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Effect of NPK Fertilizer and Animal Manure on Some Biometric Parameters of Irish Potato *Solanum tuberosum* L. in Bougham, West Region Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Authors DKN, CNK and TZSM designed the study. Author DKN performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DKN and TDA managed the analyses of the study. Author TDA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of this study was to evaluate the influence of NPK-based fertilizers and animal fertilizers on some biometric parameters of Irish potato in the Western Highlands of Cameroon.
Place and Duration: The study was conducted in Bougham, a village in the Western Highlands of Cameroon. The seeds were sown on the 4th of May 2016. Harvesting was done in August 2014.
Methodology: A total area of 250 m^2 area was cleared and prepared in to a Randomized Complete

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Block Design (RCBD). Each block was divided into nine ridges. Eight fertilizer treatments (NPK 15:1515, NPK 11:11:22, Pig dropping, Poultry dropping, and four bi-combinations of the animal and NPK-based fertilizer) and a control treatment were randomly assigned to each ridge per block. Local farmer's methods were adopted into overall agronomic activities of the study. Analysis of Variance (ANOVA) was done to evaluate differences in means and Duncan's Multiple Range Test was used to separate means at a probability level of 0.05. Correlation analysis was also evaluated between biometric parameters.

Results: Fertilizer treatments had a significant (p=.05) influence on biometric parameters (Plant emergence, LAI, Plant height, Number of leaves, Plant cover, Number of plants harvested, Number of tubers per plant). There was no significant difference (p=.05) for number of tubers of plant. Significant correlation existed between some biometric parameters: plant emergence + number of plant harvested (r = 0.0514, p =.05), plant emergence + number of tubers per treatments (r = 0.693, p=.05).

Conclusion: In this study, it is implied that soil amendment practices influenced biometric parameters of Irish potato. Animal fertilizer: poultry and pig fertilizer had a great influence on growth and yield parameters. The advantages of incorporating organic fertilizer in crop production are enormous; rapid growth, high productivity, soil physio-chemical status revitalization and overall soil microbial activity.

Keywords: Growth; pig; poultry; yield; bi-combination.

1. INTRODUCTION

Irish potato (*Solanum tuberosum* L.), cultivated all over the world and providing income to many households, belongs to the flowering plant family Solanaceae [1,2]. Potato is one of the most important vegetable crops and it is fourth among food crops after rice, wheat and maize [3] with an annual production of about 300 million tons from approximately 20 million hectares of arable land [4]. Potato is widely cultivated for its cheap source of carbohydrates, vitamins (B_1 and C) as well as minerals [5]. It is estimated that 100 g of potato tuber contains 79.9 g water, 78 kcal energy, 16.8 g carbohydrates, 2.4 g protein, 36.0 gmg calcium, 49.0 mg phosphorus, 31.0 mg ascorbic acid, 2.2 mg niacin, 1.1 mg iron, 0.12 mg thiamine and 0.06 mg riboflavin [6].

In Cameroon, potato is cultivated mainly in the highland zones (Altitude: 1,000 to 3,000 m above sea level) and in six of the ten regions of the country. The West and North West regions jointly accounts for about 80% of the total national production [7]. Potato ranks fifth in tons produced among the major staple crops behind cassava, plantain, cocoyam/taro and maize in Cameroon [8]. Since the start of this millennium, potato production has witnessed a threefold increase from 130,535 tons in 2000 to 377,257 tons in 2016 [9]. This rise in production is driven by an ever increasing home and export market to neighbouring countries like Gabon, Equatorial Guinea, Chad, and Central Africa Republic [7]. Although potato production has increased in Cameroon lately, production is still lagging behind due to increasing domestic and export market demands, pest and disease attacks, soil fertility problems and poor irrigation systems [10,11,7].

Farmers mostly rely on inorganic fertilizers (NPK 20:10:10 and NPK 12:6:20) for improved yield. With the constant rise in chemical fertilizers and the shortage or non-availability in many remote areas, organic manure is now regaining the spotlight as a source of cheap plant nutrients. Organic manure like cow dung, fowl droppings, turkey manure, pig droppings and farmyard manure have been for eternity incorporated in crop production. These organic manures are soil-incorporated or broadcasted pre-plant or during plant growth [12]. Many scientists agree that not only do organic manure provide plant nutrient, but that they also have the potential to restore soil physiochemical properties which are often degraded by inorganic fertilizers [13-15]. However, nutrient quantification from organic manure still remains a major setback, thus making its use void of sound and proper economic and environmental decisions [16].

In this study, we evaluated the effect of different quantities of organic, inorganic and composite fertilizer on potato phenology, growth and yield. We hypothesized that these different fertilizers have different effects on potato phenology, growth and yield.

2. MATERIALS AND METHODS

2.1 Study Site

Bougham is part of the mountainous West Region of Cameroon located in 5°28N, 10°25E and about 1,000 m above sea level. Bougham is characterized by densed vegetation, rich agricultural soil, and a humid equatorial climate with moderate rainfall. These conditions are very good for potato cultivation. Inhabitants are predominantly farmers, growing vegetables, fruits and rearing animals. There is abundant animal waste in this region, and the farmers incorporate this to crop production activities.

2.2 Land Preparation and Field Layout

A total of 250 m^2 area was cleared, tilled and harrowed with hand-held hoes. The experimental design was a randomized complete block design (RCBD). The field was divided into four blocks measuring 13x6 m. Each block was divided into nine ridges measuring 6x1x0.3 m. The gap between the blocks and between the ridge was 2.5 m and 0.5 m respectively. The ridges were randomly assigned different fertilizers treatments

2.3 Plant Material

Potato variety used in this experiment was "Pamina", distributed by AFRISEM GIE and imported from France. It is very smooth, pale yellow – white skinned and elongated tubers. This variety is widely used by farmers in the area.

2.4 Fertilizer (Nutrient Source)

Inorganic fertilizer (NPK – 15:15:15 and NPK – 11:11:22), organic fertilizer (poultry and pig droppings) and composite (organic + inorganic fertilizer) was used (Table 1). The fertilizers were applied pre-plant. At moulding (hilling up), a nitrogen rich fertilizer was broadcasted to boast growth in all treatment. Sulphate nitrate (100 $kg.ha^{-1}$), calcium nitrate (75 $kg.ha^{-1}$) and potassium nitrate (25 $kg.ha^{-1}$) were applied in a composite (200 $kg.ha^{-1}$). Fertilizer quantities were adopted from farmer's practice.

2.5 Planting/Sowing

Potato tuber (approximately 40 mm in diameter) was planted 10 cm deep on the 4th of May 2016. Each ridge had 20 plants separated by 0.25 m.

2.6 Agronomic Practices

The herbicide Glycot was sprayed pre-emergent for weed control. The next weed control was done bi-weekly by hand. The field was irrigated at the start of the trial, followed by rain fed irrigation. The fungicide Mancolax (Mancozeb 100 ml/18 l) and the insecticide Cypercot (Cypermethrine 100EC) were used to control diseases and insects pests respectively. The ridges were mould in order to cover the broad casted fertilizer after a month of sowing. The plants haulms were removed two weeks before harvesting so as to improve hardening of tubers.

2.7 Data Collection

2.7.1 Plant emergence

The number of plants emerged was counted after four weeks of plantings. At this time, most plants are expected to have germinated.

2.7.2 Leaf Area Index (LAI)

At the seventh week after sowing, four plants were randomly selected per ridge and a leaf from the middle quadrant was harvested. With a meter rule, the length and the width was measured. The product of the length, width and 0.75 was recorded as LAI [17].

Table 1. Different fertilizer treatments

Types of fertilizer (Treatment)		Quantity ($kg.ha^{-1}$)	Treatment code
Organic	Poultry dropping	3150	T1
	Pig dropping	3150	T2
Inorganic	NPK (15:15:15)	650	T3
	NPK (11:11:22)	650	T4
Composite	NPK (15:15:15) + poultry dropping	325 + 1575	T5
	NPK (11:11:22) + poultry dropping	325 + 1575	T6
	NPK (15:15:15) + pig dropping	325 + 1575	T7
	NPK (11:11:22) + pig dropping	325 + 1575	T8
Control	-	-	T9

2.7.3 Plant height (cm)

At the seventh week after sowing when growth was maximum four plants were randomly selected per ridge and with a meter rule, the height was measure.

2.7.4 Number of stems

At the sixth week after sowing, four plants were randomly selected per ridge and the number of stems counted. It is very easy to count the stems at this stage because the leaf vegetation is usually less dense than later stages.

2.7.5 Plant cover (m^2)

Plant cover, also referred to as soil cover, is the surface area covered by plant vegetation. Four plants per ridge was randomly selected and a rectangular wooden grid (1x0.3 m) made up of 30 smaller square grids (0.01 m^2) was placed over the plant in order to measure the plant cover. The numbers of smaller grids directly over a plant were counted and the average area estimated.

2.7.6 Yield parameters

Yield parameters on number of plants harvested, number of tubers per plant and number of tubers per treatment. All plants were harvested for the aforementioned parameters. The means of the data per ridge was used as the samples per treatment. Harvesting was done in August 2016.

2.8 Data Analysis

The data collected was subjected to Analysis of variance (ANOVA) to test the hypothesis that the different fertilizer treatments did not significantly influenced the mean scores of the measured biometric parameters. Duncan's Multiple Range Test (DMRT) was used to separate the means. All analysis was done with the use of statistical package for social sciences SPSS ver. 16 and the probability level was 0.05. Where necessary Microsoft Excel (2007) was used to produced bar charts. Pearsan Correlation between biometric parameters was evaluated. The net difference (Y) between the number of plants emerged (E) and the number of plants harvested (H) per treatment was calculated.

$$Y = E - H$$

3. RESULTS AND DISCUSSION

Table 2 shows the Analysis of variance (ANOVA) for the agronomic and yield parameters in this study. The Block effect did not significantly (p=.05) influenced any measured parameter in this study. Thus the Blocking effect was omitted in the ANOVA analysis in order to increase the Error degree of freedom (df) consequently increasing the reliability of the analyses by increasing the error effect. The effect of NPK-based and animal fertilizer was significant (p=.05) for all biometric parameters except for number of tubers per plant at harvest (p = .327).

3.1 Growth Biometric Parameters

The results indicate that the different treatments significantly (F=3.51, df=8, 28 p =.007) affected the number of plants germinated after 4 weeks after planting. Germination was highest for plants treated with organic fertilizer and control and was least for those treated with solely NPK-based fertilizers (Table 3). This trend is visible in many other NPK-based related findings [18-20]. NPK-based fertilizers impurities such as biuret, high pH, nitrite produced through nitrification of N by soil microorganisms, and ammonia formed through hydrolysis are often implicated in poor germination [21-23].

The fertilizer treatment also had a significant effect (F=14.28, df=8, 135, p = .0001) on the LAI. The highest mean LAI (16.75) was recorded from plants treated with poultry manure. The mixed fertilizer (organic and inorganic) had a higher LAI than the sole NPK-based fertilizers (Table 2). Our findings are in concordance with those of [24] and [25] who conducted similar researches. These findings are also supported by [26] who asserted that LAI values depended not only on cultivar and plant growth stage but also on fertilization regimes, irrigation and other factors. Plant height (cm) was equally significantly (F=7.364, df= 8, 135, p =.0001) influenced by the different fertilizer regimes. Poultry and pig droppings had the highest plant heights (0.57 m). However the plant height was not statistically different for the other treatments (Table 3). This result signifies the important role played by organic fertilizer on plant growth parameters like plant height.

The number of stems was also significantly affected by fertilizer treatments (F=4.219, df=8, 135, p=.001). In the entire experiment, the number of stems ranged from 3 – 4 stems per plant. The highest mean number of stems (3.23) was recorded from plants treated with poultry droppings and pig droppings (Table 3). Our finding is in accordance with those of [2].

Like other growth parameters, plant cover was also significantly (F=9.095, df=8, 135, *p*=.001) affected by fertilizer regimes and showed a similar pattern. The highest plant cover (0.23 m^2) was recorded from plants treated with poultry droppings and pig droppings. The least plant cover (0.19 m^2) was from control experiments (Table 3). [27-29] and [30] obtained similar results for growth parameters in similar trials. Poultry and pig droppings (organic manure) are known to contain essential minerals like N, P, K as well as micronutrients. The organic matter from poultry and pig droppings increase soil aggregation which in turn improves some soil physio-chemical conditions such as water holding capacity. [31] also posits that carbon content from the organic matter can be used up as food source by soil microbes, increasing soil microbial activity; converting unavailable plant nutrients to available forms through biological transformation (mineralization), thus influencing growth.

3.2 Yield Biometric Parameters

The number of plants harvested was influenced by the different fertilization regimes (Table 4). The highest number of plants harvested was 14.25 representing 71.25% of plants sown from plants treated with pig droppings. The second number highest number of plants harvested was 13.75 (68.75%) from plants treated with poultry droppings.

The number of tubers harvested per plant was highest for plant treated with poultry and pig manure although statistically not significantly different from those of the other fertilizer treatment. However, overall poultry droppings and pig droppings significantly gave the highest number of tubers per treatment (Table 4). [32] also presented a similar findings; organic fertilizer had an influence on the number of tubers produced by Irish potato. Specifically, [33] reported that poultry manure resulted in the highest values of number of potato tubers/plant, total tuber/ha and total marketable tuber/ha.

Table 2. Table of ANOVA

Parameter	Source of variation	Degree of freedom (df)	Sums of squares	Mean square	F	Sig.
Plant emergence	Between groups	8	140.056	17.507	3.514	.007
	Within groups	27	134.5	4.981		
	Total	35	274.556			
Leaf Area Index	Between groups	8	234.274	29.284	14.282	.0001
	Within groups	135	276.806	2.05		
	Total	143	511.08			
Plant Height (cm)	Between groups	8	0.108	0.014	7.364	.0001
	Within groups	135	0.248	0.002		
	Total	143	0.356			
Number of stems	Between groups	8	4.0	0.5	4.219	.0001
	Within groups	135	16.0	0.119		
	Total	143	20.0			
Plant cover (cm^2)	Between groups	8	0.026	0.003	9.095	.0001
	Within groups	135	0.048	0.000		
	Total	143	0.073			
No. plants harvested	Between groups	8	29.22	3.653	0.525	.04
	Within groups	27	187.75	6.954		
	Total	35	216.972			
No. tubers per plant	Between groups	8	7.908	0.988	1.215	.35
	Within groups	27	21.958	0.813		
	Total	35	29.865			
No. tubers per treatment	Between groups	8	566.056	70.757	0.732	.04
	Within groups	27	2608.50	96.611		
	Total	35	3174.556			

Table 3. Results of Growth biometric parameters

Treatments	Plant emergence: Mean ± sem	LAI: Mean ±sem	Plant height (m): Mean ±sem	Number of stems: Mean ±sem	Plant cover: Mean ±sem
Poultry dropping	14.75 ± 2.63 abcd (11.0-17.0)	16.03 ± 0.46a (15.44-16.56)	0.57 ± 0.05a (0.49-0.61)	3.25 ± 0.45ab (3.0-4.0)	0.23 ± 0.2a (0.21-0.26)
Pig dropping	18.25 ± 1.5a (17.0-20.0)	11.9 ± 1.53d (9.8-13.98)	0.57 ± 0.05a (0.52-0.65)	3.25 ± 0.45ab (3.0-4.0)	0.23 ± 0.1ab (0.21-0.24)
NPK (15:15:15)	13.75 ± 1.26bcd (12.0-15.0)	12.54 ± 1.68cd (10.43-14.51)	0.52 ± 0.05b (0.45-0.58)	3.0 ± 0.0b (3.0-3.0)	0.20 ± 0.2fg (0.17-0.22)
NPK (11:11:22)	11.75 ± 2.5cd (8.0 -13.0)	12.2 ± 1.73cd (10.43-1459)	0.52 ± 0.05b (0.46-0.58)	3.25 ± 0.45ab (3.0-4.0)	0.22 ± 0.01bcd (0.21-0.24)
NPK (15:15:15) + poultry dropping	11.50 ± 2.51d (9.0-15)	13.84 ± 0.62b (13.42-14.87)	0.49 ± 0.04b (0.44-0.53)	3.0 ± 0.0b (3.0-3.0)	0.21 ± 0.01def (0.20-0.22)
NPK (11:11:22) + poultry dropping	13.5 ± 2.65bcd (11.0-17.0)	11.65 ± 1.51d (9.89-13.750	0.51 ± 0.04b (0.46-0.57)	3.25 ± 0.45ab (3.0-4.0)	0.22 ± 0.01cde (0.21-0.22)
NPK (15:15:15) + pig dropping	15.25 ± 2.22abc (12.0-17.0)	13.7 ± 1.3b (11.65-15.08)	0.52 ± 0.04b (0.46-0.56)	3.5 ± 0.52a 3.0-4.0)	0.20 ± 0.04efg (0.14-0.23)
NPK (11:11:22) + pig dropping	14.75 ± 2.63abcd (12.0-17.0)	13.91 ± 2.34b (11.17-17.39)	0.52 ± 0.02b (050-0.54)	3.0 ± 0.0b (3.0-3.0)	0.23 ± 0.02abc (0.20-0.25)
Control	16.0 ± 1.63ab (14.0-18.0)	13.22 ± 0.5bc (12.74-14.01)	0.51 ± 0.04b 0.46-0.56)	3.0 ± 0.0b (3.0-3.0)	0.19 ± 0.01g (0.19-0.20)

Means in the same column with the same letter(s) are not significantly different using DMRT (probability level .05). s.e.m – standard error of means. LAI – Leaf Area Index

Table 4. Yield biometric parameters of Irish potato influence by fertilizers

Treatments	Number of plants harvested: Mean ±sem	Number of tubers/plant: Mean ±sem	Number of tubers/ treatment: Mean ±sem
Poultry dropping	13.75 ± 1.5a (12.0-15.0)	4.07 ± 0.33a (3.75-4.53)	56.25 ± 9.71ab (45.0-68.0)
Pig dropping	14.25 ± 3.10a (10.0-17.0)	3.89 ± 0.54a (3.13-4.40)	55.25 ± 13.6ab (39.0-70.0)
NPK (15:15:15)	12.00 ± 3.34ab (8.0-18.0)	4.16 ± 0.78a (3.31-5.13)	48.25 ± 7.97b (41.0-57.0)
NPK (11:11:22)	13.25 ± 2.87a (10.0-17.0)	3.75 ± 0.78a (3.00-4.23)	49.50 ± 12.12b (39.0-64.0)
NPK (15:15:15) + poultry dropping	13.25 ± 2.75a (10.0-16.0)	4.25 ± 1.33a (3.00-6.08)	54.75 ± 13.86ab (43.0-73.0)
NPK (11:11:22) + poultry dropping	12.00 ± 2.16ab (10.0-15.0)	5.30 ± 0.91a (4.13-6.30)	62.25 ± 4.11a (57.0-67.0)
NPK (15:15:15) + pig dropping	11.50 ± 0.58cb (11.0-12.0)	4.72 ± 1.05a (3.83-5.91)	53.75 ± 9.39b (46.0-65.0)
NPK (11:11:22) + pig dropping	13.50 ± 2.10a (9.0-18.0)	4.60 ± 1.49a (3.11-6.67)	58.0 ± 7.52)a (49.0-67.0)
Control	10.75 ± 0.96c (09.0-12.0)	3.89 ± 0.29a (3.54-4.23)	42.50 ± 5.07c (39.0-45.0)

Means in the same column with the same letter(s) are not significantly different using DMRT (probability level 0.05). s.e.m – standard error of means

3.3 Correlation Matrix for Biometric Parameters of Irish Potato Influenced by Fertilizer Regimes

The correlation matrix revealed that some correlation existed in the number of parameters checked (Table 5). There was a significant correlation between number of plants emerged and number of plants harvested (r=0.514, p=.05), plant emergence and number of tubers per treatment (r=0.693, p=.05). This implies that efforts geared towards improving plant emergence can also guarantee yield of Irish potato.

3.4 Net difference in the Number of Emerged and Harvested Plants

The net difference (Y) between the number of plants emerged (E) and the number of plants harvested (H) per treatment highlights information on plant mortality rate, lodging rate and state of germination (early or late germination) based on the direction of the net

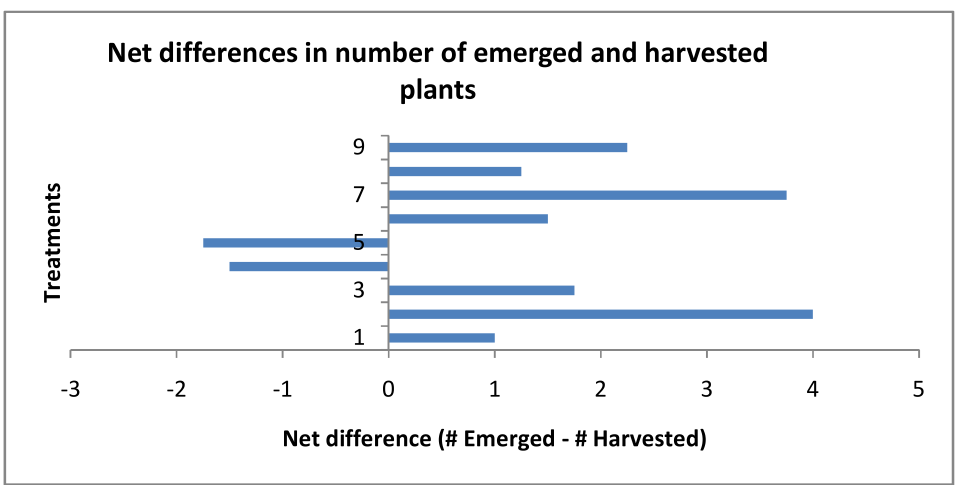

Fig. 1. Net difference in the number of emerged and Harvested plants

Table 5. Correlation matrix of biometric parameters

Parameters	Biometric parameters (numbers represent parameters in first column)						
	1	2	3	4	5	6	7
Plant emergence (1)	-						
Plant height (cm) (2)	0.456*	-	-	-			
Number of stems (3)	0.355*	0.355*	-	-			
Plant cover (4)	0.291	0.546**	0.149	-			
Number of plants harvested (5)	0.514*	0.038	0.035	0.078	-		
Number of tubers per plant (6)	0.073	0.148	0.173	0.184	0.590**	-	
Number of tubers per treatment (7)	0.693*	0.094	0.225	0.096	0.393*	0.491**	-

P=.05 (*), P=.001 (**). Parameter numbers on the columns are the same as those in the rows

difference (+ or -). Analyses revealed (Fig. 1) that pig dropping based fertilizer had the highest net positive difference; pig dropping (+4), and pig dropping + NPK (15:15:15) (+3.8). This implied that plants with pig dropping based fertilizer had a higher potential for lodging or high mortality rate. Two treatments showed a net negative value. A net negative value could imply that such treatments exhibit a delay emergence effect on the plants in question. Our results revealed that NPK (11:11:12) and NPK (15:15:15) + poultry dropping gave a net negative values of -1.5 and -1.75 respectively.

4. CONCLUSION

In this study, it is implied that soil amendment practices influenced biometric parameters, both growth and yield of Irish potato. Animal fertilizer: poultry and pig fertilizer had a great influence on growth and yield parameters, in many cases same or slightly greater than those from NPK-base fertilizers. The advantages of incorporating organic fertilizer in crop production are enormous; rapid growth, high productivity, soil physio-chemical status revitalization and overall soil microbial activity. In the face of the ever increasingly price and scarcity of NPK-base fertilizer, farmers in the Bougham are advised to incorporate organic fertilizers, which are abundant, readily available and cheap, in their agronomic practices for Irish potato production. It is safe to recommend that a long term evaluation of soil physio-chemical status, yield and cost-benefit analyses be conducted.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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