

RESEARCH ARTICLE

POTENTIAL OF SOIL SOLARIZATION AND CATTLE URINE IN CONTROLLING SOME DISEASED PLANTS AND BOOSTING THE AGRO-ECONOMIC PERFORMANCES OF IRISH POTATOES (*SOLANUM TUBEROSUM* L.) IN THE FIELD

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ABSTRACT

A field trial was conducted to evaluate the impact of soil solarization and cattle urine used alone or in combination on the agro-economic performance of irish potato (*Solanum tuberosum* var. Dosa). To achieve this, a completely randomized block experimental design was established, involving five treatments (chemical fertilizer, soil solarization, cattle urine, soil solarization-cattle urine, negative control), each of which was repeated four times. Data on growth variables (plant height), yield (tuber diameter, number of tubers per plant, yield per hectare), and plant diseases survey (severity and diseases index) were analyzed. An economic analysis involved the assessment of profits derived from treatments. Results indicate that the chemical fertilizer and soil solarization- cattle urine treatments positively affected the potato growth and yield. The highest yields accounted for chemical fertilizer (3.02 t/ha) and soil solarization-cattle urine (2.47 t/ha), compared to solely cattle urine (2.02 t/ha), solarization (1.63 t/ha), and the negative control (0.41 t/ha). Chemical and solarization + urine treatments lowered the severity rates of diseases to average 56% and 62.75% respectively. Treatments cattle urine, soil solarization, and their synergic effect significantly reduced disease incidence compared to the negative control, at respective rates of 1.07%, 0.97%, and 0.93%. The economic analysis indicated that cattle urine is the most suitable treatment under farmers' conditions, with an acceptability index (AI) close to 2, suggesting that this bio-treatment could sustainably be used as an eco-friendly alternative strategy to boost irish potatoes production in the field.

KEYWORDS

soil solarization, cattle urine, yield, diseased plants, economic analysis, *Solanum tuberosum*

1. INTRODUCTION

Originally from South America, potato was introduced in Cameroon during the German colonial period (1884-1914), but was really cultivation in the 1940s, with the introduction of new varieties (Foncho, 1982). In many other African countries, potato (*Solanum tuberosum* L.) has increasingly become popular in recent decades due to its versatility and ease of marketing (Weidmann et al., 2019). In Cameroon, studies have shown that the role of potatoes in the market economy has grown due to high demand for root and tuber crops from neighbouring countries such as Gabon and the Central African Republic, thus representing a major source of income for many farmers (Njukeng et al., 2013; Mariette et al., 2016). Potato production is often compromised by numerous diseases and pests, including insects, bacteria, fungi, viruses and other pathogens. Among these bacteria top the list and are responsible for infections such as common scab and blackleg, caused respectively by *Erwinia amylovora* and *Erwinia carotovora*. *Erwinia carotovora* is the most damaging, with severe productivity losses and reduced market value (Bachir, 2021). Another factor limiting potato production is soil nutrient depletion (Neba et al., 2015).

To ensure profitable commercial potato production, it is essential to

obtain satisfactory yields to cover the cost of purchasing planting material, such as chemical inputs (mineral fertilizers and pesticides), which, although effective in improving yields, are costly and present risks for consumer health and the environment (Estaun et al., 1997; Djè et al., 2005). Despite the considerable yields they can promote, the excessive and continuous use of these fertilizers frequently leads to problems such as groundwater pollution and water eutrophication (Balogoun et al., 2013). It would therefore make sense to develop low-cost, sustainable farming techniques to ensure sufficient food production (Thonar et al., 2017). The solution proposed here is soil solarization as a means of controlling crop diseases and weeds. The effectiveness of this technique against nematodes, fungi, bacteria and other plant pathogens has been widely documented by several authors (Greco et al., 1985; Stapleton and Devay, 1995; Siti et al., 1998; Celetti et al., 2000; Fe and Cabrera, 2002; Chellemi, 2006). This technique can be combined with the application of cattle urine to improve the soil nutrient depletion. Indeed, urine is a solution rich in essential macroelements such as nitrogen (N), phosphorus (P) and potassium (K), for plants making it a low-cost alternative to mineral nitrogen fertilizers in agricultural production (Kirchmann and Pettersson, 1995; Johansson et al., 2001; Simons and Clemens, 2004). Its effectiveness in the field has been demonstrated in increasing yields of

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barley, lettuce and leek (Johansson et al., 2001 ; Guadarrama et al., 2001 ; Båth, 2003). Hence, the aim of this study was to assess the effect of these farming practices on the agro-economic performance of potato in the field for a sustainable potato production in the Adamaoua region. More specifically, it involves : a) evaluating the effect of soil solarization, cattle urine on potato growth and yield parameters ; b) assessing the effect of the various treatments applied on the severity and incidence of attacks by pathologies encountered in the field ; c) evaluating the effect of these practices, alone or in combination on the economic profitability of potatoes.

2. METHODOLOGY

2.1 Description of the study site and plant material

The experiment was carried out in the Guinean Savannah agro-ecological zone at Dang, within the experimental field of the Unit for Applied Apidology (latitude : 7°25.3767 N ; longitude : 13°32.4353 E ; altitude : 1106 m a.s.l.) of the Faculty of Science, University of Ngaoundere. The climate is characterized by a rainy season (April to October) and a dry season (November to March), with an annual rainfall of approximately 1500 mm. The annual temperature fluctuates between 21 and 22 °C with a daily thermal amplitude varying between 6 and 7 °C (Amougou, 2015). Annual rainfall averages decrease over time. Thus, the interannual averages of the area were above 850 mm before 1999 against only 700 mm over the period 2000 – 2005 (UNDP, 2010). The plant material consisted of potato tubers of the Dosa variety, between 10 and 30 cm in size, obtained from a local seed company.

2.2 Formulation of cattle urine-based fertilizer and chemical pesticide

Freshly collected cattle urine was placed in hermetically 10 liter sealed containers and stores for 4 weeks at room temperature in the shade to eliminate potential pathogens. The obtained solution was then sanitised and stabilized according to the method described by (Maurer et al., 2006). This method consisted of diluting 1 L of cattle urine with 8 L tap water for direct application to the field. The synthetic chemical pesticide solution was prepared according to the recommendations of the phytopharmacist. Therefore, 15 g Penncozeb 720 WP and Monchamp 720 WP, 10 mL Optimal 20 SP and Cypermulck were mixed in a bucket with 5 L of water, as often used by farmers to control mildew, alternaria, bacterial wilt on irish potato plants. The shaken solution was transferred to a hand sprayer to applied onto irish potato plants in the field.

2.3 Experimental set-up

Experimental set-up was a completely randomized block with five (5) treatments each of which was repeated four times. Field trials were conducted from May to August 2024 and laid out on a 232.5 m² surface areas consisting of 20 elementary plot units grouped into 5 blocks. Each block was subdivided into four experimental units (4 m² each) arranged randomly, and separated 1.5 cm apart. On each experimental plot unit, 3 rows of four plants were spaced 40 cm apart between rows and 30 cm between plants. Treatments include : cattle urine ; soil solarization ; cattle urine + soil solarization ; chemical fertilizer and negative control.

To ensure a rapid seed tubers emergence, seeds were previously soaked for 5h30 min into tap water, to simulate the physiological functions of tubers. Pregerminated seed tubers were planted in each experimental plot unit at 10 cm depth, before they were covered with a soil layer to protect tubers from damages caused by rodents.

2.4 Application of different treatments

For soil solarized treated plots, 180 liters of water were applied, then the soil was covered with plastic film to create a thermal shock and initiate evapotranspiration. Eight weeks later, plots were uncovered, turned over and left to cool for 24 hours before tubers sowing (Simmons et al., 2016). The same day, plots for other treatments were sown. Following plant emergence, two calibrated manual sprayers were used once a week to apply treatments based chemical and cattle urine. Each sprayer was assigned to a particular treatment to prevent cross-contamination. Considering the meteorological circumstances that could affect the spraying efficacy, treatments were sprayed in the morning, between 6 a.m. and 8 a.m., to avoid strong winds that could cause deflection of product droplets or reduce their effectiveness (Oparaeke, 2005 ; Omoigui et al., 2018). Weeds were removed manually every week after sowing to prevent their proliferation. Due to the scarcity of rain after sowing, plants were watered twice a day, morning and evening, until the arrival of regular rains.

2.5 Assessment of growth and yield parameters

During the vegetative phase, growth parameters such as plant height were

determined using a graduated ruler placed at the base of the plant at ground level and then measured to the summit. The number of tubers was evaluated by direct counting of tubers formed by each plant in each experimental plot. The diameter of the tubers was evaluated by measuring the circumference of 10 tubers chosen at random per plot. At harvest, yield was calculated by weighing the total number of tubers obtained per unit area, then extrapolated to the hectare using the rule of three. Thus, tubers yield (kg/m²) was calculated using the following formula : $Y = ((P*1000)) / (SE))$, where Y = weight of tubers in kg/ha ; P = weight of tubers per experimental area unit ; SE = experimental area (m²) and 1 ha = 10000 m² (Egho and Emosairue, 2010).

2.6 Evaluation of the incidence and severity of attacks by diseases encountered in the field

The incidence of disease was calculated by nothing the number of infected plants, the number of infected leaves, the number of spots per leaf and the total number of plants in each experimental unit. It was determined using the following formula : $I (\%) = (n/N) * 100$, where : n = number of infected plants, N = total number of plants and I = incidence. The severity was assessed using a symptom rating scale from 0 to 3, where : 0 = no infection ; 1 = partial infection ; 2 = moderate infection ; 3 = severe infection. It was calculated by using the formula developed, which states that $Sev (\%) = (\sum Score/Nt*3) * 100$, where : $Sev (\%)$ = severity ; $\sum Score$ = sum of different scores of the infected plants ; Nt = total number of infected plants by (Madhavi et al., 2012).

2.7 Economic analysis of different nutrient sources

The economic analysis consisted of determining which treatment was best suited under farmers conditions by calculating the Acceptability index (AI) which is the ratio between the gross profit of each treatment and that of the control treatment, the gross profit (the difference between the gross income (GI) and the production cost (PC) which include all variable production related charges) and the gross income (average crop yield multiplied by the market price of a 40 kg box of potatoes, which was 15 000 FCFA during our study). According to the study, this analysis only included the costs associated with variable production expenses (Kaho et al., 2011). The costs of agrochemical inputs (mineral fertilizers, cattle urine and soil solarization material) as well as labour costs were evaluated based on local market price. The cost of 20-10-10 mineral fertilizer (25 000 FCFA per 50 kg bag + 75 000 FCFA for pesticide costs), cattle urine (500 FCFA per liter, with a labour cost of 18,000 FCFA for 3 workers for field application), labour costs for soil solarization set-up (25 000 FCFA + 1 500 FCFA for the bulk purchase of a 3 m² white plastic film) and chemical fertilizer application (48 000 FCFA) were therefore taken into account as variable production costs. These different economic variables were calculated according to the study, who stipulate that an Acceptability index (AI) below 1.5 indicates rejection of the treatment, an AI between 1.5 and 2 suggests reluctant adoption, and an AI greater than or equal to 2 means that the treatment is readily adopted (Kaho et al., 2011).

2.8 Statistical analysis

Data collected on the studied parameters were organized and classified in the Microsoft 2013 Excel spreadsheet. They were then transferred to Statgraphics Plus 16.0 software for analysis of variance (ANOVA), and to assess Pearson correlation tests which determine relationships between the different parameters. Duncan's test was used to compare the means of the different treatments at the indicated level of significance.

3. RESULTS AND DISCUSSION

3.1 Influence of treatments on growth and yield of potato plants

3.1.1 Average height of irish potato plants

Figure 1 illustrates the height of potato plants in centimetres as affected by different treatments (cattle urine alone (32.64 cm), chemical treatment (36.97 cm) and soil solarization + cattle urine (35.24 cm)) significantly ($p = 0.003$). Irish potatoes height as compared to soil solarization alone (29.48 cm) and the negative control (28.43 cm). In the decreasing order of effectiveness treatments were thus classified as chemical fertilizer > soil solarization + cattle urine > cattle urine > soil solarization > negative control. The low growth observed with the negative control reflects the poverty of soil, due to repeated depletion of soil from mineral elements by the plant without restitution, leading to a loss of fertility (Temgoua et al., 2017). There was however no significant difference between cattle urine and cattle urine soil + solarization. In fact urine provides the assimilable nitrogen required by plants (Heinonen-Tanski et al., 2007), combined with the effect of solarization, which improves soil structure, releases essential nutrients and stimulates beneficial microbial activity, as reported by (Benbrahim and Sayed, 2005). These results are in line with those, who reported urine and soil solarization increased size of maize (Temgoua et al., 2017).

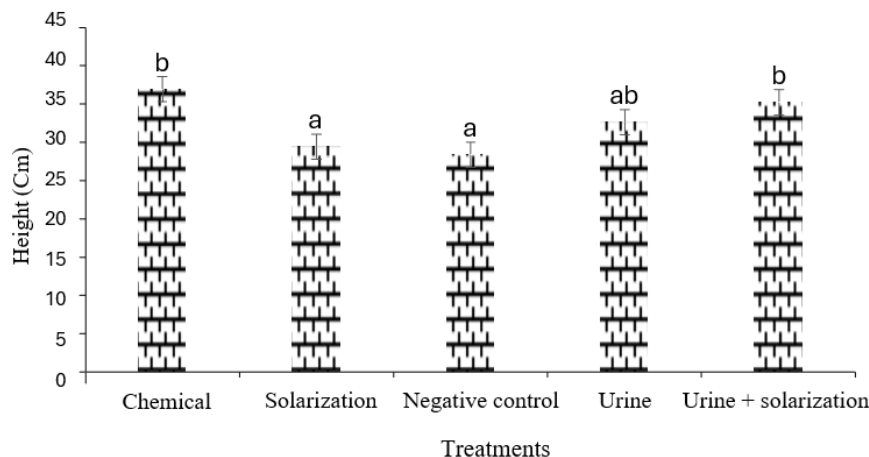


Figure 1 : Variation of Irish potato plants height under different treatments

3.1.2 Influence of treatments tuberization of Irish potatoes per plant

The average number of potato tubers formed per plant was significantly ($p = 0.02$) higher in all the treatment than that of the negative control. Chemical fertilizer and cattle urine + solarization were the most effective treatments, resulting in a tuberization 1.65 times and 1.53 times greater than that of the negative control, compared to soil solarization (1.50

times) and cattle urine (1.47 times). Thus the increasing ranking of effectiveness as far as this parameter is concerned was negative control < cattle urine < soil solarization < cattle urine + soil solarization < chemical fertilizer (Figure 2). The absence of significant difference between chemical fertilizer, soil solarization, cattle urine, cattle urine + soil solarization could indicate the similarity of the effectiveness between the chemical inputs and the organic inputs.

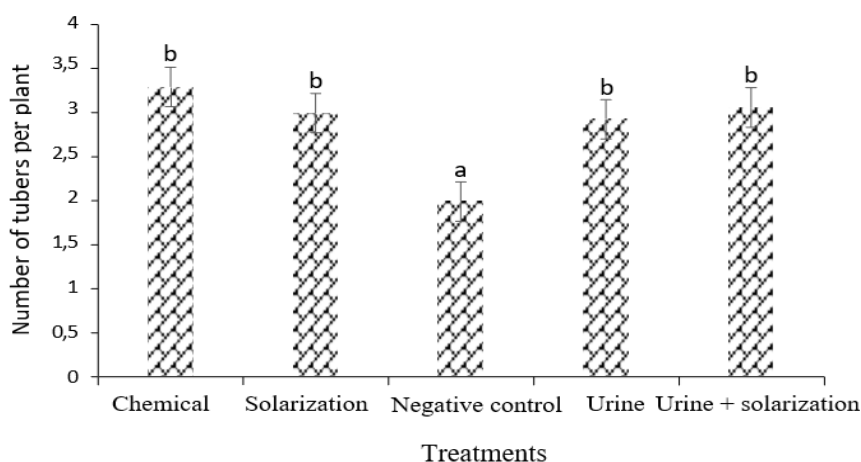


Figure 2 : Variation in the tuberization (in number) of potato plant as influenced by treatments

3.1.3 Impact of treatment on the average diameter of harvested potato tubers as influenced by treatments

Statistical analysis revealed a highly significant difference between treatments ($p = 0.009$) as far as the diameter of harvested tubers is concerned (Figure 3). The chemical, soil solarization + cattle urine and solarization treatments significantly improved tuber diameter by 2.88 cm, 2.03 cm and 1.68 cm respectively, compared to that of the negative control. Cattle urine treatment also showed improvement, with an increase of 1.48

cm over the negative control. These results can be explained by the fact that soil solarization might have considerably increased the nitrogen, phosphorus and potassium contents in the soil, thus ensuring better plant nutrition. In addition assimilable nitrogen was directly supplied by cattle urine (Loubadi, 1997 ; Benbrahim and Sayed, 2005). According to the study, nitrogen as an essential constituent of chlorophyll, plays a decisive role in plant growth and yield (Hazzar, 2017). These results corroborate those, who showed that human urine significantly increased the weight of 1000 maize seeds (Kosma et al., 2022).

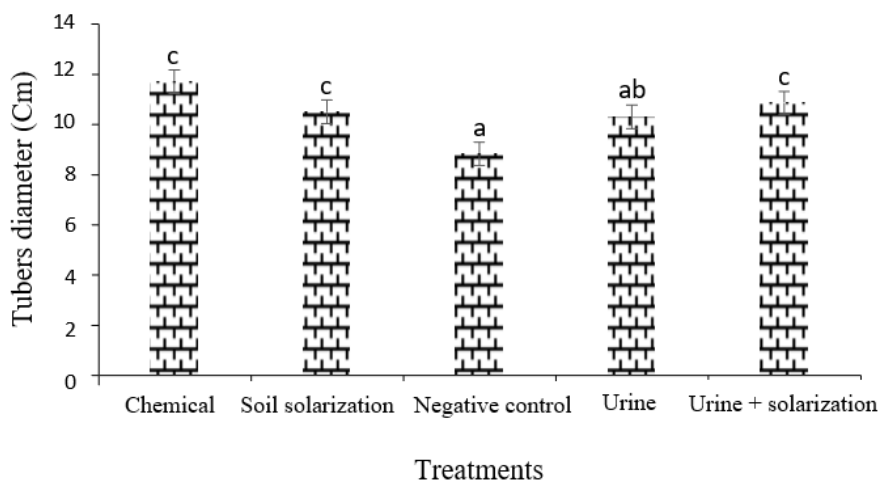


Figure 3: Differences in the average diameter of harvested potato tubers as influenced by different treatments

3.1.4 Potato yield per hectare as affected by treatments

The negative control showed the lowest yield at 1.06 t/ha, whereas the solarization and cattle urine treatments reached 1.63 t/ha and 2.02 t/ha respectively (Figure 4). Soil solarization + cattle urine proved to be the most effective biological treatment, with a yield per hectare 2.47 times greater than that of the negative control, thus close to that of the chemical treatment. The efficacy of the different treatments applied was highly statistically significant ($p = 0.001$). The means separation test (Duncan) identified five distinct levels of efficiency among the fertilizers tested, highlighting the particular effectiveness of the solarization + cattle urine treatment. This result is partly explained by the fact that cattle urine, as a source of nitrogen, can improve the growth and development of potato

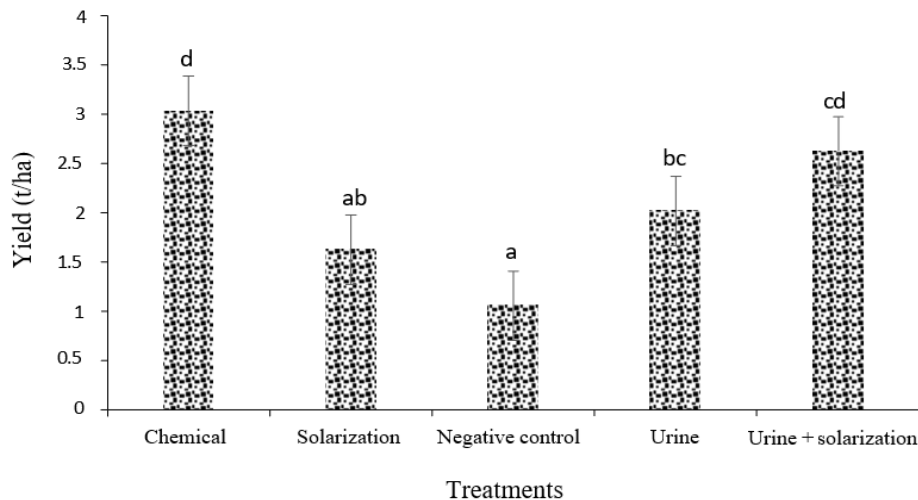


Figure 4 : Efficiency of treatments on harvested potato yield per hectare

3.2 Effectiveness of the applied treatments on the severity and incidence of attacks by pathologies encountered in the field

From Table 1 the analysis of variance revealed a significant difference ($p = 0.01$) between treatments. The highest severity damages (90.75%) accounted for the negative control, higher than 72.81% and 69.25% observed from cattle urine and soil solarization treatments respectively. The chemical and soil solarization + cattle urine treatments had the lowest severity rates, with 56% and 62.75% in average respectively, making them the most effective options for responding to pathogen attacks on potatoes in the field. The significant reduction in attacks observed with the soil solarization + cattle urine treatment could be attributed to a change in the microbiological balance in favor of antagonistic microorganisms, induced by soil solarization (Katan, 1981). Several studies have shown that these microorganisms mainly include thermotolerant genus such as *Trichoderma*, *Paecilomyces* and *Aspergillus* renowned for their antagonistic role (Jonsson et al., 2004). This effectiveness is enhanced by the improved mineral nutrition provided by cattle urine (Jonsson et al., 2004).

On the other hands, the incidence of disease caused by different

plants in a way comparable to mineral urea. These observations are in line with those, who demonstrated that the nitrogen contained in urine, used as a fertilizer on barley in Sweden, corresponded to around 90% of the efficiency of ammonium nitrate-based mineral fertilizers (Johansson et al., 2001). In fact, soil solarization used plastic film to trap heat at 10°C on the surface and 17 to 20°C in the upper layers, as well as 2 to 6°C in the deeper layers (Eddoud, 2001 ; Djerroudi, 2002). Under this plastic film, soil water and soluble nutrients, such as nitrates, migrate to the surface by capillarity, and it would be likely that the rate of organic nitrogen mineralization could be stimulated by increased humidity under the plastic film. Moreover, high temperature under the plastic film activated nitrogen mineralization and stimulated nitrification (Chen and Katan, 1980 ; Katan et al., 1987 ; Chen et al., 1991).

pathologies was significantly ($p = 0.004$) influenced by the treatments applied with the negative control indicating an incidence of 1.55%, significantly higher than that of the other treatments. Cattle urine-based treatments, soil solarization and soil solarization + cattle urine significantly reduced disease incidence compared with the negative control, by 1.07%, 0.97% and 0.93% respectively, although less effective than that of the chemical treatment, which showed an incidence of 0.77%. The significant reduction in disease incidence observed with urine-based treatments and soil solarization could be attributed to the high concentration of urea in urine, which is a primary nitrogenous compound in excreted wastes. As pointed out that urea has the ability to stimulate the activity of microorganisms beneficial to plants, while inhibiting pathogenic fungi by attacking their spores (Vincent-Phillion, 2008). The effectiveness of soil solarization in reducing populations of *Meloidogyne* sp., *Pratylenchus* sp., *Globodera* spp. and *Rotylenchus* sp. while increasing crop yields was also reported by several authors, making this technique a powerful disinfectant (Celetti et al., 2000 ; Chellemi, 2006). The effectiveness of soil solarization was also revealed in the control of necrosis and rot of *Phaseolus vulgaris* L. in Senegal (Dramé et al., 2012).

Table 1 : Variation of the incidence and severity of potato diseases as influenced by treatments

Treatments	Diseases severity	Incidence of diseases
Chemical	0.77 ± 0.28 ^a	56 ± 17.64 ^b
Soil solarization	0.97 ± 0.20 ^a	69.25 ± 20.05 ^b
Negative control	1.54 ± 0.33 ^b	90.75 ± 1.25 ^a
Cattle urine	1.07 ± 0.20 ^a	72.81 ± 6.49 ^{ab}
Cattle urine + solarization	0.93 ± 0.13 ^a	62.75 ± 5.67 ^b
Probability	0.0047	0.0156

Means with the same letter in the same column are not significantly different at 5% probability ($p > 0.05$) according to Duncan's test. Those with different letters are significantly different.

3.3 Effect of different treatments on the economic profitability of potatoes

The results of the economic analysis (Table 2) showed that the cattle urine, soil solarization + cattle urine and chemical treatments achieved the

highest gross profits compared to the negative control treatment. The results of the treatment acceptability index also showed a higher acceptability index for the cattle urine (1.91) and chemical (1.75) treatments, compared to soil solarization (0.89) and cattle urine + soil solarization (1.67) treatments. Therefore yields of the different

treatments and the cost of fertilizers had a strong influence on the economic variables of potato. This leads to the conclusion that the cattle urine treatment may be the most suitable for farmers in the growing area, as it provided an acceptability index very close to 2, lower than above reported by (Kaho et al., 2011 ; Jama et al., 2000 ; Wandji, 2022). The

acceptability index (1.75) obtained with the chemical treatment was slightly higher (1.67) than that recorded on potato cultivation in West Cameroon, showing that the chemical load was not beneficial for farmers and that it would be better to opt for organic alternatives which are less costly for greater profitability by (Wandji, 2022).

Table 2: Economic evaluation of the various applied treatments

Treatments Materials	Negative control	Treatment chemical	Treatment solarization	Treatment urine + solarization	Treatment urine
Yields (kg/ha)	1060 kg (27 cartons)	3032 kg (76 cartons)	1480 kg (37 cartons)	2623 kg (66 cartons)	2017.5 kg (55 cartons)
Chemical products	/	300000 Fcfa + 75000 Fcfa	/	/	/
Urine	/	//	/	30000 Fcfa	30000 Fcfa
Setting up solarization	/		250000 Fcfa	250000 Fcfa	/
Transport of equipment required for various treatments	/	5000 Fcfa	3000 Fcfa	3000 Fcfa	3000 Fcfa
Labour to apply the various treatments in the field	/	48000 Fcfa	20000 Fcfa	20000 +18000 Fcfa	18000 Fcfa
Production coup		428000 Fcfa	273000 Fcfa	321000 Fcfa	51000 Fcfa
Gross revenue	405000 Fcfa	1140000 Fcfa	555000 Fcfa	999000 Fcfa	825000 Fcfa
Gross profit	405000 Fcfa	712000 Fcfa	375000 Fcfa	678000 Fcfa	774000 Fcfa
Acceptability index		1.75	0.70	1.67	1.91

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