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Impact of Organic Soil Amendments on the Physical Characteristics and Yield Components of Potato (*Solanum tuberosum* L.) in the Highlands of Cameroon

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Abstract: Potato production has outstripped and even surpassed that of other staple food crops in Africa in terms of yieldsand cultivated areas. These increases are still very low looking at the existing potentialsdue to a number of restraining factors including high cost of inputs, low productivity of soils and the late blight disease severity. A field experiment was conducted in the Western Highlands of Cameroon to study the effects of *Calliandra calothyrsus*, sterilizedcompost, non sterilized compost and mineral fertilizers (NPK 11:11:22) on physical characteristics, yield components and late blight disease severity of potato (*Solanum tuberosum*). A two factorial treatment combination made up of fertilization schemes and sanitary measures were laid out in a Randomized Complete Block Design (RCBD) with four replicates and 10 treatments. Data collected were subjected to a Multivariate ANOVA and means separated with the *Dunnett t*-test with *Calliandra calothyrsus* considered as the main treatment. The results revealed that mineral fertilizers and *Calliandra calothyrsus* treatments significantly augmented potato plants stem diameter, plant height and plant vigor. Plants treated to mineral fertilizer and C*alliandra calothyrsus* showed statistically similar vigor but were significantly more vigorous that those in the other treatments. The mineral fertilizers and *Calliandra calothyrsus* treatments consistently gave significant higher total and marketable yields, despite the fact that late blight severity was high in the two treatments. The correlation matrix showed that total yield had significant and positive correlation with stem diameter (r = 0.74), plant height (r = 0.61), plant vigor (r = 0.61) and marketable yield (r = 0.99) and negative correlation (r = - 37) with late blight severity. From this study, *Calliandra calothyrsus* as organic manure was effective in improving potato production and is therefore recommended to potato farmers provided appropriate fungicide treatment is applied.

Key words: C*alliandra calothyrsus* · Late blight severity · Organic manure · Mineral fertilizers · Compost

INTRODUCTION

Food security has become a crucial issue during the past decades due to climate change, land degradation, increasing population and frequent occurrence of natural disasters such as drought. Consequently, increasingfood supply has been consistently considered among the priorities in the world's development agenda. In terms of nutritional value, adaptability to diverse environments and yield potential, potato (*Solanum tuberosum* L.) is a preferred crop, especially in developing countries where production has been on the increase over the last 10 years [1]. Its production has outstripped and even surpassed that of other staple food crops in Africa in terms of total production and cultivated areas and from all indications, this trend is expected to continue. Its present potential derives from its status as a cheap and plentiful crop that grows in a wide variety of climates and ecosystems of altitude above 1000 meters [2, 3]. Potato contributes in improving house hold food security andrepresents anadditionalsource of income for farmers who are able to market tubers surpluses and processed products [4].

Inthe Western Highlands of Cameroon, it is estimated that over 200,000 smallholder farmers, most of them women,are involved in the production of potato.Their production accounts for more than 80% of the nationalproduction, estimated at 142 000 tons per year cultivated on 45 000 hectares [5, 6]. In addition, between 1986 and 2009, these farmers were able to raise potato yields from 2.5 to 5 tons per hectare [1, 7].

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Nevertheless, these yields perunit area and totalproduction arestill very low,looking at the existing potential in the area,due to a number of restrainingfactorsincluding high cost of inputs, low productivity of soils, unsustainable farming practicesand principally the late blight disease severity which is considered as the most restrictivefactor to potato production [8]. Late blight caused bya fungus-like oomycete pathogen, *Phytophthorainfestant,*lowers potato yields, increases farmers reliance on expensive chemical fungicides and can result in a complete destruction of the crop if allowed to reach epidemic level [9]. Another factor that hinders potato production is the fact that, as a high mining crop, itneeds higher amounts of NPK elements for its economic tuber production [10].

Under limited resource conditions and unavailability of inorganic fertilizers, land productivity could be improved through the addition of organic manure in order to provide adequate nutrients in the soils [11, 12]. However, the type of organic materials to be used depends on their decomposition rate and nutrient release capacity. Organic manure isimportant not only for increasing yields, but also for maintaining soil health in general [13-15] and improvingits fertility, structure, water holding capacity, cation exchange capacity and increasing soil organic matter content in particular [16-18].

*C. calothyrsus*is one of the leguminous species that produces a fairly high quantity of nutrient-rich biomass [19, 20] and releases highN within 3-4 weeks from time of application [11, 21, 22]. Amendments with compost alsoenhance soil organic matter quality and quantity and increase accumulation of various classes of organic compounds [23].

Unfortunately, the use of organic manure has been reported to increase the severity of potato late blight disease [24, 25]. Excessive vine growthcaused by too much N fertilization has a marked tendency to increase the size of the late blight lesions on the potato leaves [26] and organic manure particularlygreen manure from leguminous treesis reported to act as a suitable substrate for the multiplication of the disease pathogen [24, 27]. Hence, agronomic recommendations available in the highlands of Cameroon to improve potato production havelaid emphasis solely on inorganic fertilizerswhich are not economically profitable to small-scale farmers [6]. Previous studies on organic and inorganic soil amendments havemainly focused on yield responses and nutrient recoverywith test crops performing better under combined than sole applications [21]. Little has been done to evaluate the impact of sole application of organic manure oncrop performance and late blight severity. This study was therefore conducted to quantify and compare the effects of sole applications of organic and inorganic soil amendments on the physical characteristics and yield of potato and to determine its influence on late blight disease severity.

MATERIALS AND METHODS

Study Site: The field experiment was carried out in 2010 at Riba Agroforestry Resource Centre, Kumbo, Bui division, located at 2000 m.a.s.l in the Western Highlands of Cameroon. Soils in the area have low fertility and many tests indicated deficiency in plant nutrients (N, P, Ca, Mg) and moderately acidity (PH < 6.5) [28-30]. The vegetation in the area varies with elevation with sub-mountain forests extending from 900 to 2500 meters elevation. Above 2000 meters, are distinct mountain grasslands, subalpine grasslands and shrub lands. Rainfall is unimodal with a mean ranging from 1500 to 2200 mm per annum. The average temperature oscillates between 14°C and 18°C.

Experimental Design: Two factors susceptible of influencing the performance of potato plants in the area were considered in the study: the fertilization scheme and the sanitary measures. The fertilization scheme consisted of two methods usually used by farmers to improve land productivity in the area (mineral fertilizers, sterilized compost), non-sterilized compost, the newly introduced approach of soil improvement using fresh leaves of *C.calothyrsus*and the control with no fertilization. Sanitary measures consisted of controlling late blight disease with fungicides and a zero application. Experimental treatments were therefore the combination of 5 schemes of fertilization and two levels of sanitary measures leading to the 10 treatments presented in table 1.

Treatment Application: The trial was laid out as a Randomized Complete Block Design (RCBD) with four replicates. In each of the four replicates, 10 treatments were randomly allocated to the 10 experimental units. Prior to planting of potato tubers, the plot was tilled the previous day using traditional hoes to a depth of 30cm after which rectangular ridges of 40 cm height and 7 meters long were formed to constitute the experimental unit. On each experimental unit, 15 potato tubers of Cipira

Table 1: various experimental treatments

		Sanitary measures	
		Late blight controlled	Late blight not controlled
Fertilization schemes	Mineral fertilization	T1	T6
	Sterilized compost	T2	T7
	Non sterilized compost	T3	T8
	C. calothyrsus	T4	T9
	No fertilization	T5	T10

varietywere planted at a distance of 40 cm. In total, 40 experimental units, one meter apart and covering an area of 290 m^2 were used for this trial on which 600 healthy sprouted tubers were planted. Before the establishment of the experiment, the plot has been fallowed for 3 years.

The various treatments were applied as follow: for the mineral fertilizer, 18 g of a simple mix-fertilizer NPK 11:11:22 was applied as basal dose per plant at planting, followed by 3 g of Urea applied during the first moulding (40 days after planting) to give a total of 120 kg of N, 180 kg of P and 100 kg of K per hectare. Similarly, 200 g of compost were applied per plant once as basal dose at planting based on farmers' estimations and common practices in the area. *C. calothyrsus* was applied as fresh leaves and twigs mulched in quantities (300g per plant) that supplied 120 kg of $N.ha^{-1}$), thus, 200g at planting and 100g during the first moulding (40 days after planting). Late blight disease was controlled by the use of fungicide. 50g of Ridomil (Mefenoxam) diluted in 15 l of water was sprayed on the plants using the knapsack sprayer after the appearance of the first symptoms, 45 DAP and spraying was repeated every 2 weeks till harvesting.

Data Collection: The following plant characteristics were measured at different stages of plant growth to assess performance. Plant height and stem diameter using a graduated ruler and vernier caliper respectively at 45 days after planting (DAP)and measured accurately to cm and mm (length and diameter) respectively for each single plant. Plant vigor were evaluated at 60 DAPusing the recommended International Potato Centre (CIP) scale for potato viguor assessment from "1" to "9" where "1" was assigned to least vigorous plants and "9" assigned to very vigorous plants. At 120 DAP, tubers were harvested and graded into 3diameter categories: commercial measuring > 30mm, non commercial measuring < 30mm and tubers with external defects. The weights and numbers of tubers in each category were recorded.

Disease Monitoring and Assessment: Assessment of late blight disease started with the onset of first symptoms, after which cumulative scoring of affected leaves and plants was done biweekly and expressed as a fraction of the infected foliage. Late blight severity was then calculated as a percentage of total number of plants affected per treatment. Harvesting took place when about 95% of the plants showed senescence.

Data Analysis: Plant height, stem diameter, plant vigor, total yield, commercialized yield and late blight severity were assessed in the trial and mean performance under the 10 treatments was analyzed. Correlations among variables measured were assessed using bivariate correlations analysis in SPSS v.17 and the strength of the linear relationship among various parameters measured assessed.For statistical comparisons, percentages of blighted plants were transformed into square roots before analysis. Inter relationshipsbetween variables measured were investigated using correlations analysis techniquesand for highly correlated variables, the fitted relation was computed using the linear model procedure of Genstat v12 software. To determine the effect of fertilization schemes and sanitary measures on potato performance on the field, data collected on different variables were subjected to a Multivariate Analysis of Variance (MANOVA) and for variables significantly affected by any of the factors, means were computed and compared using *Dunnett-t* test, assuming the use of *C. calothyrsus* as the main treatment.

RESULTS AND DISCUSSION

Effect of Soil Amendments on Physical Growth Characteristics of Potatoes: Fertilization treatments were found to influence potato plant growth variables but thelevel of variation depended onwhether the late blight disease was control with fungicide or not.. From the mean growth performances of potato under various treatments presented in Table 2, it is observed that for stem diameter, Tables 2: Mean performances of plants physical characteristics under various fertilization schemes compared to *C. calothyrsus*

Dependent Variable	Fertilization scheme	Mean Difference with *C. calothyrsus*	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Stem diameter (cm)	Mineral fertilization	-0.03	0.04	0.87	-0.08	0.15
	No fertilization	-0.21	0.04	0.00*	-0.33	-0.10
	Non sterilized compost	-0.24	0.04	0.00*	-0.35	-0.12
	Sterilized compost	-0.26	0.04	0.00*	-0.37	-0.15
Plant height (cm)	Mineral fertilization	0.27	1.21	1.00	-2.87	3.40
	No fertilization	-5.67	1.21	0.00*	-8.80	-2.54
	Non sterilized compost	-2.68	1.21	0.11	-5.81	0.46
	Sterilized compost	-3.33	1.21	0.03*	-6.46	-0.19
Plant vigor	Mineral fertilization	0.50	0.44	0.62	-0.63	1.63
	No fertilization	-1.50	0.44	0.01*	-2.63	-0.37
	Non sterilized compost	-2.50	0.44	0.00*	-3.63	-1.37
	Sterilized compost	-2.25	0.44	0.00*	-3.38	-1.12

*Statistically different

Tables 3: Mean yield lost with various fertilization schemes compared to *C. calothyrsus*

Dependent Variable	Fertilization scheme	Mean Difference with *C. calothyrsus*	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Total yield (t. ha^{-1})	Mineral fertilization	0.86	0.46	0.20	-0.31	2.04
	No fertilization	-2.11	0.46	0.00	-3.29	-0.94
	Non sterilized compost	-2.12	0.46	0.00	-3.30	-0.94
	Sterilized compost	-2.02	0.46	0.00	-3.20	-0.84
Marketable yield (t. ha^{-1})	Mineral fertilization	0.86	0.47	0.23	-0.36	2.08
	No fertilization	-2.13	0.47	0.00	-3.35	-0.91
	Non sterilized compost	-2.28	0.47	0.00	-3.49	-1.06
	Sterilized compost	-2.06	0.47	0.00	-3.28	-0.84
Non marketable yield (t. ha^{-1})	Mineral fertilization	0.01	0.09	1.00	-0.23	0.24
	No fertilization	0.02	0.09	1.00	-0.22	0.26
	Non sterilized compost	0.16	0.09	0.28	-0.08	0.39
	Sterilized compost	0.04	0.09	0.98	-0.20	0.27

plants under *C. calothyrsus*significant (*p=0.00*) surpassed those of sterilized compost, non-sterilized compost and no fertilizationwith the difference of at least 0.21±0.04 cm but not significant with mineral fertilizers (d = 0.03±0.04cm, p = 0.87). Plantsunder *C. calothyrsus* amendment were significantlytaller than those under no fertilization (p = 0.00) with d=5.67±1.21 cm and sterilized compost (p = 0.03) with d=3.33±1.21but differences in plant height were not significant (p = 0.11) with non sterilized compost (d=2.68±1.21 cm). Plants under mineral fertilizer and *C. calothyrsus* showed statistically similar vigor (d=0.5±0.44) at (*p=0.62*), but those under C. calothyrsus were significantly (*p=0.01*) more vigorous than those under no fertilization (p = 0.01), non sterilized compost (p = 0.00) and sterilized compost (p = 0.00).

The increase observed in physical growth characteristics of potato plants is attributed to the nutrient contents of the amendment used in various treatments, which supported plant growth and development. In general, treatments with mineral fertilizer and *C. calothyrsus* had better values of plant physical characteristics than the rest of the treatments. The observations from these two treatments confirm results obtained by Moyin-jesu [31] who found that mineral fertilizers are ready nutrients available for crops and that organic manure could equally supply nutrient elements needed for potato plant development. Weber [13] also found that organic manure enhances crop physical performance and consequently improves yields. The observations in this study confirmed that potato plant vigor depends on the amount of nutrient available for plant uptake as reported by Adebayo and Akoun [32]. The low vigor indices observed in the compost treatments is probably due to insufficient amount of basic nutrients provided by the treatments.

Effect of Soil Amendments on Yield Components: Like growth characteristics, application of soil amendments brought about increases in both total and marketable yields. However, only the mineral fertilization and *C. calothyrsus* treatments resulted in significantly higher total and marketable yields compared to the rest of the treatments. Table 3 presents the mean yield differences between all the treatments and *C. calothyrsus* treatment.

Mean yield differences with mineral fertilizers, although positive, were not significant ($p = 0.20$) with total yield ($d=0.86 \pm 0.46$ t.h^{-1}) and ($p = 0.23$) and withmarketable yield ($d=0.86 \pm 0.47$ t.h^{-1}). The two variables were shown to be very highly correlated (r=99%). For non marketable yields, thedifference in values recorded in all the treatments was not statistically significant though non sterilized compost produced the highest difference values (0.16 ± 0.09 t. ha^{-1}).

Mineral fertilizers and *C. calothyrsus* treatments consistently gave significantly higher total and marketable yields than the rest of the treatments despite the fact that late blight severity was high with the two treatments. This is attributed to a better nutrient balance and high plant vigor that were achieved when mineral fertilizers and *C. calothyrsus* were applied. Singh [33] reported similar results when organic manures and inorganic fertilizers were applied for potato production. The differences obtained in yield could also be attributed to various level of disease severity. Yield increases as a result of fungicide treatment appeared greater in marketable yields than in total yield. This can be explained by the fact that with fungicide application, tuber sizes were improved, therefore reducing the proportion of non marketable yield. It further appears that organic manure in addition to releasing high amounts of N also helps to improve other soil conditions such as the structure and water holding capacity, which together with balanced nutrient supply results in good crop performance.

These findings in general agree with reports from other studies in the humid tropics where application of leafy pruningsof organic materials to the soils resulted in increased in soil organic matter and higher N, P, K, Ca and Mg [34, 35] as well as improving moisture retention [20] and biological activity [36] in soils hence improving nutrient availability and nutrient use efficiency [37]. This is an indication that the leafy prunings of *C. calothyrsus* incorporated in the soil at the beginning of the trial decomposed and released nutrients especially nitrogen which enhanced crop performance [38]. The results also agree with findings of Attah-Krah [39] who reported significant maize yield increases following application of green manure. The consistently higher yields obtained in*C. calothyrsus* treatments is an indication that biomass incorporation in alley cropping systemseffectively improve crop yields [40, 41].

Though it was clear that the application of *C. calothyrsus* increase N supply, it is not certain why its application alone increased potato yields, but this can be attributed to increase in K supply through fast decomposition and also retention of it against leaching losses that presumably improved its use efficiency [11, 42]. Compost on the other hand gave significantly lower yields in the present study. This could be explained by its low nutrient content resulting from the nature of the materials used by farmers and the process of sterilization which could have affected its nutrient content and biological activities.

Eeffect of Soil Amendments on Potato Late Blight Disease Severity: Potato plants subjected to fungicide application shown no sign of foliage infection.This indicated that the fungicide used was effective in managing late blight disease of potato in the area. Late blight disease was observed exclusively on potato treatments with no fungicide application and disease severity varied between fertilization schemes. The first symptoms of the disease appeared at 45 DAP, then between 45 DAP and 60 DAP, the disease severity increasedrapidlythen progressed at a decreasing rate to reach maximum at 90 DAP (Fig. 1). Highest foliage infection was recorded in plots treated to mineral fertilizer (73.86%) followed by *C. calothyrsus* (67.66%), while the lowest infection was recorded in plots with no fertilization and no fungicide application (55.57%). It can be observed that all the treatments not subjected to fungicide application had similar type of disease development curves.

Table 4 presents the mean late blight severity differences under various treatments as compared to *C. calothyrsus*.None of the mean disease severity differences was significant although positive with mineral fertilizer.

In general, soil amendments with mineral fertilizers (T6) and *C. calothyrsus* (T9), though not significantly, increased late blight severity as compared to other treatments due to their N high content of N.The disease severity increased with N but the effect depended on disease pressure and stages of growth. Highest increase rate of late blight severity was recorded between the 45 and 60 DAP and the progress declined with time (Figure 1). This is attributed to the fact that early stage coincides with active development of plant canopy which influence disease severity and create a canopy microclimate conducive to disease development. This explains the importance of soil fertility in crop disease management to improve production. Despite the fact that plants in mineral fertilizers and *C. calothyrsus* treatments showed the highest foliage infection percentage, the yields under these treatments were higher compared to other treatments under the same sanitary conditions.

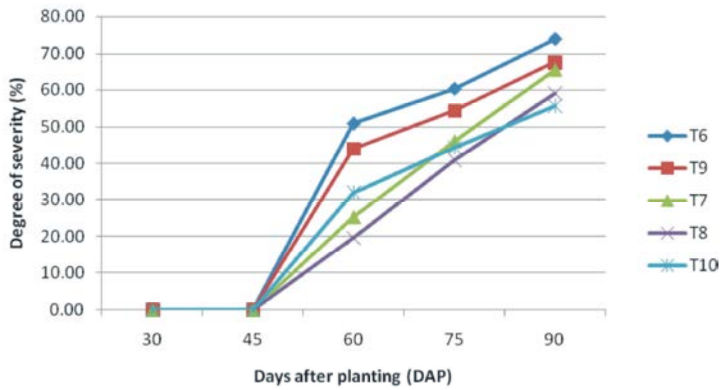

Fig. 1: Disease severity curves for various treatments

Tables 4: Late blight severity on potatoes plants under various fertilization schemes compared to *C. calothyrsus*

Dependent Variable	Fertilization scheme	Mean Difference with *C. calothyrsus*	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Disease severity 90DAP	Mineral fertilization	0.04	0.03	0.56	-0.04	0.11
	No fertilization	-0.06	0.03	0.13	-0.14	0.01
	Non sterilized compost	-0.04	0.03	0.39	-0.12	0.03
	Sterilized compost	-0.01	0.03	0.98	-0.09	0.06

Table 5: Correlations matrix among different parameters as influenced by various treatments

		Stem diameter	Plant height	Plant vigor	Marketable yield	Total yield	Non marketable yield	Late blight severity
Plant diameter	1	-						
Plant height	2	0.74***	-					
Plant vigor	3	0.75***	0.45***	-				
Marketable yield	4	0.73***	0.59***	0.60***	-			
Total yield	5	0.74***	0.61***	0.61***	0.99***	-		
Non marketable Yield	6	-0.14 ns	-0.03 ns	-0.14 ns	-0.38***	-0.28 ns	-	
Late blight severity 90DAP	7	0.05 ns	-0.09 ns	0.21 ns	-0.37***	-0.34***	0.34***	-

*ns Not significant at 0.05 probability level; *** Significant at 0.001; n=40*

This is in line with the findings of Erwin *et al.* [43] andMuchovej *et al.* [44] who found that Well-nourished plants even though attacked are stronger and could better withstand disease organisms than poorly nourished ones due to absorption of adequate nutrients through a well-established root system.Even though many questions remain unanswered about the role plant nutrition plays in late blight development, optimal soil fertility required for producing the anticipated yield should be part of an integrated late blight management program.

Correlations Matrix among Different Parameters as Influenced by Various Treatments: Eventual interrelations among variables measured were analyzed using the bivariate correlations analysis in SPSS v.17. The strength of the linear relationship among various parameters measured was also assessed. Results presented in Table 5 showed that total yield had significant ($p = 0.001$) and positive correlation with stem diameter ($r = 0.74$***), plant height ($r = 0.61$***), plant vigor ($r = 0.61$***) and marketable yield ($r = 0.99$***). Non marketable yield had negative correlation ($r = - 0.38$***) with marketable yield, but is not correlated to any other parameter measured. Late blight severity had negative but significant ($p = 0.001$) correlation with total yield ($r = - 37$***) and marketable yield ($r = - 34$***), but had positive correlation with non marketable yield ($r = 34$***). These results indicate that total yield of potato depends on stem diameter, plant height and plant vigor and was strongly correlated with marketable yield.

CONCLUSION

From this study, it has been shown that mineral fertilizers and leafy pruningsC. *calothyrsus* were effective in improving growth characteristics and yields of potato if applied in combination with appropriate fungicide against late blight disease. It was also found that total yield had significantand positive correlation with stem diameter, plant height, plant vigor and marketable yield. Though *C. calothyrsus* treatment provided interesting results, the feasibility and economic implications of the approach are yet to be evaluated. At the same time, mineral fertilizers showed positive results but may not be cost effective for small-scale farmers in the highlands of Cameroon. Further studies should investigate the effects of combine organic and inorganic treatments as well as economic analysis at the level of small-scale farmers.

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