Research Article

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Effects of potato (*Solanum tuberosum* L.)–*Mucuna pruriens* intercropping pattern on the agronomic performances of potato and the soil physicochemical properties of the western highlands of Cameroon

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Abstract: A field experiment was conducted at the teaching and research farm of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang to investigate the effects of potato–*Mucuna* intercropping pattern on the agronomic performances of potatoes and the soil physicochemical properties in western highlands of Cameroon. The experiment design was a randomized complete block with three replications. The treatments included a pure potato stand (T1), pure *Mucuna* stand (T2), 1:1 (T3), 1:2 (T4), and 2:1 (T5) potato–*Mucuna* intercropping patterns. The results revealed that potato–*Mucuna* intercropping patterns had no significant effect ($P > 0.05$) on potato growth variables, soil physical properties, and the relative crowding coefficient. The highest potato yield (24,913 kg ha^{-1}) and potato equivalent yield (81,513 kg ha^{-1}) were obtained from the 1:1 intercropping pattern. The highest total LER (2.17) and the lowest (1.38) were obtained with 1:1 and 1:2 intercropping patterns, respectively. Area time equivalent ratio values were greater than 1 in 1:1 (1.46) and 2:1 (1.29) intercropping patterns. *Mucuna* proved to be the most aggressive and competitive species according to Ap and competitive ratio values except for the 1:2 intercropping pattern with *K* indicating a yield advantage in all intercropping patterns. 1:1 and 2:1 intercropping patterns gave the best C/N (13.94) and cation exchange capacity (36.12 meq 100 g^{-1}), respectively. Late blight incidence was highest (16.88%) on potato sole crop stand and lowest (8.05%) on 1:2 intercropping pattern. Therefore, based on the findings of this experiment, 1:1 or 1:2 intercropping pattern could be recommended in potato–*Mucuna* intercropping system.

Keywords: intercropping pattern, *Solanum tuberosum*, *Mucuna pruriens*, yield, soil properties

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1 Introduction

Potato (*Solanum tuberosum* L.) is an important food crop and a major source of household income for smallholder farmers in the western highlands of Cameroon [1]. Harvesting potato tubers is a farm activity that loosens up dry soil aggregates, and the subsequent lack of soil cover renders the soil prone to erosion. Thus, the development of a sustainable cropping system characterized by high nutrient and water-use efficiency that is economical for potato cultivation is required.

Cover crops are plants cultivated in between cash crops for soil conservation. They improve and maintain soil organic matter and soil health and reduce wind and water erosion. Furthermore, cover crops help in pest management, increase soil carbon and soil biodiversity, reduce nutrient losses, and can increase nutrient availability. In some cases, cover crops have proven to enhance the increase the yield of cash crops. *Mucuna pruriens* is a promising cover crop, which is gaining importance in West and Central Africa. *Mucuna pruriens* var. Utilis is a leguminous plant that can accumulate up to 257 kg ha^{-1} N during a 6-month growing period, with 83% of the N derived from the atmosphere [2]. In the case of a cover crop with large seeds such as *Mucuna pruriens*, the seeds may contain a substantial proportion of the fixed N. Seeds may be collected to plant in other fields or for consumption [3]. As with other cultivated annual crops, *Mucuna pruriens* can be grown in sole stands or intercropped with other crop species.

Intercropping is an ancient farming practice used in agro-ecosystem. Investigations have clearly demonstrated that intercropping compared to sole cropping could increase natural resource-use efficiency [4], boost crop yield and mineral nutrient accumulation, enhance biological diversity, and lower insect, disease, and weed pressures [5–7]. Nowadays, it has attracted great attention due to the yield advantage with serious challenges of resources, environment, and food. By making better use of growth resources that would otherwise not be utilized by a sole crop, intercropping can improve yield on a given piece of land as the main goal. In the rhizosphere, interspecific interaction between species can affect nutrient availability and uptake in intercropping [8]. Nutrients, water, and light may be completely absorbed and converted to crop biomass in intercropping. This is a result of differences in the competitive ability for growth factors between intercrop components [9].

Intercropping is based on the ecological principles of competition, complementarity, and facilitation besides functional agrobiodiversity. When interspecific competition for growth factors is lower than the intraspecific competition, species share only a part of the same niche and reduced competition [10]. Interspecific competition is one of the limitations of using cover crops in intercropping. This can be solved by association patterns promoting optimal land use by reducing interspecies competition. Unfortunately, little information is available on the association patterns between potatoes and *Mucuna pruriens* var. utilis. Thus, the main objective of this study was to assess the agronomic performance of the potato associated with *M. pruriens* var. Utilis under different association patterns, in order to determine the pattern(s) that would promote the better performance of the potato and improve the physicochemical properties of the soil.

2 Materials and methods

2.1 The study site

The experiment was conducted at the teaching and research farm of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang, located at an altitude of 1,396 m a.s.l, between latitudes 5°10′ and 5°38′ North and longitudes 9°50′ and 10°20′ East. Dschang is located on the southwestern slope of the Bamboutos Mountains, dominated by a low plateau that is strongly dissected by small valleys that are sometimes marshy. The climate is characterized by a dry season from mid-November to mid-March and a rainy season from mid-March to mid-November [11]. The vegetation cover was made up of *Tithonia diversifolia*, *Mimosa pudica, Ageratum conyzoides, Cyperus* and *Bidens pilosa*. The sol is predominantly oxisols, it is well drained with a characteristic red color.

2.2 Experimental design and crop husbandry

The experiment was laid out in a randomized complete block design with three replications. Each experimental unit had a surface area of 7.8 m^2 and a spacing of 0.5 m and 1 m between the experimental units and the blocks, respectively, giving a total surface area of 166.6 m^2 for the field trial. The planting materials used were Irish potato (*Solanum tuberosum* L. Var. Desirée) and *Mucuna pruriens* (var. Utilis). Potato and *Mucuna pruriens* seeds were purchased from "*pepinière semence d'avenir*" in Dschang.

The potato and *Mucuna pruriens* were grown in sole stands and as intercrops. Pre-sprouted tubers were planted at a uniform depth of 10 cm and two *Mucuna pruriens* seeds were planted per hole. The different treatments that gave rise to the uniform density of 31,250 plants per hectare for potatoes and 62,500 plants per hectare for *Mucuna pruriens* included the following:

T1: Potato sole stand (0.4 m × 0.8 m);

T2: *Mucuna pruriens* sole stand (0.4 m × 0.8 m);

T3: Potato and *Mucuna pruriens* in 1:1 intercropping pattern (0.4 m × 0.8 m);

T4: Potato and *Mucuna pruriens* in 1:2 intercropping pattern (one row of potato alternate with two rows of *Mucuna pruriens* with the distance of 0.2 m × 1.6 m for potato and 0.4 m × 0.8 m for *Mucuna pruriens*;

T5: Potato and *Mucuna pruriens* in 2:1 intercropping pattern two rows of potato alternate with one row of *Mucuna pruriens* with the distance of 0.4 m × 0.8 m for potato and 0.2 m × 1.6 m for *Mucuna pruriens*.

NPK (11:11:22) fertilizer was applied 21 days after planting (DAP) at 200 kg ha^{-1} [12]. Weeding and mulching of potatoes and staking for *Mucuna* were carried out manually 21 DAP. The potato was sprayed against the late blight disease using the fungicide Bonsoin (30% Chlorothalonil + 6% Cymoxanil) at 1,500 g ha^{-1}. This treatment was carried out every week beginning from week 5 after sowing following the appearance of the first symptoms of the late blight disease. Tubers were harvested 70 DAP, and *Mucuna pruriens* harvested 180 DAP.

2.3 Data collection

2.3.1 Soil sampling and analysis

Top soil samples were collected using a soil auger at the depth of 0–20 cm. Before planting, a composite soil sample was collected from the experimental plot, whereas soil samples after harvest were collected and bulk to obtain composite samples according to the intercropping patterns. Collected samples were conserved and analyzed in the soil laboratory of Faculty of Agronomy and Agricultural Sciences of the University of Dschang-Cameroon. The composite samples were air-dried, grounded, and sieved for analysis of soil pH, texture, total nitrogen, C/N ratio, and CEC using standard procedures. The soil pH was measured with a digital pH meter in the supernatant suspension of 1:2.5 soils to distilled water ratio. Total nitrogen was determined following the Kjeldahl procedure as described by Cottenie [13].

2.4 Growth and yield variables

Weekly measurements of growth variables (plant height (cm), number of leaves, and collar diameter) on six randomly selected potato plants began at 26 DAP and ended at 63 DAP. Yield variables consisted of potato tuber weight and *Mucuna* grain weight. Yield (tubers and grains) was recorded in kg ha^{-1} and converted into potato equivalent yield (PEY) [14], using the following equation:

$$\text{PEY}(\text{kg ha}^{-1}) = \text{PY}(\text{kg ha}^{-1}) + \text{MY}(\text{kg ha}^{1}) \times \text{MP}(\text{CFA kg}^{-1})/\text{PP}(\text{CFA kg}^{-1}), \quad (1)$$

where PY and MY are potato and *Mucuna* yield (in kg ha^{-1}), respectively; PP is the potato market price (192 CFA kg^{-1}), and MP is the *Mucuna* market price (2,500 CFA kg^{-1}).

2.5 Biological efficiency of potato–*Mucuna* intercropping patterns

The biological efficiency of the potato–*Mucuna* intercropping patterns was accessed using appropriate indices that included the land equivalent ratio (LER), area time equivalent ratio (ATER), aggressivity (A), competitive ratio (CR), and the relative crowding coefficient (K).

2.6 LER

LER indicates the efficiency of intercropping using environmental resources compared to monocropping [15]. LER was calculated as follows:

$$\text{LER} = \text{Ypi}/\text{Ypp} + \text{Ymi}/\text{Ymp}, \quad (2)$$

where PY and MY are the yield of potato and *Mucuna*, respectively.

2.7 ATER

It is given by the formula below [16]:

$$\text{ATER} = (\text{LER}_\text{p} \times t_\text{p} + \text{LER}_\text{m} \times t_\text{m})/T, \quad (3)$$

where LER_p = Ypi/Ypp and LER_m = Ymi/Ymp.

LER_p and LER_m represent LER of potato and *Mucuna*, respectively; Ypi is the intercrop yield of potato; Ymi is the intercrop yield of *Mucuna*; Ypp and Ymp are potato and *Mucuna* sole crop yield; t_p and t_m are durations of potato and *Mucuna* in days, and T is the total duration of the intercropping system in days.

2.8 Aggressivity

Aggressivity (A) is a competitive index, which is a measure of how much the relative yield of one crop component is greater than that of another [17]. Aggressivity is expressed as

$$A_\text{potato} = [\text{Ypi}/(\text{Ypp} \times \text{Zpi})] - [\text{Ymi}/(\text{Ymp} \times \text{Zmi})], \quad (4)$$

$$A_\text{Mucuna} = [\text{Ymi}/(\text{Ymp} \times \text{Zmi})] - [\text{Ypi}/(\text{Ypp} \times \text{Zpi})], \quad (5)$$

where Zpi and Zmi represent the sown proportion of potato and *Mucuna* in intercropping, respectively.

2.9 Relative crowding coefficient (RCC or *K*)

It is a competitive index, used as a competitive power coefficient to measure the relative dominance or aggressiveness of either legume on potato or vice versa in an intercropping system. It is calculated following the equations below [18]:

$$K = K_\text{p} \times K_\text{M}, \quad (6)$$

$$K_\text{p} = (\text{Ypi} \times \text{Zmi})/[(\text{Ypp}-\text{Ypi})\times\text{Zpi}], \quad (7)$$

$$K_\text{M} = (\text{Ymi} \times \text{Zpi})/[(\text{Ymp}-\text{Ymi})\times\text{Zmi}]. \quad (8)$$

2.10 CR

CR was used to assess the competitive ability of the component crops in an intercropping system. It was calculated using the following formula below [19]:

$$CR_p = (LER_p/LER_m) \times (Zmi/Zpi), \tag{9}$$

$$CR_m = (LER_m/LER_p) \times (Zpi/Zmi), \tag{10}$$

$$CR = CR_P - CR_M. \tag{11}$$

2.11 Disease incidence of late blight

Disease incidence was evaluated according to James [20]:

$$\text{Disease incidence}(\%) = (\text{Number of disease leaves} / \text{total number of leaves examined}) \times 100. \tag{12}$$

2.12 Data analysis

Collected data were processed in Microsoft excel 2010 software. The MINITAP version 17 (INC USA) was used for one-way analysis of variance at a 5% significant level, and means were separated using Tukey's test.

3 Results

3.1 Effects of intercropping pattern on potato growth variables

The number of leaves, plant height, and collar diameter showed no significant difference ($P > 0.05$) for the different intercropping patterns studied (Table 1), indicating that the growth of potatoes was not influenced by intercropping patterns.

3.2 Intercropping pattern versus yield and potato equivalent yield (PEY)

Yield (tuber and grain) and potato equivalent yield showed a significant difference ($P < 0.05$) among intercropping patterns (Table 2). The highest potato yield (24,913 kg ha^{-1}) was recorded by 1:1 intercropping pattern compared to the other treatments in order potato sole stand (23,438 kg ha^{-1}), 2:1 intercropping pattern (21,207 kg ha^{-1}) and 1:2 intercropping pattern (17,066 kg ha^{-1}). Furthermore, potato yield in 1:1 intercropping pattern was not statistically different ($P > 0.05$) from the yield of the sole stand. Also, results showed that the grain yield of *Mucuna* (4,347 kg ha^{-1}) was significantly higher in the 1:1 intercropping pattern. However, this was comparable to the grain yield of the sole stand of *Mucuna* and the 2:1 intercropping pattern (Table 2); 1:2 intercropping pattern produced the lowest grain yield of *Mucuna* (2,568 kg ha^{-1}). PEY was highest in intercropping patterns of 1:1 (81,513 kg ha^{-1}), 2:1 (71,798 kg ha^{-1}), and 1:2 (50,500 kg ha^{-1}) as compared to the potato sole stand (23,438 kg ha^{-1}). However, PEY in the 1:2 and 2:1 intercropping patterns were not statistically different.

3.3 Biological efficiency of potato–*Mucuna* intercropping patterns

3.3.1 LER and ATER as influenced by potato–*Mucuna* intercropping pattern

LER and ATER were significantly influenced by the intercropping patterns ($P < 0.05$). Results showed that the LER of all intercropping patterns studied is greater than unity (Table 3). A maximum LER (2.17) was obtained with the 1:1 intercropping pattern followed by the 2:1 intercropping pattern (1.9). The lowest LER mean value of 1.38 was obtained with a 1:2 intercropping pattern. This

Table 1: Effects of intercropping pattern on potato growth variables

Treatment	Variables		
	No. of leaves	**Plant height (cm)**	**Collar diameter (cm)**
Potato sole stand	42 ± 36a	69.11 ± 30.61a	0.81 ± 0.2a
1:1 Intercropping pattern	47 ± 39a	72.69 ± 31.45a	0.87 ± 0.25a
1:2 Intercropping pattern	48 ± 44a	69.09 ± 29.79a	0.87 ± 0.20a
2:1 Intercropping pattern	43 ± 38a	70.90 ± 32.24a	0.83 ± 0.21a
Degree of freedom	*3*	*3*	*3*
F-value	*0.57*	*0.33*	*1.87*
P-value (5%)	*0.634*	*0.804*	*0.147*

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

Table 2: Effects of intercropping pattern on tuber yield, *Mucuna* grain yield, and potato equivalent yield (PEY)

Treatment	Variables		
	Potato yield (kg ha^{-1})	***Mucuna* yield (kg ha^{-1})**	**PEY (kg ha^{-1})**
Potato sole stand	23,438 ± 1,469ab	—	23,438 ± 1,469c
Mucuna sole stand	—	3,900 ± 316ab	—
1:1 Intercropping pattern	24,913 ± 1,016a	4,347 ± 1,141a	81,513 ± 13,856a
1:2 Intercropping pattern	17,066 ± 1,014c	2,568 ± 239b	50,500 ± 2,604b
2:1 Intercropping pattern	21,207 ± 1,347b	3885.4 ± 94.2ab	71,798 ± 851a
Degree of freedom	*3*	*3*	*3*
F-value	*23.24*	*4.83*	*39.44*
P-value (5%)	*0.000*	*0.033*	*0.000*

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

indicates a yield advantage of the intercropping system over monocropping with the 1:1 intercropping pattern being superior to the other intercropping patterns.

ATER values of the 1:1 and 2:1 intercropping patterns were higher than unity (Table 3), indicating a yield advantage of these intercropping systems over sole cropping. However, the 1:2 intercropping pattern showed a yield disadvantage (ATER = 0.88) over sole cropping.

3.4 Competitive intensity on potato–*Mucuna* intercropping pattern

A significant effect of the intercropping pattern was observed on potato aggressivity (Ap) and CR ($P < 0.05$). Ap and CR values were positive in 1:2 (1.20 and 1.78, respectively) and negative in 1:1 (−0.76 and −0.60) and 2:1 (−1.63 and −1.74) intercropping pattern (Table 4), indicating that potato was a dominated species in 1:2 but dominated *Mucuna* in 1:1 and 2:1 intercropping pattern.

Intercropping patterns did not have a significant effect on the relative crowding coefficient (K) ($P > 0.05$). However, in all intercropping patterns, K-values were greater than one which indicates a yield advantage (Table 4).

Table 3: LER and ATER of intercropping patterns

Treatments	LER	ATER
1:1 Intercropping pattern	2.17 ± 0.38a	1.46 ± 0.36a
1:2 Intercropping pattern	1.38 ± 0.12b	0.88 ± 0.11b
2:1 Intercropping pattern	1.9 ± 0.09ab	1.29 ± 0.10ab
Degree of freedom	*2*	*2*
F-value	*8.28*	*4.79*
P-value (5%)	*0.019*	*0.053*

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

3.4.1 Effects of potato–*Mucuna* intercropping pattern on late blight incidence

Intercropping patterns showed a significant effect ($P < 0.05$) on late blight incidence (Table 5). According to late blight incidence, the values were obtained from the highest to the lowest as follows: potato sole crop (16.88%), 1:1 (12.02%), 2:1 (10.42%), and 1:2 (8.05%). It can be explained by the fact that when potato rows are separated by increasing rows of *Mucuna pruriens*, late blight incidence decreases.

3.5 Soil physicochemical properties as influenced by potato–*Mucuna* intercropping patterns

There was no significant effect of intercropping patterns on soil physical properties ($P > 0.05$). Nevertheless, compared to the initial physical properties (Table 6), the sand

Table 4: Competitive intensity (Ap, CR, and K) on intercropping patterns

Treatments	Ap	CR	K
1:1 Intercropping pattern	−0.76 ± 0.73b	−0.60 ± 0.69b	12.5 ± 81.3a
1:2 Intercropping pattern	1.20 ± 0.25a	1.78 ± 0.52a	210 ± 0.350a
2:1 Intercropping pattern	−1.63 ± 0.35b	−1.74 ± 0.33b	6.13 ± 2.88a
Degree of freedom	*2*	*2*	*2*
F-value	*25.99*	*33.42*	*0.94*
P-value (5%)	*0.001*	*0.001*	*0.442*

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

Table 5: Late blight incidence as influenced by intercropping pattern

Treatments	Late blight incidence(%)
Potato sole stand	16.88 ± 12.79a
1:1 Intercropping pattern	12.02 ± 12.10ab
1:2 Intercropping pattern	8.05 ± 6.50b
2:1 Intercropping pattern	10.42 ± 11.26ab
Degree of freedom	*3*
F-value	*4.18*
P-value (5%)	*0.007*

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

content was found to decrease to 1.51%; silt and clay increase by 9.83 and 5.26%, respectively.

For soil chemical properties, pH, N (%) and OC did not vary significantly ($P > 0.05$) with intercropping patterns but intercropping patterns showed a significant effect ($P < 0.05$) on CEC and C/N (Table 6). Compared to initial soil chemical properties, there was an increase of 36.66%, 11.93%, 1.81% of N (%), OC (%), and pH, respectively, after the cropping period. C/N was decreasing for all intercropping patterns compared to potato sole crop and initial C/N at the following rate: 26.31% (1:1), 10.52% (1:2), and 5.26% (2:1). The CEC was increasing in 2:1 (36.12 meq/100 g) and decreasing in 1:1 (27.28 meq/100 g) intercropping patterns.

3.6 Relationship between plant traits and soil physical and chemical properties

Physicochemicals properties did not have a significant correlation (Table 7) with growth variables ($P > 0.05$). There was a positive correlation between growth variables and sand (%) and negative correlations with growth variables and clay (%) after harvest. Only the number of leaves gave a positive correlation with silt% (r = 0.148). Concerning chemical properties, there was a positive correlation between N (%), OC (%), C/N, and CEC with growth variables. However, pH had a positive correlation (r = 0.025) only with the plant height. *Mucuna pruriens* yield was not significantly correlated with physical properties. However, it was negatively correlated with sand (%) (r = −0.485) and silt (%) (r = −0.246) while positively correlated with clay (%) (r = 0.412). There was a significant negative correlation between *Mucuna pruriens* yield with C/N (P = 0.017; r = −0.606) and CEC (P = 0.003; r = −0.718) while positively correlated with pH, N (%) and OC (%). Potato yield and PEY were not significantly ($P > 0.05$) correlated with physicochemical properties. Amongst physical properties, only sand (%) (r = 0.492) was positively correlated with potato yield, while PEY was positively correlated with sand (%) (r = 0.062) and clay (%) (r = 0.023). Potato yield was positively correlated with chemical properties, while PEY was negatively correlated with C/N (r = −0.253) and CEC (r = −0.363).

4 Discussion

4.1 Effect of intercropping pattern on potato growth variables

The results of the analysis of variance showed that there was no significant difference (Table 1) between treatments for the number of leaves, plant height, and collar diameter. This may be due to the difference in growth duration between potato and *Mucuna*. Potato had a fast growth rate compared to *Mucuna* and the fact that

Table 6: Soil physicochemical properties before and after planting

Treatment	Physical properties (%)			Chemical properties				
	Sand	Clay	Silt	pH	CEC	C/N	N (%)	OC (%)
Initial status	79.4	12.2	8.36	6.6	32.58	20	0.30	6.10
Potato sole stand	79 ± 1a	13.6 ± 1a	7.4 ± 1a	6.6 ± 1a	40.26 ± 1a	18.98 ± 1a	0.34 ± 1a	6.44 ± 1a
Mucuna sole stand	77 ± 1a	13.6 ± 1a	9.4 ± 1a	6.5 ± 1a	32 ± 1c	15.91 ± 1bc	0.41 ± 1a	6.52 ± 1a
1:1	78 ± 1a	13.6 ± 1a	8.4 ± 1a	6.9 ± 1a	27.28 ± 1d	13.94 ± 1c	0.49 ± 1a	6.89 ± 1a
1:2	77 ± 1a	13.6 ± 1a	9.4 ± 1a	6.6 ± 1a	30.99 ± 1c	17.10 ± 1ab	0.42 ± 1a	7.40 ± 1a
2:1	78 ± 1a	12.6 ± 1a	9.4 ± 1a	7.0 ± 1a	36.12b	17.84 ± 1ab	0.39 ± 1a	6.89 ± 1a
Degree of freedom	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*
F-value	*2.10*	*0.60*	*2.4*	*0.92*	*74.74*	*10.85*	*0.99*	*0.44*
P-value	*0.156*	*0.671*	*0.119*	*0.489*	*0.000*	*0.001*	*0.458*	*0.776*

Means followed by the same letter in each column are not significantly different at the 5% probability level. N% – Total nitrogen; pH – power of Hydrogen; C/N – ratio of carbon content over nitrogen; OC – organic carbon; CEC – cation exchange capacity (meq/100 g).

Table 7: Pearson's correlation of soil properties and plant traits

	PH	NL	CD	% S	% L	% A	pH	N (%)	C/N	CEC	CO (%)	MY	PY
NL	0.921												
	0.000												
CD	0.979	0.958											
	0.000	0.000											
% S	0.323	0.378	0.323										
	0.241	0.165	0.240										
% L	−0.114	0.148	−0.066	0.357									
	0.686	0.598	0.816	0.191									
% A	−0.244	−0.134	−0.205	−0.305	0.269								
	0.381	0.635	0.463	0.268	0.332								
pH	0.025	−0.025	−0.035	0.004	−0.034	−0.160							
	0.929	0.929	0.901	0.989	0.905	0.569							
N (%)	0.021	0.271	0.064	−0.038	0.506	0.240	0.368						
	0.942	0.329	0.821	0.892	0.054	0.389	0.177						
C/N	0.199	0.072	0.222	0.002	0.482	0.273	0.274	−0.526					
	0.477	0.798	0.425	0.995	0.069	0.324	0.323	0.044					
CEC	0.120	0.052	0.093	0.395	−0.103	−0.224	0.128	−0.416	0.839				
	0.670	0.853	0.740	0.145	0.715	0.422	0.649	0.123	0.000				
CO (%)	0.171	0.433	0.222	0.002	0.482	0.273	0.274	0.876	−0.138	−0.091			
	0.542	0.107	0.425	0.995	0.069	0.324	0.323	0.000	0.623	0.747			
MY	/	/	/	−0.485	−0.246	0.412	0.107	0.330	−0.606	−0.718	0.039		
	/	/	/	0.067	0.376	0.127	0.705	0.230	0.017	0.003	0.889		
PY	0.948	0.892	0.930	0.492	−0.039	−0.359	0.152	0.075	0.116	0.155	0.144	/	
	0.000	0.000	0.000	0.063	0.890	0.188	0.589	0.792	0.680	0.581	0.609	/	
PEY	0.756	0.732	0.772	0.062	−0.237	0.023	0.108	0.237	−0.253	−0.363	0.166	0.419	0.730
	0.001	0.002	0.001	0.827	0.890	0.935	0.701	0.396	0.364	0.184	0.554	0.120	0.002

PH – plant height, NL – number of leaves, CD – colar diameter.

maximum requirements for growth resources occur at different times might have reduced competition for growth resources in each intercropping pattern. Undie et al. [21] and Muoneke et al. [22] had a similar finding in which sole maize and intercropped with soybean did not have significant differences in terms of plant height. Also, Thobatsi [23] found that maize intercropped with cowpea did not have any effect on maize plant height.

4.2 Effects of intercropping pattern on tubers, *Mucuna* grain, and potato equivalent yield (PEY)

Potato and *Mucuna* yields varied significantly with intercropping patterns (Table 2). Generally, the yield was higher in the 1:1 intercropping pattern than the other treatments but not significantly different with the potato sole stand. Similar potato yield in a 1:1 intercropping pattern and potato sole stand (Table 2) would imply a positive interaction between the two crops, which could be explained by temporal shoot architectural differences. During the early development stage of the potato, the lower–lying canopy of *Mucuna* could have enabled the potato to obtain enough solar radiation for photosynthesis, resulting in higher tuber yield. Additionally, increased ground cover due to relatively higher *Mucuna* biomass at later stages of potato development could have further benefited potatoes by reducing water loss through evaporation and lowering the temperature within the canopy [24], [25]. These results concur with earlier findings of Wang et al. [26] and Jin et al. [27] who have stated that lower temperatures promote translocation of photo-assimilates to the developing tubers leading to higher tuber yield. In addition, Addo-Quaye et al. [28] found that the spatial arrangement of a single row of maize alternating with a single row of soybean gave a higher maize grain yield compared to maize planted with double rows of soybean. The reduction of yield under 1:2 and 2:1 intercropping patterns could be due to interspecific competition between the intercropped components for light, water, air, and nutrients, and also the aggressive effect of *Mucuna pruriens* on potatoes. It also might be attributed to the highest plant population. This corroborates with the works of Kidane et al. [29], who showed a significant increase in the productivity of sole-cropped potatoes in a maize–potato intercropping system, compared to intercropped treatments.

Potato equivalent yield was higher in intercropping patterns than in sole crops and the 1:1 intercropping pattern had the highest PEY (Table 2). This could mainly be attributed to the additional *Mucuna* grain yield and its high market price (2,500 CFA kg^{-1}). Similar results were found by Gitari et al. [14] and Rahman et al. [30] when intercropped potato with legume and brinjal, respectively. Furthermore, this high PEY in the intercropping patterns could be attributed to growing spaces being varied; temporal growth variance between two varying crops; and a combined increase in making better use of light, soil moisture content, and nutrients.

4.3 Biological efficiency on potato–*Mucuna* intercropping pattern

LER values recorded under different intercropping patterns were greater than 1 (Table 3), indicating a yield advantage of intercropping potato with *Mucuna* over monocropping. Also, the integration of *Mucuna* into the potato cropping system promotes growth and yield of the companion crop. However, the 1:1 intercropping pattern gave the highest LER followed by 2:1 and 1:2, which shows an advantage of 117, 90, and 38% respectively over pure potato stand concerning the use of environmental resources for plant growth and yield as indicated earlier [31,32]. In all intercropping patterns, the ATER values were lesser than LER values indicating the overestimation of resource utilization may be due to the wide variations in the maturity periods of the crops of which *Mucuna* stayed longer on the land and had enough time to compensate for the potato competition. Bitew et al. [33] found parallel results with lupine–wheat and lupine–-barley cropping systems.

ATER varied significantly among intercropping patterns (Table 3). It was higher than the unity in 1:1 and 2:1 intercropping pattern with the highest on 1:1 which show that 1:1 intercropping pattern provides the best yield advantage of cultivating potato and *Mucuna* compared to the monocropping by taking into consideration the time taken by the components crops under the intercropping systems in the field. However, the 1:2 intercropping pattern gave an ATER value less than unity; this indicates the inefficient biological efficiency of this cropping combination. This might properly be due to the long cropping period (180 days) of *Mucuna pruriens* and somehow the interspecific competition for available resources such as soil nutrients, sunlight, and water. This result is in accordance with those of Doubi et al. [34].

4.4 Competitive intensity on potato–*Mucuna* intercropping pattern

Intercropping patterns had a significant effect on potato aggressivity (Ap) and CR (Table 4). In the 1:2 intercropping pattern, the potato was a dominant crop in terms of both aggressivity and CR. This could be mainly explained by the intraspecific competition instead of interspecific competition due to the planting distances. The negative values for potato aggressivity and CR in 1:1 and 2:1 revealed that the potato was less competitive than *Mucuna*. This was an indication of yield loss, probably due to the competitive effect of *Mucuna* on potatoes when grown in an association. The competitive nature of *Mucuna* may be attributed to the invasive nature of *Mucuna* above-ground canopy which could have affected light interception by potatoes. A similar result was reported by Ibrahiem [35] on intercropping of roselle and cowpea. CR is only used as a measure of intercrop competition (inter-specific competition) [36].

In terms of the advantage of intercropping systems, the relative crowding coefficient (K) indicates a similar trend with LER. K did not vary significantly between the intercropping patterns but had values greater than unity (Table 4). These results indicate an advantage of intercropping for exploiting the resources. Doubi et al. [34] reported a similar result with K-values greater than 1 gourd and cassava intercropping systems.

4.5 Effects potato–*Mucuna* intercropping pattern on the incidence of late blight

The results of this study showed that generally potatoes intercropped with *Mucuna* had a lower disease incidence (Table 5) compared to potato sole crop ($P < 0.05$). Gaba et al. [37] stated that multiple cropping systems as well as intercropping can regulates pests in the broadest sense by preventing their growth, reproduction, or dispersal. Pest is less efficient in locating and colonizing its host due to the resource dilution of a host plant in the plant mixture [37]. The different intercropping patterns showed that increasing *Mucuna* rows among potato rows lead to a decreasing late blight incidence (Table 5). Kassa and Sommartya [38] obtained similar results and reported that, among the proportions, 75% garlic with 25% potato

(3:1) intercropped plots showed significantly ($P < 0.05$) low disease development and high tuber yield.

4.6 Soil physicochemical properties as influenced by potato–*Mucuna* intercropping patterns

Cropping systems did not have significant effects on soil physical properties (Table 6). The high biomass production, which protected the soil particles from raindrop impact and being washed away by run-off, had led to improve their effects compared to the initial physical characteristics. Furthermore, Nyawade et al. [39] and Gitari et al. [14] found that, under intercropping systems, there is high root density, which binds soil particles, hence reducing the susceptibility of the soil to erosion.

In this study, the increasing pH, OC, and N values in potato–*Mucuna* intercropping systems (Table 6) support the importance of legume residues in improving soil fertility.

The high N content in potato–*Mucuna* treatments could be attributed to the high-quality biomass that contains high levels of N. This is in accordance with other findings reported by Muthomi et al. [40] that when legume residues are ploughed into the soil as green manure, they decompose rapidly to release N that is bound in them to the soil. This can explain the increasing pH, N, and OC values that were observed under intercropping systems, compared to initial values (Table 6). The carbon to nitrogen ratio (C:N) is an index of nutrient mineralization and immobilization whereby a low C:N ratio indicates a higher rate of mineralization and a higher C:N ratio indicates greater rates of immobilization [41]. The lowest C:N ratio was obtained from the 1:1 intercropping pattern. The 2:1 intercropping pattern recorded the highest CEC than sole treatments and other intercropping patterns. This might be attributed to the high accumulation of organic matter in this arrangement. In addition, the surface layer of organic matter which has negatively charged surfaces may have acted as an adsorption site for positively charged cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}).

4.7 Relationship between plant traits and soil physical and chemical properties

Whilst potato growth variables, yield, and PEY were not significantly ($P > 0.05$) correlated with proportions of sand, a positive correlation was nevertheless observed. This could be due to the fact that the reduction of proportions of sand after harvest, reduced water losses through evapotranspiration which facilitated nutrient uptake and enhanced crop growth and yield. A negative correlation between potato growth and yield with an increase in silt and clay could be due to the higher moisture-holding capacity of clay and silt which could have negatively affected crop emergence [42]. Furthermore, potato growth and yield had a positive correlation but non-significant ($P > 0.05$) with an improvement of chemical properties which indicates the efficient use of nutrients by potatoes when intercropping with *Mucuna pruriens*. Moreover a significant ($P < 0.05$) and negative correlation was observed between *Mucuna pruriens* yield and C/N, which is due to the high nitrogen production of *Mucuna pruriens* through symbiosis with rhizobia soil bacteria and higher *Mucuna pruriens* biomass production. This result is also observed with the positive correlation with *Mucuna pruriens* yield and N (%).

5 Conclusion and recommendation

The results of this study clearly indicate that the intercropping patterns do not affect the growth of the potato. However, the potato–*Mucuna* intercropping patterns increased potato equivalent yield over the pure potato stand. 1:1 and 2:1 intercropping patterns were found to be beneficial in improving yield resulting in high land use efficiency as compared to pure stand. Assessing competitive intensity, *Mucuna* was found to be the dominant crop species for all cropping combinations except the 1:2 cropping pattern. Potato–*Mucuna* was equally found to reduce potato late blight disease incidence, with the greatest performance observed with the 1:2 intercropping pattern, indicating that intercropping can equally help to reduce the use of pesticides. Moreover, potato–*Mucuna* intercropping pattern was equally found to improve soil physical and chemical properties and 1:1 and 2:1 intercropping patterns were the best arrangement for potato–*Mucuna* to improve C/N ratio and CEC, respectively. Thus the findings of this experiment showed that the 1:1 potato–*Mucuna* intercropping pattern could be recommended to smallholder farmers in the western highlands of Cameroon for yield advantage and to improve soil chemical properties.

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