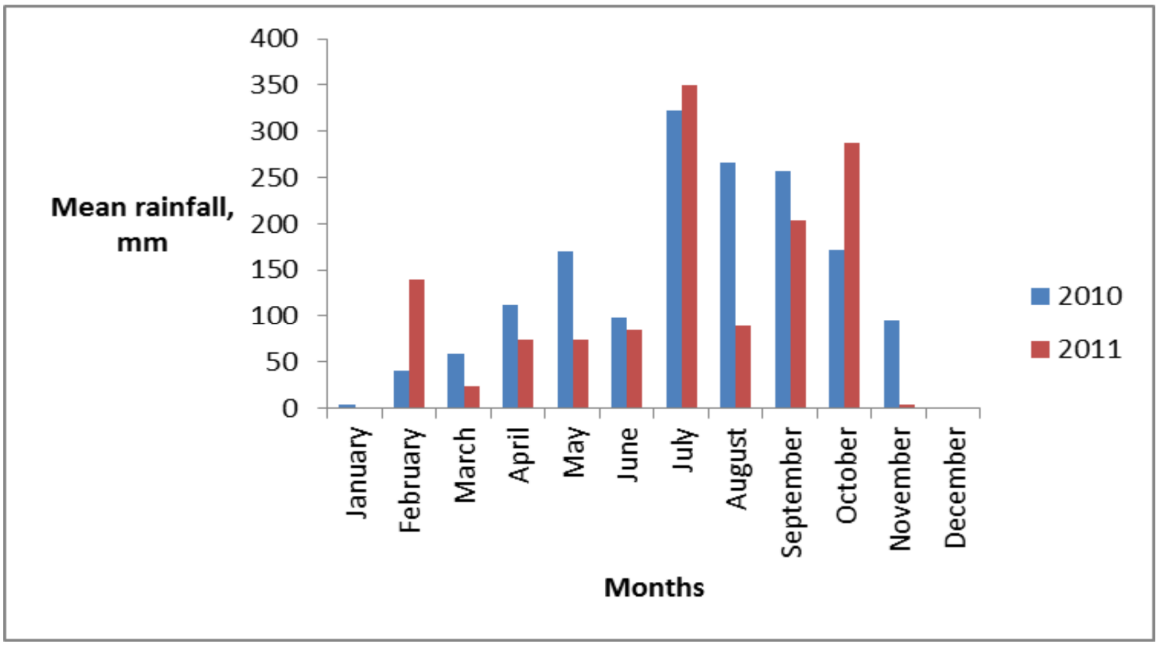

Figure1. Rainfall pattern at the experimental site, 2010 and 2011. Sourced Department of Agrometeorology and Water Management, Federal University of Agriculture, Abeokuta (FUNAAB).

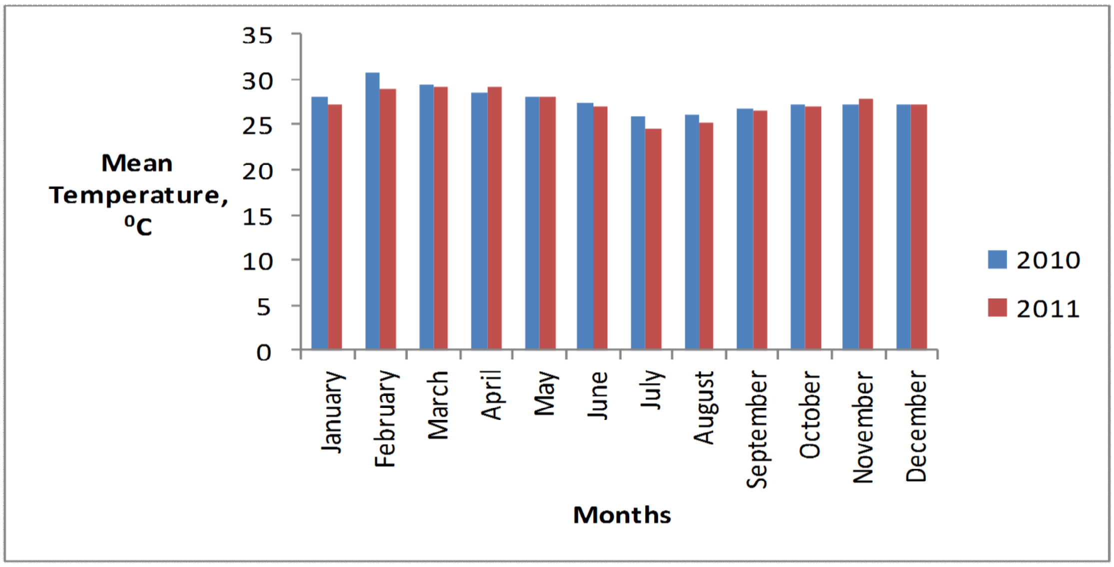

Figure 2: Temperature pattern of the experimental location in 2010 and 2011. Source: Department of Agrometeorology and Water Management, FUNAAB.

Table 2: Chemical composition of organic fertilisers used in the experiment

Organic fertiliser source	g N kg-1	P %	K %
Gateway 1	5	0.02	2
Gateway 2	6	1	3
Sunshine	3.5	1.0	1.2

Cultural practises

Land clearing was conducted manually. Soil was raised to ensure proper drainage of water in the lowland. Organic fertiliser was applied to each plot using broadcast method and incorporated into the soil two weeks before planting. Open pollinated maize variety (Swan1 yellow) was planted at the spacing of 75 cm × 50 cm. Weeding was done manually at 2nd, 4th and 6th WAP.

Sampling and measurement

Five samples were randomly collected from the net plot to determine growth, grain yield and yield components parameters (1000 grain weight, harvest index (HI), cob weight, cob length, cob girth, number of rows per cob, stover weight and shelling percentage). Growth parameters (Plant height, stem girth, leaf area and leaf area index (LAI)) were determined at 4, 8 & 12 weeks after planting (WAP) according to protocol described by Eleweanya *et al*., (2005). Leaf area (LA) was determined by the formula:

L A = leaf length × leaf breadth × 0.75 (Mongomery, 1911; Birch *et al*., 1998). While LAI was determined by the formula:

LAI = LA/S (Watson, 1847)
S = spacing (0.75 m × 0.50 m)

Shelling percentage was determined by the formula:

Shelling percentage=

$$\frac{\text{Weight of shelled grain}}{\text{Weight of unshelled}} \times 100\ \%$$

Yield obtained was taken from net plot and converted into hectare.

Statistical analysis

Data collected were subjected to combined Analysis of Variance (ANOVA). Differences between means were estimated using Least Significant Difference (LSD) at 5 % probability level. GenStat 12th edition statistical package was used for the analysis.

RESULTS

Growth parameters

Growth response of open pollinated maize to organic fertiliser types and rates in year 2010 and 2011

Fertiliser types had significant effect on plant height at 12 WAP. Open pollinated maize crop sown to plot with GF 1 was significantly ($P < 0.05$) the tallest (219.6 cm) compared to other fertiliser types. At 4 WAP significant ($P < 0.05$) differences in stem girth of open pollinated maize was in the order GF1 > GF2 > SF. At 12 WAP open pollinated maize sown in plots with GF1 had significantly more stem girth (6.3 cm), which was comparable with those with plots with SF. The least significant ($P < 0.05$) stem girth (5.9 cm) was observed in plots with GF 2. Fertiliser types had significant ($P < 0.05$) effect on leaf area at 8 WAP. Open pollinated maize plots sown with GF1 had significantly ($P < 0.05$) the highest leaf area (474.1 cm^2), while significantly ($P < 0.05$) the least (409.0 cm^2) was observed in plots sown with SF. Leaf area index of open pollinated maize at 12 WAP responded in a similar pattern to types of organic fertilisers (Table 3).

At both 8 and 12 WAP plant height of open pollinated maize depressed significantly with increasing application rates of organic fertiliser. Similar response pattern was observed on stem girth at 8 WAP with increasing application rates of organic fertiliser. At 12 WAP stem girth response with increasing application rates was in the order 10 > 20 > 0 t ha^{-1}. It was observed that at both 8 and 12 WAP there was a significant ($P < 0.05$) decrease in leaf area of open pollinated maize with increasing application rates of organic fertiliser types. There was a significant ($P < 0.05$) increase in leaf area index at 8 WAP with increase in application rates of organic fertiliser except at the rate of 20 t ha^{-1} that had the least significant ($P < 0.05$) leaf area index (0.983). Conversely at 12 WAP there was a significant ($P < 0.05$) decrease in leaf area with increasing application rate of organic fertiliser (Table 3).

Significantly ($P < 0.05$) taller open pollinated maize crop was observed in the year 2010 than 2011 at both 4 and 8 WAP. At both 4 and 12 WAP significantly ($P < 0.05$) wider stem girth was observed in 2010 than 2011. Leaf area index at all period of investigation responded in a similar pattern. Contrarily at 8 WAP, significantly ($P < 0.05$) wider stem girth was observed in 2011 than 2010 (Table 3).

Table 3: Combined effect of organic fertiliser types, rates and year on plant height, stem girth, leaf area and leaf area index of open pollinated maize variety at 4, 8 and 12 WAP.

Fertiliser (F)	Plant height (cm)			Stem girth (cm)			Leaf area (cm2)			Leaf area index		
	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP
Gateway 1	63.4	173.1	219.6	4.3	8.1	6.3	196.0	474.1	580	0.602	1.144	1.185
Gateway 2	60.5	159.9	194.1	3.9	7.6	5.9	180.9	427.8	567	0.540	1.054	1.067
Sunshine	56.0	160.4	207.7	3.5	7.5	6.3	158.8	409.0	535	0.474	1.020	1.030
LSD 0.05	NS	NS	14.38	0.4481	NS	0.3124	NS	41.11	NS	NS	NS	0.1034
Rates (R) t ha-1												
0	61.1	181.6	221.7	3.9	8.5	5.9	192.5	469.0	617	0.593	1.114	1.184
10	60.8	161.5	205.7	4.1	7.6	6.5	187.5	434.8	581	0.564	1.120	1.112
20	58.0	150.3	193.9	3.7	7.1	6.1	155.7	407.1	485	0.459	0.983	0.985
LSD 0.05	NS	15.03	14.38	NS	0.609	0.3124	NS	41.11	61.0	NS	0.1062	0.1034
Year (Y)												
2010	63.0	183.6	210.1	5.2	7.3	6.8	81.9	547.5	542	1.057	2.053	2.032
2011	57.0	145.6	204.1	2.6	8.2	5.5	75.2	326.5	580	0.020	0.092	0.155
LSD 0.05	5.28	12.27	NS	0.1800	0.497	0.2551	32.16	16.52	NS	0.1083	0.0867	0.0844
Interaction												
F×R	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
F×Y	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*
R×Y	NS	*	*	NS	*	NS	NS	NS	NS	NS	*	*
F×R×Y	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter down the column are not significantly different (*P* > 0.05), NS- Not significant, * Significant at 5 % probability level.

Grain and its attributes responses of open pollinated maize to organic fertiliser types and rates in year 2010 and 2011

Open pollinated maize sown to plot with GF2 had significantly ($P < 0.05$) the highest stover weight (2.34 g). The least significant ($P < 0.05$) stover weight (1.42 g) was observed in plots sown with SF. Plots sown with GF1 had significantly ($P < 0.05$) the highest harvest index (20.72). The least significant (16.13) harvest index was observed in plots sown with GF2, which was comparable with SF. Shelling percentage response to organic fertiliser types was in the order SF > GF1 > GF2. However there was no significant effect ($P > 0.05$) of organic fertiliser sources on the grain yield of open pollinated maize. Cob length of open pollinated maize increased significantly ($P < 0.05$) with increasing application rates of organic fertiliser types. Similar pattern was observed on stover weight, 1000 grain weight and harvest index. Conversely, there was a significant ($P < 0.05$) decrease in number of rows cob^{-1} with increasing application rates of organic fertiliser types. There was no significant ($P > 0.05$) effect of organic fertiliser sources on grain yield. Year 2010 had significantly ($P < 0.05$) more cob weight than 2011. Similar pattern was observed on harvest index and grain yield. Contrarily, year 2011 had significantly longer cob, more 1000 grain weight than 2010 (Table 4).

Table 4: Combined effect of organic fertiliser types on the yield components and yield of open pollinated maize.

Fertiliser (F)	Cob weight (g)	Cob length (l)	Cob girth (cm)	Number of rows/ cob	Stover weight (g)	1000 grain weight (g)	Harvest index	Shelling %	Grain yield (kg ha-1)
Gateway 1	0.462	13.23	12.4	13.88	1.62	189.6	20.72	70.9	1494
Gateway 2	0.504	14.42	12.4	13.61	2.34	199.0	16.13	68.6	1428
Sunshine	0.354	14.14	19.1	13.42	1.42	198.1	16.78	75.9	1131
LSD 0.05	NS	NS	NS	NS	0.671	NS	2.362	5.56	NS
Rates (R) (t ha-1)									
0	0.357	13.64	18.9	14.08	1.40	172.5	14.62	68.8	1125
10	0.453	13.40	12.7	13.98	1.65	199.0	18.01	73.8	1313
20	0.511	15.05	12.4	12.86	2.32	215.3	21.00	72.7	1616
LSD 0.05	NS	1.235	NS	0.653	0.671	10.36	2.362	NS	NS
Year (Y)									
2010	0.778	12.93	11.7	13.94	1.94	167.6	19.59	70.6	1840
2011	0.103	15.13	17.6	13.33	1.64	223.5	16.16	73.0	862
LSD 0.05	0.1662	1.008	NS	0.533	NS	8.46	1.928	NS	408.4
Interaction									
F×R	NS	NS	NS	*	NS	NS	NS	NS	NS
F×Y	NS	*	NS	NS	NS	NS	*	NS	NS
R×Y	NS	NS	NS	NS	NS	*	NS	*	NS
F×R×Y	NS	NS	NS	*	NS	NS	*	*	NS

Means followed by the same letter down the column are not significantly different ($P > 0.05$), NS- Not significant, * Significant at 5 % probability level.

DISCUSSION

Sustainable maize production in most of the resource challenged regions of the world could be improved through the right cultural practises. Organic fertiliser types have been recommended to farmers because of their availability, slow releasing properties and availability (Bengtsson *et al.,* 2005). Most of these farmers do not have access to improved hybrid maize due to financial constraint, hence the use of improved open -pollinated maize variety (Akpako and Yiljep, 2001).

The positive effect of Gateway 1 organic fertiliser on canopy architecture (leaf area and LAI) of open pollinated maize could have suggested an increase in the interception of light (Boote *et al*., 1998; Khan and Khalil, 2010). This together with a higher plant height compared to others would have aided the distribution of light into the canopy in furtherance of photosynthetic process in the plant (Nassiri *et al*., 1996). Increased stem girth by Gateway organic fertiliser could aid the storage of carbohydrate in the stem. This observation had earlier been reported for most cereals (Maduraimuthu and Desikan, 2013; Manoj and Udey, 2006). Stored carbohydrate in the stem or other shoot organs had been reported to be remobilised during the grain filling period, especially when the crop experiences adverse environmental condition (Constables and Hearn, 1978). This organic fertiliser equally increased the partitioning of assimilates into the reproductive structures as observed in higher HI compared to others. This would have informed the decrease observed in stover weight, since there is a kind of compensatory growth relationship between these two organs (Wallace and Yang, 1998). However, higher reproductive growth could not translate into higher yield in Gateway 1 organic fertiliser application, despite the higher concentration of nitrogen and potassium that was contained in it.

Increasing application rates of organic fertiliser significantly depressed all the growth characters observed especially at the beginning of growth stage. This effect could have suggested that the fertility status of the soil of the experimental site, as reflected in the soil macronutrient content and textural class (sandy loam) was sufficient to sustain growth of open pollinated maize in this agroecology. Other growth factors (temperature and rainfall) were adequate enough to support the growth of maize during the cropping season, hence could not have been a production constraint. Reduced leaf area and LAI with increasing application rates could have suggested decrease in mutual shading, hence higher photosynthetic capacity at observed in higher HI. The decreased vegetative growth parameters at the beginning of the crop ontology were reflected in the increasing HI with application rate. Earlier report had indicated that there is a compensatory relationship between vegetative and reproductive growth (Wallace and Yang, 1998). Increased 1000 grain weight and cob length with increased application rates further suggested increased reproductive growth at the expense of vegetative growth. Conversely, number of rows per cob had decreased significantly with increasing application rate. It was observed that there is a negative relationship between number and weight of the kernels. Ouattar *et al*., (1978) reported that similar physiological response pattern could be observed in the event of adverse environmental conditions. This might be due to the reduced development rate of a reproductive structure at temperature beyond its optimum, affecting partitioning of assimilate to them, with a reduction in the number that structure (Squire, 1990). The mean temperature during the cropping season was optimum for the growth of maize (C4 plant, comparatively drought tolerant); however, a decline in precipitation was observed, which could have affected reproductive growth structure.

The soil fertility status of both years was similar, except for P and K concentration that were more in 2010 than 2011. Presumably that could have reflected in the higher yield performance in that year. Phosphorus remains a major macronutrient that constrained performance of most crops in the tropics, due to its propensity to be chelated with other cations and anions (Agbede, 2009). Phosphorus is involved with most of the metabolic processes (oxidative and photophosphorylation processes, translocation of assimilate from source to sink and a component of important macromolecules in cells) in plant. This was also reflected in the increased yield components (cob length and HI) observed in 2010. Other factors could be the even distribution of rainfall observed in the late cropping season of 2010 compared to 2011, though the trial was established in the lowland, hence the possibility of the effect of residual rainfall could not be precluded, thus confounding the effect of rainfall distribution in the late cropping season of 2010.Lower grain yield performance in 2011 could also have suggested minimal effect of these organic fertilisers in the following year.

CONCLUSION

Open pollinated maize variety sown with Gateway fertiliser 1 significantly had higher vegetative growth, harvest index and shelling percentage than other organic fertiliser types. Increasing application rates of organic fertilisers significantly reduced vegetative growth characters of open pollinated maize variety. Conversely, maize cob was significantly longer, with significantly more 1000 grain weight and harvest index with increasing application rate of organic fertiliser, except number of rows cob^{-1}. Year 2010 had significantly higher vegetative growth that 2011 except on stem girth at 8 WAP. Similar pattern was observed on most reproductive growth parameters except on cob length and 1000 grain weight.

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