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Impact of Mineral Fertilizer, with 'in-situ' Mulches, on the Properties and Productivity of Soil on a Cultivated Slope in Akwa Ibom State, Nigeria

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ABSTRACT
Effect of the application of mineral fertilizer with "in-situ" mulches on selected physico-chemical properties of the soil and the grain yield of maize on a cultivated slope were investigated. The study was conducted on a 9.5% sloping farmland during the 2015 and 2016 early planting seasons, using the traditional no-till system with seeds planted through the mulch. There were four (4) treatments viz: decomposing 'in-situ' mixed mulches at 10 $Mgha^{-1}$ (designated M); fertilizer (N.P.K. 20.10.10) at 0.4 $Mgha^{-1}$ (F); mulch at 10 $Mgha^{-1}$ plus NPK fertilizer at 0.4 $Mgha^{-1}$ (MF); no mulch, no fertilizer (NMF) - the control. Experimental design was the randomized complete block design (RCBD) in six (6) replications. Soil moisture levels in mulched plots increased over the control by a range of 30 to 45 percent. Mulched plots had lower soil temperatures, ranging from 5 to 16 percent over the control. Mulching increased soil organic C levels by a range of 7 to 40 percent over the control. Post study values of total N in plots under MF were 111 and 106 percent over the control in 2015 and 2016 respectively. Treatment MF increased P levels by 14 and 16 $mgkg^{-1}$ in 2015 and 2017 respectively. Exchangeable K in mulched plots was raised by 27 to 225.6 percent over the control. Treatment MF gave highest maize grain yields of 2.66 and 2.89 $Mgha^{-1}$ for 2015 and 2016 respectively. These were significantly ($p \geq .01$) higher than values for M, F and the control (MNF).

Key words: slopes, "in-situ" mulches, grain yields, Niger Delta.

INTRODUCTION
Slopes and other marginal lands are now being more intensively cultivated by farmers in the South of Nigeria, particularly in Akwa Ibom state. This is as a result of, among other reasons, the putting of level, more productive and less fragile lands to use for urban and institutional development following the creation of new local government areas. The cultivation of these marginal lands, especially the slopes under the 'slash-and burn" farming system used to produce staple foods, present unique management challenges. Among these are the loss of plant nutrients and organic matter largely through soil erosion. According to Ekanade (1997) not only are the structural and nutrient properties of soils degraded by erosion on hill–slopes, but the textual properties of sand, silt and clay are degraded compared with forest soil. In some parts of the tropics with similar problems the approach to soil erosion control and stabilization of cultivated slopes has been to expend lots of resources on engineered soil conservation systems (Smyle and Magrath, 1993). Not only do the resource–poor farmers of south-south Nigeria, who produce the bulk of

the food consumed in the area, lack the resources to undertake such engineering projects, their acceptance of the technologies has been low. The reason, according to Smyle and Magrath (1993), is that these systems require significant changes in land use, farming practices, labour inputs and with benefits predicated almost exclusively on soil conservation. On the other hand, Stark (2000) observed that most farmers rather prefer technologies which enable them manage their farms and maintain (or restore) the productivity of their soils, such as the various forms of mulching.

Mulches are reported to conserve soil moisture, moderate soil temperature and improve soil physical properties (Amalu and Usuah, 2014). Combined with the no-till practice, mulching enhances soil and water conversation, with negligible water runoff and virtually no soil loss even on farmlands with up to 15 percent slope (Lal, 1976). However, finding sufficient amounts of mulches under the 'slash-and-burn' production systems practiced in most of the tropics presents enormous challenge, as a rich mix of plant materials from fallows are lost through burning. It is believed that such materials would be of more benefit if slashed and applied 'in-situ' as mulches as suggested by Reijntjers (2001). There is paucity of information on the use of 'in-situ' mulches to protect sloping farmlands in the 'south-south' region of Nigeria in general and Akwa Ibom State in particular. This study is intended to contribute toward such knowledge.

Materials and Methods

Study Area

The study was carried out on a 9.5% slope during the early planting season of 2015 and 2016 at the Akwa Ibom State University Teaching and Research farm at Obio Akpa, Akwa Ibom State. Obio Akpa lies within the humid tropical rainforest zone of Nigeria (latitude $4^0$30' – $5^0$30'N, longitude $7^0$30' – $8^0$20'E). It receives annual rainfall amounts in the range of 2000 to 3000mm. Temperature regimes vary from 24 to 30^0C while relative humidity ranges from 75 to 79%. The soils belong to the coastal plain sands of southern Nigeria (Babalola and Obi, 1981) and are predominantly sandy. The site had been under a two-year fallow prior to use for the study. The pre-study vegetation consisted predominantly of guinea grass (*Panicum maximum*), interspersed with siam weed (*Chromolaenaodoratum*), Calopogonium spp, Aspilia spp and other weeds. Pre-fallow crops consisted of cassava (*Maniho tspp*) intercropped with maize (*Zea mays*) and melon (*Colosynthis citrullus*).

Field Operations and Crop Management

Clearing was done in early March using the cutlass but without tilling the soil. The cleared material was chopped into smaller bits and spread as evenly as possible on the surfaces of plots to be mulched (but packed out of the no-mulch plots). Uncultivated vegetated plots separating cultivated ones were cut very low and the materials left where they were cut. Clearing was followed by soil sampling. Soil (0 – 25cm depth) was sampled for laboratory analyses with the auger from 20 spots randomly selected to cover the whole site at the beginning of the trial in 2015. Undisturbed soil samples (0 – 10cm depth) were also collected with steel core samplers (4cm in diameter, 10cm long) from six (6) spots also spread across the site at commencement of the study to determine gravimetric water content. In each case the auger samplers were composited (into four bulk samples), air-dried and sieved through a 2- mm mesh.

There were four (4) treatments as follows: (i) decomposing mulch (semi-fresh organic mulch) at 10 $Mgha^{-1}$(designated M); (ii) fertilizer (NPK 20.10.10) at 0.4$Mgha^{-1}$(designated F); (iii) mulch plus fertilizer, each at rates in (i) and (ii) respectively (designated MF); (iv) the control: zero mulch, zero fertilizer (designated NMF). The test crop was TZPB variety of maize (*Zeamays*). Each plot measure 7m by 7m (49m^2) in area. The plots were laid out such that each was separated from the next along the slope by a 4m–wide vegetative strip. The blocks were oriented across the slope. All treatments were replicated six (6) times and arranged in a randomized complete block design (RCBD).

At the end of the 2015 study five (5) auger samples (0-25cm depth) were collected from plots carrying each treatment. Four (4) undisturbed soil samples (0-10cm depth) were also taken. At the commencement, and at the end of the trial in 2016 five (5) auger samples (0 – 25cm depth) were collected from plots carrying each treatment for laboratory analyses, while four (4) undisturbed samples were similarly taken for gravimetric water contents. Soil temperatures under each plot were taken during each trial period by inserting the soil thermometer 10cm deep into the soil, usually at 15.00 hours GMT. Six (6) spots were randomly selected per plot for temperature measurements starting 3 weeks after planting and continued at two-weekly interval till end of the trial.

Cultural Practices

Seeds were sown through the mulch in mid-April. Three (3) seeds were planted per stand at a spacing of 0.5m by 0.9m, and the seedling thinned to two (2) per stand (44, 444 stands/ha) three (3) weeks after planting (3 WAP). In plots with fertilizer treatments, appropriate fertilizer doses were applied through the mulch by side band placement three (3) weeks after planting (WAP). Weeding was done as the need arose, twice (at 4 and 7 WAP) in plots without mulch, and once (6 WAP) in plots with mulch. At harvest, the maize cobs were d**e-husked, shelled, and the grains dried to constant** weights.

Laboratory Procedure

Particle size was determined by the hydrometer method; pH was determined in a 1:2, soil: water suspension using glass electrode pH meter; organic carbon was determined by wet oxidation method (Nelson and Sommers, 1982); total N was determined by the Kjeldhal apparatus (Bremner and Mulvaney, 1982); available P was extracted in Bray and Kurtz No. I solution as described by Olsen and Sommers (1982), and its concentration in the extract measured by the vandado-molybdate blue colour method (Murphy and Riley, 1962); exchangeable bases (Ca, Mg, K and Na) were extracted with one normal neutral ammonium acetate solution (IN NH_4OAc at pH7), as described by Thomas (1982); exchangeable potassium and sodium concentrations in the extract were read on an Atomic Absorption Spectrophotometer (ASS); exchangeable A1 was determined by titration using the KCl extraction method as described by McClean (1965). The undisturbed samples were placed in an oven set at 100^0C for 24 hours, and the gravimetric water content determined by the difference method. The physico-chemical properties of the soil at the commencement of the study are shown in Table 1. Data collected were subjected to analysis of variance, and significantly different means were separated using the Duncan's Multiple Range Test (DMRT).

Table 1 Selected pre-trial soil properties (0-25cm depth)

Soil Property	**Units**	**Value**
Sand	g kg^{-1}	620
Silt	g kg^{-1}	192
Clay	g kg^{-1}	188
Textual class	#	sandy loam
Soil water content	g kg^{-1}	22.4
Soil temperature (10cm depth)	^{0}C	30.8
Soil pH (water)	#	5.0
Organic carbon	g kg^{-1}	19.0
Total nitrogen	g kg^{-1}	0.95
Available phosphorus	mg kg^{-1}	11.99
Exch. calcium	$cmolkg^{-1}$	1.96
Exch. magnesium	$cmolkg^{-1}$	1.80
Exch. potassium	$cmolkg^{-1}$	0.18
Exch. sodium	$cmolkg^{-1}$	0.16
Exch. aluminum	$cmolkg^{-1}$	1.02
Exch. Acidity	$cmolkg^{-1}$	2.20
Exch. cation exchange capacity	$cmolkg^{-1}$	6.30
Base saturation	%	65.08

= no unit

RESULTS AND DISCUSSION

Soil physical and chemical properties at the commencement of the study

Particle size analysis of the soil gave values 620, 192 and 188gkg^{-1} for sand, silt and clay respectively, and a textual class of sandy loam(Table 1). Values for organic C, total N, exchangeable K and ECEC were 19.0gkg^{-1}, 0.95gkg^{-1}, 0.18cmolkg^{-1} and 6.30cmolkg^{-1} respectively. These were below their critical levels in these soils (Enwezor *et al*., 1989). The sandy nature of the soil and its low content of organic C indicate that its water-holding capacity will be low. Soils with low water-holding capacity, low organic C content and low ECEC are expected to benefit from the application of organic materials which, among other things, enhance their ability to reduce leaching losses of both intrinsic and applied plant nutrients (Onyegbule *et al*., 2013). The low exchangeable K, ECEC, total N and organic C levels are indicative of low inherent fertility status of the soil and underscore the need to put in place measures to enhance its productivity as the slope is being cultivated.

Effect of treatment on soil moisture and soil temperature regimes

Data in Table 2 show effects of the treatments on soil moisture levels and soil temperature regimes at the end of the study in both years. Treatment M (mulch only) increased soil moisture levels by 30.4 and 36.4 percent in 2015 and 2016 respectively over the control (NMF). Treatment MF (mulch plus fertilizer) gave soil moisture levels that were 37.8 and 45.5 percent higher than the control (NMF) in 2015 and 2016 respectively. This may be attributed to increased infiltration as runoff velocity down the slope would have been reduced by the "in-situ" mulches. It may also be attributed to the shading effect of mulch on the soil surface which served as "vapour barrier" against moisture losses from the soil. Agbede (2008) similarly obtained higher soil moisture contents when organic mulches were applied on no-till soils. That treatment MF gave the highest moisture content may also be attributed to increased biological activity which usually occurs during the decomposition of organic matter when adequate amounts of nitrogen are supplied. Elevated biological activity is reported to increase soil organic carbon content (Saroa and Lal, 2003) as well as total porosity due to the activity of soil organisms, typically earthworms (Lugo-Perez and Lloyd, 2009) both of which facilitate infiltration and moisture retention.

Temperatures were significantly lower in mulched plots (M and MF) compared to the zero-mulch plots (F and NMF), falling by a range of 5.4 to 15.5 percent. This may be attributed to the shading effect of mulch which protects the soil from direct solar radiation thereby lowering the soil temperature. These findings agree with those of Onyegbule *et al* (2013) and Amalu and Usuah (2014).

Table 2: Mean values of selected soil physical properties at the end of the study

	2015			2016		
Treatment	Textual class	Moisture content (gkg^{-1})	Soil Temperature (^{0}C)	Textual class	Moisture content (gkg^{-1})	Soil Temperature (^{0}C)
Pre-Trial values	Sandy loam	22.4 d	30.8ab	Sandy loam	22.4 a	22.4 a
Control (NMF)	Sandy loam	20.4 e	31.4a	Sandy loam	19.8e	19.8e
Mulch (M)	Sandy loam	26.6b	28.1d	Sandy loam	27.0b	27.0b
Fertilizer (F)	Sandy loam	24.8c	29.8c	Sandy loam	24.6 c	24.6 c
Mulch+fertilizer (MF)	Sandy loam	28.1a	27.2e	Sandy loam	28.8a	28.8a

- NMF = no mulch, no fertilizer; M =sole mulch; F = sole fertilizer; MF= mulch+fertilizer;^{0}C = Temperature 10cm depth;12.00 hrs GMT

Effect of treatment on soil organic C, total N and available P
Organic Carbon
Effect of the decomposing "in situ" mulches on soil organic C, total N and available P are shown on Table 3 for 2015 and Table 4 for 2016 trials. Plots with mulches, with or without fertilizer, had significantly higher levels of soil organic C compared to plots with the control treatment (NMF). The values were 7 and 40percent for treatments M and MF respectively over the control (NMF) in 2015, and 8.9 and 36.7 percent for M and MF respectively in 2016. Increase in soil organic C levels were due to the decomposition of the applied mulches. Khurshid *etal* (2006) and Pervaiz *et al* (2009) similarly observed significantly higher levels of soil organic C when organic mulches were applied. Mulch, combined with fertilizer (MF) gave significantly higher organic C contents. This may be attributed to the interactive effect of mulch and the fertilizer which provided more nutrients needed by soil microorganisms during the decomposition process (Brady and Weil, 2007).

Table 3: Mean values of selected chemical properties of the soil (0-25cm) at the end of the trial in 2015.

Treatment	**pH**	← **g kg^{-1}** →		**Avail P ($mgkg^{-1}$)**	← **cmol kg^{-1}** →			
		Org. C	Total N		ExchCa	ExchMg	ExchK	ExchAl
Pre-trial value	5.0	19.0 cd	0.95 cd	11.99 e	1.96b	1.80b	0.18bc	1.02a
Control (NMF*)	5.0	18.00 e	0.89cde	11.06e	1.86e	1.60e	0.11e	1.02ab
Mulch (M)	5.0	19.18 c	0.96 c	11.66d	1.91c	1.72 c	0.14d	0.94c
Fertilizer (F)	5.0	20.38 b	1.62 b	13.62b	1.91cd	1.65d	0.18b	.94 cd
Mulch+fertilizer (MF)	5.1	25.28 a	1.88 a	14.12a	2.02a	1.88a	0.22a	0.86 e

*NMF = no mulch, no fertilizer; M = sole mulch;
F = sole fertilizer; MF = mulch plus fertilizer

Table 4: Mean values of selected chemical properties of the soil (0–25cm) at the end of the trial in 2016

Treatment	**pH**	← g kg^{-1} →		**Avail P ($mgkg^{-1}$)**	← $cmolkg^{-1}$ →			
		Org. C	Total N		ExchCa	Exch Mg	Exch K	Exch Al
Pre-trial value	5.0	19.0 d	0.98 cd	11.99 c	1.96b	1.80b	0.18c	1.02ab
Control (NMF*)	5.0	18.20 e	0.96cde	10.88e	1.76e	1.44e	0.09e	1.06a
Mulch (M)	5.0	19.82 b	0.99c	11.64cd	1.89c	1.68d	0.16cd	0.90cd
Fertilizer (F)	5.0	19.62 c	1.56 b	14.66b	1.82d	1.74c	0.26b	0.92 c
Mulch plus fertilizer (MF)	5.1	24.88 a	1.98 a	16.02a	2.11a	1.86a	0.32a	0.80e

*NMF = no mulch, no fertilizer; M = sole mulch; F = sole fertilizer;
MF = mulch plus fertilizer;

Plots with fertilizer only (F) had significantly higher organic C content than those with the control treatment (NMF). The values of the increases were 13.2% and 6.7% for 2015 and 2016 respectively. This may be due to the additional nutrients supplied to the microbes which decompose soil organic matter, thereby increasing soil organic C. The results agree with those of Hobbie (2005).

Total N

There were no significant differences in the values of total N for treatments M (mulch only) and NMF (no mulch, no fertilizer) in both 2015 and 2016 (Tables 3 and 4). This may be due to the nature of the mulch, which was made up, predominantly, of guinea grass known to be low in crude protein (Onyeonagu and Eze, 2013). It may also be that the time from mulch placement to that of soil sampling and analysis was too short for the decaying plant material to be incorporated into the soil as particulate organic matter (POM). According to Bu *et al*., (2015) it is from particulate organic matter that soluble organic nitrogen would be released into the soil. Treatments F and MF gave total N values that were 82% and 111% respectively greater than those of the control in 2015. The corresponding values in 2016 were 63% and 106.3% for F and MF respectively greater than those of the control (NMF). The increases were apparently due to the nitrogen addition from the N.P.K fertilizer in treatments F and MF. The significantly (P ≥01) higher total N values for MF than the control (NMF) and F may be attributed to the interactive effect of mulch and the fertilizer. This result agrees with the observation of Aerts and Chapin (2000).

Available P

The levels of available P for treatment M were significantly (p ≥ .01) higher than those of the control (NMF) for both years (Table 3 and 4). The values were 5% and 7% for 2015 and 2016 respectively. This may be attributed to P released by the decomposing organic mulches. Sinkericiene *etal*, (2009) observed a tendency toward higher soil P content in plots with organic mulches. The significantly (p ≥ 0.1) higher available P levels obtained for treatment F in both years (13.62 and 14.66mg/kg for 2015 and 2016 respectively), and treatment MF (14.12 and 16.02 mg/kg in 2015 and 2016 respectively) compared to the control, may be attributed primarily to P contained in the NPK fertilizer. The significantly (p ≥ .01)higher levels of P for treatment MF compared to F (Tables 3 and 4) may be attributed to the interactive effect of the mulch and fertilizer. Onyegbule *et al* (2013) similarly observed increases in available P in plots where mulches were applied.

Exchangeable bases (Ca, K and Mg)

Data in Tables 3 and 4 show that treatments M, F and MF gave significantly (p ≥ .05) higher levels ofthe exchangeable bases -Ca, Mg and K - than the control (NMF) in both years. Treatment M gave values that were 2.7, 7.5 and 27 percent for Ca, Mg and K respectively higher than those of the control(NMF) in 2015. The corresponding values in 2016 were 7.4, 16.7 and 77.8 percent for Ca, Mg and K respectively. This would be attributed to cations released into the soil as the mulches decompose. Treatment MF similarly increased levels of the exchangeable cations. The values were 8.6, 17.5 and 100 percent for Ca, Mg and K respectively higher than those for the control(NMF). The corresponding values in 2016 were 19.9, 29.1 and 225.6 percent for Ca, Mg and K respectively. The significantly (p≥ .05)higher levels of these cations obtained in plots with MF than in plots with M may be due to the enhancement of the decomposition of the mulches by the NPK fertilizer and the consequent release of a greater amounts of the nutrients into the soil. Studies by Wang *et al*., (2004) observed that the addition of inorganic N accelerated the decomposition of soil labile organic matter. The figures above show that exchangeable K levels were the most positively affected by the mulches. These findings agree with those of Sinkericiene *et al* (2009) who reported significant increases in the levels of exchangeable K in soils with the use of grass mulches.

There were significant (p ≥ .05) decreases in the levels of exchangeable Al in the soils with the application of treatments M and MF compared to the control (NMF)

(Tables 3 and 4). The values were 7.8 and 15 percent for M and MF respectively in 2015. The corresponding values in 2016 were 15.1 and 24.5 percent for treatments M and MF respectively. This may be as a result of the formation of stable complexes of organic acids from the decomposing mulches with exchangeable Al (Brady and Weil, 2007) thereby removing some of the cation out of the exchange sites. Reduction of exchangeable Al with the application of organic mulches has also been reported by Khan *et al* (2002).

Effect of mulch application on plant stand count with time (WAP)

Data in Table 5 show effect of the 'in-situ' mulches on plant stand count on the slopes. Seedling stand counts taken during the first week of growth were significantly higher in zero mulch plots (NMF and F) than in mulched plots (M and MF). Plant stand counts were 8.5 to 43.0 percent lower in plots with mulch (MF and M) than in those without mulch (F and NMF). This may be attributed to "allelopathy." Studies by Usuah *et al* (2013) found that Guinea grass and Siam weed decomposing mulches significantly inhibited the germination of maize seeds.

Table 5: Effect of mulch application on plant stand count with time (WAP)

Treatment	2015				2016			
	No of stands with time (WAP)				No of stands with time (WAP)			
	1	4	8	12	1	4	8	12
Control (NMF+)	218a*	150c	122cd	120d	217ab	137cd	130cd	130cd
Mulch (M)	202c	201ab	201ab	201ab	204cd	202ab	202ab	200ab
Fertilizer (F)	218ab	138cd	135c	135c	218a	140c	138c	138c
Mulch +fertilizer (MF)	201cd	201a	201a	201a	208c	206a	206a	206a

*Means followed by same alphabets in each column are statistically similar at 1% probability level.
NMF = no mulch, no fertilizer; M = mulch only; F = fertilizer only
MF = mulch plus fertilizer; WAP = weeks after planting.

However, from week 4 to week 12, zero mulch plots (NMF and F) lost 3.1 to 44.9 percent of plant stands in 2015. The corresponding figures in 2016 were 35.8 to 40.4 percent of maize stands. The losses were largely caused by the covering and burying of young plants by debris carried down the slope by running water. On plots with mulch (M and MF), the velocity of the runoff water appeared to have been effectively slowed down and the large amount of debris carried by the water filtered. This prevented the covering seedlings in plots with mulch. Pervaiz *et al* (2009) similarly found that organic mulches significantly slowed the velocity of runoff down the slope thereby aid infiltration and reducing erosion.

Effect of decomposing mulches on maize grain yield

Data in Table 6 show the effect of the in-situ mulches on maize grain yield. Treatment M (mulch only) gave grain yields that were 2100% in 2015 and 920% in 2016 greater than that of the control (NMF). This may be attributed to the beneficial effects of the mulches, such as the enhancement of infiltration and moisture storage in the soil, moderation of soil temperature and facilitating the storage and release of nutrients to growing plants. Pervaiz *et al* (2009) also observed significant increase in maize grain yield with the use of organic mulches. Treatment F gave maize grain yields that were significantly higher than that given by M in 2015 but statistically similar (though 37.3 percent higher) in 2016. This indicates that such soils with very low fertility status will benefit a lot from the application of mineral fertilizers.

Table 6 :Effect of decomposing 'in-situ" mulches on maize grain yields.

Treatment	Grain yields (Mg ha^{-1})	
	2015	**2015**
Control (NMF+)	0.02d*	0.05d
Mulch (M)	0.44c	0.51bc
Fertilizer	0.82b	0.70b
Mulch plus fertilizer (MF)	2.66a	2.89a

*Means followed by same alphabets in each column are statistically similar at 1% probability level.
+ NMF = no mulch, no fertilizer; M = mulch only; F = fertilizer only
MF = mulch plus fertilizer

Treatment MF (mulch plus fertilizer) gave the highest maize grain yields of 2.66 and 2.89 Mg ha^{-1} in 2015 and 2016 respectively. This may be the result of interaction between the mulch and the fertilizer. While the NPK fertilizer supplied large amounts of these macro nutrients, the mulches, as stated by Khurshid *et al* (2006), improved the ecological environment of the soil. Increased moisture and organic matter contents due to mulch application, as reported earlier, created suitable soil environment for root penetration thereby enhancing moisture and nutrient uptake. Acharya and Sharma (1994) earlier observed that uptake of N and P was significantly increased by mulching. These findings agree with those of Pervaiz *et al* (2009) which observed that mulching increased soil moisture content, enhanced nutrients uptake by plants and significantly increased grain yield of maize.

CONCLUSION AND RECOMMENDATION

It can be concluded from this study that the productivity of cultivated slopes would be greatly enhanced using vegetation cleared from the site during land preparation as in-situ mulches. The use of mineral fertilizers with these mulches has also been proven to be more effective in building the slope productivity, as reflected in the grain yield of maize, than using either of these singly, and the practice is hereby recommended.

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