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Accession × Treatment Interaction, Variability and Correlation Studies of Pepper (*Capsicum* spp.) under the Influence of Arbuscular Mycorrhiza Fungus (*Glomus clarum*) and Cow Dung

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Abstract

The field experiment was conducted in the Department of Botany, University of Ibadan, Nigeria between September to December 2012. Four accessions of pepper (*Capsicum* spp.), obtained from Moor plantation in Ibadan and LUTH (Lagos University Teaching Hospital) vegetable garden, Idi-Araba Lagos were evaluated to investigate the morpho-agronomic variability and interaction of accession × treatment × days after transplant in treatment combinations of arbuscular mycorrhizal fungus (*Glomus clarum*) and cowdung. The experiment was a 4 × 4 factorial arrangement laid out in a randomized complete block design with three replications. The combined analysis of variance showed significant accession, treatment, days after transplant, and accession × treatment interactive effect for most of the growth characters at $P < 0.01$ and $P < 0.05$. The result also showed significant difference in yield related traits of fruits for pepper accessions. The number of leaves per plant was significant and positively associated with plant height ($r = 0.516$; $P < 0.05$), and highly significant and positively correlated with the number of branches ($r = 0.836$; $P < 0.01$), but

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negative and non-significantly related with stem girth. *Glomus clarum* treated plants responded significantly with higher growth and yield. It suggested that *G. clarum* treatment had higher potential in influencing crop yield compared to cowdung and untreated plants. This study further explored the relationship between *G. clarum* and cow dung in pepper production.

Keywords

***Capsicum*; *Glomus clarum*; Cowdung; Variability; Yield**

1. Introduction

Pepper (*Capsicum* spp.) is a diploid of polypod origin with (2n = 4x =52), a member of the family Solanaceae that consists of approximately 22 wild species and 5 domesticated species, *Capsicum pubescens*, *C. annum*, *C. chinense*, *C. frutescens* and *C.baccatum*. It is native to the Americans for thousands of years and now cultivated worldwide [1]. The fruit of *Capsicum* plant has a variety of names depending on places and types. They are commonly called chilli pepper, red or green pepper and sweet pepper [1]. Chilli types are usually classified by fruit characteristics based on pungency, colour, shape, flavour, size, and their uses [2]. In Nigeria, particularly in the South western part where this study was carried out, the common varieties of pepper include Atarodo, Tatase, Sombo and Bawa depending on the type, size and taste. Although, wild ancestors of *Capsicum* species evolved in Boliva and southern Brazil, probably long before human habitation [3].

C. annum can be difficult to differentiate from the cultivated *C. chinense* (the hottest pepper) and *C. fruitcens* (Tabasco pepper) due to their morphological features which overlap. These three species that share the same ancestral gene pool are sometimes called the annum-chinense-frutiscens complex. The varieties and cultivars of *C. annum* are classified based on their fruit shapes. *C. annum* Linn comprises of chilli, sweet pepper, red pepper, guinea pepper and green pepper. It is an annual, herbaceous plant with a densely branched stem with 0.5 - 1.5 m in height. *C. annum* is regarded as the most variable species of the genus and bigger with less pungent fruit than *C. frutescens*. It produces leaf throughout the year, flowers from July to September and the seed ripe from August to October. *C. frutescens* Linn is also known as the red pepper, paprika, cayenne pepper, bird pepper or African pepper. The plant is perennial, growing to 1 m by 0.6 m and it flowers from August to September. The fruits vary greatly in shape, size, pungency and colour depending on the species and varieties. The fruits of the African pepper are usually 1.5 - 3 cm long although some varieties bear elongated fruits 8 - 12 cm in length. The fruits are bright red when ripe and exceptionally pungent [4] [5]. The plant can grow in acidic, neutral and basic soils, but cannot grow in the shade.

Some of the members of the *Capsicum* have nutritional and medicinal value commercially and domestically. *Capsicum* fruit can be eaten raw or cooked in stew. They are suitable for stuffing with filling such as cheese, meat and rice. Dried peppers may be reconstituted whole, or processed into flakes or powder. The fruits of African pepper are much appreciated spices in food, as the condiment, vegetables, cooked in sauces, dried and powdered for preservation and used as flavouring [6]. Sweet pepper fruits used as medicines in Africa have been reported to be carcascidal and molluscidal due to the presence of active essential oil [7] The leaves are cooked as potherb, while the growing plants are used as insects repellent [8]. The fruit of hot pungent cultivars has rubefacient, irritant, anti-haemorrhoidal, antihelminthic, antiseptic, diaphorectic, digestive, sialogogue, carminative, antibacterial potentials and also analgesic for headache, muscular pains, rheumatism, conjunctivitis treatment of wounds and swollen feet due to high vitamin C content [8]-[11]. It is taken internally in the treatment of the cold stage of fevers, debility in convalescence or old age, varicose veins, asthma, cough, cold, heart pains, stimulate circulation, aid the removal of waste products, gastro intestinal detoxifiers, food preservatives and increasing the flow of nutrients to the tissues and digestive problems. Externally, it is used in the treatment of sprains, unbroken chilblains, neuralgia, pleurisy and bubonic plague [11].

Mycorrhiza fungi are specialised group of fungi that aid plant growth by increasing metabolic activities and accelerating transfer of nutrients from the fungus to the plants [12]-[14]. Mycorrhiza also alters hormone production especially in the root tissue which they occupy [15].

The interaction of mycorrhiza with the roots of host plants has a greater tolerance to heavy metals, root

pathogens, drought, excess salt, high soil temperature, saline soils, adverse soil, pH and transplant shock than non mycorrhizal plants [16]-[18]. [19] also confirmes that infection by mycorrhiza increases stomata conductance and root conductivity as a result of increased surface area of mycorrhiza hyphae. However, the potential of *Glomus clarum* as biocontrol agent and enhancement of growth and yield performance in maize, beans and some horticultural crops have also been reported [20]-[23]. Manures are good soil conditioners that save nitrogen. They are of different sources and could be obtained from cattles, horses, poultry (chicken), sheep and human. They tend to initiate different conformational changes in growth of different plants varieties. Nutrients found in the manure help to build and maintain soil fertility and its economic value is calculated from the availability of nitrogen (N), phosphorus (P) and potassium (K). Manure must be applied to land carefully in a calculated amount because excess nutrients can harm crop growth, contaminate the soil, cause surface and ground water pollution. In plant breeding, correlation coefficient measures the mutual relationship between various characters and determines the component on which selection can be based for genetic improvement in yield [24]. Significant positive and negative correlation coefficient of the various pairs of characters including yield related components and other morphological parts in some crops has been reported [25] [26]. The objectives of this study are to determine the interaction of Accession × Treatment × Days after transplant and to investigate some morphological traits and yield related components in pepper accessions as influenced by cowdung and *G. clarum.*

2. Materials and Methods

2.1. Study Location and Source of Experimental Materials

A field experiment was conducted at the nursery farm of the Department of Botany University of Ibadan between September to December 2012. The site was situated in the rainforest vegetation at lat 7˚ 7N and long 3˚ 36E. The soil is characterised by low organic matter and nitrogen [27]. The cowdung and AMF were collected from Lagos cattle market and the Department of Botany, University of Ibadan respectively. Four accessions of pepper (habanero chilli pepper (ata rodo), cherry pepper (bawa), bell pepper (tatase) and thai pepper) were obtained from Institute of Agricultural Research and Training, Moor plantation in Ibadan and Lagos University Teaching Hospital vegetable gardens, Idi-Araba Lagos, Nigeria (**Table 1**).

2.2. Experimental Design and Treatments

A randomised complete block design was laid out in a factorial combination of Accession × treatment × days after transplant with three replications. The treatments were; Cowdung (5 g), Cowdung (2.5 g) + AMF (2.5 g), while the untreated plant served as control (0 g).

2.3. Planting Procedure

Top soil (0 - 5 cm) used in this experiment was collected behind the nursery in the department of botany. The soil was sieved to remove particles and plant debris before sterilization in a soil sterilizing machine for 4hrs. The soil was allowed to cool before filling in polythene pot arranged in accordance to the treatments. Accessions of *C. annum* and *C. frutiscen* were raised in the nursery and transplanted to polypot three weeks after sowing. No pest infestation was observed and all agronomic practices were duly carried out. Growth and yield parameters taken include ; Plant height, stem girth, number of leaves per plant, leaf length, leaf width, number of branches per plant, fruit weight and fruit length and fruit width.

Table 1. Sources and accessions of pepper.

Accession	Pepper kind	Source	Area/state
Habanero pepper (Ata Rodo)	Hot	Moor plantation	Ibadan
Cherry pepper (Bawa)	Sweet	Moor plantation	Ibadan
Bell pepper (Tatase)	Sweet	Moor plantation	Ibadan
Thai pepper (Ata ibile)	Hot	Idi-Araba Garden	Lagos

2.4. Statistical Analysis

The data were subjected to the combined analysis to estimate the variance of accession × treatment × Days after transplant interaction according to the statistical procedure described by SAS(1992) using SAS 2.0, while treatment means were separated with Duncan multiple range test at 5% level of probability. Pearson correlation coefficient was also done to establish relationship among the evaluated characters

3. Result and Discussions

The number of leaves per plant ranged from 4.10 - 4.96 with highest mean value of 4.96 for AMF only and Cowdung + AMF were significantly different from cowdung treated plants and control (**Table 2**). This suggests that application of cowdung only inhibits the production of leaves. Thus, only AMF or combination of AMF and Cowdung could enhance leaf production. The plant height which ranged from 2.58 - 3.74 had the highest value for AMF plant, but significantly different from other treatments (**Table 2**). The growth increase could be attributed to mycorrhizal interactions which enhanced plant to acquire nutrients in accordance with the findings of [28] [29] Similar result was also observed for leaf length, leaf width, stem girth and number of branches, but cowdung + AMF treated plants produced the highest values of 1.34 cm and 3.24 cm for leaf width and leaf length respectively (**Table 2**).

The mean performance of Tatase for most agronomic characters was the best and significantly ($P < 0.05$) different from other accessions, while Rodo and Ata-Ibile were similar in performance for most of the characters (**Table 3**).

The result of **Table 4** shows that the mean performance of pepper accessions for most of the characters at 12 days after transplant (DAT) was the best, while 3DAT was the least. Significant differences ($P < 0.05$) were shown for plant height, number of leaves per plant, and leaf width at 3, 6, 9 and 12 DAT, while the performance of pepper for these characters; leaf length, stem girth and number of branches were not significantly different at 9 and 12 DAT (**Table 4**).

Result of **Table 5** shows that there is significant difference in yield related characters of fruits for all the pepper accessions. Bawa pepper produced the best fruit weight, fruit length and fruit width followed by Tatase, while Ata ibile was the least. The yield performance from the harvested pepper accessions are also shown in **Figure 1**.

Table 2. Mean Performance of pepper under different treatment for six agronomic characters.

Treatment	Plant height (cm)	Number of Leaves	Leaf width (cm)	Leaf Length (cm)	Stem girth (cm)	Number of branches per plant
Control	2.58^{d}	4.50^{c}	0.54^{d}	1.87^{d}	1.00^{b}	4.15^{a}
Cowdung only	2.97^{c}	4.10^{d}	$O.87^{c}$	2.63^{b}	0.92^{c}	4.13^{a}
Cowdung + AMF	3.47^{b}	4.96^{a}	1.34^{a}	3.24^{a}	0.94^{c}	4.19^{a}
AMF only	3.74^{a}	4.96^{a}	1.19^{b}	2.73^{b}	1.18^{a}	4.15^{a}
Error	0.027	0.021	0.030	0.040	0.017	0.029

Mean with the same value in the same column are not significantly different $P > 0.05$.

Table 3. Mean Performance for different accession of pepper for six agronomic characters.

Accession	Plant height (cm)	Number of Leaves per plant	Leaf width (cm)	Leaf Length (cm)	Stem girth (cm)	Number of branches per plant
Tatase	3.25^{a}	4.58^{b}	1.03^{a}	2.63^{a}	1.03^{a}	4.15^{a}
Bawa	3.14^{b}	4.60^{b}	0.89^{b}	2.59^{a}	0.96^{b}	4.13^{c}
Rodo	3.17^{b}	4.67^{a}	1.03^{a}	2.66^{a}	1.03^{a}	4.19^{a}
Ibile	3.19^{ab}	4.67^{a}	1.00^{a}	2.58^{a}	1.01^{b}	4.15^{a}
Error	0.027	0.021	0.030	0.040	0.017	0.029

Mean with the same value in the same column are not significantly different $P > 0.05$.

Table 4. Mean performance of pepper accession under different days after transplanting for six agronomic characters.

Days after transplant	Plant height (cm)	Number of Leaf per plant	Leaf width (cm)	Leaf length (cm)	Stem girth (cm)	Number of branches per plant
3DAT	2.92^{d}	2.96^{d}	0.73^{d}	2.33^{c}	1.07^{a}	1.77^{a}
6DAT	3.13^{c}	4.81^{c}	0.92^{c}	2.58^{b}	0.98^{b}	4.83^{b}
9DAT	3.27^{b}	5.00^{b}	1.05^{b}	2.74^{a}	0.97^{b}	5.00^{a}
12DAT	3.43^{a}	5.75^{a}	1.24^{a}	2.80^{a}	1.00^{b}	5.00^{a}
Error	0.027	0.021	0.030	0.040	0.017	0.029

Mean with the same value in the same column are not significantly different P > 0.05. DAT = Days after Transplant.

Table 5. Mean performance of pepper accessions for yield of fruit related characters.

Accession	Fruit weight (g)	Fruit Length (cm)	Fruit width (cm)
Ata Rodo	1.45c	3.10c	1.85c
Bawa	3.20a	8.50a	2.00b
Tatashe	2.45b	5.75b	3.00a
Ata Ibile	1.30cd	2.50d	1.70cd

Mean with the same value in the same column are not significantly different P > 0.05.

Habanero pepper (ata rodo) Bell pepper (tatase)

Thai pepper (Ata Ibile) Cherry pepper (bawa)

Figure 1. The yield performance of harvested pepper accessions.

The mean interactive effects of Accession × Treatment × Days After Transplant (A × T × D) is shown in **Table 6**. The accession, treatment, days after transplant and AxT interaction were highly significant (P < 0.01) for most of the agronomic characters, but non- significant for leaf length and number of branches at accession level, number of branches at treatment level and stem girth at accession × treatment level of interaction (**Table 6**). At the level of accession × DAT interaction, the leaf width and the stem girth were significant P < 0.05), number of leaves and number of branches per plant were highly significant (P < 0.01), while plant height and

leaf length were non-significant. This indicates that plant height and leaf length were not determined by the interaction of accession × DAT. Again, only leaf width was non-significant at treatment × DAT interaction. This shows that this interaction is a determinant factor for the performance of other agronomic characters apart from leaf width. Whereas, at the second level of accession × treatment × DAT, the number of leaves per plant stem girth, and number of branches were highly significant and determined by this interaction (**Table 6**).

Result of **Table 7** shows the correlation coefficient among five agronomic characters in pepper. The number of leaves per plant is positive and significantly correlated with plant height ($r = 0.516$; $P < 0.05$), leaf width ($r = 0.523$), leaf length ($r = 0.374$) and highly significant with number of branches ($r = 0.836$; $P < 0.01$), but negative and non-significant with stem girth ($r = -0.103$).

There were positive associations and highly significant relationship between the height of the plant and relationship between the height of the plant and leaf width ($r = 0.757$; $P < 0.01$), leaf length($r = 0.705$), stem girth ($r = 0.192$) and number of branches($r = 0.311$). The leaf width is positive and significantly related with leaf length ($r = 0.737$; $P < 0.05$) and number of branches, but negative and non-significant for stem girth ($r = -0.021$).The leaf length is positive and significantly associated with number of branches ($r = 0.278$; $P < 0.05$), but negative and non-significant to stem girth. Only stem girth was negatively associated and significantly related with number of branches with $r = -0.278$ at $P < 0.05$ (**Table 7**).

The performance of genotype is influenced by its genetic constituents, treatment and their interactions. The detection of significant Genotype × Treatment × Days after transplant interaction indicates variability responses with respect to accession and treatment as earlier observed by [30] [31]. The size of interaction components, relative to that of the genetic component is relevant because it directs breeders to the most likely treatment of a successful cultivar. The large interaction relative to the accessions, suggest to breeders to search for the genotype to meet the specific requirements of the treatment. The positive interrelationship between these characters

Table 6. Mean squares effects of Accessions × Treatments × Days after Transplant of six agronomic characters of pepper.

Source of variance	Degree of freedom	Plant height	Number of leaves per plant	Leaf width	Leaf length	Stem girth	Number of branches
Accessions	3	0.11^{*}	0.09^{**}	0.19^{**}	0.07^{ns}	0.05^{**}	0.03^{ns}
Treatment	3	12.73^{**}	8.14^{**}	6.20^{**}	1539^{**}	0.66^{**}	0.03^{ns}
DAT	3	2.31^{**}	67.51^{**}	2.17^{**}	2.07^{**}	0.10^{**}	121.16^{**}
Accession × treatment	9	0.05^{*}	0.07^{**}	0.18^{**}	0.20^{*}	0.02^{ns}	0.15^{**}
Accession × DAT	9	0.02^{ns}	0.12^{**}	0.06^{*}	0.05^{ns}	0.03^{*}	0.27^{**}
Treatment × DAT	9	0.06^{*}	3.51^{**}	0.02^{ns}	0.15^{*}	0.09^{*}	0.33^{**}
Accessions × treatment × DAT	27	0.01^{ns}	0.06^{**}	0.04^{ns}	0.06^{ns}	0.04^{**}	0.11^{**}
Error	128	0.04					
Total	192						
Corrected Total	191						
CV (%)							

$^{*}P < 0.05$ = significant, $^{**}P < 0.01$ = highly significant, ns = non-significant, DAT = Days after Transplant; Mean with the same value in the same column are not significantly different at $P > 0.05$.

Table 7. Correlation coefficient among the characters of pepper accessions.

	Plant height	Number of leaves per plant	Leaf width (cm)	Leaf length (cm)	Stem girth (cm)
Leaf number	0.516^{*}				
Leaf width (cm)	0.757^{**}	0.523^{**}			
Leaf length (cm)	0.705^{**}	0.374^{*}	0.737^{**}		
Stem girth (cm)	0.192^{*}	-0.103^{ns}	-0.021^{ns}	-0.087^{ns}	
Number of branches	0.311^{*}	0.836^{**}	0.359^{*}	0.278^{*}	-0.278^{*}

$^{*}P < 0.05$ = significant, $^{**}P < 0.01$ = highly significant, ns = non-significant; Mean with the same value in the same column are not significantly different at $P > 0.05$.

leaf number, leaf width, leaf length, stem girth and number of branches indicate that these attributes are the most important component for yield selection and direct selection for these characters as similarly confirmed by [26].

Since yield is a complex polygenic quantitative characters greatly influenced by treatment, accession and their interactions, therefore yield and yield components evaluation in breeding should not be based on selection of superior genotypes only, but the treatment and characters associated could also be considered as similarly observed by [30] [32]

4. Conclusion

It could then be inferred from this study that *G. clarum* could be an alternative to persistent application of inorganic fertilizer which had adverse effect on the soil crumb and pH in Nigeria soil.

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