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Research Article

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Effect of Jatropha curcas L. Press-cake and Inorganic NP Fertilizers on the Productivity of Potato (*Solanum tuberosum* L.) and Soil Properties

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Abstract
Low soil fertility is a major constraint to potato production in Ethiopia. A field experiment was conducted at rare research farm, main campus of HU in Ethiopia, during the main growing season of 2011 under supplementary irrigation to evaluate the effects of J. curcas L. press-cake and inorganic NP fertilizers on the productivity of potato (S. tuberosum L.) and soil properties. The treatments consisted of four rates of J. press-cake (0, 2, 4 and 6 t ha^{-1}) and 5 rates of combined mineral NP (0 + 0; 0 + 46; 50 + 0; 50 + 46; 100 + 92 kg N + P, respectively, ha^{-1}) fertilizers. The experiment was laid out as a RCBD in a factorial arrangement and replicated three times. The plot sizes were 3.75 m x 3.9 m. The distance between plots and blocks was maintained at 1 and 2 m, respectively. All agronomic and soil data were collected and analysis of variance was done. The results indicated that J. Press-cake along with mineral fertilizer significantly enhanced potato tuber yields and soil OM. From the results of the study, it could be deduced that 2 t J. press.-cake ha^{-1} resulted in an optimum total tuber yield.

Introduction
Land degradation, food insecurity and access to energy are major challenges for Ethiopia. Increasing population pressure, deforestation, and continued cultivation of the land for crop production with little efforts to conserve the natural resources have exacerbated the problems. Furthermore, these practices have contributed to global warming and environmental pollution. The causes of land degradation in Ethiopia as it had been stated by Belay are cultivation on steep and fragile soils with inadequate investments in soil conservation or vegetation cover, erratic and erosive rainfall patterns, declining use of fallow, limited recycling of dung and crop residues to the soil, deforestation and overgrazing [1].

Potato consumption has increased in the developing countries, and over the last decade, global potato production has increased at an annual average rate of 4.5 percent [2]. Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops cultivated in Ethiopia for local consumption and income source. The potato crop was introduced to Ethiopia around 1858 by Schimper, a German botanist [3]. Ethiopia is endowed with suitable climatic and edaphic conditions for potato production. However, the national average yield is estimated at 8.2 t/ha, which is very low by any standards compared to the world average of 17.4 t/ha [4]. One of the contributing factors to this low yield is the inadequate application of proper agronomic management practices particularly in fertilizer and manorial use by potato growers.

In Ethiopia, low soil fertility is one of the factors limiting productivity of crops, including potato [5, 6]. Tamirie speculated that this might be caused as a result of the removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residues from farmland and lack of proper crop rotation program.

At present, the issue of soil productivity has become a global concern. According to Brady and Weil the two major interactive worldwide problems are widespread hunger and malnutrition, and the deterioration of quality of the environment resulting from injudicious attempts made to alleviate hunger and malnutrition [7]. Soil fertility depletion is the fundamental biophysical root cause for declining per capita food production in the Sub-Sahara Africa (SSA) countries in general and in Ethiopia in particular [8]. The most important issue of our time is therefore, how to increase agricultural production in the right places while at the same time conserving the quality of environment and the productive capacity of land and water resources [9].

On top of the major interactive worldwide problems arising from injudicious use of chemical fertilizers, the increasing cost of inorganic fertilizers and chemicals and their hazards to the environment and humans as integrated means of control has to be thought over. Long-term N fertilization depletes soil organic carbon by promoting the decomposition of crop residues and soil organic matter leading to deterioration of soil quality. Fertilizer practices in Ethiopia have been mainly based more on inorganic and little on organic fertilizers like cow dung and other manures. According to Tesfsye and Sahlemedhin, organic matter content and nutrient supplying power of most cultivated soils in Ethiopia is low [10]. Therefore, there is a need to conduct research on the potential use of plant and animal by-products as organic fertilizers.

Organic fertilizer increases the organic matter content of the soil along with the major and minor organic nutrients. The combined interaction of the nutrient ingredients in organic fertilizer supplies the soil with the full range of nutrients within a relatively short time, and their effects last longer for the standing crop to benefit directly. Organic fertilizer is therefore unique in its action in stabilizing and enhancing the nutrient status of the soil, and thereby increasing crop productivity [11].

Jatropha curcas L. is one among the selected plant for the production of bio-fuel in Ethiopia. It is a small tree or large shrub, up to 5-7 m tall, belonging to the Euphorbiaceae family. It adapts well to semi-arid marginal sites, its oil can be processed for use as a diesel fuel substitute and it can be used for erosion control [12]. The residue from the biodiesel or biogas digester can be used further as a fertilizer [13]. Although the physic nut is of Mexican and Central American origin, it is cultivated in many other Latin American, Asian and African countries as a hedge and it was an important export product from the Cape Verde Islands during the first half of this century Heller [14]. The Ethiopian government is engaged in a proactive bio-fuel development policy to decrease dependency on imported fossil fuel as energy source. Press-cake is a major by-product of Jatropha oil extraction, representing around 70% of the total processed biomass [13]. Disposal of the press-cake has been a major challenge so far, but there is evidence that it can be used to enhance soil fertility. Biodiesel by-product (de-oiled seed cake) contributes to environmental pollution unless properly disposed off or recycled safely as in the form of organic fertilizer or for other economic use for enhanced economic returns.

A lot is known about Jatropha and its cake utilization for soil fertility improvement in different parts of the world including Africa Heller [14]. However, the authors confirmed that nothing is known about the status of this residue nutrient content in Ethiopia since no work has been done yet now. Crop specific organic fertilizer formulation of the de-oiled seed cake has not been attempted to enhance the confidence of the farmer to get yield at par with inorganic fertilizers. The authors finally suggested that application of mineral fertilizers and organic manure is essential to sustain high yields, better quality and more profit.

Thus, every effort should be directed to maintain the physical, biological and socio-economic environments for production of food crops, livestock, wood and other products through sustainable use of the ecosystem. This study is focused on the use of Jatropha press-cake for enhancing soil fertility as an alternative source of organic soil nutrients amendment. Oil cake appears to be a very attractive proportion as it contains all the macro and micro-nutrients and it is an excellent organic fertilizer unlike inorganic fertilizers that supply only few nutrients [15].

While a lot of work has been devoted to the study of the influence of mineral fertilizers on yields and quality of plant foods, only limited data are available concerning the efficiency of organic fertilizers particularly bio-waste organics. Additionally, even though the past studies have demonstrated that bio-waste applications improve yields, however, tailored crop specific formulations have not yet being developed. Environmentally, some of the organic wastes are accumulated unless it is recycled to be used as organic soil amendments to realize as possible the safety standard limits of pollution prevention of the agricultural sector.

There is, therefore, an urgent need to develop low cost and safe input technology to get higher production from intensive cropping apart from maintaining soil fertility. Hence, balanced fertilization in proper proportion using both organic Jatropha press-cake and inorganic combined N and P sources is one of the promising techniques for improving long term soil productivity and increasing potato yield. Singh and Chauhan reported that nutrients from mineral fertilizers enhance the establishment of crops while those from mineralization of organic manure promoted yield when both fertilizers were combined [16].

A number of questions concerning the long-term and cumulative impacts of *Jatropha curcas* L. press-cake on soils have not been addressed. Thus, systematic investigations into the influence of applied Jatropha press-cake as an organic fertilizer under specific agro ecologies is very important to come up with relevant recommendations in order to help farmers increase the productivity of food crops and promote the eco-friendly Jatropha plant cultivation for its tremendous advantage including carbon capture in large scale.

This study was conducted to examine the effects of *J. curcas* L. press-cake and inorganic NP fertilizers on the productivity of potato (*Solanum tuberosum* L.) and soil properties.

Materials and Methods

The trial was conducted on a fluvisol, with a subsoil stratified as sandy clay loam at Experimental Farm of Haramaya University, situated at 9°42’ N latitude and 42°03’ E longitude and at the altitude of 1980 meters above sea level with average annual rainfall and temperature of 760 mm and 17°C, respectively, during the main growing season in 2011 under supplementary irrigation. Weather conditions during the growing season of 2011 are depicted on TABLE 1. Initially, the soil of the site contained about 0.74% organic carbon, 0.08% total nitrogen and 9.94 mg kg^{-1} soil available phosphorus,0.14 cmol (+) kg^{-1} soil potassium and has a pH of 7.84 (H_2O).

Table 1: Seasonal meteorological data of the study area for the experimental period of 2011

Months	Days with PPT	Average Temperature (°C)		Average RH % (mm)	Total Rainfall (mm)	Wind Speed 100ms	Sun Shine Hours
		Maximum	Minimum				
May	17	25.3	13.7	60.6	113.4	48.8	212
June	12	25.3	15.1	61.8	56.4	58	213
July	13	24.8	13.9	59.1	125.3	65.4	196
August	19	23.1	13.9	73.1	227	54.8	209
September	13	22.7	13.4	67	161	35.5	179
October	0	24.8	4.45	29.4	0	43.3	295
November	1	23.6	5.34	48.7	11.5	41.7	266

The Jatropha press-cake had chemical properties shown in Table 2. Urea and triple Superphos Phate (TSP) were used as sources of N and P, respectively. The treatments consisted of four rates of Jatropha press-cake (0, 2, 4 and 6 t ha^{-1}) and five rates of combined mineral N and P (0, 0; 0, 46; 50, 0; 50, 46; 100, 92 kg ha^{-1}) fertilizers. The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times (Figure 1a, b).

Table 2: Some chemical properties of Jatropha press-cake fertilizer used

Characteristics								
Oil % Content	Moisture Content%	Weight of 1m^3	Total Macro-nutrients Concentration (%)					Rate
11.2	6.31	528.92 Kg	5.33	1.06	2.8	0.21	0.29	t ha^{-1}
EC (1:2.5) mS/cm	OC (%)	C:NRatio	Total Macro-nutrients (mg kg^{-1})					
3.52	54.92	1.32	pH (1:2.5)	Fe	Mn	Cu	Zn	B
			6.22	606.4	21.68	11.2	8.6	5.5

Treatments were assigned to each plot randomly. Well sprouted medium-sized potato tubers of a potato variety named Badhasa were planted on 30 May 2011. Seed tubers were planted at the spacing of 75 cm between rows and 30 cm between plants (Figure 2b). The size of each plot was 3.75 m × 3.90 m (Figure 1b). The distance between plots and blocks was maintained at 1 m and 2 m, respectively (Figure 1a, b). Seed pieces were covered with 10 cm soil directly after planting in a 20 cm deep furrow (Figure 2b) and were hilled twice in the course of the growing period (Figure 3a).

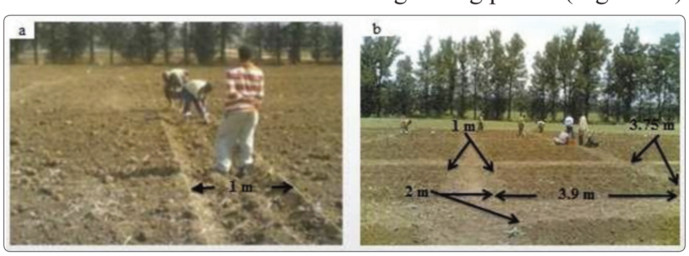

Figure 1: Lay outing of experimental field

The entire manually ground and sieved Jatropha press-cake (Figure. 4a,b), containing about 6.31% moisture, (Table2), was incorporated into the soil on a dry weight basis in furrows by hand-drilling to a depth of 15 cm three weeks before planting the potato crop (Figure 2a). Similarly, the entire rate of phosphorus fertilizer was applied at planting while nitrogen was applied in split doses half at planting and the remaining 45 days after planting. Furrow irrigation was used to supplement the crop with water once in the growing season (Figure 3b).

Tubers were harvested on 11 November 2011 using a manual hoe digger from the central three rows by excluding the two side border hills to avoid edge effects (Figure 5a). Tubers were graded as marketable and unmarketable (those were rotten, green and under-sized, less than 25 g). Tubers weighing < 25, 25-75 and > 75 grams were grouped in the small, medium and larger tuber categories, respectively as described by Lung'aho, et al (Figure 5b) [17]. For economic evaluation, cost and return, and benefit: cost ratio was calculated according to the procedure given by CIMMYT [7].

Figure 2: Incorporating Jatropha press-cake (a) and planting the potato tubers on experimental plots (b)

Statistical analysis was performed using GenStat analytical software for a two-way factorial RCBD and Fisher's protected LSD mean comparison test was used at 5% level of significance. Interactions were tested and were significant in some of the parameters under studied. Relationships between Jatropha press-cake, combined N and P and all parameters considered were examined by calculating the Pearson correlation coefficient.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

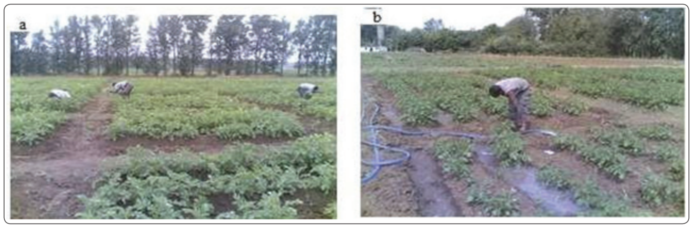

Figure 3: Hilling (a) and irrigating (b) the experimental plots

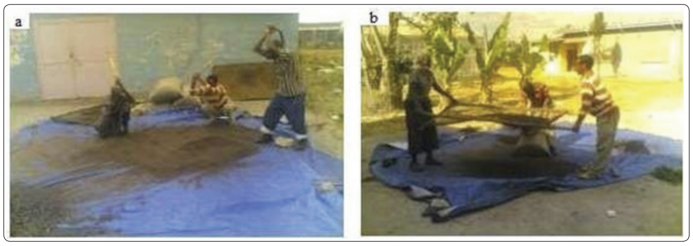

Figure 4: Manual coarse Jatropha press-cake grinding (a) and sieving (b)

Figure 5: Tuber harvesting (a) and grading (b) (marketable and unmarketable in three size categories

Results and Discussion

Effect of Jatropha Press-cake and Combined N and P Fertilizers on Phenology and Growth Attributes of the Potato Crop

Days to emergence

The results showed that the main effect of combined N and P fertilizer highly significantly ($P < 0.01$) influenced days to potato tuber shoot emergence (Table 3). However, either application of the sole Jatropha Press-cake or its combination with combined N and P fertilizers did not show significant influence on 50% tuber shoot emergence.

Increasing the combined inorganic N and P fertilizers from (0, 0) to (100, 92) kg ha-1 delayed 50% tuber shoot emergence by about 37%.

In support of the results of this study, Mehmood et al., revealed non-significant difference in days to seedling emergency of maize in response to manuring treatments [18]. While, Jalaluddin and Hamid reported that addition of triple phosphate and manure in soil at 300 mg/kg of soil had better germination rate and was highest at 500 mg/kg [19].

Days to First Day and 50% Flowering

The number of days required to reach first day flowering was highly significantly ($P < 0.01$) affected by the applied combined effect of N and P rates (Table 3).The application of 50/46 kg N and P ha^{-1} significantly increased the days to fist day flowering as compared to control, which resulted in longer flowering period by about 1 day. Nevertheless, increased rates of N and P combined fertilizer rates beyond this level did not show statistically significant differences between the treatment means shown in Table 3.

Table 3: The main effects of Jatropha press-cake and combined inorganic N and P fertilizers application rate on potato phenology parameters

Treatments	Phenological parameters			
	Days to emergency	Days to 1st dayflowering	Days to 50% flowering	Days to 50% maturity
Jatropha cake (t ha^{-1})				
0	17.40	42.53	48.87	106.13c
2	17.47	42.67	49.00	111.87b
4	17.80	42.73	49.47	116.47b
6	17.53	42.47	49.33	124.33a
	Ns	Ns	ns	**
NP (kg ha^{-1})				
0/0	14.25b	42.08c	47.83	107.83b
0/46	19.25a	42.67ab	50.08	118.33a
50/0	15.25b	42.58b	48.17	116.67a
50/46	19.42a	43.00a	49.42	116.17a
100/92	19.58a	42.67ab	50.33	114.50a
	**	**	ns	**
CV (%) =	15.2	1.1	5.5	6.0

Means within the same column followed by the same letter do not differ significantly at the 5 % and 1% significance levels of probability; ns = non-significant.

However, days to 50% flowering was not significantly affected by the main effect of Jatropha press-cake and by the combined N and P mineral fertilizers as well as by the interaction effects of the two factors (Table 3).

Days to Maturity

Application of both sole Jatropha press-cake and combined N and P fertilizers had shown significant influence on days to 50% physiological maturity ($P < 0.01$) (Table 4). Increasing both Jatropha press-cake and combined N and P application rates from 0 to 6 t ha^{-1} and (0, 0) to (100, 92) kg ha^{-1} prolonged the time required to attain 50% physiological maturity of potato from about 106 to 124 days (18 days increment) and from 108 to 118 days (10.5 days increment), respectively. However, there appeared to be found no statistically significant differences between the treatment means of the applied 2 and 4 t Jatropha press-cake ha^{-1}. Similarly, statistical parities were observed between the combined N and P fertilized treatment means of days to maturity.

That applying organic and inorganic fertilizers in combination prolonged days to physiological maturity might be due to the availability of nutrient supply especially nitrogen in Jatropha press-cake as well in combined N and P fertilizers, which is known to promote vegetative growth and delay maturity in many horticultural and field crops [20-23]. Delayed maturity due to increased supply of nitrogen and phosphorus indicates longer favourable time for cell division, growth, phostosynthesis, and accumulation and eventual partitioning of photoassimilates to various plant parts. Moreover, it could be due to the improvement of soil water holding capacity as mentioned earlier by Roe and Cornforth [24]. In case of the Jatropha press-cake, this tends to improve the soil water holding capacity thereby the soil ability to provide water over longer time, which extends the vegetative development culminates in delaying senescence of the potato crop [25-27]. In the present finding both factors were not interacted to significantly influence ($P > 0.05$) on the physiological maturity

Plant Height

The main effect of Jatropha press-cake significantly ($P < 0.01$) affected plant height (Table 4). However, neither the main effect of combined N and P nor its combination with Jatropha press-cake fertilizers significantly influenced this parameter of the plant. Increasing Jatropha press-cake from 0 to 2 t ha-1 did not significantly increase plant height. However, increasing the application of the press-cake from 0 to 4 and then to 6 t ha-1 significantly increased plant heights by about 12 and 16%, respectively, (Table 4). Similar results were reported by Powon et al., who stated that application of FYM increased potato stem height by 25% and 5% over the control treatment [28]. Additionally, Merghany and El- Fakharani found that organic manure had a significant effect on growth characters of potato plants when compared with the application of the same level of nitrogen obtained from inorganic N fertilizers [29,30]. In accordance with this result, Tyagi and Alam reported the de-oiled seed cake of neem was associated with significant improvements in enhanced growth of mungbean, chickpea and pea [31,32].

The increase in plant height due to the increased application of the Jatropha press-cake may be attributed to the inherent nutrient contents of the press-cake (Table 2) whereby it may have contributed to the nutrient supply of the soil from which the plants could have drawn nutrients. In addition, the enhanced soil physical properties of the soil such as heightened moisture contents due to the press-cake may have contributed to the enhanced growth of the potato plants.

Therefore, Jatropha press-cake may have played a consequential role by supplying nutrients and improvement the solubility of some elements and also by producing biological active substances which favour the photosynthesis effectively and enhance growth and development of plants [21-23,33,34]. The result of this study is in agreement with that of Deshmukh in case of Gillardia. Additionally, increase in plant height is likely to be due to typical favourable effect of N and P on promoting vigorous plant growth through efficient photosynthesis and dry matter production as N is the main constituent of chlorophyll molecule and P is the major component of ATP and sugar phosphate needed for effective carbon fixation [20,35-38].

The reason why the main effect of Jatropha press-cake showed significant influence on plant height but not the inorganic combined N and P may further be ascribed to the fact that organic fertilizer like Jatropha press-cake has the property of reducing leaching losses by binding to nutrients and also can give sustained supply of nutrients over a period of time, unlike inorganic N and P that are liable to denitrification, volatilization, leaching, ammonium fixation and phosphate fixation [39-43]. This is in line with the assertion of Akalan who pointed out that addition of organic manure is one of fundamental processes to minimize the nutrients losses from soil by means of leaching and denitrification [44]. So, sustainable farming by using such organic manure in agriculture is considered to be a strategy to preserve the environment and prevent chemical pollution. Corroborating this suggestion, Ibrahim et al., described that the effect of organic fertilizers like Jatropha press-cake is not solely attributed to its content of macro and micro nutrients (Table 2) but also due to its beneficial effects on the soil structure and its effect in decreasing the soil pH and used releasing and making available to plants fixed macro and micro nutrients [45].

Table 4: The main effects of Jatropha press-cake and combined inorganic N and P fertilizers application rate on some potato growth parameters

Treatments	Growth parameters	
	Plant height (cm)	Average stem number
Jatropha cake (t ha^{-1})		
0	96.41b	2.96
2	99.05b	2.93
4	108.31a	2.94
6	111.65a	2.80
	**	Ns
NP (kg ha^{-1})		
0/0	101.49	2.98
0/46	105.58	2.88
50/0	105.78	2.78
50/46	101.61	3.04
100/92	104.83	2.86
	Ns	Ns
CV (%) =	6.5	12.6

Means within the same column followed by the same letter do not differ significantly at 5% significance levels of probability; ** = significant at 1% significant levels of probability; ns = non-significant.

Average Stem Number

As it has been described by considerable number of researchers, even if stem number is one of the most important yield components in potato, the present study showed that the main as well as interaction effects of Jatropha press-cake and combined N and P fertilizers were non-significant [46,47]. This result is consistent also with the proposition of Lynch and Tai, De la Morena et al., Lynch and Rowberry that stem number is determined very early in the ontogeny of the tuber. Additionally, Allen and many other workers reported stem number is the reflection of storage condition, physiological age of the seed; variety and tuber size [48-53]. Thus, external supply of nutrients may not affect it.

Average Number of Leaves

Data presented in Table 5showed both forms of Jatropha press-cake and combined N and P fertilizers as well as their combinations had highly significantly affected average numbers of leaves per plant in the present studies. As increasing the rate of fertilizer combinations from the lowest to the highest, significantly increased average number of leaves by about 568% over the control. This could be explained by the enhanced vegetative growth of crops as a result of sustained and balanced supply of nutrients due to the applied organic and inorganic fertilizers. However, regardless of increasing the rate of fertilizer combinations statistical parities between the fertilized and the control and within the fertilized treatment means were observed. This might be attributed to the inherent soil fertility status of the experimental plots gained from the preceding cropping seasons. In support of the present findings, data obtained from Agbed showed mixed treatments or applications of organic and inorganic fertilizers significantly increased vine length, number of leaves and leaf area of yam [54]. Similarly, reported combined applications of organic and inorganic fertilizers significantly increased growth parameters of coffee seedlings, average leaf number of carrot and stem amaranth, respectively [55,56].

Table 5: Interaction effects of Jatropha press-cake and combined inorganic N and P fertilizer rates on average number of leaves per plant

Treatments	Average number of leaves per plant**					
	Combination NP rate kg ha^{-1}					Mean
Jatropha cake t ha^{-1}	0/0	0/46	50/0	50/46	100/92	
0	103.6f	268.51c-f	247.23c-f	126.16f	181.83ef	185.47
2	170.6f	316.94c-f	285.48c-f	164.72f	324.96c-f	252.54
4	198.7d-f	260.8c-f	543.04b-e	550.90b-d	449.42c-f	400.58
6	554.8b-d	1624.3a	383.56c-f	1624.3b	594.24bc	956.21
Mean	256.93	617.63	364.83	616.51	387.61	
CV (%) = 26.80						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability; ** = indicates significant difference at 1% significant levels of probability.

Total Leaf Area per Plant

Leaf area (LA) and leaf area index (LAI) are very important plant growth parameters because effectiveness of photosynthesis depends on large and efficient assimilating area, an adequate supply of solar energy and CO_2 and favorable environmental conditions [57,58]. The total products of photosynthesis throughout the life time of crop growth in a given circumstance depends on the size of assimilating area, the efficiency with which it functions and the length of the period during which it is active.

In the present studies combinations of Jatropha press-cake and inorganic combined N and P fertilizers highly significantly affected total leaf area of potato crop (Table 6). Similarly, both sole forms of Jatropha press-cake as well as combined N and P fertilizers also highly significantly affected total leaf area per plant of the potato crop. However, irrespective of increasing the rate of fertilizer combinations from the lowest to the highest statistical parities were observed between the fertilized and the control and within the fertilized treatment means.

The findings of Rajeshwari and Agbede supported the present studies in that the highest leaf area was observed on the combined application of inorganic fertilizer through different organics [54,59]. This result is also in harmony with those outlined by Baye et al., in case of potato who stated that leaf area of the plants was significantly affected due to the interaction effect of organic and inorganic fertilizers application [60].

Furthermore, organic manure activates many species of living organisms, which release phytohormones and may stimulate the plant growth and absorption of nutrients [61]. Such organisms need nitrogen for multiplication. This may be a plausible reason that the use of organic manure with inorganic fertilizer leads to increase in the leaf area which increased the amount of solar radiation intercepted thereby increasing days to flowering, physiological maturity, plant height and dry matter accumulation [62,63].

Leaf area Index

The main effect of Jatropha press-cake highly significantly ($P < 0.01$) influenced leaf area index of potato Table 7. The main effect of combined mineral N and P fertilizer also influence this parameter. Further, Jatropha press-cake and combined mineral N and P fertilizers interacted to significantly ($P < 0.05$) influence leaf area index of the crop plant.

The significantly highest leaf area index was recorded at the combined application of 6 t Jatropha seed cake ha^{-1} + (0 + 46) kg N and P ha^{-1} fetilizers despite it showed satatistical parities between fertilized treatment means of 4 t Jatropha press-cake + (50 + 0), 6 t Jatropha press-cake ha^{-1} + (0 + 0) kg combined N and P ha^{-1} and 6 t Jatropha press-cake ha^{-1} + (1000 + 92) kg combined N and P ha^{-1}. However, regardless of increasing the rates of fertilizer combinations from the lowest to the highest plots that received 0 t Jatropha press-cake ha^{-1} + (0 + 46) kg combined N and P ha^{-1}, 0 t Jatropha press-cake ha^{-1} + (50 + 0) kg combined N and P ha^{-1}, 0 t Jatropha press-cake ha^{-1} + (50 + 46) kg combined N and P ha^{-1}, 0 t Jatropha press-cake ha^{-1} + (100 + 92) kg combined N and P ha^{-1}, 2 t Jatropha press-cake ha^{-1} + (0 + 0) kg combined N and P ha^{-1}, 2 t Jatropha press-cake ha^{-1} + (50 + 0) kg combined N and P ha^{-1}, 2 t Jatropha press-cake ha^{-1} + (50 + 46) kg combined N and P ha^{-1}, 4 t Jatropha press-cake ha^{-1} + (0 + 0) kg combined N and P ha^{-1} and 4 t Jatropha press-cake ha^{-1} + (0 + 46) kg combined N and P ha^{-1} not showed statistically significant difference over the control. Besides, regardless of increasing the amount of Jatropha press-cake from 0 to

6 t ha^{-1} in combination with the respective amount of combined N and P fertilizers, no significant increases in leaf area indices occurred between most of fertilized treatments. This could be ascribed to the inherent soil fertility status coupled with long growing seasons and favourable weather conditions in the course of the experiment (Table 1) might favoured the plants to grow successfully even on the unfertilized plots (Figure 6 a, b).

Table 6: Interaction effects of Jatropha press-cake and combined inorganic N and P fertilizer rates on total leaf area per plant

Treatments	Total leaf area per plant (m^2) ***					
	Combination NP rate kg ha^{-1}					
Jatropha cake t ha^{-1}	0/0	0/46	50/0	50/46	100/92	Mean
0	1.04f	2.69b-f	2.47d-f	1.26f	1.82d-f	1.85
2	1.71ef	3.17b-f	2.85b-f	1.65ef	3.25b-f	2.53
4	1.99d-f	2.61c-f	5.43bc	5.51b	4.49b-e	4.01
6	4.64b-d	16.99a	3.84b-f	8.72a	4.64b-d	7.76
Mean	2.34	6.36	3.65	4.28	3.55	
CV (%) = 21.60						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability; *** = indicates significant difference at 1% significant levels of probability

This result is in conformity with the findings of Najm et al., in 2005 and 2006 experimental years and Efthimiadou et al., who found significant influences of organic and inorganic fertilizers on height (cm), dry weight (kg ha^{-1}) and leaf area index (LAI) in case of potato and maize, respectively [64,65]. Results obtained by other researchers clearly demonstrated the beneficial effects of combined use of inorganic fertilizers, vermicompost and bio-fertilizer on the LAI of crops (okra, cabbage, respectively) [66,67]. It is also interesting to note that the results of the present study could probably be attributed to the role and beneficial effect of applied Jatropha press-cake used as a nutrient store, improves soil structures, stimulates soil biological activity and enhances the solubility of phosphorus applied as fertilizer in the soil [68]. These impacts may have increased LAI, yield and yield components of the potato crop in our study.

Thus, the fact that increased concentration of Nitrogen fertilizer can increase the nitrogen uptake. This increase has a positive effect on the chlorophyll concentration, the photosynthetic rates, the leaf expansion, the total number of leaves and thereby LAI and the dry matter accumulation [64]. Fertilizer application to wheat particularly N during early stages of development greatly increased leaf area by delaying leaf senescence, sustained leaf photosynthesis and extended leaf area duration which ultimately resulted in maximum LAI compared with control [57,58]. Consequently, Nitrogen fertilizer contained in Jatropha press-cake and combined N and P fertilizers plays an important role in canopy development especially on the shoots dry matter, the LAI and the plant height [69-74]. Other researches [71,75, 76] showed that, LAI, shoots weight, plant height and tuber yield can be increased by application of organic fertilization.

Table 7: Interaction effects of Jatropha press-cake and combined inorganic N and P fertilizer rates on potato leaf area index

Treatments	Leaf area index***					
	NP combination rate (kg ha^{-1})					
Jatropha cake t ha^{-1}	0/0	0/46	50/0	50/46	100/92	Mean
0	(0.62)0.89g	(1.13)1.02fg	(1.02)0.97fg	(0.73)0.92fg	(0.92)0.97fg	0.95
2	(0.83)0.93fg	(1.43)1.09ef	(1.22)1.05e-g	(1.44)1.02fg	(1.60)1.12d-f	1.04
4	(1.60)1.07e-g	(1.16)1.04e-g	(4.38)1.44ab	(2.96)1.31b-d	(2.36)1.22c-e	1.22
6	(3.32)1.34a-c	(5.48)1.53a	(1.62)1.13d-f	(2.48)1.24c-e	(3.69)1.38a-c	1.32
Mean	1.06	1.17	1.15	1.12	1.17	
CV (%) = 10.85						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability; *** = indicates significant difference at 1% significant levels of probability.

Lower LAI influences final seed yield, because both the rate of leaf initiation and expansion during vegetative growth and the rate of leaf area decline during the reproductive period affect the potential carbon fixation [77]. As stated by Sane and Amla, the most productive and highly competent species are those that have high LAI [78]. This is because, increase in LAI can increase radiation absorption (particularly at the time of tuber initiation) having a positive effect on the final tuber yield [22].

Effect of Jatropha Press-cake and Combined N and P Fertilizers Above and Below Ground Biomass Yield

Above Ground Biomass Yield

The data showed that statistically highly significant ($P < 0.01$) differences were recorded in terms of above ground fresh biomass yield, due to the sole forms as well combinations of Jatropha press-cake and inorganic N and P fertilizers of potato under the present study (Table 8). The maximum (702.1 and 68.81g) of fresh and dry weight of above ground biomass per hill, respectively, was recorded from the combination of 6 t Jatropha press-cake ha^{-1} with (0+46) kg combined N and P ha^{-1} fertilizers. The combination of 0 t Jatropha press-cake ha^{-1} with 0+0 combined N and P ha^{-1} gave the minimum (44.8 and 15.4 g) fresh and dry weight of above ground biomass per hill, respectively.

However, regardless of increasing the rates of fertilizer combinations, non-significant differences in fresh biomass yield were observed between the control and the fertilized plots treatment means except treatment combination of 2 t Jatropha press-cake ha^{-1} + (0+46, 50+46 and 100+92 kg N and P ha-1), 4 t Jatropha press-cake ha^{-1} + (0+0, 50+0, 50+46 and 100+92 kg N and P ha^{-1}) and all 6 t Jatropha press-cake ha^{-1} combinations showed significant differences over the control. Besides, except plots that received 6 t Jatropha press-cake ha^{-1} + (0 + 46 and 50 + 46) kg combined N and P ha^{-1}, respectively that showed statistical differences over the control and between the fertilized plots, the rest fertilized plots had shown statistical parity with each other (Table 8).

Likewise, irrespective of increasing the rates of fertilizer combinations, non-significant differences in dry biomass yield were exhibited between the control and the fertilized plots treatment means except that treatment combinations of 0 t Jatropha press-cake + (0 + 46 and 100 + 92 kg combined N and P ha^{-1}), 2 t Jatropha press-cake ha^{-1} + (0+46) kg combined N and P ha^{-1}, 4 t Jatropha press-cake ha^{-1} + (0+0, 50+0, 50+46 and 100+92 kg combined N and P ha^{-1}) and all 6 t Jatropha press-cake ha^{-1} plus with the respective combined N and P kg ha^{-1} combinationsshowed significant differences over the control. This inconsistent results might be attributed due to the over fertilization of the experimental plots during the preceding years of cropping seasons coupled with the prevailing favourable weather conditions (Figure. 6 a, b) that might made the treatment effects inconsistence over the control as well as between the fertilized treatment means. Supporting this inconsistence present findings, Powon et al. [28] also had found the high tuber and shoot dry weights in potato at the Kitale site in 2002 even where there was no fertilizer application. They ascribed that this could be attributed to high soil fertility in the experimental area.

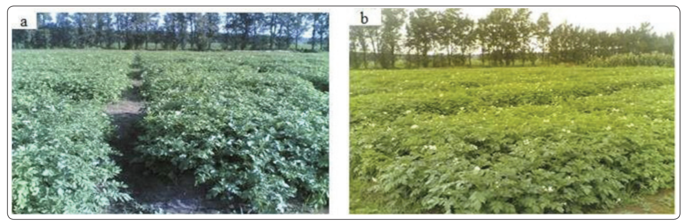

Figure 6: Experimental Field Performances

Table 8: Interaction effects of Jatropha press-cake and combined inorganic N and P fertilizer rates on potato above ground fresh biomass yield

Treatments	Total leaf area per plant (m2) ***					
	Combination NP rate kg ha^{-1}					
Jatropha cake t ha^{-1}	0/0	0/46	50/0	50/46	100/92	Mean
0	44.80j	116.07e-j	106.87g-j	54.53ij	78.60h-j	80.17
2	73.73h-j	137.00d-i	123.40e-j	214.90cd	140.47d-h	137.90
4	188.40c-g	112.73f-j	234.73c	238.13c	194.27c-f	193.65
6	239.80c	702.10a	165.80c-g	376.90b	200.70c-e	337.06
Mean	136.68	266.98	157.70	221.12	153.51	
CV (%) = 27.71						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability; *** = indicates significant difference at 1% significant levels of probability.

However, the maximum recorded above ground fresh and dry weight in this present finding due to the combinations of 6 t Jatropha press-cake ha^{-1} + (0+46) kg combined N and P ha^{-1} fertilizers might be attributed to the increased concentration and continuous supplying of essential nutrient elements due to the applied high dose organic Jatropha press-cake in combination with the desired combined N and P rate to attain this value. This implies that the desired amount of N might be supplied from Jatropha press-cake and there might not be additional need of inorganic N source to attain this value.

Additionally, this might be account for by the synergistic effect of organic manure with the inorganic fertilizer through supplying nutrient elements to the plant and also by improving soil physical characteristics and as also explained under section 4.1.3, 4 and 8 [7,79,80]. This is might be due to the fact that increasing nitrogen and other nutrients by the application of high dose of Jatropha press-cake produces taller plants, longer internodes more sympodial axillaries branches, higher leaf dry weights, higher stem dry weights, lower leaf: stem ratios, higher root dry weights, higher shoot: root ratios which is associated with the increased partitioning of dry matter to shoots rather than tubers resulted in a great increase in shoot biomass from high application of nitrogen. In support, data obtained by other researchers revealed continuous supply of N as it is elicited in this study due to the applied high dose Jatropha press-cake to plants promotes shoot and root growth, and prevents tuberization [81,82]. Additionally, this result was in conformity with the finding Solaiman et al., who found that interaction, effect of organic and inorganic fertilizers and mulching showed statistically significant influence on above ground biomass yield of potato and turnip, respectively [83]. In line with, Myintet al., also investigated in 2007 WS experiment;

soybean plants amended with 3 ton of Jatropha press-cake gave higher plant dry weight (7214.17 kg ha^{-1}) than other treatments [84].

Below Ground Biomass Yield

Applications of Jatropha press-cake significantly ($P < 0.01$) influenced below ground fresh as well as dry ($P < 0.05$) biomass yields of the potato crop. From the data presented in Table (9), it is evident that increasing the sole application rates of Jatropha press-cake from 0 to 6 t ha^{-1} significantly increased below ground fresh ($P < 0.01$) and dry ($P < 0.05$) biomass yields in comparison with the unfertilized plot. However, the sole combined N and P as well as its combination effects with Jatropha press-cake was not showed significant influences on below ground fresh and dry biomass yields ($p \geq 0.05$) in the present study. Nonetheless, increasing the rates of Jatropha press-cake from 0 to 2, 2 to 4 and 4 to 6 t ha^{-1} statistical parity between the respective fresh biomass yield treatment means were observed. Similarly, increasing the rates from 0 to 4 and 2 to 6 t ha^{-1}, no statistical differences were observed between the respective below ground dry biomass treatment means.

This is consistent with observations by Gamal and Ragab that the positive effects of organic fertilization, like Jatropha press-cake in this study, on vegetative growth parameters could be attributed to their effects on supplying plants with various nutrients as a relatively long times, as well as, their effect on lowering soil pH which could aid in facilitating availability of soil nutrients and improving physical characters in favour of root development and nutrient uptake [85]. Similarly, results of Aowad and Mohamed revealed that application of organic manure at the rate of 30 m^3/field along plus 30 kg N/field resulted in the highest values of dry matter accumulation (g/plant) and LAI at all growth stages of sunflower [86]. They ascribed this increase in growth attributes to the role of nitrogen fertilizer, as it is also found in the applied Jatropha press-cake in this study, on structure of protein molecule, which is necessary for biological activity and improvement of plant metabolism as well as growth of stems and leaves [87-89].

Supporting the results of this study, experimental results of Chaturvedi et al. [23, 34] showed that the application of 2 t ha^{-1} mixture of composted Jatropha press-cake and tobacco waste (in ratio 2:1) resulted in an increase of 22.88% in fresh bulb weight, 29.52% in dry bulb weight per plant and 18.3% in average yield of bulb as compared to control in case of Garlic (*Allium sativum* L) [23,24]. Other workers reported that dry weight of different peanut organs and the fresh weight of nodules were increased as a result of organic wastes fertilization alone or combined with bio-fertilizer as compared to chemical fertilizer treatment [90]. Additionally, Solaimanet al., reported different manures and fertilizers resulted in statistically significant variation in terms of fresh weight of modified root per plant of turnip (*Brassica rapa* Sub sp. *Rapifera*) at harvest [83]. Similarly, Ibrahim reported that amendments of organic manures improved shoot and root growth of maize plants in sandy soil [91]. Likewise, Aisueni et al., reported that supplementation of poultry manure with ammonium sulphate enhanced the dry matter yield of date palm seedlings [92].

In contrast to this study, however, Ouda and Mahadeen reported fresh and dry weights of broccoli (Brassica oleracea) shoots were not significantly affected by application of different doses of organic (chicken, sheep and cow manure at ratio 1:1:1) and inorganic (green leaves 20-20-20 + trace elements) fertilizers [63]. Equally, the findings of and Nilsson showed that the dry matter content of lettuces and cabbage, respectively, was not significantly affected by either organic or mineral fertilizers [93-95]. Yet, from repeated experiments Schuphan on lettuce and spinach and Schudel et al., on spinach obtained higher dry matter contents when these vegetables were supplied with compost rather than with NPK mineral fertilizers [96,97]. Moreover, Lairon et al., found significantly higher dry matter content in organically grown cos lettuce [98].

Table 9: The main effects of Jatropha press-cake and combined inorganic N and P fertilizers application rate on potato below ground biomass yield

Treatments	Below ground biomass yield (g $hill^{-1}$)	
	Fresh	Dry
Jatropha cake (t ha^{-1})		
0	1075.00c	253.10b
2	1177.00bc	276.50ab
4	1250.00ab	289.50ab
6	1407.00a	314.30a
	*	*
NP (kg ha^{-1})		
0/0	1199.00	283.10
0/46	1348.00	303.50
50/0	1130.00	265.30
50/46	1245.00	291.40
100/92	1216.00	273.40
	Ns	ns
CV (%) =	18.2	19.8

Means within the same column followed by the same letter do not differ significantly at the 5 % significance levels of probability; *= indicates significant difference at 5% significance levels of probability, ns = non-significant.

Effect of Jatropha Press-cake and Combined N and P Fertilizers on Potato Tuber Yields

Total tuber yield

The main effect of Jatropha press-cake significantly ($P < 0.05$) influenced the total tuber yield of the potato crop Table10. However, the main effect of combined N and P application did not affect total tuber yield. Similarly, Jatropha press-cake and combined N and P fertilizers application did not interact to influence total tuber yield. Increasing the rate of Jatropha press-cake from nil to 2 t ha^{-1} significantly increased total tuber yield of potato by about 12%. However, increasing the rate of the organic fertilizer beyond this level did not affect total tuber yield (Table 10). Thus, total tuber yields obtained in response to the application of 2, 4, and 6 tonnes of Jatropha seed-cake were all in statistical parity (Table 10). The result revealed that the level of Jatropha press-cake to be applied to potato for optimum total tuber yield at the study site was 2 tonnes per hectare of land. Thus, increasing the rate of the organic fertilizer beyond this level was supra-optimal and was of no use for increasing the total tuber yield of the crop.

The increase in total tuber yield in response to increasing the rate of Jatropha pres-cake may be attributed to increased nutrient content of the organic fertilizer as well as its capacity to improve other physico-chemical soil properties as corroborated by Hati et al., [99]. Furthermore, organic manures activate many species of living organisms which release phytohormones and may stimulate the plant growth and absorption of nutrients and such organisms need nitrogen for multiplication [63,100]. Consistent with the results of this study, Chaturvedi et al., indicated that application of Jatropha based organic fertilizer formulations had a positive impact on growth of tubers of *Polianthes tuberosa* L [23,24]. which was significantly higher than that corresponding to chemical fertilizer. Lack of response to the further increased rate of Jatropha press press-cake beyond 2 tonnes per hectare may be attributed to the fact that too much supply of the organic material is not required for increasing total tuber yield. This is consistent with the results of Ngoma who also found that the optimum rate of Jatropha press-cake for high yield of cabbage was below 2 tonnes per hectare [101]. That combined N and P application had no significant effect on total tuber yield may be attributed to the inherent high N and P content of the soil.

Table 10: The main effects of Jatropha press-cake and combined inorganic N and P fertilizers application rate on potato total, marketable and unmarketable tuber yield

Treatments	Tuber Yield (t ha^{-1})			
	Total	Marketable	Unmarketable	ATW
Jatropha cake (t ha^{-1})				
0	35.91b	32.19b	3.73c	62.36b
2	40.10a	35.50ab	4.61bc	66.16ab
4	40.57a	35.44ab	5.13ab	71.37a
6	43.27a	37.39a	5.88a	69.90a
	*	*	**	**
NP (kg ha^{-1})				
0/0	38.34	33.86	4.48	66.90
0/46	42.63	37.88	4.75	68.85
50/0	41.49	36.92	4.57	70.86
50/46	38.67	33.63	5.04	64.55
100/92	38.70	33.36	5.34	66.07
	Ns	Ns	ns	ns
CV (%) =	12.5	13.9	26.6	11.7

Means within the same column followed by the same letter do not differ significantly at the 5 % and 1% significance levels of probability; ATW = Indicatesaverage tube weight, **, *= significant difference at 5% and 1% significance levels of probability, respectively, ns = none significant.

This may imply that nutrient utilization efficiency declined with increased rates of application or due to the high inherent soil fertility status in the experimental area gained from continuous applications of fertilizers in the preceding cropping seasons that resulted to vigorous growth even where there was no fertilizer application. Additionally, the case also may be attributed to high N levels due to the application of high dose Jatropha press-cake can cause excessive vegetative growth and can encourage competition between the source and sink, and can also delay tuber initiation, which could ultimately lead to yield reduction and delayed maturity [64,102-104]. Excessive top growth due to high levels of early season N can also deplete soil moisture reserves that could have been better used later in the season to support tuber growth [105].

The significant effect of Jatropha press-cake on total tuber yield can be justified with the results of shoots. Especially with LAI, because the increase in LAI can be increased radiation absorption, (particularly at the time of tuber initiation) which ensures a higher photosynthesis potential and then promotes the synthesis and accumulation of reserve carbohydrates in the potato tuber which has a positive effect on the final tuber yield [22]. This is corroborated by the observation of Birietiene et al., organic fertilizer like Jatropha press-cake application improves potato growth, development and nutrition conditions, extends nutrient uptake time, which in turn results in a higher tuber yield [106].

Other researches showed that, LAI, shoots weight, plant height and tuber yield can be increased by application of organic fertilization [71,75,76]. Likewise, reported FYM application increases root length density and LAI, which results to increase in tuber yield [107]. In support, applications of Jatropha press-cake increases P availability and hence increase in tuber and shoot dry weight with increase in Jatropha press-cake application [108,109]. This finding is further supported with Abou-Hussein et al., who expressed that increase of the soil nutrients can encourage the increase haulm growth which increases the photosynthetic rates and assimilation rates [71]. Hence, it is logical that a plant with a larger haulm and root system can absorb more water and support photosynthesis thereby the yield components and total yield increase.

In addition, El-Fakharani and Abdel-Ghani and Bakry found that organic manure had a significant effect on growth characters and tuber yield of potato plants when compared with application of the same level of nitrogen from inorganic nitrogen fertilizers [30,110]. Data obtained by Abou-Zeid and Bakry indicated there was a significant increase in tuber yield (ton/field) as a result of applying bio-fertilizers + a half dose of ammonium sulphate or amendment of soil by chicken manure or fertilized with ammonium sulphate compared with control without a significant differences between them [111].

Marketable Tuber Yield

The main effect of combined N and P application did not affect marketable tuber yield (Table 10). Similarly, Jatropha press-cake and combined N and P application did not interact to influence total tuber yield. Increasing the rate of Jatropha press-cake from nil to 6 t ha^{-1} significantly increased marketable tuber yield of potato by about 16%. However, increasing the rate of the organic fertilizer from nil to 4 t ha^{-1} did not show significant difference on marketable tuber yield. Similarly, increasing application rate of Jatropha press-cake from 2 to 6 t ah1 resulted in non-significant differences between the fertilized treatments. Thus, marketable tuber yields obtained in response to the application of 2, 4, and 6 tonnes of Jatropha seed-cake were all in statistical parity (Table 10). As noted previously, the solely significant main effect of Jatropha press-cake on marketable tuber yield might be attributed to the beneficial effect of organic manure on sustained nutrient supply, soil properties and crop production as it was explained in section 4.1.3, 4, 8 and 4.2. Furthermore, many researchers investigated in long term studies, organic manures have been shown to largely improve soil physical conditions such as moisture retention capacity and aggregate soil stability, crop water use efficiency, improve soil fertility, crop performance and yield and supply of the macro and trace elements not contained in the inorganic fertilizer [23,34,99,112-116].

Unmarketable Tuber Yield

The unmarketable tuber yield was highly significantly ($P < 0.001$) affected by the applied Jatropha press-cake (Table 10). The maximum (5.88) and minimum (3.73) unmarketable tuber yield t ha^{-1} was attained from the application of 6 t Jatropha press-cake ha-1 and the control plots, respectively. However, data presented in Table (10) showed the increased application rates of Jatropha press-cake from 0 to 2, 2 to 4 and 4 to 6 t ha^{-1}, respectively, exhibited statistically on par results over the control and within fertilized treatment means of unmarketable tuber yields. More importantly, the reason that unmarketable tuber yield increased highly significantly in response to increased Jatropha press-cake levels might probably ascribed to its effect on physiological activities of the plant and the effect in availing macro an micro nutrients unlike inorganic fertilizer that contain only single nutrient element in increasing total tuber yield by increasing yield of all tuber size grades.

Average Tuber Weight

This experimental evidence shows that the main effect of Jatropha press-cake significantly influenced ($P < 0.01$) average tuber weight g $hill^{-1}$ over the control (Table 10). However, increasing rates of Jatropha press-cake from 2 to 6 t ha^{-1} showed on par statistical results between the fertilized treatment means despite they are exhibited inconsistent increasing trend (Table 10). This result may be attributed to the case mentioned in detailed in section 4.3.1. Additionally, the increase in average tuber weight of tubers with the supply of fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthates which helped in producing bigger tubers, hence resulting in higher yields [117]. In other words, the increased size and duration of the haulm stemming from improved supply of nutrients favored the tuber weight [118]. In support, Birietiene et al., showed organic fertilizer application improves potato growth, development and nutrition conditions, extends nutrient uptake time, which in turn results in a higher tuber yield [106]. Similarly, the main effects of inorganic combine N and P as well as interaction with Jatropha press-cake were not showed significant influences on average tuber weight g hill-1 (Table10).

Total, Marketable and Unmarketable Tuber Number

Both sole forms as well as combination of Jatropha press-cake and combined N and P fertilizers did not show significant influence ($P \geq 0.05$) on total, marketable and unmarketable tuber numbers except the main effect of Jatropha press-cake showed significant influence only on unmarketable large sized tuber numbers. In agreement with the present finding, a non-significant increment in tuber number in response to different organic and inorganic fertilizers application has been reported by various authors [49,28,119,120. This could be attributed to other biotic and abiotic factors and is not necessarily ascribable to nutrient supply in the soil. Thus, the observed results may be linked to the difference in season, inherent nutrient status of a soil and location which could have exerted their effects in determining the number set by the potato plant. Tuber number is not an important yield limiting component while studying mineral nutrition that could be due to the inverse association between tuber number and average tuber weight [49,50,120].

However, contradicting results have been reported by different investigators regarding the effect of mineral nutrition on the number of tubers set per plant. For instance many researchers, reported significant difference in tuber numbers due to different organic and inorganic fertilization[81,50,121-125]. The result of these observations might be attributed to soil mineralization from the soil due to the available carbon for microbial respiration, provision of nitrogen and phosphorus [126]. The availed nitrogen in the soil is important in tuber initiation and tuber enlargement [127]. Additionally, the observed tuber number increment due to fertilization could be also attributed to an increase in stolon number in response to N treatment (found in all organic or inorganic fertilizers) which is known to influence the rate of Gibralic acid biosynthesis in the potato plant. The involvement of gibberellins in regulating stolon number through stolon initiation was reported by Kumar and Wareing [128].

Effect of Jatropha Press-cake and Combined N and P Fertilizers on Some Quality Components of Potato

Potato tuber size categories

Data presented in Table 11 and Figure 5b depicts that the main effect of Jatropha press-cake and combined N and P fertilizers on potato tuber size categories. The finding revealed that the sole application of Jatropha press-cake showed significant influence ($P < 0.05$) only on large sized tuber weight category. However, medium and small sized tuber weight categories were not affected either with the sole forms of Jatropha press-cake and combined N and P or with their combination. Increasing application rate of Jatropha press-cake from nil to 6 t ha-1 significantly increased large sized tuber yield of potato by about 31%. However, increasing the rate of Jatropha press-cake from nil to 4 t ha-1 resulted in non-significant difference of large sized tuber yield of the potato crop. Similarly, increasing the rate of Jatropha press-cake from 2 to 6 t ha-1 did not affect large sized tuber yield of the potato crop.

It is evident from the results presented (Table 11) that increasing rate from 0 to 6 t Jatropha press-cake ha-1 showed that pronounced parallel increase in the number of tubers in the large sized (>75 g) at the expenses of medium (25-75 g) and small (< 25 g) sized tubers category. This may be attributed to the availing of Jatropha press-cake relatively more nitrogen or other plant nutrients to the plant and improving soil properties. In accord with the result of the current study, also noted that nitrogen increased the quantity of larger size tubers and total yield [129]. Similarly, Gardner and Jones found that higher level of nitrogen increased the number of large size tubers and the lower rates tended to result in a greater proportion of smaller tubers. In support, Sharma and Arora, from their investigation on the effects of mineral nutrition on size categories of the potato tuber, showed that increase in the yield of tubers with applied nutrient was associated with increase in the number of tubers in the medium (25-75 g) and large (>75 g) grades (size) at the expense of the small (< 25 g) tubers[120,129].

Table 11: Main effects of Jatropha press-cake and combined inorganic N and P fertilizers on potato tuber size categories

Treatments	Tuber size categories and dry matter yield (g hill^{-1})			
	Large	Medium	Small	Dry matter
Jatropha cake (t ha^{-1})				
0	366.40b	399.90	41.80	193.13b
2	427.20ab	429.50	43.60	217.64a
4	436.60ab	421.00	40.30	219.33a
6	481.60a	441.20	50.70	235.69a
	*	ns	ns	**
NP (kg ha^{-1})				
0/0	416.00	385.00	42.50	199.75b
0/46	476.00	440.70	42.20	236.35a
50/0	461.00	424.80	47.80	233.55a
50/46	375.00	449.30	45.60	205.53b
100/92	411.00	414.80	42.40	207.05b
	Ns	ns	ns	**
CV (%) =	24.90	16.50	24.50	14.75

Means within the same column followed by the same letter do not differ significantly at the 5 % levels of the LSD test; *,**= indicates significant difference at 5% and 1% significant levels of probability, respectively, ns= none significant.

Tuber Dry Matter Yield (G Hill^{-1})

Both sole forms of Jatropha press-cake and inorganic N and P fertilizers significantly affected ($P < 0.05$) tuber dry matter production (Table 11).Nonetheless, Jatropha Press-cake and combined N and P fertilzers were not interacted to significantly influence tuber dry matter production in the present findings. Increasing the rate of both Jatropha press-cake and combined N and P fertilizers from 0 to 6 and from (0+0) to (50+0) significantly increased tuber dry matter by about 13% and 18%, respectively. However, increasing the rate of Jatropha press-cake beyond 2 t ha-1 did not affect tuber dry matter. Similarly, increasing the rate of combined N and P fertilizer beyond (50+0) did not show significant differences over the control.

This finding agree with Anwar who reported application of fertilizer NPK and manure alone and in combination significantly increased the herb (fresh weight), dry matter, and oil yield in basil over control (no manure or fertilizer) [130]. This result appeared to support the general views that yield is a function of the amount of carbon assimilates produced times the proportion of this assimilate partitioned to the yield (tuber) [131]. The concomitant increment in yield with the increase in dry matter yield of a plant may be explained by the fact that as more dry matter is produced by the plant more assimilates would be partitioned to harvestable parts and thereby increasing potato tuber yield. The reason might be attributed to sustained availability of sufficient amount of N and P nutrients from the applied Jatropha press-cake and thereby plants might fulfil more of the nutrient demand in most of the growing seasons. This enhanced the plant to produce more dry matter production. In support, Opena and Porter explained that the increase in root and shoot dry weight with increase in organic and inorganic application can be attributed to increased root length and density and Leaf Area Index (LAI) which positively correlates with potato tuber yield [107]. Thus, any management practices that provide favourable influences on these variables are likely to enhance tuber yield.

Specific Gravity

In the present study Jatropha press-cake and combined N and P fertilizers interacted to significantly influence ($P < 0.05$) potato tuber specific gravity (SG) (Table 12). The main effect of Jatropha press-cake and combine N and P fertilizers did not show significant effect on tuber SG Besides, regardless of increasing the rate of fertilizer combinations from the lowest to the highest levels consistent statistical differences were not observed within the fertilized and between the fertilized and the control means. This inconsistent result might be attributed to differences in inherent soil nutrient status and management, prevailing favorable weather condition. This result is corroborated by Pervez et al. [132] who revealed that SG and yield of potatoes increased by using combined application of farmyard manure and potassium [132]. In accord with the present findings, Abou-Hussein et al.,reported that potato tubers yield and its specific gravity increased with combined application of cattle manure and chicken litter [71,76].

Table 12: Interaction effects of Jatropha press-cake and combined inorganic N and P fertilizers on potato tuber specific gravity

Treatments	Specific gravity*					
	Combined NP rate (kg ha^{-1})					
Jatropha cake t ha^{-1}	0/0	0/46	50/0	50/46	100/92	Mean
0	1.0812d	1.0821d	1.0879b-d	1.0834cd	1.0868b-d	1.0843
2	1.0883b-d	1.0853b-d	1.0922a-d	1.0955a-c	1.0959a-c	1.0914
4	1.0961a-c	1.0979ab	1.0925a-d	1.0968ab	1.0870b-d	1.0941
6	1.0891b-d	1.1055a	1.0799d	1.0804d	1.0873b-d	1.0884
Mean	1.0887	1.0927	1.0881	1.0890	1.0893	
CV (%) = 0.7						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability, * = indicates significant difference at 5% significant levels of probability.

From the data presented in Table (12), it is noteworthy to mention that application of 2 t Jatropha press-cake ha^{-1} in combination with the intermediate P rate found in combined N and P (50+46) kg ha^{-1} fertilizer rate significantly increased the potato processing quality by about 2% as many studies conducted on the texture of cooked potato tubers have shown the relationship, which existed between texture and specific gravity of row tubers [133]. This result is in harmony with those outlined by Nelson and Shaw who stated that tubers with high SG were noted to have high starch contents and they tend to be mealy in texture and to slough when cooked [134]. In addition, tubers of higher SG tended to have less moisture and less turgor than tubers of lower specific gravity [135]. In accordance with, Sayre et al., reported that potatoes with high SG can be processed into good quality French fries and good quality chips with high yield [134,136,137]. The preferred SG for chipping potato tubers is between 1.0900 and 1.0990 [138]. Thus, when quality is a requirement, special consideration should be given to the application of nutrients, as SG is a good indicator of potato tuber quality.

Dry Matter Content

Interaction effect of Jatropha press-cake and combined N and P fertilizers resulted significant differences ($P \leq 0.01$) on tuber dry matter percentage under the present trial (Table 13). Unlike the interaction effect neither the main effect of Jatropha press-cake nor combined N and P fertilizers were not showed significant influences ($p \geq 0.05$) on tuber dry matter percentage. Nevertheless, irrespective of increasing the rate of fertilizer combinations from the lowest to the highest levels, consistent statistical differences were not observed within the fertilized and between the fertilized and the control means as like happened in tuber SG. This might be attributed to dry matter content is affected by various factors, among which the most significant are the following ones: tuber maturity, growth character and plant nutrient and water uptake [139].

Exhibited high dry matter content (25.7%) under integrated use of 2 t Jatropha press-cake ha^{-1} organic manure and reduced level of (50 + 0) kg combined N and P ha^{-1} inorganic fertilizer in the present study might be attributed to subjected long growing seasons of the crop coupled with the prevailing favorable weather conditions. Hence, these conditions might favor the steadily supplying and thereby availability of ample amount of nutrients in soil solution in the course of growing seasons particularly due to the applied organic Jatropha press-cake. This in turn increased uptake of nutrients and effective utilization of these nutrients for increased synthesis of carbohydrates, greater vegetative growth and subsequent partitioning and translocation from leaf (source) to the tuber (sink) might favored the plants to accumulate high dry matter contents Chatterjee [140]. In support, Iwama et al., reported that increasing the growing period of potato increased the dry mass of the leaves, stems and roots [141]. Furthermore, dry matter content is subjected to the influence of both the environment and genotypes [40,142].

In this context, Kabira and Berga reported that potatoes with a dry matter content of 20 to 24% are ideal for making French fries while those with a dry matter content of up to 24% are ideal for preparing crisps [137]. Additionally, Pavlista described that dry matter content varies from 15% to 24% between potato types and cultivars [143]. On the other hand, excess Nitrogen due to native and added in organic or inorganic forms might has a negative effect on tuber quality and the environment and in the similar fashion as happened in tuber SG [144-146]. It is also interesting to note that utilizations of 4 t Jatropha press-cake ha^{-1} in combination with (0+46) kg combined N and P fertilizer ha^{-1} showed 17% increment of tuber dry matter percentage over the control mean thereby improved the tuber processing quality since this largely governs the weight of processed products which can be obtained from a given weight of raw tubers [147,148]. It is also one of the main determinants of quality, both for processing and for cooking. This is in line with the assertion of Blumenthal et al., that higher dry matter content (higher specific gravity) in raw product improves recovery rate during processing and directly influences texture and appearance, and indirectly influences the color of potato chips and French fries [138]. This is consistent with observations by Nelson and Shaw, high dry matter content has been reported to be desirable because of less sugar accumulation and water content [134]. In support, Storey and Davies observed that tubers with high dry matter content required less energy input during frying or dehydration to remove water; resulted in greater product yield per unit fresh weight than tubers with lower solid content and absorbed less oil during frying [149].

Table 13: Interaction effects of Jatropha press-cake and combined inorganic N and P fertilizers on potato tuber dry matter percentage

Treatments	Dry matter (%)*					
	NP Combination rate (kg ha^{-1})					
Jatropha cake t ha^{-1}	0/0	0/46	50/0	50/46	100/92	Mean
0	22.47e	23.39c-e	24.24a-e	23.72b-e	25.38a-d	23.84
2	23.74b-e	23.03de	25.71a-c	24.97a-d	23.07de	24.10
4	24.21a-e	26.29a	26.07ab	23.05de	22.19e	24.36
6	24.24a-e	25.68a-c	23.94a-e	22.41e	24.54a-e	24.16
Mean	23.67	24.60	24.99	23.54	23.80	
CV (%) = 6.1						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability.
* = indicates significant difference at 5% significant levels of probability

Data obtained from Makaraviciute illustrated that farmyard manure (FYM) application increased dry matter and starch contents in the tuber, where potato tuber yield increased by 20% with FYM [150]. On contrary,Baniuniene and Zekaite revealed that higher starch and dry matter contents were identified in potato tubers grown without FYM [151].

Effect of Jatropha Press-Cake and Combined N and P Fertilizers on Harvest Index

The main effect of Jatropha press-cake showed significant influence ($P < 0.05$) on harvest index of the potato crop (Table 14). However, the main effect of combined N and P as well as interaction effect with Jatropha press-cake application resulted in non-significant differences ($P \geq 0.05$) in harvest index in fresh weight basis (Table 14). While, increasing the application of Jatropha press-cake from 0 to 4 and 6 t Jatropha press-cake ha^{-1} decreased harvest index in fresh weight bases from 89.5 to 86.2 and 84.7, respectively. However, increasing the rate of Jatropha press-cake from 0 to 2 and from 2 to 6 t Jatropha press-cake ha^{-1} did not show statistically significant differences between the treatment means of the control and 2 t Jatropha press-cake ha^{-1} and within 2 and 6 t Jatropha press-cake ha^{-1} fertilized treatment means. This may be attributed to the inherent soil fertility status of the experimental field gained during the preceding cropping seasons.

Table 14: The main effects of Jatropha press-cake and combined inorganic N and P fertilizers application rate on harvest index

Treatments	Harvest index
Jatropha cake (t ha^{-1})	
0	89.49a
2	87.80ab
4	86.22b
6	84.72b
	*
NP (kg ha^{-1})	
0/0	89.02
0/46	85.19
50/0	86.96
50/46	89.02
100/92	85.11
	Ns
CV% =	5.0

Means within the same column followed by the same letter do not differ significantly at 5% significance levels of probability; * = indicates significant difference at 5% significance levels of probability and ns= none significant

The reduction in harvest index could be attributed to the effect of steadily availing of high levels of N which is found in applied Jatropha press-cake (Table 2)in promoting top growth at the expense of tuber growth. This is corroborated by Millard and Marshall who reported that nitrogen application increased aboveground biomass yield of potato [131]. Similarly, increasing N fertilization increased partitioning of assimilates to the shoots rather than to the tubers [152]. Similar to the short term effects of short photoperiods, withholding N fertilization increased starch content of the leaves, increased the percentage export of assimilates from the leaves, and reduced the activity of sucrose phosphate synthase [153].

The reduction in harvest index due to Jatropha press-cake did not appear to be associated with a decrease in total tuber yield. This is because the total biomass increased more than the harvestable portion in response to the application of Jatropha press-cake. Therefore, the yield advantage obtained through the use of Jatropha press-cake fertilizer might not be attributed to its effect on increment of harvest index; rather a parallel increase in both harvestable and non-harvestable parts was apparent. In general, this finding pointed out that although harvest index is commonly used as a key measuring plant parameter of the proportion assimilates partitioned to harvested organs and used by plant physiologist and breeder in the selection of high yielding cultivars, it may not necessarily correlate with high yield [154]. This implies that a cultivar with low harvest index may not necessarily be low yielder or vise versa. This is possible where the applications of mineral nutrients enables a potato crop to exhibit a high rate of assimilate production (high total biomass) and maintain active growth later in the season [154].

High value recorded result of harvest index in this finding (Table 14) might be attributed to the late biomass data collection made at late senescence stage of the plants that favored high assimilates partitioned to harvested organs. Beukema and Van der Zaag indicated that in temperate zone harvest indices of 0.75 - 0.85 are quite common but in warmer climates, the harvest index tend to be lower and often a wider variation is also observed between cultivars or growing conditions [155]. The consequent prolonged shoot growth and the increased duration of a canopy for light interception usually produces a much higher final of tubers than in plots that receive no Jatropha press-cake fertilizer. This is in spite of the fact that the unfertilized plants have a much higher harvest index [156]. Fertilization may enhance above ground biomass faster than economic yield.

Effect of Jatropha Press-Cake and Combined N and P Fertilizers on Plant Tissue Nutrient Content

The production of photosynthates and their translocation to sink depends largely upon the adequate supply of mineral nutrients from the soil. Most of the photosynthetic pathways depend on enzymes and coenzymes which are synthesized and catalysed by nutrient elements. Further, these nutrient elements play a major role in increasing the growth and ultimately yield of crops. The concentration of nutrients in plants decreases with the age of the crop. This might be attributed to the dilution effect caused by an increase in the plant biomass and translocation of the nutrients from vegetative parts to the reproductive parts.

Potato Leaf N and P Nutrient Concentration

Results presented in Table15 show that application of sole forms or combination of Jatropha press-cake and inorganic combined N and P fertilizers did not show significant influence ($P > 0.05$) on potato leaf N concentration. However, leaf P concentration was significantly affected ($P < 0.05$) only by the inorganic combined N and P fertilizer application. Similarly, the two factors were not interacted to significantly influence potato leaf P concentration. Further increase of combined N and P fertilizer above (0 + 46) kg ha^{-1} did not show significant difference on the concentration of leaf P between the fertilized and over the control means. As well as that, leaf P concentration increased significantly from 0.3 to 0.31% due to the application of (0 + 46) kg combined N and P ha^{-1} in the present study.

As regards leaf N concentration, Lairon reported also no general variation was found in the mineral concentration of the lettuce under the influence of organic as well as inorganic fertilization [98]. Similarly, Shokalu et al., observed no significant increase in the concentrations of N and Ca in celosia tissues with the addition of compost [157]. In this context, Rajeshwarirevealed that concentration of nitrogen in maize (Zea mays L.) plant tissues was not affected significantly due to integrated nitrogen supply [59]. While, Agbede reported that both mixtures of organic fertilizers and their sole forms as well as sole form of inorganic fertilizer showed significant increases ($P < 0.05$) in leaf N, P, K, Ca and Mg concentrations of yam compared with control treatment [54].

In support of the non-significant effect of organic fertilizer on leaf P concentration, Ibiremo [158] reported the P, K and Mg contents of cashew leaf were not significantly influenced by addition of organic fertilizer in two ecologies [158]. In support, Svec et al., too found comparable levels of phosphorus and magnesium in lettuce, but potassium and calcium levels were lower in the organically grown vegetables [159]. Additionally, Shokalu et al., reported non-significant differences over the control on leaf P concentration of celosia tissue grown organically [157]. In same context, Kansal et al., reported comparable contents of spinach in phosphorus, zinc and copper and higher contents in iron and manganese when organically fertilized [160]. In the same vein, Hansen did not find significant differences in phosphorus, potassium, calcium, magnesium and sodium concentration of curly kale grown either conventionally or bio-dynamically [161]. Equally, Rajeshwari reported the concentration of phosphorus was not affected significantly due to integrated nitrogen management in maize (Zea mays L.) plant tissues [59]. To sum up, from the results described here, and taking into account the subsequently described results, it seems difficult to point out definitive conclusions on the respective influence of organic or mineral fertilization on the mineral concentration of vegetables tissues.

Table 15: The main effects of Jatropha press-cake and combined inorganic N and P fertilizers application rate on potato leaf and stem N and leaf P content

Treatments	Potato nutrient content (%)		
	Leaf N	Leaf P	Stem N
Jatropha cake (t ha^{-1})			
0	5.13	0.29	1.08b
2	5.32	0.30	1.14b
4	5.38	0.29	1.16b
6	5.38	0.29	1.50a
	Ns	Ns	*
NP (kg ha^{-1})			
0/0	5.06	0.28b	1.13
0/46	5.41	0.31a	1.31
50/0	5.27	0.29b	1.37
50/46	5.21	0.29ab	1.23
100/92	5.33	0.29ab	1.07
	Ns	*	ns
CV(%)	7.73	8.21	24.35

Means within the same column followed by the same letter do not differ significantly at 5% significance levels of probability; *, = indicates significant difference at 5% significance levels of probability and ns= none significant.

Potato Stems N and P Nutrient Concentration

In the present study, the results of potato stem nutrient analysis for N showed that only the main effect of Jatropha press-cake was significantly influenced ($P < 0.05$) potato stem N nutrient concentration (Table 15). It is evident from the results presented in Table (15) increasing the rates of Jatropha press-cake from 0 to 6 t Jatropha press-cake ha^{-1} has increased the stem N nutrient concentration from 1.1 to 1.5%, respectively. This could be attributed to the higher N and P nutrient content of Jatropha press-cake (Table 2) and a slow and sustained availability of the nutrients as observed by several workers in green gram and in maize and potato [162,163]. Additionally, the increased concentration of this nutrient might be due to increased supply of nutrients which enhanced proliferation of root system under balanced nutrient application which in turn facilitated better absorption of water and nutrients along with improved soil physical environment [26]. This is in agreement with Ebelhar who stated that the application of an element has a dominant effect on the concentration of that element found in the plant as well as on the uptake and concentration of one or more other elements [164]. This result is in harmony with those outlined Anwar et al., in French basil; Chandrakala, in chilli; Shokalu, in *Celosia argentea* tissues, in soybean straw, Abdo, in wheat straw, in maize straw, in sorghum straw, and in amaranth stem who stated that sole as well as combinations of organic and inorganic fertilizers application showed significant influence on the N and P concentration in specified respective plants tissue [54,56,130,157,165-169].

However, increasing the rates of Jatropha press-cake from 0 to 4 t ha-1 had not showed significant differences between the fertilized and the control treatment means despite a slight consistent increasing trend was observed. This finding agrees with Son et al., who did not found significant different between fertilized treatments in case of soybean straw N concentration [166]. This might be due to residual effect of added fertilizer that was applied in previous plant crop. The other considerable point is insignificant difference ($P \geq 0.05$) of stem P concentration between fertilized and unfertilized plots either due to the sole forms or combination of organic and inorganic fertilizers amendment in the present findings. In support, Lairon et al., and Rajeshwari reported the concentration of phosphorus was not affected significantly due to integrated nutrient management in lettuce and maize, respectively [59,94].

Potato Tuber N and P Nutrient Concentration

Potato tuber N and P concentrations were not significantly affected ($P \geq 0.05$) either due to the sole forms or combination of organic and inorganic fertilizers amendment in the present findings. This is in line with the assertion Yoldas in onion bulb observed non-significant differences in N and P concentration of these plant parts due to the interaction effect of organic and inorganic fertilizers application [170].

Effect of Jatropha Press-Cake and Combined N and P Fertilizers on Soil Physico-Chemical Properties

Among many factors that influence soil productivity and crop yields a variety of physicochemical properties including infiltration; plant-available water; permeability; soil texture and structure; chemical composition of soils such as soil pH, organic matter, total nitrogen, available phosphorus and trace elements takes major parts and remain a major constraint to crop production in large scale in most parts of Ethiopia.

Table 16: The main effects of Jatropha press-cake and combined N and P fertilizers on soil bulk density, pH, EC and AWHC

Treatments	Bulk density (g/cm^3)	Porosity (%)	pH (1:2.5) H_2O	EC (mS/cm)	AWHC (%)
Jatropha cake (t ha^{-1})					
0	1.62	34.25	8.19	0.144b	12.48
2	1.61	34.13	8.13	0.165ab	13.06
4	1.63	33.22	8.15	0.159a	12.36
6	1.55	36.42	8.15	0.162a	11.92
	ns	Ns	Ns	*	ns
NP (kg ha^{-1})					
0/0	1.60	35.20	8.18	0.139	12.23
0/46	1.58	35.45	8.18	0.159	12.15
50/0	1.60	34.50	8.13	0.173	12.91
50/46	1.59	34.77	8.12	0.160	12.28
100/92	1.64	32.62	8.16	0.157	12.71
	ns	Ns	Ns	ns	ns
CV (%) =	5.56	10.56	0.98	8.99	21.50

Means within the same column followed by the same letter do not differ significantly at 5% significance levels of probability; *= indicates significant difference at 5% levels of probability, ns= none significant.

Soil Physical Properties

Bulk Density and Total Porosity

Application of both Jatropha press-cake and combined N and P fertilizers alone or in combination did not show significant effect ($P \geq 05$) on soil bulk density and total porosity in the present finding (Table 16). Chandrakala observed a similar result in his work on organic and inorganic amendments in Vertisol belonging to textural class clay [165]. Likewise, Adeli et al., observed that both commercial fertilizer and lower rate of broiler litter did not show significant effect on soil bulk density and total porosity on a Loring silt loam soil series [171]. They ascribed the reason that soil bulk density and total porosity was unaffected at the lower rates of broiler litter applications because the amount of organic matter applied to the experimental silt loam soil type, with original organic matter content of 10.59 g kg^{-1}, was not enough to make a significant difference in soil bulk density. Similarly, in the present study, the low Jatropha press-cake rate which is limited to one season application might appear to be the reason for the lack of significant influence on soil bulk density and porosity.

Field Capacity (Fc), Permanent Wilting Point (Pwp) and Available Water Holding Capacity (Awhc)

The moisture contents at FC and PWP of the soil also showed significant variations ($P < 0.05$) due to the sole as well as combination effect of Jatropha press-cake and combined N and P fertilizers; despite the sole application effect of Jatropha press-cake did not has significant effect on soil water content at PWP (Table 17 and Table 18). The increased moisture content should have enhanced root growth and water and nutrient uptake, apart from the fact that nutrients released from Jatropha press-cake and combined N and P fertilizers had direct effect on growth and tuber yield. Nonetheless, available water holding capacity (AWHC) was not showing significant differences ($P \geq 0.05$) in all amendments (Table 16).

Increasing the rate of fertilizers combination from 0 t Jatropha press-cake ha^{-1} + (0 +0) kg N and P ha^{-1} to 2 t Jatropha press-cake ha^{-1} + (50 + 0) kg N and P ha^{-1} resulted in increasing soil moisture content at FC by about 28%. However, regardless of increasing the rate of fertilizer combination from the lowest to the highest non-significant differences on soil moisture content at FC were observed between the fertilized and the control plots. However, plots that received 2 t Jatropha press-cake ha^{-1} + (50 + 46) kg N and P ha^{-1}, 4 t Jatropha press-cake ha^{-1} + (50 + 0) kg N and P ha^{-1} and 6 t Jatropha press-cake ha^{-1} + (0 + 46) kg N and P ha^{-1} did show statistically significant differences over the control plot of soil moisture content at FC (Table 17).

Table 17: Interaction effects of Jatropha press-cake and combined N and P fertilizers on soil FC

Treatments	Field capacity (FC)%**					
Jatropha cake (t ha^{-1})	NP Combination rate (kg ha^{-1})					
	0/0	0/46	50/0	50/46	100/92	Mean
0	25.46ed	25. 67ed	23.90e	24.26ed	25.28ed	24.73
2	23.46e	24.59ed	32.80a	30.64a-c	27.07b-e	27.71
4	29.09a-d	24.26ed	31.23a-c	23.06e	24.13e	26.35
6	24.40ed	31.92ab	26.47c-e	24.18ed	24.85ed	26.36

Mean	25.60	26.92	28.60	25.54	25.33	
CV (%)=11.32						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability. ** = indicates significant difference at 1% significant levels of probability.

Similarly, increasing the rate of fertilizers combination from 0 t Jatropha press-cake + (0 + 0) kg N and P ha^{-1} to 6 t Jatropha press-cake ha^{-1} + (0 + 46) kg N and P ha^{-1} resulted in increasing soil moisture content at PWP by about 60%. However, regardless of increasing fertilizers combination rate from the lowest to the highest non-significant difference on soil moisture content at PWP between the fertilized and the control plots were observed. Nonetheless, plots that received 2 t Jatropha press-cake ha^{-1} + (50 + 0) kg N and P ha^{-1}, 2 t Jatropha press-cake ha^{-1} + (50 + 46) kg N and P ha^{-1} and 4 t Jatropha press-cake ha^{-1} + (50 + 0) kg N and P ha^{-1} did show statistically significant differences on soil moisture content at PWP (Table18).

To sum up, these variations in moisture contents of the soil at FC and PWP may be due to reflection of variations in added and native soil organic matter as soil organic matter makes the soil to retain water by increasing its surface area and improving the structure of the soil [172,173]. Additionally, it may be also the colloidal and hydrophobic nature of Jatropha press-cake. This result was in conformity with the findings of Taye and Shaaban who reported combined effect of organic and inorganic fertilizers showed significant influence on soil water content at 1/3 bar and 15 bar and 0.1 and 15 bar, respectively [27,55]. However, conflicting to the present finding Ogunwole et al., reported that results of soil moisture content at -33kPa and - 1500kPa, showed no significant difference due to organic and inorganic soil amendment in both cases [174].

Soil Chemical Properties

Soil pH

Soil pH is the single soil characteristic, which elucidates an overall picture of the medium for plant growth including nutrient supply trend, fate of added nutrients, salinity/sodicity status and soil aeration, soil mineralogy and ultimate weather conditions of the region. The numerical values are always within range of 8.0 to 8.4 in normal soil while pH of the experimental site was ranged from 8.1-8.2 in Haramaya after post-harvest soil analysis. In the present study soil pH was not affected either with the sole forms of Jatropha press-cake and inorganic combined N and P fertilizers or with their combination ($P \geq 0.05$) (Table 16), corroborated with [54,175-177]. This result was also in conformity with the finding of Olukemi who found that organic and inorganic fertilizer treatments had no significant effect on soil pH after cropping for two years on Alfisol [178]. Though several researcher observed significant changes in soil pH on addition of organic manure owing to OM oxidation and release of CO_2 in the soil [179-181]. However, this contradiction may be due to high buffering capacity of the soils or due to short duration of present study.

Table 18: Interaction effects of Jatropha press-cake and combined N and P fertilizers on soil PWP

Treatments	Permanent wilting point (PWP)%**					
Jatropha cake (t ha^{-1})	NP Combination rate (kg ha^{-1})					
	0/0	0/46	50/0	50/46	100/92	Mean
0	12.46ef	12.06ef	13.87c-f	11.37f	12.43ef	12.44
2	11.15f	12. 56ef	18.08a-c	18.18ab	13.30ef	15.18
4	15.87a-e	13.29ef	17.60a-d	12.17ef	11.06f	14.00
6	14.00b-f	19.96a	13.23ef	11.31f	13.72d-f	14.44
Mean	13.37	15.10	15.70	13.26	12.63	
CV (%)=18.57						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability. ** = indicates significant difference at 1% significant levels of probability.

Electrical Conductivity (EC)

Electrical conductivity is a soil parameter that indicates indirectly the total concentration of soluble salts and is a direct measurement of salinity. In the present studies, electrical conductivity (EC) increased significantly ($P < 0.05$) from 0.1 to 0.2 mS/cm with the increased application rates from 0 to 6 t Jatropha press-cake ha^{-1} (Table 16). However, application of recommended inorganic fertilizer alone or in combination with Jatropha-press cake did not influence ($P \geq 0.05$) the EC values of soils (Table 16). This might be attributed to the fact that decomposition of organic materials like Jatropha press-cake released acids or acid forming compounds that reacted with the sparingly soluble salts already present in the soil and either converted them into soluble salts or at least increased their solubility. The results of this study comply with reports by Goyal et al., and Antil and Singh who observed that the continuous application of organic manures to soil resulted in an increase in the EC of the soil [182,183]. Furthermore, such similar results have been reported in the literature, which indicated that EC increased in acidic as well as alkaline soils when organic materials of different nature were applied to the soil [184-186].

In contrastto the present study, observations of Tripathi et al., in that an increase in soil EC with the continuous application of N and P fertilizers over the initial value was marginal in a salt-affected rice field of coastal region of India [176]. In support of this finding, recent studies of Rajeshwari had shown that EC were not significantly influenced by integrated nitrogen management practices on Vertisol belonging to textural class clay under maize production [59]. Equally, a similar non-distinct periodic variation in the EC values of the soils treated with organic amendments, even at the time of harvest, was found in the study of Walker and Bernal [187]. Conflicting to this finding, Balaguraviah et al., and Antil and Singh reported that a significant increase in EC of the soil was found with the combined application of organic manures plus N and P fertilizers over application of N and P fertilizers alone [183,188]. This conflicting result may be attributed to short duration of present study as like of soil pH and bulk density results as it has been discussed previously.

Cation Exchange Capacity

Cation exchange capacity of a soil is a measure of soils negative charge and thus of the soils capacity to retain and release cations for uptake by plant roots. The cation exchange capacity of a soil is strongly related with the organic matter content of a soil [7]. As the amount of organic matter in the soil increases, the total negative charge in the soil is increased which in turn increase the CEC of the soil? This relationship was also observed in the present study (Table 19). Only a small percentage of the essential plant nutrient cations (K^+, Ca^{2+}, Mg^{2+}, and NH^{4+}) will be 'loose' in the soil water and thus available for plant uptake. Thus the CEC is important because it provides a reservoir of nutrients to replenish those removed from the soil water by plant uptake. Similarly, cations in the soil water that are leached below the root zone by excess rainfall or irrigation water are replaced by cations formerly bound to the CEC.

Table 19: Interaction effects of Jatropha press-cake and combined N and P fertilizers on soil CEC

Treatments	Cation exchange capacity (CEC) (cmol (+)/kg)**					
Jatropha cake (t ha^{-1})	NP Combination rate (kg ha^{-1})					
	0/0	0/46	50/0	50/46	100/92	Mean
0	14.80ed	13.86e	17.12c-e	14.10e	13.88e	14.75
2	14.21e	15.43ed	21.56a-c	23.36a	16.15ed	18.14
4	18.81b-d	15.23ed	22.55ab	14.85ed	14.39ed	17.17
6	13.66e	21.99ab	18.02b-e	13.96e	15.92ed	16.71
Mean	15.37	16.63	19.81	16.57	15.09	
CV (%)=16.50						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability. ** = indicates significant difference at 1% significant levels of probability.

It is evident from the results presented in (Table 19) indicate that both the main as well as the interaction effects of Jatropha press-cake and combined N and P fertilizers showed significant effect ($P < 0.01$) on the negative charge or cation exchange capacity (CEC) of soil in the present study. Cation exchange capacity (CEC) as one of the major soil quality indexes in the present findings varied between 14.8 and 23.4 cmol kg^{-1} indicating a considerable improvement in nutrient exchange capacity of the soils treated with organic and mineral fertilizers amendments. The largest increase in CEC cmol kg^{-1} was observed in the plots receiving 2 t Jatropha press-cake ha^{-1} + (50+46) kg combined N and P ha^{-1} fertilizers. Singh and Chauhan [16] reported that the increased organic carbon and CEC of soil may be due to enhanced root growth leading to accumulation of more root residues in the soil as reported earlier.

In support of this finding, recent studies had shown that sole organic and inorganic fertilizers and in combinations increased soil CEC [158,167,171,189-192]. In contrast, Adeli et al., reported that commercial fertilizer N applications did not has a significant effect on soil CEC compared to the control [171]. However, in most of the plots the values of CEC were not showed consistent significant differences that might be attributed to the inherent sandy clay loam textural class soil properties of the experimental site.

Organic Carbon

Data shown in Table 20 revealed that application of Jatropha press-cake and combined N and P fertilizers interacted to significantly ($p < 0.05$) influence soil organic carbon (OC) as corroborated by Selvakumari et al., Shivanand, Sarwaret al., due to addition of organic matter through organic Jatropha press-cake manure [184,186,193]. Equally, the sole application of Jatropha press-cake as well as combined N and P fertilizers also showed a significant effect ($P < 0.05$) on soil organic carbon content in accordance with Sarwar et al., investigations [194]. Organic N sources comparatively mineralized slowly than mineral N which resulted improvement in soil OC. The reason for the increase in OC status is very clear. Application of Jatropha press-cake resulted in overall increase of the soil organic matter level. The status of organic matter in the soil had a relationship with the quantity applied.

Increasing application rate of fertilizers combinations from 0 t Jatropha press-cake ha^{-1} + (0 + 0) kg N and P ha^{-1} to 2 t Jatropha press-cake + (50 + 0) kg N and P ha^{-1} resulted in increasing soil OC by about 50%. However, regardless of increasing the rate of fertilizers combination from the lowest to the highest resulted in non-significant differences on soil OC between the fertilized and the control plots as shown in Table 20.Nevertheless, plots that received 6 t Jatropha press-cake ha^{-1} + (0 + 46, 50 + 0 and 100 + 92) kg N and P ha-1, respectively, showed statistically significant differences over the control plot. It is noteworthy to mention that a buildup of OC due to Jatropha press-cake + combined N and P fertilizers application from 0.6 to 0.9 % might be due to the inorganic fertilizer supplying the needed energy and nutrient for the decomposition of complex organic matter and converting them to mineralized organic colloids which are added to the soil organic matter reserves and rapid multiplication in the microbial population. The increase in OC content might be ascribed to direct incorporation of Jatropha press-cake or organic matter to the soil which might have resulted in better soil aggregation.

However, the inconsistent statistical observed differences between the fertilized and the control treatment means complied with the report of Gupta et al., [195]. The build-up in OC content in the present study was not in the proportion of quantity of organic manure applied. Furthermore, this might be due to variation in the decomposition rate that might be caused due to variation in the inherent decomposing factors in each experimental plot (soil microbial biomass, inorganic inputs, soil temperature and the likes) and thereby nutrient release patterne into the soil. Additionally, it might be attributed to the inherent soil fertility status, subjected long growing seasons coupled with favorable environmental conditions culminated in comparable yielding of both above and belowground biomass, which on decomposition add to the soil organic matter. In a word, this might be favored plants to grow luxuriously even in the control plot and, consequently, high rhizodeposition of carbonaceous materials through root and sloughed off tissue may be increased organic carbon status of the soil inconsistently in treated and untreated plots [196-198].

As noted previously, soil OC level increased following integrated use of organic and chemical fertilizers amendments. This led to development of more microbial biomass C and N and increased microbial activity. The addition of organic amendments increased the pool of labile C and N, which is mineralized rapidly to provide nutrients to growing crop. It has also been reported that the contents of some major nutrients in the soil were slightly dependable on the level of organic matter [199]. Organic matter shows a greater capacity to retain nutrients in forms that can easily be taken up by plants over a longer period of time. These improvement in organic matter and microbial activities due to use of organic fertilizers along with inorganic amendments can help in sustaining the long-term productivity of the soil. Singh and Chauhan reported that nutrients from mineral fertilizers enhance the establishment of crops while those from mineralization of organic manure promoted yield when both fertilizers were combined [16].

Table 20: Interaction effects of Jatropha press-cake and combined N and P fertilizers on soil organic carbon

Treatments	Organic carbon (OC)%*					
Jatropha cake (t ha^{-1})	NP Combination rate (kg ha^{-1})					
	0/0	0/46	50/0	50/46	100/92	Mean
0	0.63e-f	0.61e-f	0.66c-f	0.55f	0.66c-f	0.62
2	0.57ef	0.62e-f	0.93a	0.76a-d	0.64e-f	0.70
4	0.73b-e	0.69b-f	0.71b-f	0.65e-f	0.58ef	0.67
6	0.68b-f	0.96ab	0.83a-c	0.59e-f	0.85ab	0.78
Mean	0.65	0.72	0.78	0.64	0.68	
CV (%)=15.69						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability.
* = indicates significant difference at 1% significant levels of probability.

The present study showed that balanced fertilization in proper proportion using both organic and inorganic sources is important for the maintenance of soil OC content and long term soil productivity. This results is also suggests a highest residual effect of Jatropha press-cake with regards to sequestration of C in soil. An accumulation of soil OC is not only beneficial to soil in relation to agriculture but also represents a sequestration of carbon from atmospheric carbon dioxide. The C sequestration in agricultural soils is controlled by the balance of added organic and inorganic inputs and microbial oxidation of both added C and native soil organic matter [200]. Carbon sequestration by agricultural soils is important to reduce the increase of greenhouse gases in the atmosphere.

To sum up, increased soil OC content is indication of soil quality improvement. This is because it regarded as the ultimate source of nutrients and microbial activity and plays decisive factor in soil structure, water holding capacity, infiltration rate, aeration and porosity of the soil. Hence, the positive response of potato to the applied fertilizers was due to the initial low fertility status of the soils on which the experiment was carried out. The greater yield increase due to the applied fertilizers during this experiment might be due to their ability to make nutrients steadily and more readily available to crop plants. Additionally, comparatively more biomass production in different treatments also contributed towards the improvement of organic matter status of the soil. Thus, if only one soil parameter of productivity is to be considered that may be organic matter.

Total Nitrogen

The sole application of Jatropha press-cake and combined N and P fertilizers as well as their combination had no statistically significant effect ($P \geq 0.05$) on the total nitrogen (TN%) content of the soils in the present findings. This is corroborated by who found no significant effect on soil TN% due to organic and inorganic fertilizers application[59,201,202]. In support, lack of significant change in soil TN% could be as a result of increased uptake of nitrogen by plant for their growth and development or higher organic carbon of the top soil and thus, reduced mineralization. Additionally, the soil, being light textured and alkaline in nature, may be expected to lose fertilizer N via immobilization by microorganisms or denitrification and nitrogen loss through NH3 volatilization and leaching beyond the sampling depth (0–30 cm depth) during the course of the experiment [79,203-206]. In this way, the pathway of leaching may be attributed to high rainfall distribution along the growing seasons may affect the nutrient status of the soil and contributed potential N loss beyond the root zone (0-30 cm soil sampling depth)

Table 1: It has also been reported that N is taken up faster and therefore competed for under potato and other weeds growing system in and/or out of experimental time up to the end of post-harvest soil sampling period [207]. Besides, a part of the N might have been converted to such forms, which were not extracted in alkaline $KMnO_4$. It is noteworthy to mention that either the sole or combination of organic and inorganic inputs also had not showed a significant effect ($P \geq 0.05$) on C: N ratio of the soil in the present findings. This might be attributed to the gradual mineralization process that might not be caused a significant difference in this short and one season studies.

Available Phosphorus

Statistical analysis evidence of the present finding showed that soil available phosphorus was distinctly affected ($P < 0.01$) by the application of sole as well as combination of Jatropha press-cake and combined N and P fertilizers (Table 21). Increasing the application rate of fertilizers combination from 0 t Jatropha press-cake ha^{-1} + (0 + 0) kg N and P ha^{-1} to 0 t Jatropha press-cake ha^{-1} + (100 + 92) kg N and P ha^{-1} resulted in increasing soil available P by about 82%. However, regardless of increasing the rate of fertilizers combination from the lowest to the highest resulted in non-significant differences on soil available P between the fertilized and the control plots (Table21). In contrast, plots that received 0 t Jatropha press-cake ha^{-1} + (100 + 92) kg N and P ha^{-1}, 2 t Jatropha press-cake ha^{-1} + (50 + 0 and 50 + 46) kg N and P ha^{-1}, 4 t Jatropha press-cake ha^{-1} + (0 + 46, 50 + 0 and 50 + 46) kg N and P ha^{-1} and 6 t Jatropha press-cake ha^{-1} + (50 + 46 and 100 + 92) kg N and P ha^{-1}, respectively, resulted in statistically significant differences on soil available P over the control plot (Table 21).

In support of the present findings, similar results have also been reported by Chand et al., and Shivanand showing a noticeable increase in available P level due to the addition of combination of organic and inorganic fertilizers to soils [193,208]. Similar trend of P availability was reported by Dekamedhi et al., and Santhy et al., under upland paddy [209,210]. Equally, Anwar et al., reported that organic C, available N, and P were higher in post-harvest soils that received inorganic fertilizer in combination with organic manure than control and inorganic fertilizer treated soil which was in close agreement with our findings[130]. The present result is also further supported by the findings of Jayathilake et al., who reported that the available phosphorus in soil increased with application of bio-fertilizers in combination with organic and chemical fertilizers[211]. The increase in P might be due to addition of P through inorganic fertilizer and organic manure. As well, the incorporation of organic manure has been shown to increase the amount of soluble organic matter which are mainly organic acids that increase the rate of desorption of phosphate and thus improves the available P content in the soil [212]. It is obvious that phosphorus is relatively immobile nutrient in soil and diffusion is the major process controlling its movement.

Addition of organic manure increased soil moisture contents, which may be the reason of improved P availability in soil [213]. Hence, indirectly soil moisture regulates soil P mobility [179]. Furthermore, the increase in available P of the soil resulting from the application of organic manures may be due to the mineralization of organic P; the production of organic acids, which solubilizes soil P and organic amines thus retards the fixation of added as well as native phosphorus in soil [198]. Production of organic legends in soil by increased microbial activity might be responsible for desorption of P from mineral compounds[179]. Hence, the organic acids released from Jatropha press-cake and additional supply of P through organics along with inorganic phosphorus lead to increased phosphorus content in soil. In support, P status of soil improved due to partial recovery of applied P by crops and that due to biological activities of soil microorganisms may be ascribed to increased solubility of unavailable native soil phosphate with slightly existing but might be flourished phosphate solubilizing bacteria due to the added organic Jatropha press-cake fertilizer besides extraction of P from deeper layers by Vesicular Arbuscular Mycorrhiza hyphae. This indicates that application of organic amendments like Jatropha press-cake have contributed significantly to the available P pool of the soils.

On another way, reduction in P content between most of treatments may be attributed to increased dry matter production and hence higher nutrient P removal by the potato crop following N application. This may be due to N effect in promoting dry matter production. It could also be attributed to the synergistic interaction between N and P, whereby the availability and P uptake was increased hence the reduction of P in the soil that was observed in most of the treatments in this study [214]. Similar trend of P uptake was observed by Chand [215]. To sum up, changes in available P were generally low in most of the plots because P is relatively immobile and strongly adsorbed by soil particles [216].

Exchangeable Bases

Na^+

Except soil exchangeable Ca among the four types of basic cations (Ca, Na, K and Mg) of the experimental soil had shown significant variation ($P < 0.05$) due to the sole as well as the combination of combined N and P with Jatropha press-cake fertilizers amelioration (Table 22 and Table 23). The data depicted on Table (22) show that the peak exchangeable Na concentration value (0.1) was recorded on a plot that received 6 t Jatropha press-cake ha^{-1} + (50 + 0) kg combined N and P ha^{-1} fertilizers combination. Similarly, the minimum exchangeable Na concentration value (0.05) was recorded on a plot that received 2 t Jatropha press-cake ha^{-1} + (0 + 46) kg combined N and P ha^{-1} fertilizers amendment. However, regardless of increasing the rates of fertilizer combination, there appeared to be found no statistically significant variations within the fertilized and between the control treatment means in the present findings. This might be attributed to the inherent soil fertility status of the experimental plots in the preceding cropping seasons.

The present finding is corroborated with observations by Shivanand who reported that application of organic material like FYM or VC in combination with inorganic fertilizer improved soil chemical properties like CEC, available P and K, and Exchangeable Na, Ca and Mg [193]. Furthermore, Adediran and Titilola reported that the combination of organic and inorganic fertilizers significantly increased the exchangeable Na concentration over the control in maize and cowpea and cassava-based cropping system studies, respectively [190,217].

Table 21: Interaction effects of Jatropha press-cake and combined N and P fertilizers on soil available phosphorus

Treatments	Available P (mg/kg)**					
Jatropha cake (t ha^{-1})	NP Combination rate (kg ha^{-1})					
	0/0	0/46	50/0	50/46	100/92	Mean
0	7.24f	11.89b-f	8.98ef	6.69f	13.15a-e	9.59
2	8.58ef	7.66f	16.44a-c	17.09ab	13.61a-e	12.68
4	8.50ef	13.59a-e	13.88a-e	16.51a-c	18.42a	14.18
6	10.69d-f	10.77d-f	11.55c-f	15.06a-d	15.75a-d	12.76
Mean	8.75	10.98	12.71	13.84	15.23	
CV (%)=26.50						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability. ** = indicates significant difference at 1% significant levels of probability.

This result is also in consonance with that of Ibiremo who reported that the Ca^{2+}, Mg^{2+} and Na^{+} in Uhonmora soil were higher than that of Ibadan by 8%, 47% and 22%, respectively, due to incorporation of organic fertilizer fortified with phosphate fertilizers and arbuscular mycorrhizal fungi inoculation in case of cashew growth in two ecologies in Nigeria [158]. This could be attributed to the application of the starter inorganic nutrients and the release of basic cations into the soil solution up on decomposition of the organic materials [218]. The observed significant variation in soil exchangeable Na might be also attributed to organic fertilizers increased soil organic matter content and thereby the soil organic matter is known to form chelate with micronutrients, and is also a source of cations due to the presence of exchange sites on organic colloid. Jimenez and Garcia also noted that the addition of composts into the soil is associated with the greater production of functional groups, which are responsible for the production of surface charge [219]. In support, the increase in cations (K, Na and Mg) in soil amended either with organic or inorganic fertilizers might possibly be the reason for increase in CEC in the present studies. The higher CEC adsorbed and retained more cations. Therefore the exchange capacity of the soils is attributed to the Na from the addition of the Jatropha press-cake.

Table 22: Interaction effects of Jatropha press-cake and combined N and P fertilizers on soil exchangeable Na

Treatments	Exchangeable Na^{+*}					
Jatropha cake (t ha^{-1})	NP Combination rate (kg ha^{-1})					
	0/0	0/46	50/0	50/46	100/92	Mean
0	0.07c-f	0.09b-d	0.06e-f	0.06c-f	0.07b-f	0.07
2	0.05ef	0.05f	0.1bc	0.09b-e	0.06c-f	0.07
4	0.09b-d	0.06c-f	0.1b	0.06e-f	0.06e-f	0.07
6	0.07c-f	0.09b-d	0.1a	0.07c-f	0.08b-f	0.08
Mean	0.07	0.07	0.09	0.07	0.07	
CV (%)=28.70						

Means followed by the same letter within the same column or rows are not significantly different at 5% significance levels of probability. * = indicates significant difference at 5% significant levels of probability.

K^{+}

Data presented in Table (23) shows that soil exchangeable K increased significantly ($P < 0.05$) with increased application rate of combined N and P fertilizers. The optimum value (0.6) was recorded at the rate of (50 + 0) kg combined N and P ha^{-1} fertilizer application. Similarly, the minimum exchangeable K value (0.5) was obtained on the control plot. However, increasing combined N and P rate from (0 + 0) to (50 + 46) and then (100 + 92) kg ha^{-1} resulted statistical parity between the fertilized and unfertilized treatments. Similarly, increasing the rate from (0 + 46) to (50 + 0) and from (50 + 46) to (100 +92) kg combined N and P fertilizer ha^{-1}, respectively, resulted statistical parity between treatments. This inconsistency results might be attributed to the over fertilization of the experimental plots during the preceding cropping seasons.

The results of this study complied with reports by Agbede who revealed that application of inorganic fertilizer significantly increased ($P < 0.05$) soil total N, available P, exchangeable K, Ca and Mg compared with control, but did decrease soil pH and organic C in case of yam production studies on Alfisol in Southwest Nigeria [54]. The present finding was also further supported by Taye reported application of inorganic fertilizer increased mainly exchangeable K, Ca and Mg [55]. This might be attributed to the application of the starter inorganic nutrients and hence, low and high mineralization processes of applied organic fertilizer that may occur in the unfertilized and fertilized plots, respectively.

Ca^{2+}

In the same vein, soil exchangeable Ca was not significantly ($P \geq 0.05$) affected either with the sole forms or combination of Jatropha press-cake and combined N and P fertilizers amendment in the present studies (Table 23). This might be attributed to the low inherent soil Ca levels of the soil or high removal of it by the potato crop from the experimental soil in the course of the growing seasons. On the other way, this may be related to the short period of residue application and the decomposition rate of the organic waste achieved by the end of the study. This finding indicated that the gradual net depletion of soil cations if not compensated by fertilizer and manure inputs, would eventually affect crop yields. In support of this findings, reported soil exchangeable Ca was not found to be significantly affected by inorganic and either with the sole or their combination of organic and inorganic fertilizers application, respectively [220].

Table 23: Main effects of Jatropha press-cake and combined N and P fertilizers on soil exchangeable bases

Treatments	Soil exchangeable bases		
	K^+	Ca^{2+}	Mg^{2+}
Jatropha cake (t ha^{-1})			
0	0.54	27.53	4.14
2	0.56	27.67	3.71
4	0.56	25.91	3.47
6	0.57	26.6	4.06
	Ns	Ns	ns
NP (kg ha^{-1})			
0/0	0.52bc	25.07	3.74a-c
0/46	0.61ab	25.94	4.37ab
50/0	0.64a	30.26	4.60a
50/46	0.49c	25.28	3.01c
100/92	0.53bc	28.14	3.53bc
	*	Ns	**
CV (%)	21.89	24.78	28.21

Means within the same column followed by the same letter do not differ significantly at 5% significance levels of probability; *,** = indicates significant difference at 5% and 1% levels of probability, ns= none significant.

Mg2+

On the other hand, soil exchangeable Mg showed statistically significant difference ($P < 0.05$) due to the main effect of combined N and P fertilizer applications (Table 23) corroborated by [55; 54]. However, the difference between the fertilized and control plots was not statistically significant despite there appeared to be found statistically significant differences within the fertilized plots. The reason behind might be attributed to same explained in section 4.7.2.7 for Na and K increment.

Effect of Jatropha Press-Cake and Combined N and P Fertilizers on Economic Evaluation

The acceptance of any technology developed by the farmers ultimately depends on the economics of the crop production. Among the different indicators of monitory efficiency, the economics in terms of net returns and B: C ratios have a greater impact on the practical utility and acceptance of technology. Partial budget analysis of the present findings revealed that all the treatments selected from the dominance analysis had shown values below the minimum acceptable rate of return (below 100%). Thus, economic analysis of the present studies indicated no significant gross and net benefits, which could be attributed to the high transport and application cost of the press-cake. However, on the onset the experimental field, other facilities in the University and nearest to export market prompted the authors to conduct the research in the Haramaya University. The marginal analysis results of the present findings were further checked and supported by the highest observed residuals value at the levels of 0 t Jatropha press-cake ha^{-1} treatment. Therefore, it is not advisable to adopt this technology and apply integrated nutrient management (Jatropha press-cake combined with mineral fertilizers) to reduce the cost of fertilizer and maximizing of tuber yield ha^{-1} in this domain area, despite it is a one season and location studies. Nevertheless, if this study was conducted at nearby suppliers of Jatropha press-cake and thereby the cost of transportation minimized, it might have shown significant economic returns.

Conclusion

This study clearly demonstrated that the use of Jatropha press-cake as organic fertilizer source leads to the desired increase in soil fertility and yields of the potato crop. Additionally, the present study also has successfully demonstrated that the yield advantage that could be secured through Jatropha press-cake application could be more exploited. Thus, it is evident that there is a room to produce more tuber yield t ha^{-1} with low and economical application of Jatropha press-cake. Therefore, this finding would open new avenues for Jatropha press-cake to be used as organic fertilizer for food crops, commercial floriculture and others thereby use of Bio-wastes not only ensures sustainable development but also reduces nutrient leaching and the cost of farming while increasing the overall health of the soil. More importantly the result indicates that growing Jatropha has multiple potential benefits for countries like Ethiopia, beyond the immediate use as energy crop.

A judicious use of chemical fertilizers and organic sources of plant nutrients should be integrated to maintain the soil organic matter and health so as to drive synergies of increased productivity when mineral N and P fertilizers are applied. Since it is a one season and one site study to come up with the desired recommended application rate additional investigation deserves in different locations, seasons and crops where there is nearby supply of the Jatropha press-cake for feasible economic returns. Additionally, the effect of composted as well as fresh Jatropha press-cake in dry and wet seasons should also deserves further research attention. Finally, to make the biodiesel production sustainable and economically viable, Research and Development efforts are needed to fill the knowledge gaps for basic agronomic characteristics of Jatropha and for the production of other value added products.

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