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Soil Amendments and Their Residual Influences on Jute Mallow Performance

Tajudeen B. Akinrinola[1*], Samuel A. Adegoke[2], Olajire Fagbola[2]
[1]Department of Crop and Horticultural Sciences, University of Ibadan, Ibadan.
[2]Department of Soil Resources Management, University of Ibadan, Ibadan.
*Corresponding Author's Email: tb.akinrinola@gmail.com

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ABSTRACT

Continuous cultivation of *Corchorus Olitorius* L. results in the rapid depletion of soil nutrients (particularly, soils with limited available phosphorus). Applying inorganic fertilizers to improve yield are expensive and reduces yield quality, thus, an alternative source of phosphorus is required. Therefore, this study was carried out to evaluate the response of jute mallow to different soil amendments. In a repeated 3 x 4 factorial field experiment, three varieties of jute mallow (Amugbadu, Eleti-eku and Oniyaya) and four soil amendments [Arbuscular Mycorrhizal Fungi (AMF) inoculation, Ogun Rock Phosphate (RP), AMF+RP and control] were evaluated in a randomized complete block designs with 5 replications. Subsequently,the residual effects were assessed. The RP was applied at 30 kg/ha P2O5. Each plot size was 2 m × 2 m and one stand/plant was planted at a spacing of 0.50 m × 0.20 m. Data on growth parameters were analyzed using analysis of variance at p <0.05. The results showed that RP significantly improved jute mallow plant height, while AMF+RP significantly enhanced total leaf area, fresh and dry shoot weights compared to the other treatments. The AMF+RP treatment significantly increased dry shoot weight at 15.90 and 13.70 g/plant in Eleti-eku and Oniyaya, respectively, while Amugbadu (10.98 g/plant) was better with RP application. The trend observed under the residual influences of soil amendments, variety and their interaction were similar to the responses observed under the main cropping in the two periods of planting. Therefore, the Eleti-eku variety of jute mallow treated with AMF+RP was recommended.

Keywords: Jute mallow, Ogun rock phosphate, Arbuscular mycorrhizal fungi, dry shoot weight

INTRODUCTION

Corchorus Olitorius L. commonly known as jute mallow, is an important leafy mucilaginous vegetable cultivated in many tropical countries of Africa, Middle East and Asia. The stems are also a good source of jute, but it is considered to be inferior to the fibre obtained from *C. capsularis* (Mahapatra1, *et al.,* 2009). The proximate analysis of the leaves showed that it contains 84.49% moisture, 12.40% ash, 6.64% lipid, 29.18% protein, 27.88% carbohydrate, 20.86% fibre, 27.71 mg/100 g β- carotene (Traoré *et al.,* 2017). Also, the leaf contains approximately 345 kcal energy; 2105 mg Ca, 24.6 mg Fe, 2.6 mg Zn, 0.9 μg Thiamine, 3.10 μg Riboflavin; 690 μg Folate and 468 mg Vitamin C per 100 g of leaves dry matter (Grubben *et al.,* 2014). These indicates the significant importance of the vegetable in meeting or improving the daily nutrient requirement of rural households in Africa. The leaves of the vegetable are eaten either fresh or as powdered dried leaves. The vegetable is ususlly grown on the market garden sites and home gardens. However, the supply of this vegetable to urban residents is mainly from smallholder farmers, who see it as an economic opportunity to improve their living conditions (Schreinemachers *et al.*, 2018).

The increase in the production of the vegetable in response to demands by the increasing population has compelled the smallholder farmers to continually cultivate the small available land which has resulted to reduction in yield due to soil nutrient mining. The vegetable yield (1,566 kg/ha) in Nigeria is far below average compared to South East Asia, where the yield ranged from 6-10 t/ha per crop cycle as a result of production intensification and modernization (Garjila *et al.,* 2017; Traoré *et al.,* 2017). For continued maintenance or a boost in the yield of the vegetable, there is need for the application of soil amendments to soils highly depleted of available phosphorus among other nutrients. In addition, to avoid further degradation of soil P status resulting from production intensification of the vegetable, there is need for the addition of P to improve vegetable production. The P inputs are required for optimum plant vegetables growth and adequate food production. Subsequently, the intake of adequate amounts of P through food, such as jute mallow promotes normal metabolic processes for healthy animals and human beings (Zapata and Roy, 2004). The challenges of decline in soil fertility on small-holder farmers' field have necessitated the need for fertilizer use. The required quantity of manure or other organic sources of fertilizer to get a reasonable yield is mostly unavailable (Ayeni and Oye, 2017). Consequently, the recommendation of water-soluble P fertilizers (superphosphates) is often suggested to ameliorate deficiencies in P. Applying mineral P in jute mallow cultivation has been reported to improve yield (Olaniyi and Ajibola, 2008). However, the application of mineral fertilizer is expensive and the quality of the vegetable is lowered (Olaokiki and Adejumo, 2021). Hence, the need to explore alternate sources of P without the adverse effect of mineral fertilizers on vegetable quality for yield sustainability or improvement. When locally available, application of rock phosphate has proved to be an economically and agronomically reliable alternative to the more expensive superphosphate fertilizers (Zapata and Roy, 2004).

Studies have indicated that not all phosphate rock sources are suitable for direct application (Zapata and Roy, 2004). There are many deposits of phosphate rock in Nigeria with the potential of reducing the importation on phosphate fertilizer (Obaje *et al.,* 2013). Reports showed that though the phosphate rocks available in Nigeria are considered potent in improving crop performance, they are of lower grades compared to SSP as crop response to their application are low (Fayiga and Obigbesan, 2017). The relative effectiveness of rock phosphate application in P availability for enhancing crop performance has been reported to be lower compared to SSP (Akande *et al.,* 2010). However, inoculation with vesicular arbuscular mycorrhizae among other means (such as phosphate solubilizing micro-organisms, phospho-composting, and P-efficient plant genotypes) can be used to improve their agronomic effectiveness (Bagyaraj *et al.,* 2015; Habibzadeh, 2015). In Nigeria, there is limited information on the use of the readily available phosphate rock and the application of AMF for enhanced P uptake and the performance of leafy vegetables such as jute mallow. This study was therefore aimed at evaluating the performance of jute mallow under the influence of Ogun rock phosphate combined with arbuscular mycorrhizal fungi inoculation as a means of obtaining a more sustainable source of P for the production of the crop in Nigeria.

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Materials and Methods

The experiments were conducted in 2017 at the research field of the Department of Crop and Horticultural Sciences, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria (with the respective coordinates of 7˚27′05.5″N 3˚53′31.0″E and 7˚27′05.2″N 3˚53′47.1″E for the first and second cropping fields). Soil samples were collected from the fields at the depth of 0-15 cm for routine analysis to determine the soil chemical and physical properties. Also, the microbial population prior to the commencement of the study (from the 2 cropping fields) was determined and is as shown in Table 1.

Table 1: Pre-cropping physical, Chemical and microbiological properties of the experimental soil

Parameters	1st cropping	2nd cropping
pH (H2O,1:1)	6.59	6.4
Organic Carbon (g/kg)	7.0	1.17
Nitrogen (g/kg)	1	1.68
Available P (mg/kg)	0.67	0.5
Exchangeable Cations (Cmol/kg)		
Ca	0.43	2.93
Mg	0.33	0.51
K	0.06	0.12
Na	0.5	0,41
Exchangeable Acidity	0.1	0,08
Micronutrient (mg/Kg)		
Mn	86.44	56.6
Fe	80	10.4
Cu	1.54	4.0
Zn	1.17	9.5
Particle size		
Sand	858	788
Clay	70	100
Silt	72	120
Textural class (USDA)	Loamy sand	Sandy loam
Fungal Count (x10^5 cfu/g soil)	2.02	1.98
Bacterial Count (x10^5 cfu/g soil)	5.09	5.11

Experimental Design and Treatments

The studies were carried out in 3 x 4 factorial experiments comprising three varieties of *Corchorus olitorius*, (Amugbadu, Eleti-eku and Oniyaya) and four soil amendments (control, Arbuscular Mycorrhizal Fungi inoculation (AMF), Rock Phosphate (RP) and AMF+RP). The pot and field experiments were laid out in completely randomized design, and randomized complete block design, respectively with five replications. The RP was applied at 30 kg/ha P_2O_5. The experiments consisted of 60 treatment units.

The three varieties of *Corchorus olitorius* namely, the Amugbadu, Eleti-eku and Oniyaya were sourced from National Horticultural Research institute (NIHORT), Ibadan. Arbuscular mycorrhizal fungi (*Glumus mossea*) inoculum used was collected from the Soil Microbiology Laboratory, Department of Soil Resources management, University of Ibadan, Ibadan while the rock phosphate (Ogun rock phosphate) fertilizer used was obtained from the Department of Crop and Horticultural Sciences, University of Ibadan, Ibadan. Each plot size was 2 m × 2 m with 0.50 m between blocks. The spacing was 0.50 m × 0.20 m. The plots that required AMF inoculation according to the treatment were inoculated with 5 g of AMF, while RP was placed about 10 cm away from the transplanted seedling at 5 cm depth at the rate of 30 P_2O_5 kg/ha.

Nursery and field management

Jute mallow seeds were soaked in hot water to break the dormancy before planting as recommended by Schippers *et al.* (2000). The three varieties were planted in separate nursery trays containing sterilized soils for a period of three weeks before they were transplanted unto the field. Weeding was done manually at 4 weeks after transplanting. The residual effects of the soil amendments applications were evaluated after the first and second cropping periods.

Data Collection

The experiment was terminated at 8 weeks after transplanting in each of the cropping cycles. The plant height was measured from the base of the plant to the tip using a metre rule, while leaf area was determined using the equation reported by Peksen (2007).

$LA = 0.919 + 0.682LW$

where L = length of the leaf, W = breadth the leaf.

At harvest, the fresh weight of plants harvested and the dry shoot weights were measured (using Camry digital scale model EK5350) after the samples had been oven dried at 65 ˚C for 4 days. Mycorrhizal root colonization was determined by the method described by Phillips and Hayman (1970).

The second cropping was sited adjacent to the first cropping, while the residual effects of the treatments were evaluated immediately after each of the cropping.

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using the Genstat discovery statistical package, Edition 4. Significant means were separated at 5% level of probability as described by Gomez and Gomez (1984).

RESULTS

Response of jute mallow vegetative parameters to soil amendments, variety their interactive effects

The application of RP significantly improved jute mallow plant height compared to the other treatments in the first and second cropping periods (Table 2). The application of soil amendments did not significantly improve the total leaf area observed in both cropping periods. However, the plants treated with AMF+RP and the control had the highest and lowest total leaf areas, respectively, in the two cropping periods. Significantly higher fresh shoot weight was observed in the plants treated with AMF+RP compared to the plants treated with RP, AMF inoculation and control in the two cropping periods. The mean highest and lowest values of fresh shoot weight were observed in the plants treated with AMF+RP and the control, respectively. Soil amendments had no significant effect on improving jute mallow dry shoot weight in the first cropping, however, the highest value was observed in the AMF inoculated plants. In the second cropping, significant increase in dry shoot weight was observed in the AMF+RP treated plants compared to RP or AMF which were significantly higher than the control.

Significant increase in plant height was observed in the Amugbadu variety compared to Eleti-eku, while the Oniyaya variety was not significantly different from the other varieties in the two croppings. The three varieties of jute mallow did not differ significantly with respect to total leaf area observed in the two cropping, but varieties Eleti-eku and Amugbadu had the highest and lowest total leaf area, respectively. Variety Oniyaya and Eleti-eku had the highest fresh shoot weight in the first and second cropping periods, respectively, while the lowest in the two croppings were observed in the Amugbadu variety. The mean values of fresh shoot weight indicated that Oniyaya had the highest fresh shoot weight, while Amugbadu had the lowest with no significant difference observed among the varieties. Variety Eleti-eku had the highest dry shoot weight, while Amugbadu had lowest, with no significant difference observed among the treatments in the first cropping. In the second cropping however, dry shoot weight was significantly higher in the Eleti-eku and Oniyaya compared to Amugbadu. Similar trend was observed in the mean values with the highest dry shoot weight observed in Eleti-eku.

The interaction of soil amendments and varieties indicated significant effect among treatments in the two cropping (Table 3). The response of Amugbadu to RP resulted in the highest plant height, while Eleti-eku inoculated with AMF had the lowest plant height in both cropping periods. The Eleti-eku variety of jute mallow treated with AMF+RP gave the highest total leaf area and the lowest observed in the control treatments of Amugbadu in the two cropping of jute mallow. In the first and second cropping, the respective Amugbadu and Eleti-eku varieties treated with AMF+RP inoculation had significantly higher fresh shoot weight compared to the other treatments except Eleti-eku and Oniyaya treated with AMF+RP in the first cropping. The mean values of fresh shoot weight in both cropping periods revealed that Eleti-eku with AMF+RP treatment had significantly increased value compared to the other treatments excluding Oniyaya with AMF+RP treatment. The interactions between soil amendments and jute mallow varieties showed significant variations in dry shoot weight among the treatment combinations in the first and second croppings. The highest dry shoot weight was observed in the treatments involving RP with Amugbadu and AMF+RP inoculation with Eleti-eku in the first and second cropping, respectively. However, the mean dry shoot weight revealed that AMF+RP inoculation with Eleti-eku had significantly higher values compared to the other treatments, except for AMF+RP with Oniyaya treatment.

Table 2: Effect of soil amendments on the performances of jute mallow varieties in the two cropping periods

Treatments	Plant height (cm) 1	2	mean	Total leaf area (cm^2) 1	2	mean	Fresh shoot weight (g) 1	2	mean	Dry shoot weight (g) 1	2	mean
Soil amendments												
Control	64.13	57.53	60.83	354.94	269.10	312.02	18.14	10.61	14.37	4.87	5.40	5.14
AMF	62.53	56.48	59.51	437.52	329.23	383.38	19.90	27.16	23.53	5.01	16.06	10.53
RP	73.40	67.61	70.51	430.15	320.38	375.26	19.05	39.99	29.52	4.97	17.66	11.31
AMF+RP	64.13	57.13	60.63	485.26	393.87	439.57	22.10	55.78	38.94	4.97	21.24	13.11
LSD	6.99	6.86	6.88	ns	ns	ns	1.54	11.02	5.41	ns	3.19	1.57
Variety												
Amugbadu	69.75	63.65	66.70	365.40	273.81	319.61	19.27	28.49	23.88	4.86	12.00	8.43
Eleti-eku	62.40	56.06	59.23	467.22	370.45	418.84	19.55	36.04	27.80	5.06	16.75	10.90
Oniyaya	66.00	59.36	62.68	448.28	340.17	394.23	20.57	35.63	28.10	4.95	16.52	10.73
LSD	6.06	5.94	5.96	ns	ns	ns	ns	ns	ns	ns	2.76	1.36

AMF = Arbuscular mycorrhizal fungi; RP = Rock phosphate; 1 = 1st cropping; 2 = 2nd cropping; ns = Not significant at 5% level of probability

Table 3: Soil amendments and variety interaction effects on the performances of jute mallow in two cropping periods

Interactions		Plant height (cm) 1	2	Mean	Total leaf area (cm^2) 1	2	mean	Fresh shoot weight (g) 1	2	mean	Dry shoot weight (g) 1	2	mean
Control	x Amugbadu	64.40b	58.20b	61.30b	313.47	231.88	272.68	17.17d	12.48d	14.82d	4.46c	5.12f	4.79f
	x Eleti-eku	66.40b	58.80bc	62.60b	423.19	342.86	383.03	18.12cd	9.94d	14.03d	5.04a-c	5.81f	5.42f
	x Oniyaya	61.60bc	55.60b	58.60bc	328.17	232.56	280.36	19.13cd	9.41d	14.27d	5.12a-c	5.28f	5.20f
AMF	x Amugbadu	68.20b	62.20b	65.20b	340.58	269.91	305.24	18.27cd	19.69d	18.98d	4.96a-c	11.51e	8.24e
	x Eleti-eku	50.80c	45.40c	48.10c	503.75	352.69	428.22	20.75a-c	21.39cd	21.07cd	4.98a-c	19.37b-d	12.17b-d
	x Oniyaya	68.60b	61.84b	65.22b	468.24	365.09	416.66	20.67a-c	40.41bc	30.54b	5.10a-c	17.29b-d	11.19b-d
RP	x Amugbadu	81.00a	75.60a	78.30a	413.79	307.23	360.51	18.51cd	40.95b	29.73bc	5.32a	16.63c-e	10.98cd
	x Eleti-eku	70.60ab	65.84ab	68.22ab	380.77	288.05	334.41	18.70cd	39.40bc	29.05bc	4.98a-c	15.26de	10.12c-e
	x Oniyaya	68.60b	61.40b	65.00b	495.88	365.86	430.87	19.95bc	39.61bc	29.78bc	4.60bc	21.07a-c	12.84bc
AMF+RP	x Amugbadu	65.40b	58.60b	62.00b	393.77	286.23	340.00	23.13a	40.82b	31.98b	4.70a-c	14.73de	9.72de
	x Eleti-eku	61.80bc	54.20bc	58.00bc	561.17	498.21	529.69	20.64a-c	73.44a	47.04a	5.24ab	26.55a	15.90a
	x Oniyaya	65.20b	58.60b	61.90b	500.85	397.18	449.02	22.54ab	53.09b	37.81ab	4.98a-c	22.43ab	13.70ab
SE		4.25	4.17	4.18	22.92	21.82	20.08	0.93	6.69	3.29	0.24	1.94	0.95

AMF = Arbuscular mycorrhizal fungi; RP = Rock phosphate; 1 = 1st cropping; 2 = 2nd cropping; In a column, figures with same letter(s) or without letters do not differ significantly, while figures with dissimilar letter differ significantly according to DMRT; ns = Non-significant at 5% level of probability

Mycorrhizal root infection of jute mallow as influenced by soil amendments, variety their interactive effects

The effects of soil amendments on the mycorrhizal infection count observed in jute mallow under two cropping periods and their mean values were as shown in Figure 1. The results indicated that the least and highest mycorrhizal infection counts were observed in the control and AMF+RP treatments, respectively during the observations. Significantly higher mycorrhizal infection counts were observed in plants inoculated with AMF and AMF+RP compared to the control and RP treatments in the first cropping, while AMF+RP treatment significantly improved mycorrhizal infection counts compared to AMF and RP treatments, which significantly increased mycorrhizal infection counts than the control in the second cropping period. The mean values of the cropping periods indicated that mycorrhizal infection counts among the treatments were in the order of AMF+RP > AMF > RP > control.

The varieties did not differ significantly with respect to mycorrhizal infection counts observed in the first cropping, but in the second cropping, Eleti-eku had significantly higher mycorrhizal infection counts than the other varieties (Figure 2). The mean values indicted that the varieties did not differ significantly, though Eleti-eku and Amugbadu had the highest and lowest mycorrhizal infection counts, respectively.

The interactive effects of soil amendments and jute mallow varieties on mycorrhizal infection count revealed varying levels of significance, with the highest values in both cropping periods observed in the AMF+RP treatment with Eleti-eku (Figure 3). Also, higher mycorrhizal infection counts with respect to other varieties were observed under AMF+RP amendment in both cropping periods.

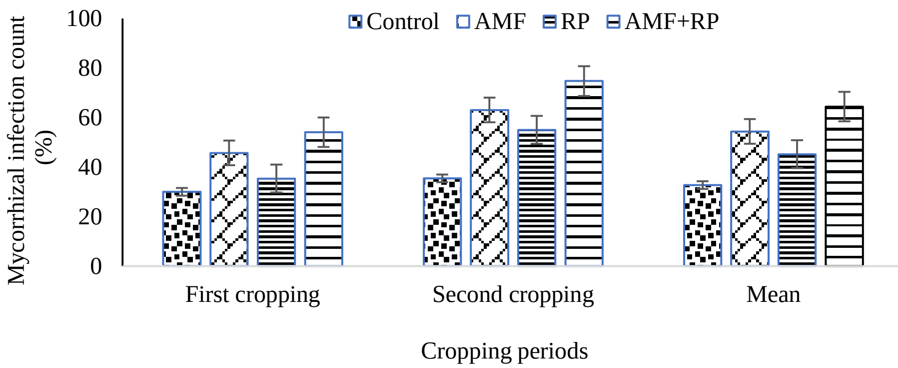

Figure 1: Effects of soil amendments on the mycorrhizal infection count under two cropping periods

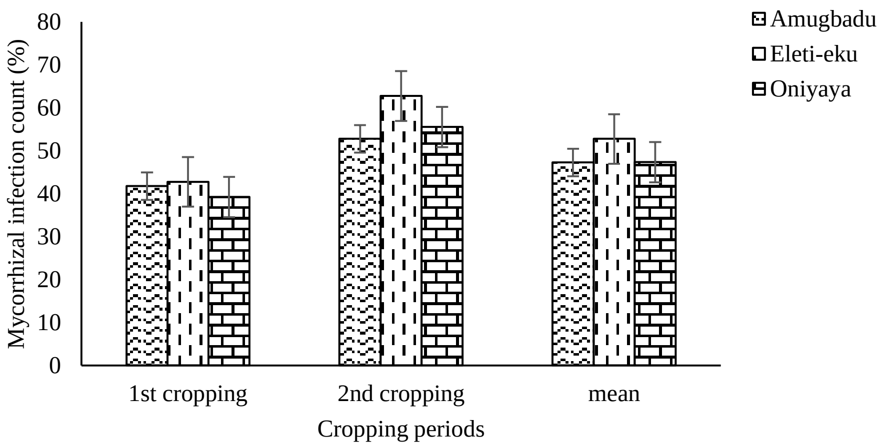

Figure 2: Varietal response of jute mallow to mycorrhizal infection count under two cropping periods

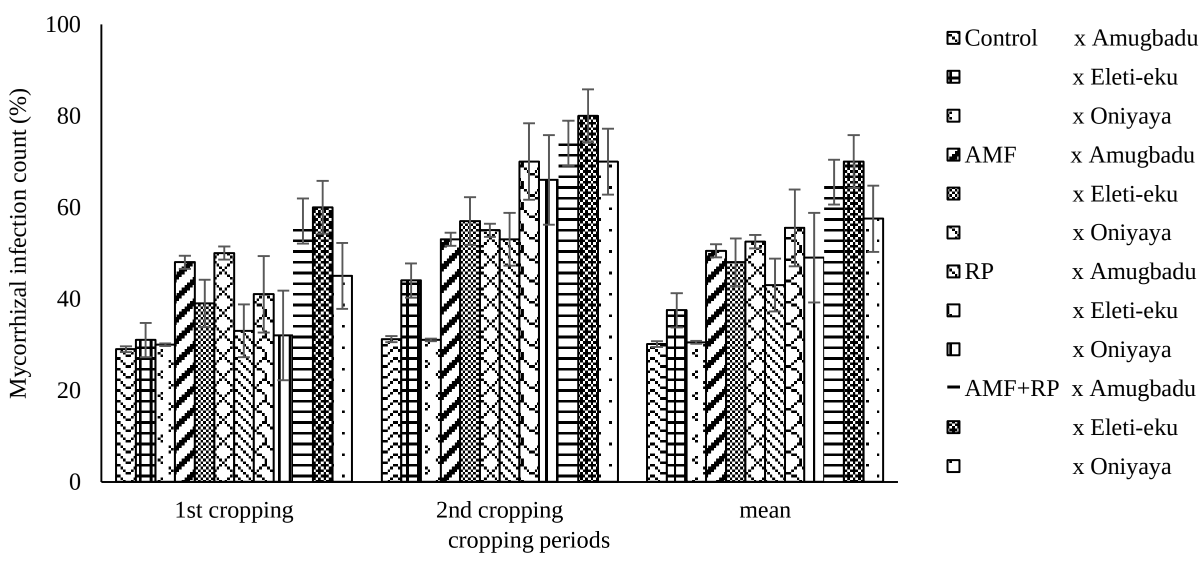

Figure 3: Soil amendments and varietal response of jute mallow on mycorrhizal infection count under two cropping periods

The influence of soil amendments residual on the performances of the different varieties of jute mallow

The evaluation of the residual effects of soil amendments, jute mallow cropping and their interactions indicated that a varying degree of significance was observed among the treatments (Table 4). The effect of soil amendments on plant height did not vary significantly among the treatments in the first residual cropping. In the second residual cropping, AMF inoculation significantly increased jute mallow plant height compared to the control. However, the mean values indicated that the residual effects of soil amendments on jute mallow plant height did not differ significantly. The residual effects of RP, AMF and AMF+RP treatments sufficiently improved total leaf area in both croppings of jute mallow. Similarly, the fresh shoot weights observed showed that the residual of RP, AMF and AMF+RP treatments significantly improved jute mallow fresh shoot weight compared to the control in both residual croppings, except for the AMF inoculated plants in the second cropping. The mean values revealed that fresh shoot weight was significantly improved by the residual effects of RP, AMF and AMF+RP treatments compared with the control. The response of jute mallow to the residual effects of soil amendments revealed that AMF+RP and RP treatments significantly increased dry shoot weight of jute mallow compared to the other treatments in both cropping, except the application RP in the second cropping. In the mean value of the two croppings, the residual effects of the treatments revealed significant differences in the dry shoot weight among treatments, with the highest observed in the AMF+RP treatment.

Among the varieties, Oniyaya and Amugbadu had the highest plant height at the first and second cropping, with no significant difference observed (Table 4). Similarly, the mean values did not differ significantly. Also, the total leaf area observed did not differ significantly among the treatments in both cropping and the mean values of the two cropping. However, variety Eleti-eku had the highest value. Furthermore, the highest fresh shoot weight was observed in variety Eleti-eku with no significant difference among the varieties in the two cropping and the mean values of the different cropping periods. The results observed for dry shoot weight revealed significantly higher difference in varieties Eleti-eku and Oniyaya compared to Amugbadu in both cropping periods and the mean of the two periods.

The Eleti-eku variety of jute mallow inoculated with AMF had significantly higher plant height compared to the RP treated, but was similar to the other treatments in both cropping periods (Table 5). The total leaf area differs with varying level of significance among the treatments. Varieties Oniyaya and Eleti-eku treated with AMF inoculation and RP were highest in the first and second cropping, respectively. The mean of the two-cropping indicated that Oniyaya variety with AMF inoculation had the highest total leaf area in the residual planting. Similar trend as observed for total leaf area was recorded with respect to fresh shoot weight in the residual of first and second cropping periods. However, even though the treatment involving Oniyaya variety with AMF inoculation had significantly higher mean value from the cropping, it was similar to the mean values observed for Eleti-eku and Amugbadu treated with RP. The treatment involving the application of AMF+RP under Eleti-eku variety had significant increase in dry shoot weight compared to other treatments in both cropping periods, except for AMF+RP with Oniyaya treatment in the first cropping.

Table 4: Residual effect of soil amendments and variety on the performances of jute mallow under two cropping periods

Treatments	Plant height (cm)		mean	Total leaf area (cm^2)		mean	Fresh shoot weight (g)		mean	Dry shoot weight (g)		mean
	1	2		1	2		1	2		1	2	
Soil amendments												
Control	43.27	30.87	37.07	513.61	267.24	390.43	17.37	23.48	20.43	4.91	5.14	5.02
AMF	44.20	38.47	41.33	1169.04	462.02	815.53	41.37	36.39	38.88	10.42	10.49	10.46
RP	41.87	31.93	36.90	1122.52	488.54	805.54	36.45	42.73	39.59	12.82	11.36	12.09
AMF+RP	41.6	32.33	36.97	1092.29	502.21	797.25	35.85	40.69	38.27	14.11	13.11	13.61
LSD	ns	6.79	ns	191.14	100.10	108.52	15.82	15.29	12.13	1.63	1.57	1.42
Variety												
Amugbadu	41.25	33.65	37.45	954.27	424.13	689.20	33.14	31.53	32.33	9.17	8.40	8.78
Eleti-eku	42.65	33.15	37.90	978.91	454.64	716.78	34.54	39.88	37.21	11.21	10.90	11.06
Oniyaya	44.30	33.40	38.85	989.91	411.25	700.58	30.62	36.06	33.34	11.32	10.77	11.05
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.41	1.36	1.23

AMF = Arbuscular mycorrhizal fungi; RP = Rock phosphate; 1 = 1st cropping; 2 = 2nd cropping; In a column, figures with same letter(s) or without letters do not differ significantly, while figures with dissimilar letter differ significantly according to DMRT; ns = Non-significant at 5% level of probability

Table 5: Residual effect of soil amendments on the performances of different varieties of jute mallow and their interactions under two cropping periods

Treatments		Plant height (cm)		mean	Total leaf area (cm^2)		mean	Fresh shoot weight (g)		mean	Dry shoot weight (g)		mean
		1	2		1	2		1	2		1	2	
Control	x Amugbadu	41.40ab	31.40ab	36.40a-c	441.56d	162.84e	302.20f	13.12d	12.50c	12.81d	4.49f	4.79f	4.64f
	x Eleti-eku	44.20ab	30.20b	37.20a-c	448.44d	274.56de	361.50ef	16.66cd	24.17bc	20.42cd	5.42ef	5.42ef	5.42f
	x Oniyaya	44.20ab	31.00ab	37.60a-c	650.83cd	364.32cd	507.58de	22.34b-d	33.78a-c	28.06a-d	4.80f	5.20f	5.00f
AMF	x Amugbadu	40.60ab	37.60ab	39.10a-c	1062.02ab	491.38a-c	776.70a-c	32.62a-d	29.81a-c	31.22a-d	8.12de	8.10de	8.11e
	x Eleti-eku	48.60a	42.00a	45.30a	1063.50ab	445.88a-d	754.69a-c	35.16a-d	39.75ab	37.46a-c	10.92cd	12.17bc	11.55cd
	x Oniyaya	43.40ab	35.80ab	39.60a-c	1381.59a	448.81a-c	915.20a	56.34a	39.60ab	47.97a	12.23bc	11.19bc	11.71cd
RP	x Amugbadu	47.80a	35.60ab	41.70ab	1223.93ab	539.55ab	881.74ab	49.54ab	43.74ab	46.64a	12.90bc	10.98bc	11.94b-d
	x Eleti-eku	34.80b	27.60b	31.20c	1200.91ab	557.52a	879.22ab	42.44a-c	52.83a	47.64a	12.04bc	10.12cd	11.08cd
	x Oniyaya	43.00ab	32.60ab	37.80a-c	942.73bc	368.56b-d	655.65cd	17.38cd	31.62a-c	24.50b-d	13.54bc	12.99b	13.26bc
AMF+RP	x Amugbadu	35.20b	30.00b	32.60bc	1089.58ab	502.74a-c	796.16a-c	37.26a-d	40.05ab	38.66a-c	11.16c	9.72cd	10.44de
	x Eleti-eku	43.00ab	32.80ab	37.90a-c	1202.80ab	540.58ab	871.69ab	43.88a-c	42.78ab	43.33ab	16.47a	15.90a	16.18a
	x Oniyaya	46.60ab	34.20ab	40.40a-c	984.50b	463.29a-c	723.90bc	26.40b-d	39.24ab	32.82a-d	14.71ab	13.70ab	14.21ab
SE		4.27	4.12	3.54	96.15	60.82	65.94	9.61	9.29	7.37	0.99	0.95	0.86

AMF = Arbuscular mycorrhizal fungi; RP = Rock phosphate; 1 = 1st cropping; 2 = 2nd cropping; In a column, figures with same letter(s) or without letters do not differ significantly, while figures with dissimilar letter differ significantly according to DMRT; ns = Non-significant at 5% level of probability

DISCUSSION

Crop performance is generally affected by the nutrient status of the soil. With adequate supply of nutrient essential for crop development, crop growth and yield are optimum to support the growing population demand for food (James and McDonald, 1994; Oguntegbe *et al.*, 2018). The nutrient status observed in the two soils used in the study indicated insufficiency in the nutrients, therefore, not likely to support satisfactory crop growth. Furthermore, the soil from the first cropping showed lower status in nutrient (particularly with respect N content), poorer texture and lower in microbial count relative to the soil used in the second cropping. The increase in the availability of the nutrient and soil qualities encouraged the normal physiological processes of the crop, thereby improving the crop performance in the second soil compared to the first cropping soil of lower nutrient status (James and McDonald, 1994). This was evident in the differences in the performances of the jute mallow planted during the two cropping periods.

The increase in the performance of jute mallow through the application of soil amendments showed the importance of adequate P nutrition for jute mallow in the two cropping periods. The impact of AMF treatment in improving jute mallow in all parameters observed compared to the control was in support of Nwangburuka *et al.* (2012) report that the application of AMF inoculation improved jute mallow performance. These may be attributed to the influence of AMF inoculation in aiding the root system to acquire the P that is not within the reach of the plant. Hence, inoculation with AMF resulted in greater fungal-acquired nutrient thereby improving the plant growth and development of jute mallow. This according to Shao et al. (2018) can be achieved through the increase in total root length and volume resulting in the expansion of the absorption range of roots and improve the ability of plants to absorb essential plant nutrients required for enhanced growth. The importance of AMF root infection in increasing jute mallow performance has also been reported by Makinde et al. (2011) and Mahbub et al. (2016). The enhanced performance in plant height, fresh and dry shoot weights observed with respect to RP application compared to the influence of AMF inoculation on jute mallow suggest that the applied RP is accompanied by other soil nutrients and not just the actual P for which it serves as a source. This claim was supported by Akinrinde and Obigbesan (2006) and Fayiga and Obigbesan (2017) reported on the composition of Ogun RP, that it contains plant nutrients required for enhanced plant growth. The accumulation of nutrients in the plant through the application of RP increased fresh and dry shoot dry weight and plant height of jute mallow. The growth increases in jute mallow as a result of combined application of AMF+RP on all the parameters observed indicated the synergistic effects of AMF and RP application. This finding supports Wahid et al. (2018) report that the growth of maize can be enhanced by inoculation with AMF in the presence of tricalcium phosphate better than their sole applications. They attributed the increase in maize plant growth to the conveyance of more P and other nutrients (mainly diffusion limited nutrients) contained in the RP towards the plant root for absorption thereby resulting in enhanced P solubility and bioavailability for increased growth (Bagyaraj et al 2015; Wahid *et al.*, 2018). The variations in the effectiveness of the treatments were evident in the mycorrhizal root infection observed. The combined inoculation of AMF with RP (AMF+RP) stimulated more mycorrhizal root infection compared to either AMF inoculation or RP application alone. The increased availability of P in the soil stimulates the proliferation of mycorrhizal fungi as evident in the results, therefore increased the ability of the crop to assess more nutrients for development. This study support Mohsin *et al.* (2020) claim that mineralization of organic P fractions into inorganic for improve crop yield through P input was achieved by the improved microbial activities in the soil.

There were differences in the growth performance of the varieties used in the study. The variation in the vegetative parameters may be attributed to some differences in the traits of individual variety. These results can be explained in line with Denton *et al.* (2014) and Ngomuo *et al.* (2017) reported, that jute mallow varies in their morphological traits. They reported that the mean height of jute mallow to be 78.08 cm, which was in the range of plant height observed in the study. However, the plant height was highest in Amugbadu variety, while Eleti-eku had the highest total leaf area and dry shoot weight and Oniyaya with the highest fresh shoot weight. The better response observed under the Eleti-eku could be attributed to the increase in mycorrhizal infection in the root system of the variety.

The interactions between the soil amendments and jute mallow varieties indicated that when these varieties when grown under low nutrient P (as indicated in the soil properties), the genetic variation with reference to nutrient efficiency is minimal across the observed parameters. However, with increase in P supply, the variability increases. This was evident in the results with no appreciable difference observed in the varieties under the control, while higher differences were observed with the application of soil amendments. Amugbadu responded better with respect to plant height under RP application. However, the similarity in shoot fresh weight in

Amugbadu and Eleti-eku under RP and differences in dry shoot weight signify that Amugbadu encourages higher moisture content than Eleti-eku. combined application of AMF+RP was better with respect to dry shoot weight for Eleti-eku. The ability of the AMF+RP treatment to perform better than the other treatments can be linked to the enhanced influence of AMF+RP treatment on mycorrhizal root infection observed under the treatment. This finding was in support of Fernández *et al*. (2016) report that the addition of biological inoculant favoured the P use efficiency of rock phosphate within short duration after application in pasture.

The residual effects from jute mallow and soil amendments that did not confer any appreciable difference among AMF inoculation, RP and AMF+RP treatments, except with the control signified equal response to the treatments. However, while the other parameters were similar, AMF+RP had better dry shoot weight, implying that the treatment could support a more sustainable production of jute mallow. This could be the result of making available leftover nutrients from the initial cropping that may be locked up in the root system of the previous crop. This was in accordance the report of Ibrikci et al. (2005) that residual phosphorus will be made slowly available to the rooting zone of the succeeding crops. The similarities in performances due to the residual effect of cropping with different variety showed the degree to which the previous crop had mined the soil nutrients or the ability of the varieties to perform under low nutrient status. Varieties Eleti-eku and Oniyaya proved better than Amugbadu under low nutrient status in the residual. The trend observed under residual cropping were similar to the responses observed under the previous cropping. The pattern of the results indicated the beneficial effect of combining AMF with RP in improving crop performance. Despite the improved performances in the treatments with AMF+RP with Eleti-eku, it still performed better in the residual cropping. This was an indication that not all the applied P was utilised during the initial cropping, Part of the fixed P from the applied RP must have been made available aside from the other nutrient with the aid of AMF present in the soil. The finding supports Ibrikci et al. (2005) and Mohsin et al. (2020) reports that residual fixed P are made available for crop uptake with the presence of microbial organisms such as AMF root infection.

CONCLUSION

The application of phosphate fertilizer aimed at maintaining the level of the nutrient in the optimum range for crop yield increase and improved quality have received a wide attention However, attempts to enhance the performance of the leafy vegetable crop through the application of Ogun rock phosphate (that is abundantly available in the country) with biofertilizer is a welcomed development in order to meet the increase in food demand. The application of Ogun rock phosphate proved to be suitable for improving jute mallow performance. Similarly, root infection with arbuscular mycorrhizal inoculation further enhanced the response of jute mallow to Ogun rock phosphate application. Combining arbuscular mycorrhizal inoculation with Ogun rock phosphate increased arbuscular mycorrhizal colonization in jute mallow root system. The varieties of jute mallow planted were similar in their performances, however, arbuscular mycorrhizal colonization was higher in Eleti-eku than in the other varieties. The combined application of arbuscular mycorrhizal inoculation with Ogun rock phosphate under Eleti-eku proved to be superior to the sole application of arbuscular mycorrhizal inoculation or Ogun rock phosphate. However, the performances of varieties Amugbadu and Oniyaya were respectively better under Ogun rock phosphate and arbuscular mycorrhizal inoculation applications. The residual effect of arbuscular mycorrhizal inoculation with Ogun rock phosphate combined, improved jute mallow performance with respect to other soil amendments. Hence, the combined application of arbuscular mycorrhizal inoculation with Ogun rock phosphate was recommended for a sustainable production of jute mallow.

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