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Research Article
Responses of Potato (*Solanum tuberosum* L.) Varieties to Green Manure

C.M. Tankou, H.D. Beyegue, E.B. Kouam, J.V.L.M. Essam and A. Ngouenet

Genetics, Biotechnology, Agriculture and Plant physiology Research Unit, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon

Abstract
Background and Objective: In Cameroon, negative nutrient balances have been reported here for the major farming systems. Smallholder farmers have limited ability to purchase soil fertility inputs especially inorganic fertilizers. This experiment aimed to determine the effectiveness of *Tithonia diversifolia* (Hemsley) A. **Materials and Methods:** Tithonia green manure was tested on potato in two experiments (2017 and 2019). Four cultivars (two in each experiment) were evaluated with different rates of tithonia green manure in a randomized complete block design with a split-plot arrangement. Analysis of variance and contrast analysis were conducted on the untransformed data and means were separated using the Newman Keul's method at the 5% probability level where appropriate. **Results:** In the first experiment there was a significant linear contrast with respect to yield and other yield-related variables, while in the second experiment where higher rates of tithonia were applied, there was a significant quadratic contrast with respect to yield and other yield-related variables. There was no significant interaction (p>0.05) between the rate of tithonia applied and potato variety. The average fresh tuber yields of 'Dosa' and 'Servante' in the first experiment were 19.2 and 18.7 t ha^{-1}, respectively while the yields of 'Desirée' and 'CIPIRA' in the second experiment with higher rates of tithonia applied, were 30.83 and 18.83 t ha^{-1}, respectively. **Conclusion:** The yield of potato in the region under conventional nutrient supply systems is estimated at 10-30 t ha^{-1} which implies that tithonia fertilization can satisfactorily improve potato production based on the results obtained from these experiments.

Key words: Potato varieties, tithonia green manure, growth-related variables, Cameroon

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Corresponding Author: C.M. Tankou, Genetics, Biotechnology, Agriculture and Plant physiology Research Unit, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Limited land for cultivation due to demographic pressure has led to intensive land-use and unsustainable practices have led to declining in soil fertility and yields of food crops in Cameroon and most sub-Saharan countries[1-3]. Land is intensively used either in space as is the case with intercropping or in time, as is the case with sequential cropping. In Cameroon like in other parts of Sub Saharan Africa, negative nutrient balances have been reported for the major farming systems. Agriculture is the mainstay of the economy of Cameron and over 80% of the nation's food crops are produced by small scale farmers[4]. Potato (*Solanum tuberosum* L.) is the fourth most important crop worldwide after wheat, maize and rice[5]. Potato is ranked fifth in terms of tons produced in Cameroon[6]. Potato is cultivated either sole or intercropped with maize, beans and leafy vegetables as companion crops in the Western Highland agroecological zone of Cameroon. Different potato varieties (improved, imported or local) characterized by diverse forms, plant height and skin colour are found in Cameroon. These include: Cipira, Tubira, Bambui Wanda, Desiree, Cardinal, Banso, Mondial, Spunta and Diamant[7]. However, the certified varieties only include: Cipira, Tubira, Bambui Wanda, Jacob and Maffo. Potato production is economically important because of the variety of ways by which it is transformed. These include hotpot, fried, boiled, porridge, pounded, flour, mashed, omelette and salad[7]. Amongst the varieties evaluated in this study, Cipira is more suitable for frying, mashing and roasting while Dosa is better suited for mashing and roasting[7]. Owing to its high economic importance and short life cycle, the crop is often grown in sequence on the same piece of land for between two and four times a year especially where irrigation is practiced during the off-season.

The present level of chemical fertilizer used by farmers in Cameroon stands at 7-10 kg ha^{-1} due to their poor economic status, compared to about 150 kg ha^{-1} and above in Asia and Europe[8]. Green manures are natural sources of plant nutrients that can ensure the sustainability and efficiency of crop production. *Tithonia diversifolia* is a particular green manure which has been shown to provide adequate nutrients for field crop cultivation and has a lot of potentials to improve potato cultivation because of its high content in potassium[9]. The potato plant is considered as a heavy feeder of potassium and nitrogen and the inadequate supply of these elements makes the plant more susceptible to various kinds of biotic and abiotic stresses[10]. The use of agroecological farm inputs such as organic fertilizers, natural nutrient cycling techniques, high-quality genetic planting materials and conservation agricultural techniques which could circumvent the difficulties in crop production, is hindered by the ignorance of farmers to these technologies[4]. It is against this backdrop that this research was carried out in order to contribute to the production of potato through the study of the effects of variety and tithonia green manure on the performance of potato. This study has as specific objectives, to evaluate the response of potato to different rates of tithonia, to evaluate the response of two varieties and to evaluate the interaction between tithonia rates and varieties.

MATERIALS AND METHODS

Description of the study area: The experiments were carried out in 2017 and 2019 during the first cropping season (March-July) in the Western Highlands agro-ecological zone of Cameroon at the University Research and Demonstration Farm, situated at 1400 masl with a tropical climate. Based on analysis of climatic data of the study area, the average maximum and minimum temperatures are 13.02 and 26.73°C respectively with diurnal temperature amplitude of 13.71°C. The annual rainfall is between 1800 and 2000 mm. The sunshine duration is estimated at 1864 h annually with an average of 8.5 h daily in the dry season and 2.2 h daily in the rainy season. Soil properties in the 0-60 cm depth over all plots were as given in Table 1. Soil pH was measured on a 2:1 water: soil mixture. Soil organic matter was determined by dry combustion. Soil phosphorus (P) was extracted with Na_2CO_3 and analyzed spectrophotometrically. Soil potassium (K) was extracted with sodium acetate and determined by atomic absorption. Total nitrogen was analysed using the Kjeldahl method through digestion, distillation and titration.

Table 1: Results of soil analysis in the 2017 and 2019 experiments

Soil characteristics	Soil levels: 2019 experiment	2017 experiment
Texture	Sandy clay	Sandy clay
pH	5.90	5.60
$CaCO_3$ (%)	3.20	8.52
K (mg kg^{-1})	1.19	0.47
CEC (meq/100 g)	33.50	-
OM (%)	6.57	9.90
N total (%)	0.22	0.28
C/N	17.00	-
P (mg kg^{-1})	11.53	11.69

CEC: Cation exchange capacity, OM: Organic matter, N: Nitrogen, C/N: Carbon/nitrogen ratio, P: Phosphorus

Experimental design and treatments: In the 2017 experiment, four rates (0, 12750, 25500, 51000 kg ha^{-1}) of tithonia biomass were tested on two potato varieties (Dosa and Servante), while in the 2019 experiment, 6 rates (0, 51000, 68653.84, 86307.69, 103961, 121615 kg ha^{-1}) of tithonia biomass were tested on two potato varieties (Cipira and Désirée) in a randomized complete block design with a split-plot arrangement. Each plot size was 20 m^2. The crop was planted at 80 cm between the rows and 30 cm within the rows in both experiments.

Data analysis: The variables used for the evaluation were crop cover fraction, stem diameter and the number of stems (recorded at the different phonological growth stage of the crop) including the yield (recorded at harvest). Crop cover fraction was determined by placing an 80 by 30 cm frame subdivided into 24-1 cm^2 squares on each sampled plant. The number of squares covered by the foliage of sampled plants was recorded and expressed as a percentage of the total (24). Tuber yield was determined by harvesting 6 plants at the middle of each experimental unit and determining both the fresh weight and dry weight (at a temperature of 80°C). Untransformed data were subjected to analyses of variance and means were separated using the Student Neuman Keul's method at the 5% probability level where applicable. Single degree of freedom contrast analyses were used to explain the response curves. Correlation analyses were also conducted to establish inductive tools

RESULTS

Effect of the rate of tithonia applied on the yield of potato varieties: In the 2017 experiment the analysis of variance showed a significant linear contrast between the rate of tithonia applied and the yield of the two varieties. The significant linear relationship (Fig. 1a) showed that the optimum rate of tithonia was not attained. However in the 2019 experiment where higher rates of tithonia were tested, a significant quadratic relationship between rate of tithonia applied and yield (Fig. 1b) was recorded on the two varieties tested.

Effect of crop cover fraction on the yield of potato varieties: In the 2017 experiment, a significant cubic relationship was found between the crop cover fraction at 37 days after emergence and the yield (Fig. 2a) (y = -152.12+1269x-3118.28x^2+2531.07x^3). However a quadratic curve gave a reasonable fit to the data from the 2019 experiment between the yield and crop cover fraction at 44 days after emergence (y = 419.21-968.66x 579.27x^2) (Fig. 2b).

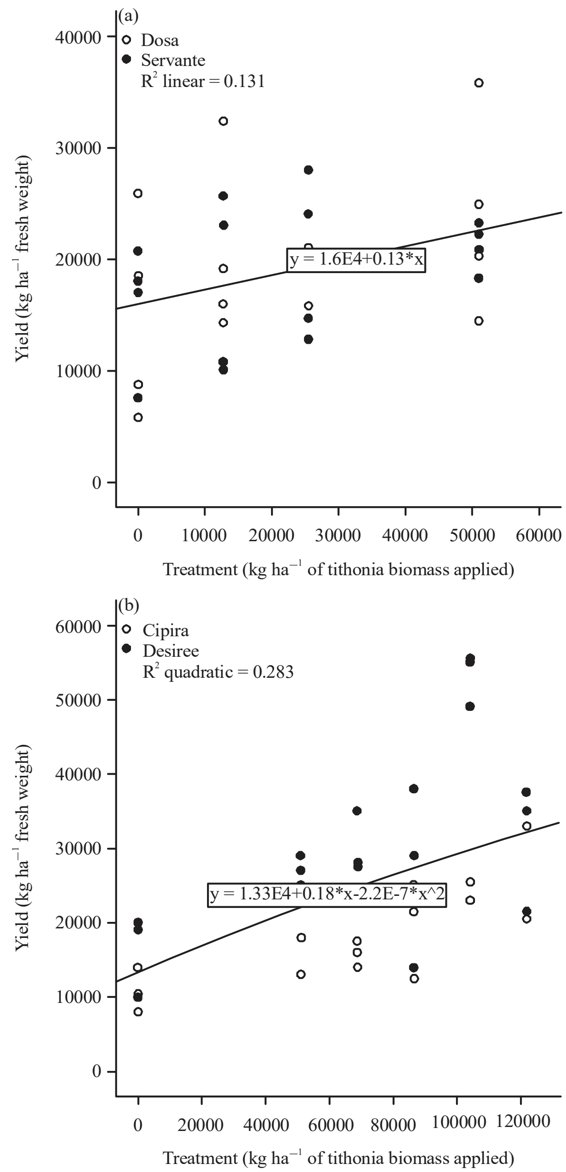

Fig. 1(a-b): Relationship between the rate of tithonia applied and the yield in the (a) 2017 and (b) 2019 experiment

Effect of rates of tithonia applied on growth-related variables and the yield of potato varieties: In the 2017 experiment, the variation in the rate of tithonia biomass applied showed a general increase in mean values of the variables measured as the rate applied increased except for average number of stems per plant where there was no significant difference (p>0.05) (Table 2). The average stem diameter at 51 days after emergence (DAP) of the control treatment (7.5 cm) was significantly smaller than the other treatments while the average number of stems per plant at 44 DAP varied between 3.25 and 3.63 but showed no significant difference between the treatments.

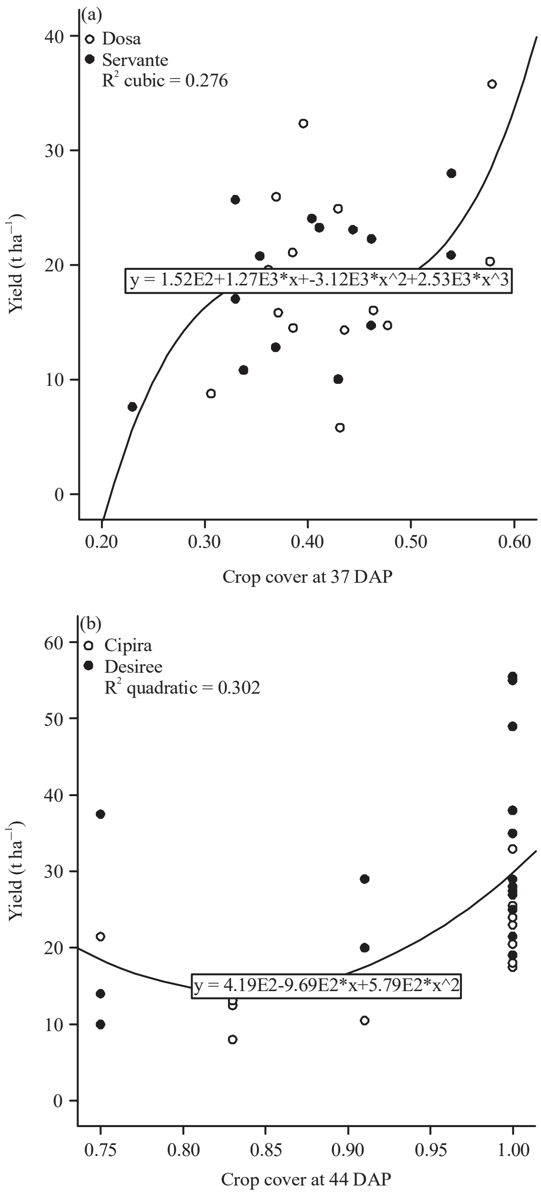

Fig. 2(a-b): Influence of crop cover on (a) Yield 37 days after emergence (DAP) in the 2017 and (b) Yield 44 days after emergence (DAP) in the 2019 experiment

Table 2: Effect of rate of tithonia applied on the means of growth-related variables and yield in the 2017 experiment

Treatments (kg ha^{-1} of tithonia biomass)	Collar diameter (cm) at 51 days after emergence (DAP)	Crop cover fraction at 51 DAP	Number of stems at 44 DAP
0	7.5^a	0.5^a	3.25^a
12750	8.3^b	0.7^b	3.50^a
25500	8.6^b	0.7^b	3.38^a
51000	9.0^b	0.9^c	3.63^a

Means followed by the same letter(s) in each column are not significantly different at the 5% probability level

Table 3: Effect of variety on mean yield in the 2017 and 2019 experiments

Variety	Yield (t ha^{-1})	Yield (t ha^{-1})
Dosa	19.2^b	
Servante	18.7^a	
Desirée		30.83^b
Cipira		18.83^a

Means followed by the same letter in each column are not significantly different at the 5% probability level

Yield response of potato varieties in the two trials: Significant differences were revealed by the analysis of variance ($p<0.05$). The different genotypes evaluated in the two experiments showed significant yield differences where 'Servante' showed a significantly lower yield than 'Dosa' in the 2017 experiment and 'Cipira' showed a significantly lower yield compared to 'Desirée' in the 2019 experiment (Table 3).

Yield-influencing variables in potato cultivation: In an attempt to determine growth related variables which could act as yield predictors, correlation analyses with yield, crop cover fraction (CC), collar diameter (CD) and number of stems (NS) at different days after emergence were carried out. Only the crop cover fraction showed significant correlation with yield (Table 4).

DISCUSSION

Increasing rates of tithonia applied resulted to increasing performance of the potato crop with respect to all the variables studied in the two experiments except for average number of stems per plant. The linear relationship observed between the rate of tithonia biomass application and the tuber yield in the 2017 experiment is similar to the results found by Nazli *et al.*[11] who observed a progressive increase in tuber yield with each incremental level of added K up to 155 kg ha^{-1}. The 2019 experiment however showed the supra optimal level of tithonia biomass application where the tuber yield dropped after the optimum tithonia biomass rate of 103961 kg ha^{-1}. Similar results were shown by Nazli *et al.*[11] who showed that tuber dry matter contents increased with increase in potassium fertilizer rates up to a certain level and then decreased. The potential of tithonia and other green manure species have been shown in many studies. This positive relationship has been associated with the high amounts of nitrogen, phosphorus, potassium, magnesium boron, manganese and zinc found in the green manure of tithonia which are absorbed and allocated as dry matter in the potato tubers[12]. Palm[13] observed that the application of 5 t ha^{-1} of tithonia green manure was equivalent to the

Table 4: Correlation of variables in the experiment (N = 32)

Variables	Yield	CC30	CC37	CC44	CC51	CC58	CD30	CD37	CD44	CD51	NS30	NS37	NS44	NS51
Yield														
Correlation	1	0.160	0.411*	0.354*	0.407*	0.265	-0.071	-0.163	0.020	0.152	-0.074	0.062	-0.011	-0.006
Significant (2-tailed)		0.383	0.019	0.047	0.021	0.142	0.700	0.372	0.911	0.406	0.688	0.737	0.953	0.975
CC30														
Correlation	0.160	1	0.677**	0.690**	0.641**	0.662**	-0.296	-0.177	-0.217	-0.018	0.527**	0.510**	0.589**	0.527**
Significant (2-tailed)	0.383		0.000	0.000	0.000	0.000	0.100	0.331	0.232	0.920	0.002	0.003	0.000	0.002
CC37														
Correlation	0.411*	0.677**	1	0.848**	0.787**	0.576**	-0.177	-0.095	0.078	0.098	0.392*	0.435*	0.456**	0.431*
Significant (2-tailed)	0.019	0.000		0.000	0.000	0.001	0.333	0.603	0.671	0.593	0.027	0.013	0.009	0.014
CC44														
Correlation	0.354*	0.690**	0.848**	1	0.943**	0.784**	-0.245	-0.073	-0.063	0.133	0.383*	0.375*	0.523**	0.465**
Significant (2-tailed)	0.047	0.000	0.000		0.000	0.000	0.176	0.693	0.733	0.467	0.030	0.035	0.002	0.007
CC51														
Correlation	0.407*	0.641**	0.787**	0.943**	1	0.871**	-0.388*	-0.166	-0.163	0.006	0.397*	0.395*	0.558**	0.522**
Significant (2-tailed)	0.021	0.000	0.000	0.000		0.000	0.028	0.364	0.371	0.974	0.024	0.025	0.001	0.002
CC58														
Correlation	0.265	0.662**	0.576**	0.784**	0.871**	1	-0.429*	-0.194	-0.246	-0.083	0.351*	0.377*	0.623**	0.565**
Significant (2-tailed)	0.142	0.000	0.001	0.000	0.000		0.014	0.287	0.174	0.650	0.049	0.033	0.000	0.001
CD30														
Correlation	-0.071	-0.296	-0.177	-0.245	-0.388*	-0.429*	1	0.623**	0.672**	0.700**	-0.721**	-0.680**	-0.673**	-0.725**
Significant (2-tailed)	0.700	0.100	0.333	0.176	0.028	0.014		0.000	0.000	0.000	0.000	0.000	0.000	0.000
CD37														
Correlation	-0.163	-0.177	-0.095	-0.073	-0.166	-0.194	0.623**	1	0.678**	0.754**	-0.575**	-0.748**	-0.667**	-0.700**
Significant (2-tailed)	0.372	0.331	0.603	0.693	0.364	0.287	0.000		0.000	0.000	0.001	0.000	0.000	0.000
CD44														
Correlation	0.020	-0.217	0.078	-0.063	-0.163	-0.246	0.672**	0.678**	1	0.777**	-0.570**	-0.665**	-0.682**	-0.700**
Significant (2-tailed)	0.911	0.232	0.671	0.733	0.371	0.174	0.000	0.000		0.000	0.001	0.000	0.000	0.000
CD51														
Correlation	0.152	-0.018	0.098	0.133	0.006	-0.083	0.700**	0.754**	0.777**	1	-0.617**	-0.719**	-0.636**	-0.713**
Significant (2-tailed)	0.406	0.920	0.593	0.467	0.974	0.650	0.000	0.000	0.000		0.000	0.000	0.000	0.000
NS30														
Correlation	-0.074	0.527**	0.392*	0.383*	0.397*	0.351*	-0.721**	-0.575**	-0.570**	-0.617**	1	0.891**	0.806**	0.876**
Significant (2-tailed)	0.688	0.002	0.027	0.030	0.024	0.049	0.000	0.001	0.001	0.000		0.000	0.000	0.000
NS37														
Correlation	0.062	0.510**	0.435*	0.375*	0.395*	0.377*	-0.680**	-0.748**	-0.665**	-0.719**	0.891**	1	0.884**	0.923**
Significant (2-tailed)	0.737	0.003	0.013	0.035	0.025	0.033	0.000	0.000	0.000	0.000	0.000		0.000	0.000
NS44														
Correlation	-0.011	0.589**	0.456**	0.523**	0.558**	0.623**	-0.673**	-0.667**	-0.682**	-0.636**	0.806**	0.884**	1	0.961**
Significant (2-tailed)	0.953	0.000	0.009	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000
NS51														
Correlation	-0.006	0.527**	0.431*	0.465**	0.522**	0.565**	-0.725**	-0.700**	-0.700**	-0.713**	0.876**	0.923**	0.961**	1
Significant (2-tailed)	0.975	0.002	0.014	0.007	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

CC30, CC37, CC44, CC51, CC58: Crop cover fraction at 30, 37, 44, 51 and 58 days after emergence respectively, CD30, CD37, CD44, CD51, CD58: Stem diameter at 30, 37, 44, 51 and 58 days after emergence respectively, NS30, NS37, NS44, NS51: Number of stems per plant at 30, 37, 44 and 51 days after emergence respectively, *Pearson correlation is significant at the 0.05 level (2-tailed), **Pearson correlation is significant at the 0.01 level (2-tailed)

application of 60 kg ha^{-1} of N as diammonium phosphate while Nziguheba *et al.*[14] showed that the application of tithonia to the soil reduced Phosphorus sorption rate better than Triple Super Phosphate. This was supported by the findings of Cong[15] who showed that tithonia applied to the soil increased the soil pH and decreased extractable aluminum which is associated with P sorption. Ganunga *et al.*[16] reported that tithonia as green manure can bring about positive changes in soil N and P level in a manner comparable to inorganic fertilizer. Mohamed *et al.*[17] reported positive significant relationship between sunhemp green manure rates and potato yield.

The crop cover fraction showed significant correlation with the yield and significant cubic and quadratic relationships with yield in the 2017 and 2019 experiments respectively. This shows that the crop cover fraction could be used as a predictor of the yield of the potato crop. Similar findings were reported by Tankou[18] who observed significant quadratic relationships between crop cover fraction and average number of tubers per potato plant and also between crop cover fraction and the average potato tuber weight per plant. The variation of the crop cover fraction was associated to the nutrient availability to the plant which is a function of the photosynthetic surface area provided by the plant. Similar finding were shown by Taiz and Zeiger[19] who postulated that leaf area and other growth related variables could be considered as important determinations used to describe crop performance since it influences the carbon assimilation rate of the potato plant system and its ultimate conversion in to sink or tubers. Meka *et al.*[20] reported a fresh tuber of 'Cipira' under conventional production system at 11.9 t ha^{-1} in a multilocational trial. They also reported that the average fresh tuber yield of potato is below 3 t ha^{-1} which is attributed to Poor farming practice, lack of information on the supply of improved planting material, a high cost of seed tubers, disease and pest problems, inadequate storage and low soil fertility and management. Under optimal fungicide treatments, Fontem *et al.*[21] obtained 25.3 and 29.5 t ha^{-1} for 'Desiree' and 'Cipira' respectively which were not significantly different. The treatment differences observed with respect to stem diameter were also showed by Getachew *et al.*[22]. In their experiment, they noticed significant differences in stem diameter of potato due to variation in plant spacing. The differences were attributed to improved photosynthetic efficiencies provided by the spacing. The photosynthetic efficiency in our study would be attributed to the different rates of tithonia biomass applied. The average stem diameter per plant in the 2017 experiment at 44 days after emergence varied between 3.25 and 3.63 but showed no significant difference between the treatments. These findings are contrary to the results obtained by Getachew *et al.*[22]. The variation of the stem diameter was attributed to earthing up at critical phonological growth stages of the plant. In this experiment, earthing up was done at the early vegetative stage.

A good picture of the response curve of potato to tithonia rates would be obtained using the same varieties for the different rates.

CONCLUSION

The results of this experiment indicate that growth related variables such as collar diameter and crop cover fraction were influenced by tithonia biomass application rates. It is also clear from the results of this study that tithonia biomass can serve as green manure for potato cultivation and an excess application of this input would result to a negative performance of the crop.

SIGNIFICANCE STATEMENT

This study has brought to light the contributions of tithonia green manure in the satisfactory production of potato. Other researchers have exploited this green manure source for its high nitrogen content mostly for the cultivation of cereals. In this study, the contribution of this green manure in the production of a high potassium demanding crop based on its high potassium content that has not yet been demonstrated has now been brought out.

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