Original Research Article

Influence of soil amendment on the relative growth rate and net assimilation rate of *Phaseolus vulgaris* and *Vigna aconitifolia*

Abstract

Background: Soil pH is one of the most influential factors that affects crop growth and productivity. This research was designed to assess the influence of soil amendment using organic manure and agricultural lime on the relative growth rate (RGR) and net assimilation rate (NAR) of *Phaseolus vulgaris* and *Vigna aconitifolia*.

Methodology: The three locations were: Akamkpa with pH 4.0, Calabar Municipality with pH 7.0 and Odukpani with pH of 9.0. The treatments were; control (0g), OM_1 (100g organic manure), OM_2 (200g organic manure), AL_1 (100g agricultural lime), AL_2 (200g agricultural lime), OM_1 + AL_1 (50g organic manure + 50g agricultural lime) and OM_2 +AL_2 (100g organic manure and 100g agricultural lime.

Results: Results obtained on the RGR of the leaf dry weight of *P. vulgaris* treated with OM_2 was the highest (0.50 $gg^{-1}wk-^{1}$) followed by OM_1 (0.41 $gg^{-1}wk-^{1}$). OM_1 + AL_1 had the highest RGR of the stem dry weight of *P. vulgaris* grown on soil from Calabar Municipality. In the RGR of the root dry weight, OM_2 had the highest mean value in both plants grown on Akamkpa soil. Results obtained at 4 weeks after planting (WAP) revealed that there was significant ($P<0.05$) increase in NAR of plants grown on soil from Akamkpa. The highest NAR was obtained for *V. aconitifolia* treated with OM_2 (0.0447 $gg^{-1}wk-^{1}$) followed by OM_2 + AL_2 (0.0057 $gg^{-1}wk-^{1}$) for both *V. aconitifolia* and *P. vulgaris*. *P. vulgaris* grown on Akamkpa and Odukpani soils treated with AL_2 (0.0032 $gg^{-1}wk-^{1}$), OM_1 + AL_1 (0.0041 $gg^{-1}wk-^{1}$) and OM_2+ AL_2 (0.0062 $gg^{-1}wk-^{1}$) had the highest NAR at 8 WAP.

Conclusion: The RGR and NAR of the two bean varieties were greatly improved following treatments with organic manure and agricultural lime.

Keywords: Relative growth rate, Net assimilation rate, dry matter and soil

Introduction

Phaseolus vulgaris (L.) and *Vigna aconitifolia* (Jacq.) are two important beans in the family Fabaceae. This is the third largest family of angiosperms after orchidaceae (orchids) and Asteraceae, and second only to Poaceae (grasses) in terms of agricultural and economic importance (Garg *et al.,* 2014). The family includes a large number of domesticated species for human and horticultural purposes (Lewis *et al.,* 2005). Beans are globally important leguminous vegetables that have been used for centuries (Brink and Belay, 2006) as food for humans and feed for animals (Amira *et al.,* 2003). Primarily, beans are rich in protein and relatively low in fiber making them a potentially valuable ingredient for all livestock species. Beans are also a major source of calories. In addition, its consumption provides mineral especially iron and zinc for which it compliments cereals. Most legumes have symbiotic nitrogen-fixing bacteria in the root nodules, hence they play a key role in nitrogen fixation in soil. *P. vulgaris* and *V. aconitifolia* are considered important sources of dietary protein for the majority of the people who cannot afford expensive animal protein thereby eliminating human malnutrition. The leaves are also occasionally used as vegetable and the straw as fodder (Ndakidemi *et al.*, 1998).

The performance of plants depends very much on the soil factors. Acidic and alkaline soil have been found to affect the yield and development of legumes (Brady and Weil, 2008; Thakuria *et al*., 2016). The fundamental factors associated with acidic and alkaline soils include, nutrient deficiencies such as phosphorous, calcium, nitrogen, and the presence of phytotoxic substances such as soluble aluminum and manganese (Carren, 1991). In the soil, plants absorb nutrients mainly in soluble form. Under acidic and alkaline conditions, some of these vital nutrients such as phosphorous, calcium and magnesium are unavailable or are only present in minute quantities (Liu *et al.*, 2010). It has been found that herbaceous plants are more sensitive to the effects of acidic and alkaline soils than woody plants (Heckle *et al.*, 2005). Adverse impacts of nutrients deficiency on plants include chlorosis, stunting, senescence and several other symptoms (Evans *et al.*, 1997). Legumes production require large amount of nutrients for their growth and development otherwise, physiological deficiencies can occur (Takahashi, 1981).

Over the years, inorganic fertilizers have been used worldwide to support and optimize the growth of plants. However, the use of organic fertilizers has gained more global interests in the last few decades due to concerns about the impacts of inorganic fertilizers in food chains, human health and the environment (Shehata *et al.*, 2011). There is large increase in the use of organic fertilizers over inorganic fertilizers as nutrient source on many farms (Kannan & Savannah, 2006; Joshi et al., 2016, Effa et al., 2019; Menon et al., 2010; Adeoye et al., 2011). Apart from improving the fertility, structure and some biological properties of the soil, organic materials has the capacity to reduce soil acidity and aluminum saturation. A number of possible mechanisms have been suggested by several workers decades ago in their quest to elucidate how this occurs (Gaur, 1991). Several liming materials such as crushed limestone ($CaCO_3$), dolomitic lime ($CaMgCO_3$), slaked lime ($Ca(OH)_2$), quick lime (CaO) have been used to reduce soil acidity (Lathwell 2012; Buri *et al.*, 2005; Kisinyo *et al*., 2005; Kisinyo *et al*., 2005; Rothwell and Dodd (2014). Studies have shown that apart from reducing the acidity of the soil by counteracting the effects of excess hydrogen and aluminum ions (Fageria and Baligar, 2005), liming also has several other benefits including, its ability to reduce the toxicity effects of some micro elements by lowering their concentrations while increasing the availability of plant nutrients such as calcium, phosphorus, molybdenum and magnesium in the soil (Naidu *et al.*, 1990) and reducing the solubility and leaching of heavy metals (Sauve *et al.*, 2000). The use of organic manure and agricultural limes as independent treatments notwithstanding, reports have shown that a combination effect of the two fertilizer sources can be more effective in improving crop growth and yield components (Effa et al., 2019; Reyhand and Amiraslani (2006); Luqueno *et al.* (2010), Manivannan *et al.* (2009) and Joshi *et al.* (2016). The present study was designed to assess the influence of organic manure and agricultural lime singly and in combination on the relative growth rate and net assimilation rate of *Phaseolus vulgaris* and *Vigna aconitifolia*.

MATERIALS AND METHODS

Study location

The experimental site for this study was at the Greenhouse, Department of Plant and Ecological Studies, University of Calabar with an average temperature of 25 ± 3^0 C. Calabar is located between latitudes 4^0 78' and 5^0 09' N and longitudes $8^0$15' and 8^0

26' E and lies between the valleys of two rivers: The Great Qua River on the Eastern side and the Calabar River on the West. The total annual rainfall for the area is between 2109.5 mm and 4168.7 mm.

Seeds collection and planting materials

Seeds of *P. vulgaris* and *V. aconitifolia* were obtained from Institute of Agricultural Research and Training (IAR and T) Moor Plantation in Ibadan, Nigeria. Polythene bags (planting bags) were obtained from Ministry of Agriculture, Calabar. Agricultural lime was obtained from Cross River Agricultural Development Project while organic manure was obtained from the Department of Soil Science, Faculty of Agriculture, University of Calabar, Calabar.

Soil sampling, collection and preparation

Soil samples (0-20 cm) depth were collected from three Local Government Areas of Southern Cross River State. Soils with pH 4.0 were collected from three villages in Akamkpa (Old Netim, Ayaebam and Awi), soils with pH 7.0 were collected from Calabar Municipality in designated locations (Forestry and Wild-Life Plantation, University of Calabar, Esuk Atu Community, Lemna dumpsite – Itung Effanga) and soils with pH 9.0 were collected from three villages in Odukpani Local Government Area (Akpan 18 Community, Akim-Akim and Okoyong-Usang Abasi) using an auger. Soils from the same Local Government area with same pH were properly mixed to give a composite soil sample. The map of Southern Cross River showing the geographical locations of the soil samples is shown in figure 1. Soil for germination and growth of plants were bulked air dried for three days, sieved through a 2 mm mesh to remove debris and were taken to Soil Science Laboratory, University of Calabar for the physico-chemical analysis.

Experimental design and layout

The experiment was conducted using a 2x3x7 factorial experimental layout in a Randomized Complete Block Design (RCBD) with 3 replicates. Factor one were the two plant varieties (*P. vulgaris* and *V. aconitifotia*), factor two were the three locations where soil samples were collected (Akamkpa-AK, Calabar Municipality-CM and Odukpani-OD) while factor three were the seven levels of treatment: control (0 g), OM_1 (100 g organic manure), OM_2 (200 g organic manure), AL_1 (100 g agricultural lime), AL_2 (200 g agricultural lime), OM_1 + AL_1 (50 g organic manure + 50 g agricultural lime) and OM_2 +AL_2 (100 g organic manure and 100 g agricultural lime).

Planting procedure and treatment application

One hundred and twenty-six experimental polybags (16 cm internal diameter) perforated at the bottom were filled with 5 kg of each soil sample. These were divided into three groups of 42 polybags based on the three soil samples. In each soil sample, there were 21 polybags each for the two plant varieties using randomized complete block design (RCBD) replicated three times. The soils were treated with agricultural lime (AL) and organic manure (OM) singly and in combinations. The treated soils were allowed to stay for two weeks before seed sowing. This time lapse before planting was to allow for microbial activities and interaction within treatment combinations. Each polybag was sown with three seeds each of *P. vulgaris* and *V. aconitifotia* at a depth of 2 cm. Following germination, seedlings stalk were watered and grown for 8 weeks.

Determination of leaf, stem and root dry weight

Seven plants were carefully uprooted from each treated soil. In order to prevent some portions of the root from breaking off, the plants were placed in a container of water and the soil gently washed off. The stem of each plant was cut off from the root with a scissor while the leaves were picked from the stem by hand. The leaf, stem and root were dried to constant weight (DW).

Determination of relative growth rate

The relative growth rate (RGR) measured the change in dry weight (dw) of different samples of *P. vulgaris* and *V. aconitifolia* grown on acidic and alkaline soil treated with different grams of organic manure and agricultural lime. The differences were calculated between plants grown on acidic and alkaline treated soils by the method of (Hoffmann and Poorter, 2002) and the fresh weight of whole plant was used in the determination of RGR.

$$RGR = \frac{(\text{In } W_2 - \text{In } W_1)}{t_2 - t_1} \text{ (gg-1wk-1)}$$

Where:

In = natural logarithm.

W_1 = initial dry mass or weight.

W_2 = final dry mass or weight.

t_1 = initial growth period.

t_2 = final growth period.

$t_1 - t_2$ = time interval during which time biomass increased from $W_1 - W_2$.

Determination of net assimilation rate (NAR)

NAR was calculated as the change in total plant biomass per leaf weight and time (Heilmeier *et al.,* 1986). Time was used to show the photosynthetic effectiveness between *P. vulgaris and V. aconitifolia* grown on acidic and alkaline soils treated with organic manure and agricultural lime.

$$NAR = \left(\frac{\text{In}A_2 - \text{In}A_1}{A_2 - A_1}\right)\left(\frac{W_2 - W_1}{t_2 - t_1}\right) \text{(gg-1wk-1)}$$

Where:

In = Natural logarithm.

A_1 = Initial leaf area.

A_2 = Subsequent leaf area.

W_1 = Initial leaf dry weight.

W_2 = Final leaf dry weight.

t_1 = Initial growth period.

t_2 = Final growth period.

Statistical analysis

Data obtained on the relative growth and net assimilation rates were taken as the mean measurements of three replicates. Statistical analysis was performed using the statistical package for social sciences (SPSS) version 20.0 under a two-way analysis of variance (ANOVA). Significant means were separated using the Duncan multiple range test at $p<0.05$.

Results

Effect of agricultural lime and organic manure on leaf dry weight (g/plant-1)

Leaf dry weight (LDW) of *V. aconitifolia* grown in soils from Akamkpa and Odukpani treated with OM_1+ AL_1 and OM_2 showed significant ($P<0.05$) increase at 4 WAP and 8 WAP when compared to the plant grown on untreated soil (Table 1). The highest LDW of *V. aconitifolia* treated OM_1+ AL_1 had the mean value of 3.47 g from Akampkpa soil and 4.79 g from Odukpani soil at 4 WAP as against untreated soil values of 0.57 g and 1.86 g. At 8 WAP, *V. aconitifolia* grown with OM_1+ AL_1 had significant ($P<0.05$) increase in LDW of 6.94 g and 9.58 g in Akamkpa and Odukpani soils compared to the controls (1.13 g and 3.71 g). Leaf dry weight of *P. vulgaris* and *V. aconitifolia* grown on AK soil treated with $AL_1$and AL_2 resulted in a decrease in LDW compared to the control at 4 WAP and 8 WAP. There was no significant ($P>0.05$) difference in LDW at 4 WAP and 8 WAP for both plants grown on CM treated and untreated soils.

Effect of agricultural lime and organic manure on stem dry weight (g/plant^{-1})

Results of mean stem dry weight (SDW) of *P. vulgaris* and *V. aconitifolia* grown on acidic soil from Akamkpa, Odukpani and Calabar Municipality treated with agricultural lime and organic manure are presented in Table 2. Some soil amendment caused significant ($P<0.05$) increase and decrease in SDW of plants when compared to the control. There was a significant ($P<0.05$) increase in mean stem dry weight of *P. vulgaris* grown on soil from AK treated with OM_2 + AL_2, OM_1 and OM_1 + AL_1 with 1.57 g, 1.14 g and 1.02 g at 4 WAP compared to the control values of 0.37 g. *P. vulgaris* grown on acidic soil from AK treated with OM_2 + AL_2 at 8 WAP had the highest SDW with mean value of 3.14 g compared to untreated soil value of 0.74 g. *V. aconitifolia* grown on soil from OD treated with OM_2 had the highest stem dry weight value of 7.89 g compared to untreated soil value of 2.70 g at 8 WAP. There were no significant ($P>0.05$) difference in stem dry weight of *P. vulgaris* and *V. aconitifolia* grown on neutral soil from CM treated with agricultural lime and organic manure at 4 WAP and 8 WAP.

Effect of agricultural lime and organic manure on root dry weight (g/plant-1)

Results of root dry weight (RDW) of *P. vulgaris* and *V. aconitifolia* grown on soils from different locations treated with agricultural lime and organic manure at 4 WAP and 8 WAP are presented in Table 3. The final root dry weight was higher than the initial in both plants. *V. aconitifolia* grown on soils from Akamkpa and Odukpani with treated with OM_1 + AL_1 showed significant ($P<0.05$) difference in RDW (0.36 g and 0.79 g) compared to untreated soils (0.13 g and 0.31 g). Results showed significant ($P<0.05$) variations in the root dry weight of both plants grown on Odukpani soil. The root dry weight of *P. vulgaris* and *V. aconitifolia* grown on treated and untreated soil from Calabar Municipality did not differ statistically. However, both *P. vulgaris* and *V. aconitifolia* produced statistically similar root dry weight at 4 WAP and 8 WAP obtained from OM_2 (0.79 g) in *V. aconitifolia* during the final harvest when compared with the control (Table 3).

Effect of agricultural lime and organic manure on relative growth rate of leaf dry weight (gg^{-1}wk^{-1})

The results revealed that the relative growth rate of leaf dry weight of plants grown on treated soil from Akamkpa and Calabar Municipality did not differ statistically ($p>0.05$) from the untreated. However, plants grown on soils from Odukpani under treatment revealed significant ($P<0.05$) increase in RGR of leaf dry weight when compared to the control. *P. vulagris* grown on soil from Odukpani treated with OM_2 had the highest RGR of leaf dry weight (0.50 $gg^{-1}wk$-^{1}) followed by OM_1 (0.41 $gg^{-1}wk$-^{1}), OM_1 + AL_1 (0.37 $gg^{-1}wk$-^{1}) and AL_1 (0.36 $gg^{-1}wk$-^{1} compared to the control value of 0.13 $gg^{-1}wk$-^{1}. Results have shown that *P. vulgaris* and *V.*

aconitifolia grow on Odukpani soil treated with AL and OM had the highest RGR of leaf dry weight (Table 4).

Effect of agricultural lime and organic manure on relative growth rate of stem dry weight ($gg^{-1}wk^{-1}$)

Stem dry weight of *P. vulgaris* and *V. aconitifolia* grown on soils from Akamkpa and Odukpani treated with AL and OM did not differ from the control. There was significant ($P<0.05$) increase in the relative growth rate of stem dry weight of *P. vulgaris* and *V. aconitifolia* grown on soil from Calabar Municipality compared to the control. *P. vulgaris* grown on CM soil treated with OM1 + AL_1 had the highest RGR of stem dry weight of 0.48 $gg^{-1}wk$-^{1} followed by OM_1 + AL_1 (0.36 $gg^{-1}wk$-^{1}) and OM_1 (0.23 $gg^{-1}wk$-^{1}) compared to the control (0.11 $gg^{-1}wk$-^{1}). The relative growth rate of stem dry weight of *V. aconitifolia* were for AL_2 (0.33 $gg^{-1}wk$-^{1}) and OM_1 (0.24 gg^{-1}wk-1) to the control value of 0.15 $gg^{-1}wk$-^{1} (Table 5).

Effect of agricultural lime and organic manure on relative growth rate of root dry weight ($gg^{-1}wk^{-1}$)

The result of relative growth rate of root dry weight of *P. vulgaris* and *V. aconitifolia* depicted a trend of variation among treatments compared to the control. Soil from Akamkpa showed significant ($P<0.05$) variation in relative growth rate among the different treatments. *P. vulgaris* grown on Akamkpa soil treated with OM_2 had the highest relative growth rate (0.25 $gg^{-1}wk^{-1}$). The relative growth rate of *V. aconitifolia* grown on Akamkpa soil treated with OM_2 had the highest relative growth rate of root dry weight (0.38 $gg^{-1}wk^{-1}$) compared to the control (0.15 $gg^{-1}wk^{-1}$) as shown in Table 6.

Effect of agricultural lime and organic manure on net assimilation rate ($gg^{-1}wk$-^{1})

The results on the net assimilation rate (NAR) of *P. vulgaris* and *V. aconitifolia* grown on soils from Akamkpa, Calabar Municipality and Odukpani treated with organic manure and agricultural lime are presented in Table 7. Results obtained at 4 WAP revealed that there was significant ($P<0.05$) increase in NAR of plants grown on soil from Akamkpa. The highest NAR was obtained for *V. aconitifolia* treated with OM_2 (0.0447 $gg^{-1}wk$-^{1}) followed by OM_2 + AL_2 (0.0057 $gg^{-1}wk$-^{1}) for both *V. aconitifolia* and *P. vulgaris*. There were no significant differences in NAR for both plants grown on soil from Calabar Municipality at 4 WAP ($P>0.05$). At 6 WAP *V. aconitifolia* grown on soil treated with OM_2 (0.0621 $gg^{-1}wk$-^{1}) had the highest NAR followed by OM_2 + AL_2 (0.0314 $gg^{-1}wk$-^{1}) which were significantly ($P<0.05$) higher than other treatments for soil from Akamkpa. At 6 WAP *P. vulgaris* grown on soil from Akamkpa treated with OM_1 (0.392 $gg^{-1}wk$-^{1}), OM_1 + AL_1 (0.401 $gg^{-1}wk$-^{1}), OM_2 (0.411 $gg^{-1}wk$-^{1}) and OM_2 + AL_2 (0.319 $gg^{-1}wk$-^{1}) had the highest NAR. At 8 WAP, NAR for both plants grown on treated soil from all the treatments from Akamkpa had similar NAR which were significantly ($P<0.05$) higher than the control ($P>0.05$). *Phaseolus vulgaris* grown on Akamkpa and Odukpani soils treated with AL_2 (0.0032 $gg^{-1}wk$-^{1}), OM_1 + AL_1 (0.0041 $gg^{-1}wk$-^{1}) and OM_2+ AL_2 (0.0062 $gg^{-1}wk$-^{1}) had the highest NAR at 8 WAP (Table 7).

TABLE 1

Effect of agricultural lime and organic manure on relative growth rate of leaf dry weight ($gg^{-1}wk^{-1}$) of *Phaseolus vulgaris* and *Vigna aconitifolia*

Plant species	Treatment	4 WAP Locations AK	CM	OD
Phaseolus vulgaris	Control	$0.22^{e}\pm0.12$	$0.11^{a}\pm0.01$	$1.29^{f}\pm1.10$
	AL_1	$0.12^{e}\pm0.07$	$0.03^{a}\pm0.06$	$0.43^{g}\pm0.29$
	AL_2	$0.06^{e}\pm0.06$	$0.00^{a}\pm0.00$	$0.96^{g}\pm0.22$
	OM_1	$0.80^{e}\pm0.21$	$0.07^{a}\pm0.01$	$0.31^{g}\pm0.28$
	OM_1+ AL_1	$0.95^{e}\pm0.11$	$0.08^{a}\pm0.13$	$0.67^{g}\pm0.66$
	OM_2	$0.89^{e}\pm0.61$	$0.18^{a}\pm0.13$	$0.22^{g}\pm0.09$
	OM_2 + AL_2	$1.26^{d}\pm0.54$	$0.03^{a}\pm0.06$	$2.44^{e}\pm1.83$
Vigna aconitifolia	Control	$0.57^{e}\pm0.29$	$0.06^{a}\pm0.10$	$1.86^{f}\pm1.84$
	AL_1	$0.22^{e}\pm0.12$	$0.07^{a}\pm0.13$	$1.69^{f}\pm1.17$
	AL_2	$0.34^{e}\pm0.17$	$0.04^{a}\pm0.07$	$0.61^{g}\pm0.23$
	OM_1	$0.80^{e}\pm0.21$	$0.02^{a}\pm0.02$	$2.09^{e}\pm1.50$
	OM_1+ AL_1	$3.47^{b}\pm4.28$	$0.01^{a}\pm0.02$	$4.79^{c}\pm0.98$
	OM_2	$0.85^{e}\pm0.61$	$0.19^{a}\pm0.08$	$3.94^{d}\pm4.07$
	OM_2 + AL_2	$1.0^{d}\pm0.57$	$0.23^{a}\pm0.16$	$1.61^{f}\pm0.64$
		8 WAP		
Phaseolus vulgaris	Control	$0.44^{e}\pm0.24$	$0.22^{a}\pm0.02$	$2.58^{e}\pm2.21$
	AL_1	$0.24^{e}\pm0.14$	$0.06^{a}\pm0.11$	$0.52^{g}\pm0.40$
	AL_2	$0.12^{e}\pm0.11$	$0.00^{a}\pm0.00$	$1.91^{f}\pm2.43$
	OM_1	$1.60^{d}\pm0.43$	$0.15^{a}\pm0.02$	$0.61^{g}\pm0.56$
	OM_1+ AL_1	$1.91^{d}\pm1.41$	$0.15^{a}\pm0.27$	$1.34^{f}\pm1.32$
	OM_2	$1.77^{d}\pm1.23$	$0.36^{a}\pm0.25$	$0.43^{g}\pm0.17$
	OM_2 + AL_2	$2.52^{c}\pm1.08$	$0.07^{a}\pm0.12$	$4.89^{c}\pm3.66$
Vigna aconitifolia	Control	$1.13^{d}\pm0.59$	$0.12^{a}\pm0.21$	$3.71^{d}\pm3.69$
	AL_1	$0.43^{d}\pm0.23$	$0.14^{a}\pm0.25$	$3.38^{a}\pm3.43$
	AL_2	$0.68^{d}\pm0.33$	$0.08\ ^{a}\pm0.14$	$1.21^{f}\pm0.45$
	OM_1	$1.60^{d}\pm0.43$	$0.03^{a}\pm0.04$	$4.18^{c}\pm2.99$
	OM_1+ AL_1	$6.94^{a}\pm8.55$	$0.02^{a}\pm0.03$	$9.58^{a}\pm1.95$
	OM_2	$1.69^{d}\pm1.22$	$0.38^{a}\pm0.15$	$7.88^{b}\pm8.13$
	OM_2 + AL_2	$2.00^{c}\pm1.14$	$0.46^{a}\pm0.33$	$3.21^{b}\pm1.29$

Mean values with different superscripts along the same vertical axis are significantly different from each other ($p<0.05$). WAP – Weeks after planting, Control - 0g, AL1 -Agricultural lime , OM1 -Organic manure, AL2 -Agricultural lime, OM1 - Organic manure, OM1 + AL1 – 50 g organic manure + 50 g Agricultural Lime, OM2 - Organic manure, OM2 + AL2 – 100 g organic manure + 100 g Agricultural Lime. AK: Akamkpa, CM: Calabar Municipality, OD: Odukpani

TABLE 2

Effect of agricultural lime and organic manure on relative growth rate of stem dry weight ($gg^{-1}wk^{-1}$) of *Phaseolus vulgaris* and *Vigna aconitifolia*

Plant species	Treatment	4 WAP Locations AK	CM	OD
Phaseolus vulgaris	Control	$0.37^{d}\pm0.12$	$0.12^{a}\pm0.02$	$1.35^{de}\pm0.33$
	AL_1	$0.32^{d}\pm0.12$	$0.04^{a}\pm0.08$	$0.68^{e}\pm0.22$
	AL_2	$0.25^{d}\pm0.25$	$0.00^{a}\pm0.00$	$1.13^{de}\pm0.26$
	OM_1	$1.14^{bc}\pm0.21$	$0.12^{a}\pm0.02$	$0.34^{e}\pm0.08$
	$OM_1+ AL_1$	$1.02^{bc}\pm0.48$	$0.03^{a}\pm0.06$	$0.78^{e}\pm0.04$
	OM_2	$0.62^{d}\pm0.28$	$0.14^{a}\pm0.06$	$0.39^{e}\pm0.07$
	$OM_2 + AL_2$	$1.57^{bc}\pm0.85$	$0.01^{a}\pm0.02$	$1.46^{de}\pm0.74$
Vigna aconitifolia	Control	$0.58^{d}\pm0.33$	$0.08^{a}\pm0.13$	$1.74^{de}\pm1.83$
	AL_1	$0.30^{d}\pm0.13$	$0.10^{a}\pm0.17$	$1.38^{de}\pm1.18$
	AL_2	$0.28^{d}\pm0.21$	$0.04^{a}\pm0.07$	$0.60^{e}\pm0.28$
	OM_1	$1.14^{bc}\pm0.21$	$0.10^{a}\pm0.10$	$1.62^{de}\pm0.86$
	$OM_1+ AL_1$	1.48d±0.89	$0.01^{a}\pm0.02$	$2.71^{cd}\pm0.45$
	OM_2	$0.53^{d}\pm0.21$	$0.11^{a}\pm0.03$	$3.95^{e}\pm4.59$
	$OM_2 + AL_2$	$0.87^{d}\pm0.41$	$0.92^{a}\pm0.11$	$1.25^{de}\pm1.00$
		8 WAP		
Phaseolus vulgaris	Control	$0.74^{d}\pm0.24$	$0.23^{a}\pm0.32$	$2.70^{cd}\pm1.67$
	AL_1	$0.64^{d}\pm0.23$	$0.09^{a}\pm0.15$	$1.35^{de}\pm10.45$
	AL_2	$0.50^{d}\pm0.50$	$0.00^{a}\pm0.00$	$2.24^{cd}\pm2.48$
	OM_1	$2.27^{ab}\pm0.43$	$0.24^{a}\pm0.05$	$0.68^{e}\pm0.39$
	$OM_1+ AL_1$	$2.03^{ab}\pm0.96$	$0.07^{a}\pm0.12$	$1.55^{de}\pm1.38$
	OM_2	$1.24^{bc}\pm0.55$	$1.27^{a}\pm0.13$	$0.77^{e}\pm0.13$
	$OM_2 + AL_2$	$3.14^{a}\pm1.70$	$0.02^{a}\pm0.04$	$2.92^{cd}\pm1.47$
Vigna aconitifolia	Control	$1.16^{bc}\pm0.06$	$0.15^{a}\pm0.27$	$3.48^{c}\pm3.66$
	AL_1	$0.59^{d}\pm0.26$	$0.19^{a}\pm0.03$	$2.76^{cd}\pm2.36$
	AL_2	$0.53^{d}\pm0.47$	$0.08^{a}\pm0.13$	$1.21^{de}\pm0.56$
	OM_1	$2.27^{ab}\pm0.43$	$0.21^{a}\pm0.19$	$3.24^{c}\pm1.72$
	$OM_1+ AL_1$	$2.95^{ab}\pm1.78$	$0.02^{a}\pm0.03$	$5.41^{b}\pm0.91$
	OM_2	$1.06^{bc}\pm0.42$	$0.21^{a}\pm0.05$	$7.89^{a}\pm1.17$
	$OM_2 + AL_2$	$1.73^{bc}\pm0.81$	$0.26^{a}\pm0.23$	$2.49^{cd}\pm0.40$

Mean values with different superscripts along the same vertical axis are significantly different from each other ($p<0.05$). WAP – Weeks after planting, Control - 0g, AL1 -Agricultural lime , OM1 -Organic manure, AL2 -Agricultural lime, OM1 - Organic manure, OM1 + AL1 – 50 g organic manure + 50 g Agricultural Lime, OM2 - Organic manure, OM2 + AL2 – 100 g organic manure + 100 g Agricultural Lime. AK: Akamkpa, CM: Calabar Municipality, OD: Odukpani

TABLE 3

Effect of agricultural lime and organic manure on relative growth rate of root dry weight ($gg^{-1}wk^{-1}$) of *Phaseolus vulgaris* and *Vigna aconitifolia*

Plant species	Treatment	Locations		
		AK	CM	OD
		4 WAP		
Phaseolus vulgaris	Control	0.09^{bc}±0.03	0.02^{a}±0.01	0.20^{c}±0.04
	AL_1	0.05^{bc}±0.02	0.01^{a}±0.01	0.09^{c}±0.02
	AL_2	0.04^{bc}±0.04	0.00^{a}±0.00	0.12^{c}±0.08
	OM_1	0.12^{ab}±0.02	0.03^{a}±0.01	0.08^{c}±0.04
	OM_1+ AL_1	0.09^{bc}±0.04	0.02^{a}±0.03	0.08^{c}±0.08
	OM_2	0.04^{c}±0.01	0.03^{a}±0.01	0.07^{c}±0.02
	OM_2 + AL_2	0.12^{ab}±0.04	0.01^{a}±0.02	0.19^{c}±0.11
Vigna aconitifolia	Control	0.07^{bc}±0.03	0.01^{a}±0.02	0.16^{c}±0.10
	AL_1	0.05^{c}±0.03	0.01^{a}±0.01	0.16^{c}±0.12
	AL_2	0.10^{ab}±0.14	0.01^{a}±0.01	0.10^{c}±0.06
	OM_1	0.12^{ab}±0.02	0.02^{a}±0.02	0.21^{c}±0.14
	OM_1+ AL_1	0.18^{ab}±0.12	0.00^{a}±0.00	0.18^{c}±0.07
	OM_2	0.06^{bc}±0.05	0.02^{a}±0.01	0.40^{b}±0.35
	OM_2 + AL_2	0.10^{ab}±0.04	0.03^{a}±0.02	0.14^{c}±0.03
		8 WAP		
Phaseolus vulgaris	Control	0.17^{ab}±0.04	0.04^{a}±0.01	0.36^{bc}±0.09
	AL_1	0.10^{ab}±0.04	0.01^{a}±0.02	0.18^{c}±0.05
	AL_2	0.08^{bc}±0.07	0.00^{a}±0.00	0.24^{c}±0.17
	OM_1	0.23^{ab}±0.04	0.05^{a}±0.02	0.16^{c}±0.08
	OM_1+ AL_1	0.17^{ab}±0.07	0.03^{a}±0.06	0.16^{c}±0.15
	OM_2	0.08^{bc}±0.02	0.06^{a}±0.02	0.13^{c}±0.03
	OM_2 + AL_2	0.23^{ab}±0.09	0.02^{a}±0.03	0.38^{bc}±0.22
Vigna aconitifolia	Control	0.13^{ab}±0.06	0.02^{a}±0.04	0.31^{bc}±0.19
	AL_1	0.10^{ab}±0.27	0.01^{a}±0.02	0.32^{bc}±0.23
	AL_2	0.20^{ab}±0.04	0.01^{a}±0.02	0.19^{c}±0.11
	OM_1	0.23^{ab}±0.23	0.03^{a}±0.03	0.42^{b}±0.27
	OM_1+ AL_1	0.36^{a}±0.05	0.01^{a}±0.01	0.79^{a}±0.14
	OM_2	0.11^{ab}±0.09	0.04^{a}±0.02	0.31^{bc}±0.01
	OM_2 + AL_2	0.19^{ab}±0.09	0.05^{a}±0.04	0.27^{c}±0.07

Mean values with different superscripts along the same vertical axis are significantly different from each other ($p<0.05$). WAP – Weeks after planting, Control - 0g, AL1 -Agricultural lime , OM1 -Organic manure, AL2 -Agricultural lime, OM1 - Organic manure, OM1 + AL1 – 50 g organic manure + 50 g Agricultural Lime, OM2 - Organic manure, OM2 + AL2 – 100 g organic manure + 100 g Agricultural Lime. AK: Akamkpa, CM: Calabar Municipality, OD: Odukpani

TABLE 4

Effect of agricultural lime and organic manure on relative growth rate of leaf dry weight ($gg^{-1}wk^{-1}$) of *Phaseolus vulgaris* and *Vigna aconitifolia*

		Locations		
Plant species	Treatment	AK	CM	OD
Phaseolus vulgaris	Control	$0.17^{a}\pm0.03$	$0.18^{a}\pm0.02$	$0.13^{b}\pm0.01$
	AL_1	$0.17^{a}\pm0.02$	$0.00^{a}\pm0.00$	$0.36^{ab}\pm0.02$
	AL_2	$0.19^{a}\pm0.\ 06$	$0.00^{a}\pm0.00$	$0.12^{b}\pm0.01$
	OM_1	$0.20^{a}\pm0.04$	$0.26^{a}\pm0.03$	$0.41^{b}\pm0.03$
	OM_1+AL_1	$0.19^{a}\pm0.05$	$0.24^{a}\pm0.04$	$0.37^{ab}\pm0.02$
	OM_2	$0.17^{a}\pm0.01$	$0.22^{a}\pm0.01$	$0.50^{a}\pm0.01$
	$OM_2 + AL_2$	$0.21^{a}\pm0.07$	$0.23^{a}\pm0.03$	$0.13^{b}\pm0.04$
Vigna aconitifolia	Control	$0.02^{a}\pm0.00$	$0.10^{a}\pm0.01$	$0.20^{b}\pm0.02$
	AL_1	$0.13^{a}\pm0.04$	$0.17^{a}\pm0.02$	$0.19^{b}\pm0.04$
	AL_2	$0.15^{a}\pm0.07$	$0.30^{a}\pm0.04$	$0.17^{b}\pm0.03$
	OM_1	$0.12^{a}\pm0.01$	$0.19^{a}\pm0.02$	$0.20^{b}\pm0.01$
	OM_1+AL_1	$0.06^{a}\pm0.01$	$0.24^{a}\pm0.01$	$0.16^{b}\pm0.02$
	OM_2	$0.23^{a}\pm0.06$	$0.18^{a}\pm0.02$	$0.19^{b}\pm0.01$
	$OM_2 + AL_2$	$0.19^{a}\pm0.04$	$0.21^{a}\pm0.04$	$0.18^{b}\pm0.03$

Mean values with different superscripts along the same vertical axis are significantly different from each other ($p<0.05$).Control - 0g, AL1 -Agricultural lime , OM1 -Organic manure, AL2 -Agricultural lime, OM1 - Organic manure, OM1 + AL1 – 50 g organic manure + 50 g Agricultural Lime, OM2 - Organic manure, OM2 + AL2 – 100 g organic manure + 100 g Agricultural Lime. AK: Akamkpa, CM: Calabar Municipality, OD: Odukpani

TABLE 5

Effect of agricultural lime and organic manure on relative growth rate of stem dry weight ($gg^{-1}wk^{-1}$) of *Phaseolus vulgaris* and *Vigna aconitifolia*

		Locations		
Plant species	Treatment	AK	CM	OD
Phaseolus vulgaris	Control	$0.15^{a}\pm0.02$	$0.11^{ef}\pm0.01$	$0.12^{a}\pm0.01$
	AL_1	$0.17^{a}\pm0.09$	$0.21^{cde}\pm0.03$	$0.12^{a}\pm0.01$
	AL_2	$0.19^{a}\pm0.\ 04$	0.00f±0.00	$0.11^{a}\pm0.02$
	OM_1	$0.14^{a}\pm0.01$	$0.23^{cde}\pm0.02$	$0.11^{a}\pm0.02$
	OM_1+AL_1	$0.19^{a}\pm0.01$	$0.36^{ab}\pm0.04$	$0.14^{a}\pm0.03$
	OM_2	$0.17^{a}\pm0.02$	$0.22^{ab}\pm0.06$	$0.12^{a}\pm0.02$
	$OM_2 + AL_2$	$0.21^{a}\pm0.03$	$0.48^{a}\pm0.01$	$0.14^{a}\pm0.03$
Vigna aconitifolia	Control	$0.10^{a}\pm0.01$	$0.15^{de}\pm0.03$	$0.12^{a}\pm0.04$
	AL_1	$0.13^{a}\pm0.02$	$0.23^{de}\pm0.02$	$0.19^{a}\pm0.06$
	AL_2	$0.15^{a}\pm0.04$	$0.33^{bc}\pm0.01$	$0.14^{a}\pm0.04$
	OM_1	$0.17^{a}\pm0.02$	$0.24^{bcd}\pm0.03$	$0.16^{a}\pm0.01$
	OM_1+AL_1	$0.16^{a}\pm0.04$	$0.00^{f}\pm0.00$	$0.13^{a}\pm0.02$
	OM_2	$0.19^{a}\pm0.01$	$0.23^{de}\pm0.01$	$0.15^{a}\pm0.01$
	$OM_2 + AL_2$	$0.19^{a}\pm0.01$	$0.16^{de}\pm0.02$	$0.15^{a}\pm0.01$

Mean values with different superscripts along the same vertical axis are significantly different from each other ($p<0.05$).Control - 0g, AL1 -Agricultural lime , OM1 -Organic manure, AL2 -Agricultural lime, OM1 - Organic manure, OM1 + AL1 – 50 g organic manure + 50 g Agricultural Lime, OM2 - Organic manure, OM2 + AL2 – 100 g organic manure + 100 g Agricultural Lime. AK: Akamkpa, CM: Calabar Municipality, OD: Odukpani

TABLE 6

Effect of agricultural lime and organic manure on relative growth rate of root dry weight ($gg^{-1}wk^{-1}$) of *Phaseolus vulgaris* and *Vigna aconitifolia*

		Locations		
Plant species	Treatment	AK	CM	OD
Phaseolus vulgaris	Control	$0.15^{b}\pm0.04$	$0.14^{b}\pm0.01$	$0.12^{a}\pm0.01$
	AL_1	$0.19^{b}\pm0.02$	$0.19^{ab}\pm0.02$	$0.15^{a}\pm0.03$
	AL_2	$0.20^{ab}\pm0.01$	$0.00^{b}\pm0.00$	$0.23^{a}\pm0.06$
	OM_1	$0.23^{ab}\pm0.03$	$0.21^{ab}\pm0.02$	$0.14^{a}\pm0.01$
	OM_1+AL_1	$0.24^{ab}\pm0.01$	$0.23^{ab}\pm0.01$	$0.11^{a}\pm0.03$
	OM_2	$0.25^{ab}\pm0.02$	$0.22^{ab}\pm0.01$	$0.18^{a}\pm0.02$
	$OM_2 + AL_2$	$0.23^{ab}\pm0.01$	$0.12^{b}\pm0.02$	$0.12^{a}\pm0.04$
Vigna aconitifolia	Control	$0.15^{b}\pm0.01$	$0.15^{b}\pm0.03$	$0.16^{a}\pm0.04$
	AL_1	$0.21^{ab}\pm0.06$	$0.19^{ab}\pm0.04$	$0.20^{a}\pm0.03$
	AL_2	$0.07^{b}\pm0.02$	$0.00^{b}\pm0.00$	$0.26^{a}\pm0.02$
	OM_1	$0.23^{ab}\pm0.04$	$0.24^{a}\pm0.02$	$0.15^{a}\pm0.03$
	OM_1+AL_1	$0.18^{b}\pm0.06$	$0.00^{b}\pm0.00$	$0.20^{a}\pm0.05$
	OM_2	$0.38^{a}\pm0.07$	$0.16^{b}\pm0.04$	$0.17^{a}\pm0.03$
	$OM_2 + AL_2$	$0.12^{b}\pm0.01$	$0.21^{ab}\pm0.06$	$0.11^{a}\pm0.04$

Mean values with different superscripts along the same vertical axis are significantly different from each other ($p<0.05$).Control - 0g, AL1 -Agricultural lime , OM1 -Organic manure, AL2 -Agricultural lime, OM1 - Organic manure, OM1 + AL1 – 50 g organic manure + 50 g Agricultural Lime, OM2 - Organic manure, OM2 + AL2 – 100 g organic manure + 100 g Agricultural Lime. AK: Akamkpa, CM: Calabar Municipality, OD: Odukpani

TABLE 7

Effect of agricultural lime and organic manure on net assimilation rate (ggcm^{-2}wk^{-1}) of *Phaseolus vulgaris* and *Vigna aconitifolia*

		4 WAP			6 WAP			8 WAP		
Plant species	Treatment	AK	CM	OD	AK	CM	OD	AK	CM	OD
Phaseolus vulgaris	Control	0.0001^{d}±0.0001	0.0008^{a}±0.0001	0.0005^{d}±0.0003	0.0012^{d}±0.0001	0.0082^{a}±0.0001	0.0001^{c}±0.0001	0.0010^{b}±0.0001	0.00^{a}±0.00	0.0038^{c}±0.0001
	AL$_1$	0.0006^{d}±0.0002	0.0007^{a}±0.0001	0.0004^{d}±0.0002	0.0006^{d}±0.0001	0.0007^{a}±0.0001	0.0361^{b}±0.0001	0.0006^{a}±0.0001	0.00^{a}±0.00	0.0004^{d}±0.0001
	AL$_2$	0.0005^{d}±0.0002	0.00^{a}±0.00	0.0004^{d}±0.0002	0.0012^{d}±0.0001	0.00^{a}±0.00	0.0360^{b}±0.01	0.0031^{a}±0.0001	0.00^{a}±0.00	0.0072^{a}±0.0003
	OM$_1$	0.0031^{c}±0.0001	0.0008^{a}±0.0001	0.0016^{c}±0.0001	0.0041^{c}±0.0002	0.0006^{a}±0.0001	0.0392^{a}±0.01	0.0032^{a}±0.0001	0.00^{a}±0.00	0.0010^{c}±0.0001
	OM$_1$+ AL$_1$	0.0039^{c}±0.0002	0.0007^{a}±0.0001	0.0032^{b}±0.0003	0.0044^{c}±0.0002	0.0008^{a}±0.0001	0.4019^{a}±0.02	0.0041^{a}±0.0002	0.00^{a}±0.00	0.0061^{a}±0.0003
	OM$_2$	0.0032c±0.0001	0.0008^{a}±0.0001	0.0036^{b}±0.0002	0.0038^{c}±0.0001	0.0007^{a}±0.0001	0.411^{a}±0.02	0.0032^{a}±0.0001	0.00^{a}±0.00	0.0066^{a}±0.0003
	OM$_2$ + AL$_2$	0.0057^{b}±0.0003	0.00^{a}±0.00	0.0018^{c}±0.0001	0.0061^{c}±0.0003	0.00^{a}±0.00	0.319^{a}±0.0001	0.0062^{a}±0.0003	0.00^{a}±0.00	0.0057^{b}±0.0003
Vigna aconitifolia	Control	0.0006^{d}±0.0003	0.0018^{a}±0.0001	0.0002^{d}±0.0003	0.0022^{d}±0.0003	0.0016^{a}±0.0001	0.0041^{c}±0.0001	0.0006^{b}±0.0003	0.00^{a}±0.00	0.0031^{c}±0.0001
	AL$_1$	0.0023^{c}±0.0001	0.0016^{a}±0.0001	0.0031^{c}±0.0002	0.0031^{c}±0.0001	0.0015^{a}±0.0001	0.0032^{c}±0.0001	0.0051^{a}±0.0003	0.00^{a}±0.00	0.0033^{c}±0.0001
	AL$_2$	0.0025^{c}±0.0001	0.0018^{a}±0.0001	0.0036^{c}±0.0001	0.0032^{c}±0.0001	0.0020^{a}±0.0001	0.0031^{c}±0.0001	0.0031^{a}±0.0002	0.00^{a}±0.00	0.0023^{c}±0.0001
	OM$_1$	0.0006^{d}±0.0001	0.0019^{a}±0.0001	0.0036^{c}±0.0001	0.0061^{c}±0.0003	0.0015^{a}±0.0001	0.0051^{c}±0.0002	0.0032^{a}±0.0002	0.00^{a}±0.00	0.0022^{c}±0.0001
	OM$_1$+ AL$_1$	0.0201^{c}±0.0001	0.0018^{a}±0.0001	0.0021^{c}±0.0001	0.0051^{c}±0.0003	0.0018^{a}±0.0001	0.0044^{c}±0.0003	0.0031^{a}±0.0002	0.00^{a}±0.00	0.0013^{c}±0.0001
	OM$_2$	0.0447^{a}±0.0002	0.0021^{a}±0.0001	0.0561^{a}±0.0003	0.0621^{a}±0.0003	0.0018^{a}±0.0001	0.0511^{b}±0.0003	0.0041^{a}±0.0002	0.00^{a}±0.00	0.0026^{c}±0.0001
	OM$_2$ + AL$_2$	0.0057^{b}±0.0003	0.0019^{a}±0.0001	0.0311^{b}±0.0001	0.0314^{b}±0.0002	0.0019^{a}±0.0001	0.0481^{b}±0.0003	0.0042^{a}±0.0002	0.00^{a}±0.00	0.0031^{c}±0.0001

Mean values with different superscripts along the same vertical axis are significantly different from each other ($p<0.05$). WAP – Weeks after planting, Control - 0g, AL$_1$ -Agricultural lime , OM$_1$ -Organic manure, AL$_2$ -Agricultural lime, OM$_1$ - Organic manure, OM$_1$ + AL$_1$ – 50% organic manure + 50% Agricultural Lime, OM$_2$ - Organic manure, OM$_2$ + AL$_2$ – 100% organic manure + 100% Agricultural Lime. AK: Akamkpa, CM: Calabar Municipality, OD: Odukpani

Discussion

Growth is of paramount ecological importance for plant and it is highly influenced by soil nutrients. A good determination of growth rate in any plant will help in strategizing measures for its improvement through adoption of reliable agronomic tools. Results of this study revealed that *V. aconitifolia* grown on organic manure singly and in combination produced consistently higher leaf, stem and root dry weights than *P. vulgaris*. The controls had lower dry matter yield while the dry matter of plants grown on soil from Calabar Municipality in all the treatments were low and statistically similar. This may suggests that soil from Calabar Municipality lack the necessary nutrients needed for plant growth and yield. The findings corroborates with the works of Badar and Qureshi (2012) and Badar *et al.* (2015) which reported increase in shoot and root dry weight of cowpea following biofertilizer application. This positive growth response of *P. vulgaris and V. aconitoflia* following application of agricultural lime and organic manure may be related to the ability of the treatments to increase the soil pH resulting in availability of nutrients for optimum plant growth.

Relative growth rate is the exponential increase in the size relative to the size of plant present at the start of a given time interval. It is a prominent indicator of plant productivity related to environmental stress and disturbance regimes. The relative growth rate of leaf dry weight was higher in *P. vulgaris* grown on Odukpani soil treated with organic manure and combination of organic manure and agricultural lime. The relative growth rate of stem and root dry weight also showed higher values with organic manure especially with 200 g organic manure. The implication is that, organic manure may have the potential to enhance the growth rate of plant singly and in combination with agricultural lime. It has been earlier remarked by Shipley (2002) that the variation in the net assimilation rate is the main determinant of the relative growth rate. This may be the reason for the similar pattern of results obtained for net assimilation rate and relative growth rate.

Net assimilation rate is defined as the increase in plant dry weight per unit leaf area per unit time. It is a function of the photosynthetic effectiveness of leaves of a plant and its leafiness. It is a complex physico-chemical variables associated with photosynthetic and respiration rates (Komings, 1989). In the present study, the net assimilation rates were consistently higher in plants treated with organic manure and combination of organic manure with agricultural lime. The earlier report of Effa *et al.* (2019) reveled that organic manure and a combination of organic manure and agricultural lime promoted faster growth rates in *P. vulgaris* and *V. aconitifolia*. It is therefore possible that plants with faster growth rate may likely have higher net assimilation rate as seen in the present study. This result is in line with an early finding by Li *et al.* (2016), plants with faster-growth had high net assimilation rates and plants with high assimilation rates always grew faster.

Conclusion

Explicitly, the results reveled that organic manure is more influential in contributing to the relative growth of *P. vulgaris* and *V. aconitifolia*. Interestingly, a combined effect of the two manures promoted higher growth rates and net assimilation rates than single effect.

Competing interest

Authors have declared that no competing interests exist.

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