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Influence of Water hyacinth - based Vermicompost and Cassava – groundnut Intercropping on some Physical Properties of a Tropical Soil

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Abstract
The study was aimed at observing the effects of a mix of water hyacinth and animal manure-based vermicomposts and mineral fertilizer on bulk density and total porosity of soil under cassava planted sole and intercropped with groundnut. The treatments consisted of four nutrient sources (0 kg i.e. no mineral fertilizer or vermicompost, 200 kg NPKMg 12:12:17:2; 40 tons of a mix of dry water hyacinth and poultry manure based-vermicompost-VP, and 40 tons of a mix of dry water hyacinth and cow dung-based vermicompost-VC), three cropping densities (50,000, 100,000 and 200,000 plants ha^{-1}) and two cropping patterns (sole cassava and cassava-groundnut intercrop). The experiment was arranged in a 4x3x2 factorial with a randomized complete block design using three replicates. Results show that the organic nutrient sources significantly ($P< 0.05$) reduced bulk density than mineral fertilizer. On average, cassava-groundnut mixtures reduced bulk density by 4.5% relative to sole cassava. A non-significant increase in total porosity was observed in this study. The positive influence of the vermicomposts on soil structural properties is expected to result in improved crop yield and quality.
Keywords: Water hyacinth, soil bulk density, total porosity, vermicompost. Cassava, groundnut

1. Introduction

Environmental degradation of cropland under continuous cultivation without appropriate soil management practices has contributed to reduced crop yield in tropical Africa during the last 30 years (Bationo *et al.* 2006), due to deterioration in physical, chemical and biological soil properties (Juo and Lal, 1977). Since physical properties are highly correlated with crop production, it is necessary for farmers to adopt farm practices which will result in soil with proper physical properties. Such properties as texture, plasticity, structure, temperature and moisture relationships determine soil fertility and crop performance (Nnaji *et al*. 2005).

In recent years, much attention has been paid to the use of different organic manures over chemical fertilizers in enhancing crop yield. The advantages of organic farming are that it reduces pollution levels such as acidification, nitrate leaching and heavy metal concentrations, hence preserves ecological balance, enhances productivity and ensures sustainable agriculture by keeping the soil fertile (Meelu, 1996). These are achieved through improvement in physical soil attributes.

Cassava (*Manihot esculenta* Crantz) is a staple food crop in many nations of the tropics. It supplies about 70% of daily caloric intake of 50 million Nigerians (Ugwu *et al*. 1983). According to Nweke (1997), cassava generates about 25% of cash income from all food crops grown by both urban and rural farmers in Nigeria, constituting the most important single source of cash income for the rural populace. Nnaji *et al*. (2005) noted that since cassava performs best in soils of friable nature to permit expansion of tubers, farmers have adopted application of organic materials in form of green manure, animal manure and farm yard manure as a management strategy towards conserving soil properties. Beyond the economic goal of cassava/legume-based farming systems, such as cassava/groundnut mixtures, integration of legumes may also have a positive ecological role on the soil by fixing soil nitrogen.

The use of non-traditional organic resources such as weeds for soil fertility improvement has been studied and several researchers (Jama *et al.* 2000; Chukwuka and Omotayo, 2008) have established the high potential of these resources in improving soil nutrient status and subsequently crop yield in soils amended by these resources. Wilson *et al.* (2005) recognized water hyacinth, *Eichhornia crassipes* (Mart) Solms, a floating aquatic weed, as the most harmful weed in the world because of its negative effects on waterways and threat to fishing activities, and presently efforts at water hyacinth control in Nigeria by physical removal of the weeds have been unsuccessful and cost of operation expensive. Experts have suggested that the best way of controlling water hyacinth is its utilization. Findings from many investigators have shown that water hyacinth weeds can be used as soil fertilizers (Woomer *et al.* 2000; Gupta *et al.* 2004). They noted its potential to increase soil fertility and crop yield when applied as green manure or compost.

Increase in organic matter of soil which consequently results in improved physical soil properties using water hyacinth manure for maize cultivation has been reported by Gashamura (2009) and Chuwuka and Omotayo

(2009). Wanas (2006) observed 15% and 12.3% reduction in soil bulk density under shallow and deep ploughing respectively using water hyacinth compost when compared to control without organic amendments. Average bulk density values were 1.20 and 1.22 gm^{-3} for shallow and deep ploughing depths respectively. The study further noted increased total porosity of 12.41% and 10.49% for the same ploughing depths. Studies on vermicompost used as source of nutrients indicate that it increases macropore space ranging from 50 x 10^{-4} m to 500 x 10^{-4} m resulting in improved air-water relationship in the soil which favourably affects plant growth (Marinari *et al*. 2000). Kumar *et al*. (2009) also noted that crop plot sites with organic amendment in form of farm yard manure (FYM) and vermicompost showed decrease in bulk density from 1.41 gcm^{-3} (untreated soil) to 1.27 gcm^{-3}.

A limited number of studies exist, on impact of vermicompost and intercropping with groundnut on physical properties of soils under cassava, a 12-24 months duration crop in Nigeria. In other to promote water hyacinth utilization among Nigerian farmers as a possible measure of its control, this study seeks to achieve the following objectives:

-To examine the overall impact of *Eichhornia crassipes*- based vermicompost on changes in physical soil properties, with special emphasis on bulk density and total porosity under sole cassava and cassava-groundnut intercrop and,

-To evaluate the effect of varying populations of sole cassava and cassava-groundnut mixtures on some physical soil properties.

2. Materials and Methods

A field experiment was conducted at the Teaching and Research Farm of the Delta State University, Abraka, Nigeria (latitude 5^0 46' and longitude 6^0 5') between July 2008 to June 2009 cropping seasons. Prior to commencement of experiment in 2008, surface (0-20 cm depth) soil samples were taken randomly from experimental site, bulked, air-dried and 2 mm sieved for analysis of soil physico-chemical properties. Particle size analysis (Bouycous method) showed 760 g kg^{-1} sand, 100 g kg^{-1} silt, 140 g kg^{-1} clay; pH in water = 5.4; 0.7 g kg^{-1} total N (Kjedahl method), and 47.1 g kg^{-1} organic matter (wet dichromate oxidation method).

In other to prepare the vermicompost, methods described by Daniel *et al.* (2005) were used. Water hyacinth, *Eichhornia crassipes* was manually harvested from a nearby creek, chopped into pieces of less than 10 cm and air-dried until constant weight was attained. Cow dung and poultry manure were air-dried. To make a 100 kg mix of water hyacinth and animal manure-based vermicompost either of poultry manure (VP) or cow dung (VC), 75 kg of water hyacinth was mixed with 25 kg of dry poultry manure or cow dung. The biomass of water hyacinth and animal manures biomass were thoroughly mixed, well wetted to have a moisture content of 30-40%. Each 100 kg substrate (a mixture of 75 kg water hyacinth and 25 kg animal manure) was 100cm long, 100cm wide and 50cm high. This was covered with a coarse material to reduce moisture loss. A simple shed was constructed to provide shade for each 100 kg of the substrate to prevent direct heat of the sun. After about two weeks 200 earthworms were introduced into each 100 kg of the substrate. The substrate was stirred and turned once a week. Water was sprinkled when it is too dry and the bed remade. The vermicompost was ready for use after 45 days.

Four nutrient levels (control i.e 0 kg; 200kg NPKMg 12:12:17:2; 40 tons of VP, and 40 tons of VC, three cropping densities (50,000, 100,000, and 200,000 plants ha^{-1}) and two cropping patterns (sole cassava and cassava-groundnut intercrop) were arranged in a 4x3x2 factorial experiment with a randomized complete design in three replicates. The NPKMg and vermicompost rates used were based on recommended rates for mineral fertilizer and organic manure for the area, while the cropping densities of 50,000 and 200,000 plants ha^{-1} are low and high densities respectively relative to recommended rate of 100,000 plants ha^{-1} for cassava in the area of study. Cassava (*Manihot esculenta* Crantz) and groundnut (*Arachis hypogaea* L.) were intercropped in ratio 1:2 for all densities. Improved cassava (var.TMS 30572) and groundnut (var. Spanish 205, early maturing 100-110 days) were planted on 6 x 4.5 m^2 plots.

Soil samples for bulk density were taken using the core method. Five undisturbed core (5 cm diameter, 12 cm deep) soil samples were collected and bulked for each plot. This was done at 2, 4, 6, 8, 10 and 12 months after planting (MAP). Soil from core samplers were transferred to a container and placed in an oven at 105^0C, and dried until constant weight. Dried soil weight was recorded and bulk density calculated by the formula of Black and Hartge (1986):

$$\text{Bulk density} = \frac{\text{Oven dry weight of soil (g)}}{\text{Sample volume (cm}^{-3}\text{)}}$$

Total soil porosity was calculated from bulk density assuming a particle density of 2.65 mg m^{-3} mainly used for tropical soils (Mbagwu *et al.* 1983) with the formula of Black and Hartge (1986):

$$\text{Total porosity} = 1 - \frac{\text{Bulk density}}{\text{Particle density}}$$

Data were subjected to appropriate analysis of variance (ANOVA) for factorial and randomized complete block designs (Gomez and Gomez, 1984), using bivariate techniques for analyzing intercropping trials (Mutsaers *et al*., 1997). Comparison of means was made by the least significant difference, LSD (P< 0.05).

3. Results

3.1 Total Soil Porosity

A non-significant increase in total porosity was observed in this study. A mix of water hyacinth and poultry manure or cow dung-based vermicompost increased soil total porosity than the mineral fertilizer and the control treatments in both sole and intercropped cassava populations (Figures 1-3). Mean total porosity under the influence of organic manures increased by 9.9, 11.2, and 11.9 % under sole cassava cropping at 4, 8, and 12 MAP. Under cassava-groundnut mixtures, vermicomposts on average increased total porosity by 7.8, 9.2, and 11.3% relative to untreated soils at 4, 8 and 12 MAP. The order of effectiveness of nutrient sources in slightly increasing soil total porosity was VC>VP>NPKMg>control. Increasing plant population density resulted in improved soil total porosity for both sole cassava and cassava-groundnut mixtures, with 200,000 plants ha^{-1} having the mean highest values of 50.0 and 52.8% at 12 MAP.

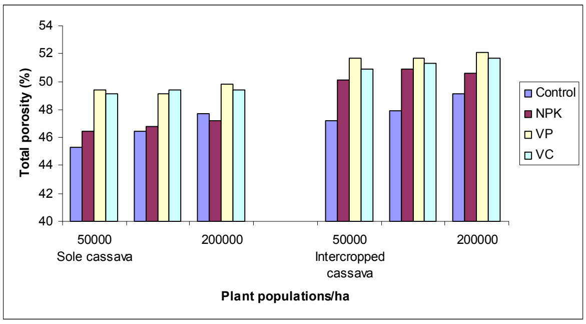

Figure 1: Changes in soil total porosity 2MAP

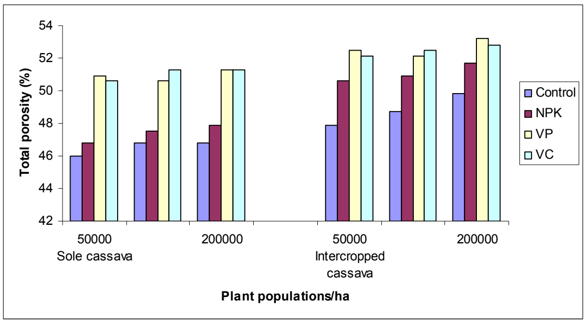

Figure 2: Changes in soil total porosity 4MAP

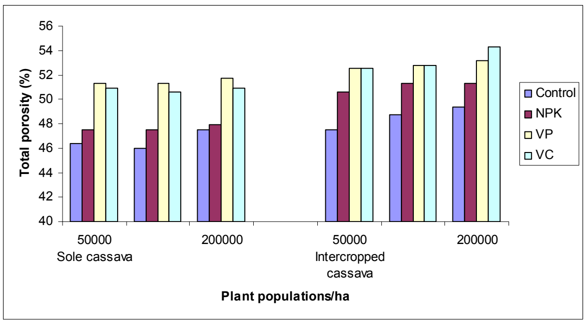

Figure 3: Changes in soil total porosity 6MAP

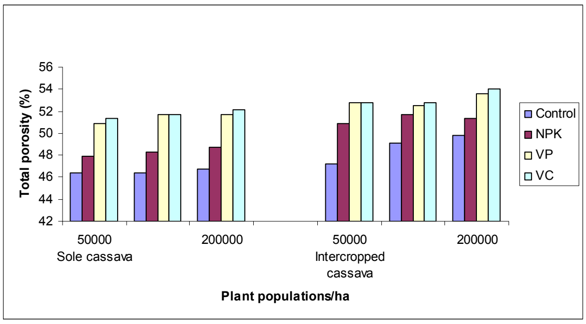

Figure 4: Changes in soil total porosity 8MAP

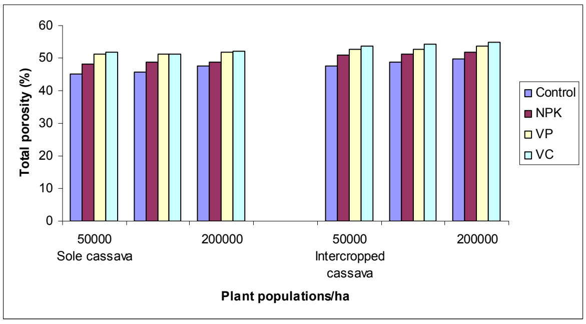

Figure 5: Changes in soil total porosity 10MAP

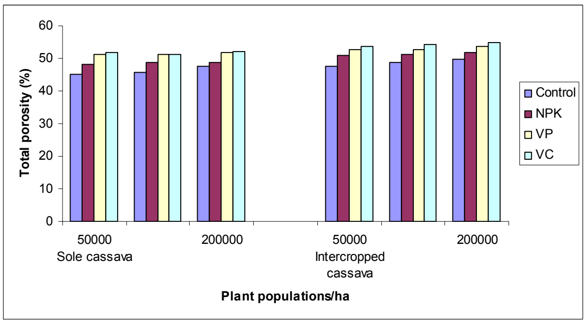

Figure 6: Changes in soil total porosity 12MAP

3.2 Soil Bulk Density

Application of mix of water hyacinth and animal manure-based vermicomposts significantly (*P*< 0.05) reduced soil bulk density throughout the growth period of the crops in both sole cassava and cassava-groundnut populations as shown in Tables 1. Reduction of bulk density by vermicomposts was more pronounced in cassava-groundnut mixtures compared to sole cassava. Bulk density reduced from 1.42 gm^{-3} (untreated soil) to 1.22 gm^{-3} (VP) and 1.21 gm^{-3} (VC). On average organic manures when compared with the untreated soil, significantly (*P<0.05*) reduced soil bulk density by 9.2, 10.9, and 11.7% at 4, 8, and 12 months after planting(MAP) respectively in sole cassava populations. Significant reductions in bulk density of soil under cassava-groundnut mixtures were 6.3, 9.7, and 12.4% at 4, 8 and 12 MAP respectively.

Within the first 6 months after planting (MAP), water hyacinth/poultry manure-based vermicompost reduced bulk density more than vermicompost with cow dung/water hyacinth mixture. The organic nutrient sources reduced bulk density than mineral fertilizer. The order of effectiveness of nutrient sources in improving bulk density was VC>VP>NPKMg>control in both sole cassava and cassava-groundnut mixtures. There was neither significant increase in bulk density between VC and VP or NPKMg and the control. Significance (*P<0.05*) was only observed between organic sources (VP and VC) and mineral fertilizer and control.

Although plant population reduced soil bulk density, significant (*P< 0.05*) reduction was only observed at 6 MAP (Table 1) in both sole cassava and cassava-groundnut intercrops. Increasing plant population from 50,000 to 200,000 plants ha^{-1} significantly (*P<0.05*) reduced bulk density in sole cassava by 0.1 and 2.2% at 6 and 10 MAP, while a non-significant reduction of 1.4, 1.5, 1.5 and 1.5% was observed at 2, 4 8 and 12 MAP. However, in soils planted with cassava-groundnut intercrops a significant reduction of 3.1% was observed for soil bulk density at 6 MAP. Slight reduction in bulk density of soil by 1.5, 2.3, 2.3, 3.1 and 2.3% were also observed at 2, 4, 8, 10 and 12 MAP in soils planted with cassava-groundnut intercrop. Lowest bulk density of 1.32 gm^{-3} (10 MAP) and 1.26 gm^{-3} (12 MAP) in sole cassava and cassava-groundnut mixtures respectively, were observed in highest plant population of 200,000 plants ha^{-1}(Table 1).

On the average, cassava-groundnut mixtures reduced bulk density than sole cassava. Mean reduction in bulk density by cassava-groundnut mixtures relative to sole cassava was 4.5, 3.7, 4.4, 3.7, 4.5 and 4.5% at 2, 4, 6, 8, 10 and 12 MAP respectively, although significant ($P<0.05$) reductions were only observed at 2, 6 and 12 months after planting.

Net changes in soil bulk density and total porosity

A mix of water hyacinth and cow dung-based vermicompost resulted in a more pronounced net decrease in bulk density between 2 MAP and 12 MAP (Table 2) under sole cassava (-0.07) and cassava-groundnut intercrops (–0.08). Net decrease in bulk density at varying plant populations between 2 MAP and 12 MAP in sole cassava populations were -0.04 (50,000 plants ha^{-1}), -0.03 (100,000 plants ha^{-1}) and -0.04 ((200,000 plants ha^{-1}), while cassava-groundnut populations had -0.04 (50,000 plants ha^{-1}), -0.03 (100,000 plants ha^{-1}) and -0.03 (200,000 plants ha^{-1}). However, no variation was observed between the net decrease in the bulk density between 2 MAP and 12 MAP in sole cassava and cassava-groundnut mixtures as both had the same value of -0.04 (Table 2).

Net increase in soil total porosity between 2 MAP and 12 MAP were positive and more pronounced with mix of water hyacinth and cow dung-based vermicompost sole cassava (+2.50) and cassava-groundnut mixtures (+2.90). At varying planting populations highest net increase in total soil porosity were observed in 50,000 plants ha^{-1} sole cassava (+1.60) and cassava-groundnut (+2.70) (Table 2).

Table 1: Soil bulk density under cassava-groundnut intercrop as influenced by nutrient sources and cropping density

	Sole cassava						Cassava-groundnut intercrop					
Treatments	Months after planting											
Nutrients	2	4	6	8	10	12	2	4	6	8	10	12
0kg	1.42a	1.42a	1.41a	1.42a	1.42a	1.43a	1.38a	1.36a	1.36a	1.36a	1.36a	1.36a
200kg NPKMg	1.41a	1.39a	1.39b	1.37ab	1.36a	1.36b	1.31b	1.30ab	1.30b	1.29a	1.29b	1.29b
40 tons VP	1.34b	1.30b	1.29d	1.29b	1.29b	1.29c	1.28b	1.26b	1.25c	1.25a	1.25b	1.24c
40 tons VC	1.35b	1.30b	1.30c	1.28b	1.28b	1.28c	1.29b	1.26b	1.24d	1.24a	1.22c	1.21c
Density												
50000 plants ha^{-1}	1.39a	1.36a	1.35a	1.35a	1.35a	1.35a	1.33a	1.31a	1.31a	1.30a	1.30a	1.29a
100000 plants ha^{-1}	1.38a	1.35a	1.35a	1.34a	1.35a	1.35a	1.31a	1.30a	1.29b	1.29a	1.28a	1.28a
200000 plants ha^{-1}	1.37a	1.34a	1.34b	1.33a	1.32b	1.28c	1.31a	1.28a	1.27c	1.27a	1.26a	1.26a

In each column means followed by the same letter (s) are not significantly different at 5% LSD.

Table 2: Net changes in soil bulk density and total porosity as influenced by nutrient sources, plant population and cropping pattern

Soil bulk density (g cm^{-3})						
	Sole cassava			Cassava- groundnut intercrop		
Nutrients	2MAP	12MAP	Net change	2MAP	12MAP	Net change
0	1.42	1.43	+0.01	1.38	1.36	-0.01
200kg NPKMg	1.41	1.36	-0.05	1.31	1.29	-0.02
40 tons VP	1.34	1.29	-0.05	1.28	1.24	-0.04
40 tons VC	1.35	1.28	-0.07	1.29	1.21	-0.08
Cropping density						
50000 plants ha^{-1}	1.39	1.35	-0.04	1.33	1.29	-0.04
100000 plants ha^{-1}	1.38	1.35	-0.03	1.31	1.28	-0.03
200000 plants ha^{-1}	1.37	1.33	-0.04	1.31	1.26	-0.05
Cropping pattern	1.38	1.34	-0.04	1.34	1.28	-0.04
Total porosity (%)						
Nutrients						
0	46.5	46.2	-0.30	48.0	48.7	+0.70
200kg NPKMg	46.8	48.6	+1.80	50.5	51.3	+0.80
40 tons VC	49.4	51.4	+0.20	51.8	53.1	+1.30
40 tons VP	49.2	51.7	+2.50	51.3	54.2	+2.90
Density						
50000 plants ha^{-1}	47.6	49.2	+1.60	48.5	51.2	+2.70
100000 plants ha^{-1}	47.9	49.3	+1.40	50.2	51.8	+1.60
200000 plants ha^{-1}	48.5	50.0	+1.50	50.9	52.8	+1.90
Cropping pattern	48.0	49.5	+1.50	50.4	51.8	+1.40

4. Discussion

If decomposable organic matter is added to a soil, there is a rapid improvement in the stability of soil structure. This is brought about partly by the production of polysaccharide gums by the soil bacteria and partly by the growth of fungal and actinomycete hyphae growing over the soil particles (Russell, 1973). These influence of decomposable organic matter on soil physical properties help to maintain functional capacity of soil for crop growth (Islam and Weil, 2000; Min *et al*., 2003).

The significant decrease in soil bulk density with an associated increase in total porosity under cow dung (VC) and poultry manure (VP) water hyacinth- based vermicomposts may be due to greater amount of organic matter deposition (Haynes, 2000; Agbede *et al*., 2008). Since bulk density is inversely related to total porosity, which provides a measure of the porous space left in the soil for air and water movement (Tester, 1990; Min *et al*., 2003), the lower bulk density attributed to the water hyacinth based vermicomposts implies greater pore space and improved aeration, resulting in a suitable environment for biological activity (Min *et al*., 2003; Sultani *et al*., 2007).

The application of organic matter in form of water hyacinth based vermicomposts may have specifically influenced soil structural properties enmeshing soil primary particles and microaggregates into microaggregation through the direct physical action of cassava and groundnut roots, and production of cementing agents from enhanced microbial activities. These aggregation processes may have reduced soil bulk density and increased porosity with the soil having greater capacity for water retention and transmission (Goldhamer *et al*., 1994; Sultani *et al*., 2007). Moreover, the introduction of earthworm in the composting processes may have also increased the activities of macroorganisms and microorganisms, whose activities creates stable and continuous macropores that reduce soil compaction (Tian *et al*., 2000). In a related study, Lal (1987) reported that eliminating earthworms led to high soil bulk density and massive structure. The superiority of cow dung based vermicompost relative to that of poultry manure and inorganic fertilizer may be attributed to the balanced and gradual release of nutrients which promote microbial and plant root growth (Ofosu-Anim and Leitch, 2009).

As earlier noted by Russell (1973), plant roots are the most important group of agents that create structural pores in undisturbed soils. The roots of many plants grow by forcing their root tips into soil pore and making the pore larger. Thus the more intimately the roots permeate through such a soil, the more intimate will be the system of cracks and pores that will be developed. Hence the decrease in soil bulk density and corresponding increase in total porosity under high plant populations in both sole cassava and cassava-groundnut mixtures may be due to increase in soil granulation and development of larger pores by the plant roots with the soil being more likely regulated by macropores over micropores. Such changes in pore network could result in changes in the storage and transmission of water which in turn may lead to improved crop performance (Barzegar *et al.*, 2007).

Although groundnut being a self-fertilizing crop, is usually classified to be very exhaustive compared to other legumes, as very little portion of the plant is left in the soil after harvesting (Varade and Urkude, 1982; Singh and Jagadeesh, 2009), its inclusion in the cassava based farming system in this study may have contributed to the improvement in soil structural properties. Earlier reports (Adediran *et al*., 2000; Chikowo *et al*., 2004) have affirmed the role of legumes in increasing soil organic matter and consequently improved soil structural properties.

Considering the salient findings of this study, organic farming, using mix of water hyacinth and animal manure -based vermicomposts, favorably influenced soil physical properties which in turn may pave way for better crop yield and quality. The adoption of this form of vermicompost will also greatly contribute to cleaning the terrestrial and aquatic environments.

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