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Effect of different levels of fertilizers and Neem cake on soil health growth and yield of potato (*Solanum tuberosum* L.) CV. Kufri Jyoti

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Abstract
Potato is a starchy, tuberous crop. Potato has become a staple food in many parts of the world and an integral part of much of the world's food supply. It is the world's fourth-largest food crop, following maize, wheat, and rice. An experiment was carried out at Research Farm of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, during the winter season of 2017- 2018 to know the "Effect of different levels of fertilizers and Neem cake on soil health, growth and yield of Potato (*Solanum tuberosum* L.) cv. Kufri Jyoti". The experiment was laid out in 3×3 Factorial Randomised Block Design (RBD) with three replicates for each treatment. The fertilizer applied for the crop was N P K and Neem cake @ 120 kg $ha^{-1,}$ 100 kg ha^{-1}, 120 kg ha^{-1} and 1250 t ha^{-1} respectively, which showed significant influence on the soil, growth and yield of Potato crop. Based on the above research work, it is concluded that application of NPK followed by Neem cake (100% and 100%) *i.e.,* the treatment T_8@[NPK 100% Recommended Dose of Fertilizer (RDF)+ Neem cake 100 kg ha^{-1}] was found more beneficial and significantly improved soil, growth parameters and tuber yield of Potato grown under Allahabad Agro-climatic conditions. This treatment also showed maximum gross return, net return and benefit: cost ratio *i.e.,* (2.74) respectively.

Keywords: Soil properties, nitrogen, phosphorus, potassium, neem cake, growth, yield and potato

1. Introduction
The potato is a starchy, tuberous crop from the perennial nightshade *Solanum tuberosum*. Potato can be produced in a wide range of soils, ranging from sandy loam, silt loam, loam and clay soil. Soils for Potato should be friable, well aerated, fairly deep and well supplied with organic matter. Well drained sandy loam and medium loam soil, rich humus are not suitable for Potato. Soil structure and texture has marked effect on the quality of the tuber. Light soils are preferred because they tend to promote more uniform soil temperature and make harvesting easier. Alkaline and Saline soil is not suitable for the cultivation of potato. They are well suited to acidic soil (pH 5.5-7.5) with regards to growth and the leaves become dull dark green without being lustier.

Potato is one of the major crops contributing to the world food requirement (Karam *et al*., 2009) [10]. The word "potato" may either refer to the plant itself or to the edible tuber. It is the world's fourth largest food crop, following maize, wheat and rice. Potato was introduced to India from Europe in the 17th century (Singh, 2010) [10].

In 2014, world production of potatoes was 382 million tonnes, an increase of 4% over that of 2013 and led by China with 25% of the world total. Other major producers are India, Russia, Ukraine and the United States. India ranks as the world's third largest potato producing nation, with production in 2007 of around 26 million tonnes. This crop is grown throughout the world. The present world production is some 321 million tonnes fresh tubers from 19.5 million hectare. Potato plays a strong role in developing countries with its ability to provide nutritious food for the poor and hungry. The demand for Potato is growing as both fresh and processed food. However, the local importance of Potato is variable and rapidly changing. It remains an essential crop in Europe (especially eastern and central Europe), where per capita production is still the highest in the world, but the most rapid expansion over the past few decades has occurred in southern and eastern Asia.

In order of importance for food production among twenty major food crops (on fresh weight basis) Potato ranks 6th in the developing countries, 4th in the developed countries and 3rd in India.

Nutrients uptake is at its greatest during tuber bulking up. The amount of nutrients removed by a Potato crop is closely related to yield. Usually, twice the yield will result in twice the removal of nutrients. Nutrients need to be applied as accurately as possible to the zone of uptake, slightly before, or at the time that the crop needs them. Failure to ensure that each plant gets the right balance of nutrients can spoil crop quality and reduce yield.

Nitrogen (N) must be added in organic or inorganic form; mineral nitrogen fertilization can increase shoot weights, leaf area, plant height and subsequently can reduce tuber yield. Also, excess N can have a negative effect on the tuber quality and the environment (Najm *et al.*, 2010) [14]. Nitrogen is a first limiting nutrient in Potato production and thus has a great influence on crop growth, tuber yield and its quality. A mature crop of potato yielding 25-30 t ha^{-1} tubers removes 120-140 kg N ha^{-1}. The Indian soils are generally deficient in organic matter thus being unable to release N at the rate required to maintain adequate supply to the growing plant. Therefore, application of nitrogen in the form of fertilizers and manures becomes indispensable to meet the needs of the crop (Trehan *et al.*, 2008) [20].

Phosphorus (P) is important for early root and shoot development, providing energy for plant processes such as ion uptake and transports. Roots absorb phosphate ion only when they are dissolved in the soil water. Phosphorus deficiencies can occur even in soils with abundant available P, if drought, low temperatures, or disease interfere with P diffusion to the root, through the soil solution. These deficiencies will result in stunt root development and inadequate function.

Phosphorus is one of the most essential elements for plant growth after Nitrogen. However, the availability of this nutrient for plants is limited by different chemical reactions especially in arid and semi-arid soils. Phosphorus plays a significant role in several physiological and biochemical plant activities like photosynthesis, transformation of sugar to starch, and transporting of the genetic traits (Mehrvarz *et al*., 2008) [13].

Potassium (K) improves the tuber yield by increasing the size of tuber. K increases the leaves area and its duration and helps in utilizing nitrogen more efficiently. Besides imparting resistance against diseases and water stresses, it also provided frost resistance to the plant. Potassium enhances Potato plant height, resistance against drought, frost and diseases, tuber yield and also develops the quality of Potato tubers. K has an important role in the control of the plant water status and internal ionic concentration of the plant tissues, with a special focus on the stomatal functioning. The deficiencies of K reduce the yield, size, and quality of the Potato crop. K is involved in the activation of a number of enzymes, metabolic activities and translocation of photosynthetic to the tubers, thus increasing yield of potato (Ayyub *et al.*, 2011) [5].

Neem Cake organic manure protects plant roots from nematodes, soil grubs and white ants probably due to its residual limonid content. It also acts as a natural fertilizer with pesticidel properties. Neem cake also reduces alkalinity in soil, as it produces organic acids on decomposition. Being totally natural, it is compatible with soil microbes, improves and rhizosphere microflora and also enhances the fertility of the soil. Neem cake improves the organic matter of the soil, helping improve soil texture, water holding capacity, and soil aeration for better root development.

2. Materials and Methods

The field experiment was conducted to study the effect of different levels of fertilizers and Neem cake on soil health, growth and yield of Potato. The field experiment was carried out during the Rabi season 2017-2018 at the research farm of Department of Soil Science and Agricultural Chemistry, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (U.P.) located at 25°.57' N latitude 81°.57' E longitude and 98m above mean sea level.

Soil samples were taken from 0-15cm depth of soil randomly prior to tillage operations, air dried and passed through 2 mm sieve. Then the composite sample was taken for mechanical and chemical analysis. Bouyoucos hydrometer method (1957) was used for the mechanical analysis of soil to determine sand, silt and clay percentage in the sample.

Chemical analysis of the soil showed a neutral pH (7.14), 0.144 dSm^{-1}EC, 0.450% Organic carbon, 217.25 kg ha^{-1} Nitrogen, 18.47 $kgha^{-1}$Phosphorus, and 154.76 $kgha^{-1}$ exchangeable Potassium. Recommended dose of N, P and K (120:100:120 kg N, P_2O_5 and K_2O ha^{-1}) were applied. Full dose of P and K were applied along with 50 per cent of N at the time of planting. The remaining 50 per cent N was applied at time of earthling up.

Agro climatically, Allahabad district represents the subtropical belt of the South East of Uttar Pradesh, and is endowed with extremely hot summer and fairly cold winter. The maximum temperature of the location ranges between 46 °C – 48 °C and seldom falls below 4 °C – 5 °C. The relative humidity ranges between 20-94%. The average rainfall of this area is around 1100mm annually.

The experiment was carried out in RBD (Randomised Block Design) with three replications for each treatment. The inorganic source of fertilizers was satisfied with Urea, MOP (Muriate of Potash), DAP (Di-ammonium Phosphate) (as N, P, K) and organic source as Neem cake which had a significant effects on the growth and yield of Potato. The treatment combination was laid out as T_0- Control, T_1-NPK 0% Recommended Dose of Fertilizer (RDF)+ Neem cake 50 kg ha^{-1} T_2- NPK 0% RDF+ Neem cake 100 kg ha^{-1}, T_3-NPK 50% RDF+ Neem cake 0 kg ha^{-1}, T_4-NPK 50% RDF+ Neem cake 50 kg ha^{-1}, T_5-NPK 50% RDF+ Neem cake 100 kg ha^{-1}, T_6-NPK 100% RDF+ Neem cake 0 kg ha^{-1}, T_7-NPK 100% RDF+ Neem cake 50 kg ha^{-1}, T_8-NPK 100% RDF+ Neem cake 100 kg ha^{-1} respectively.

3. Results and Discussions

3.1 Plant height (cm)

The effect of different levels of NPK and Neem cake on plant height at 30 DAS (Days after sowing) was found significant. The maximum plant height (23.94cm) was of treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) followed by treatment T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1}) (21.77cm) whereas, the minimum was recorded 11.11cm in treatment T_0 (Control). At 60 DAS the maximum plant height of 38.90cm was observed at treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) followed by T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1})

(36.75cm) and the lowest of 23.61cm was recorded in treatment T_0 (Control). The plant height at 90 DAS was found maximum at treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) (57.13cm) and the lowest of 36.01cm was in treatment T_0 (Control).

This may be due to the fact that relatively higher dose of Nitrogen application results in increase in cell size, elongation and enhancement of cell division which increases plant height, number of branches, fresh and dry foliage, number of tubers per plant, tuber weight and tuber percentage and chemical composition of foliage and tubers, as stated by Arafa (2004) [4].

3.2 Number of leaves plant^{-1}

The effect of different levels of NPK and Neem cake on number of leaves at 30 DAS was found significant. The maximum number of leaves (15.70) was of treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) followed by treatment T_7 ((NPK 100% RDF+ Neem cake 50 kg ha^{-1}) (13.18) whereas, the minimum was recorded 9.44 in treatment T_0 (Control). At 60 DAS the maximum number of leaves of (50.27) was observed at treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) followed by T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1}) (45.66) and the lowest (29.21) was recorded in treatment T_0 (Control). The maximum number of leaves (78.05) at 90 DAS recorded with treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) which was followed by (75.61) in treatment T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1}), whereas the minimum number of leaves (50.34) was obtained in T_0 (Control).

Potassium increases leaf expansion particularly at early stages of growth and extends leaf area duration by delaying leaf shedding near maturity. The application of Potassium activates a number of enzymes involved in photosynthesis, carbohydrate and protein metabolism; and assists in the translocation of carbohydrates from leaves to tubers (Sharif *et al.*, 2014) [1].

Nitrogen fertilization has been reported to increase leaf number per plant (Kandil *et al.*, 2011) [9]. Similar findings were also reported by Amana *et al.* (2016).

3.3 Number of branches plant^{-1}

The effect of different level of NPK and Neem cake on number of branches at 30 DAS was found significant. The maximum number of branches (4.15) was of treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) followed by treatment T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1}) (3.06) whereas, the minimum was recorded 2.45 in treatment T_0 (Control). At 60 DAS the maximum number of branches of (7.72) was observed at treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) followed by T_7 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) (7.33) and the lowest (5.27) was recorded in treatment T_0 (Control). The maximum number of branches (12.28) at 90 DAS recorded with treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) which was followed by (11.61) in treatment T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1}), whereas the minimum number of leaves (8.67) was obtained in T_0 (Control). All the organic manure, applied with the recommended dose of NPK were positively correlated with tuber yield and disease development in comparision to the control (Mamta *et al.*, 2005). Similar finding were also reported by Ghulam *et al.* (2016).

3.4 Tuber length (cm)

From the field experiment it was observed that the maximum tuber length of 7.98 cm was found at treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}), followed by T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1}) and the minimum was recorded at T (Control) with 3.75 cm. All the treatment combination showed significant increase over Control. The maximum tuber length with treatment T_8 could be due to availability of different nutrients from organic manure and inorganic fertilizers, which contributed significantly to growth of the crop. The effects of manures and fertilizers have significant impact on the growth, yield and physiological properties of potato (Boke, 2014) [17].

3.5 Tuber yield (t ha^{-1})

It has been recorded that the maximum number of yield of 40.64 t $ha^{-1}$was found in treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}), followed by treatment T_7 (NPK 100% RDF+ Neem cake 50 kg ha^{-1}) with 33.03 t ha^{-1}. And the minimum tuber yield was found in treatment T_0 (Control) with 12.25 t ha^{-1}. Application of both NPK and Neem cake resulted in significantly higher tuber yield as compared to Control. The tuber yield of Potato was found to be significant, Potatoes cv. Kufri Chandramukhi grown in a sandy loam soil and given no fertilizer or 100 kg N, N+ 50 kg, P, NP + 100 kg K or 150 kg N + PK ha^{-1}gave tuber yields 40.56 and 32.95 t/ha respectively (Krishnappa, 1989) [11].

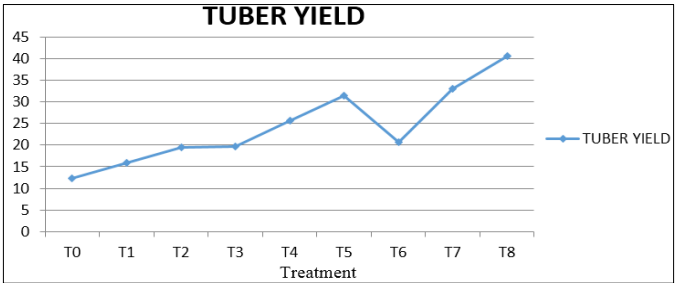

Fig 1: Effect of different levels of fertilizer and Neem cake on Tuber Yield (t ha^{-1}) of potato

3.6 Bulk density (g cm^{-3})

The effect of different levels of NPK and Neem cake also showed significance on bulk density in soil after harvest of Potato. The minimum bulk density was recorded at T_0 (Control) with value 1.28 and the maximum value was recorded at T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) 1.34 g cm^{-3}. The experiment indicates that the chemical properties of soil and availability of potassium were significantly influenced by application of inorganic, organic and bio-fertilizer. Similar kind of finding was also reported by Ojha *et al.* (2009) [15].

3.7 Particle density (g cm^{-3})

The effect of treatment combination of NPK and Neem cake at different levels on particle density after harvest was found significant. The particle density of soil significantly increased with increase in levels of NPK and neem cake. The maximum particle density value 2.49g cm^{-1} was found at treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) and minimum particle density 2.40 g cm^{-1} was recorded in treatment T_0 (Control). Similar findings were also reported by Ghulam *et al.* (2016).

3.8 Pore Space (%)

The % pore space of soil significantly increased with increase in levels of NPK and Neem cake. The maximum % pore space (55.02 %) was found in treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) and the minimum % pore space (51.35 %) was recorded in T_0 (Control). The findings proved that the effect of NPK and Neem cake was significant with respect to % pore space. Ghulam *et al.* (2016) also reported similar findings.

3.9 Organic carbon (%)

The result shows that soil Organic Carbon (OC) (%) increases with increase in levels of NPK and Neem cake. The maximum soil O.C. (%) of 0.52 % was observed in treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}), and the minimum soil O.C. (%) of 0.44 % was recorded in T_0 (Control). Similar findings have also been reported by Ojha *et al*. (2009) [15].

3.10 Soil pH

The highest pH (7.58) was recorded with treatment T_0 (Control) followed by treatment T_1(NPK 0% RDF+ Neem cake 50 kg ha^{-1}), (7.66); whereas the lowest value was observed with treatment combination T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) (7.58). The decrease in soil pH may be due to formation of bicarbonate and ammonium nitrate by the application of urea that reacts with H^+ ions which caused reduction in acidity. Similar findings were reported by Roshan *et al*. (2014**).** Similar kind of finding was also reported by Ojha *et al.* (2009) [15].

3.11 Electrical Conductivity (d Sm^{-1})

The maximum Electrical Conductivity (EC) value 0.96 dsm^{-1} was found at treatment T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}) and minimum electrical conductivity 0.93 dsm^{-1} was recorded in treatment T_0 (Control).The application of various fertilizers raised the EC of the soils to different levels, and the highest was recorded at treatment receiving full dose of inorganic and organic fertilizers *i.e.*,T_8 (NPK 100% RDF+ Neem cake 100 kg ha^{-1}). Esawy *et al.* (2009) [7] observed that the maximum EC value under higher dose of Inorganic and Organic fertilizer, which is in agreement with the present findings. Similar findings was also reported by Ojha *et al.* (2009) [15].

3.12 Available Nitrogen (kg ha^{-1})

The maximum available N of 235.00 kg ha^{-1} was recorded at treatment T_8(NPK 100% RDF+ Neem cake 100 kg ha^{-1}), which was followed by 232.64kg ha^{-1} at treatment T_7(NPK 100% RDF+ Neem cake 50 kg ha^{-1}). And the minimum available N was recorded at T_0(Control) with 176.89 kg ha^{-1}. Organic or inorganic fertilizers when applied is known to ameliorate soil N status (Ajebesone *et al.*, 2011). Similar findings has also been reported by Ojha *et al.* (2009) [15].

3.13 Available Phosphorus (kg ha^{-1})

The maximum available P of 22.33 kg ha^{-1} was recorded at treatment T_8(NPK 100% RDF+ Neem cake 100 kg ha^{-1}), which was followed by 22.00kg ha^{-1} at treatment T_7(NPK 100% RDF+ Neem cake 50 kg ha^{-1}). And the minimum available P was recorded at T_0(Control) with 16.33kg ha^{-1}. The increase in available P have also been reported by Ojha *et al.* (2009) [15], Shuh *et al.* (2015) [19].

3.14 Available Potassium (kg ha^{-1})

The maximum available K of 169.33 kg ha^{-1} was recorded at treatment T_8(NPK 100% RDF+ Neem cake 100 kg ha^{-1}). And the minimum available K was recorded at T_0(Control) with 131.97kg ha^{-1}. The results are conformity with the finding of Ojha *et al.* (2009) [15].

Table 1: Analysis of soil before sowing of Potato

Parameters	**Result**
Sand (%)	70.10
Silt (%)	17.20
Clay (%)	12.70
Texture of Soil	**Sandy Loam**
Bulk density (g cm^{-3})	1.33
Particle density (g cm^{-3})	2.41
Pore space (%)	51.87
Soil colour	Light yellowish brown
P^H	7.14
EC (dSm^{-1})	0.14
OC (%)	0.45
Available Nitrogen ($kgha^{-1}$)	217.25
Available Phosphorus ($kgha^{-1}$)	18.47
Available Potassium ($kgha^{-1}$)	154.76

Table 2: Effect of NPK and Neem cake on growth parameters, yield and economics of Potato

Treatment combination	**Plant height (cm)**	**Number of leaves $plant^{-1}$**	**Number of branches $plant^{-1}$**	**Tuber length (cm)**	**Tuber yield (t ha^{-1})**	**Gross return (≠ ha^{-1})**	**Cost benefit ratio**
T_0	36.01	50.34	8.22	3.75	12.25	98000	1.32
T_1	37.65	55.89	8.66	4.62	15.871	126960	1.36
T_2	40.13	60.44	9.28	5.73	19.47	155760	1.39
T_3	44.82	67.89	10.11	4.35	19.64	157120	2.02
T_4	48.89	71.05	11.00	4.67	25.69	205520	2.13
T_5	50.67	71.77	11.77	7.72	31.41	251280	2.18
T_6	36.93	68.11	11.61	7.05	20.58	164640	2.02
T_7	57.13	75.61	12.28	7.72	33.03	264240	2.64
T_8	58.22	78.05	12.78	7.98	40.64	325120	2.74
F-test	S	S	S	S	S		
SE. d (±)	7.51	1.70	0.56	0.08	0.48		
C. D. at 5%	15.93	1.30	1.18	0.16	1.01		

Table 3: Effect of NPK and Neem cake on soil properties after harvest of Potato

Treatment combination	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Pore Space (%)	OC (%)	Soil pH	EC (dSm^{-1})	Av. Nitrogen (kg ha^{-1})	Av. Phosphorus (kg ha^{-1})	Av. Potassium (kg ha^{-1})
T_0	1.28	2.40	51.35	0.44	7.67	0.93	176.89	16.33	131.97
T_1	1.29	2.42	51.69	0.47	7.66	0.94	187.67	16.69	140.33
T_2	1.30	2.43	51.69	0.48	7.65	0.94	191.33	17.33	142.00
T_3	1.31	2.43	52.05	0.48	7.63	0.94	218.67	16.67	155.67
T_4	1.32	2.46	52.69	0.50	7.62	0.93	229.00	21.33	159.00
T_5	1.32	2.46	53.35	0.51	7.60	0.94	231.00	21.67	164.67
T_6	1.31	2.44	52.35	0.49	7.63	0.94	222.33	20.78	156.33
T_7	1.33	2.48	54.02	0.51	7.59	0.94	232.67	22.00	168.00
T_8	1.34	2.49	55.02	0.52	7.58	0.96	235.67	22.33	169.33
F-test	S	S	S	S	S	S	S	S	S
SE. d (±)	0.01	0.01	0.05	0.02	0.01	0.01	0.25	0.09	0.24
C. D. at 5%	0.02	0.02	0.11	0.04	0.02	0.01	0.54	0.19	0.51

Note: Av= Available

Bulk Density and Particle Density

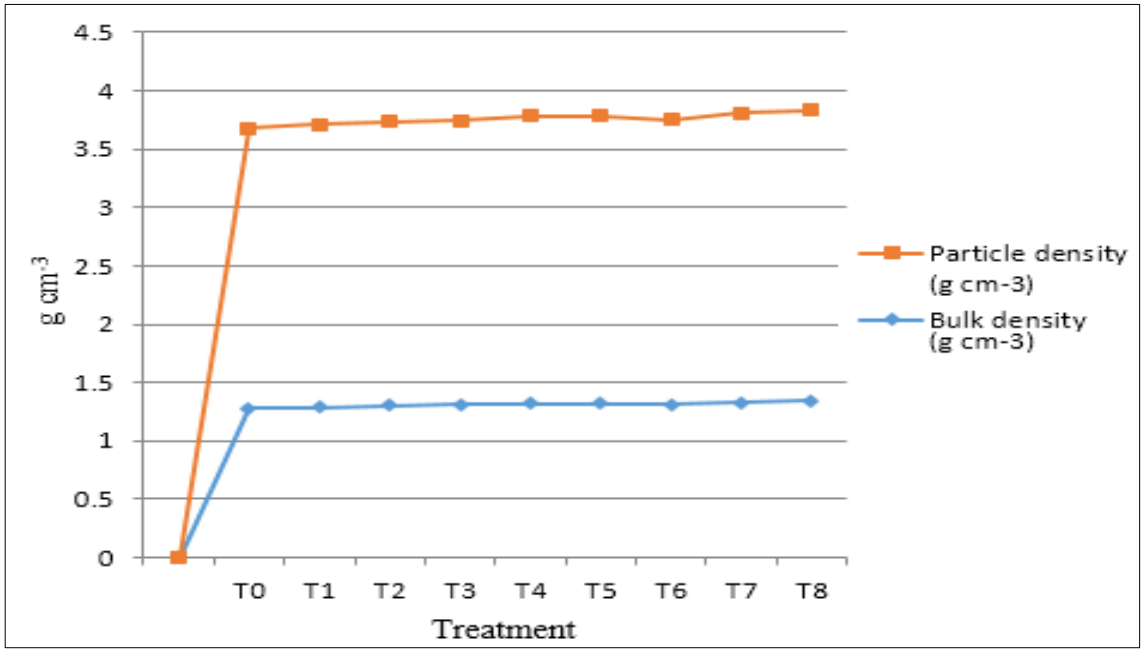

Fig 2: Effect of different levels of fertilizer and Neem cake on Bulk Density and Particle Density (g cm^{-3}) of potato

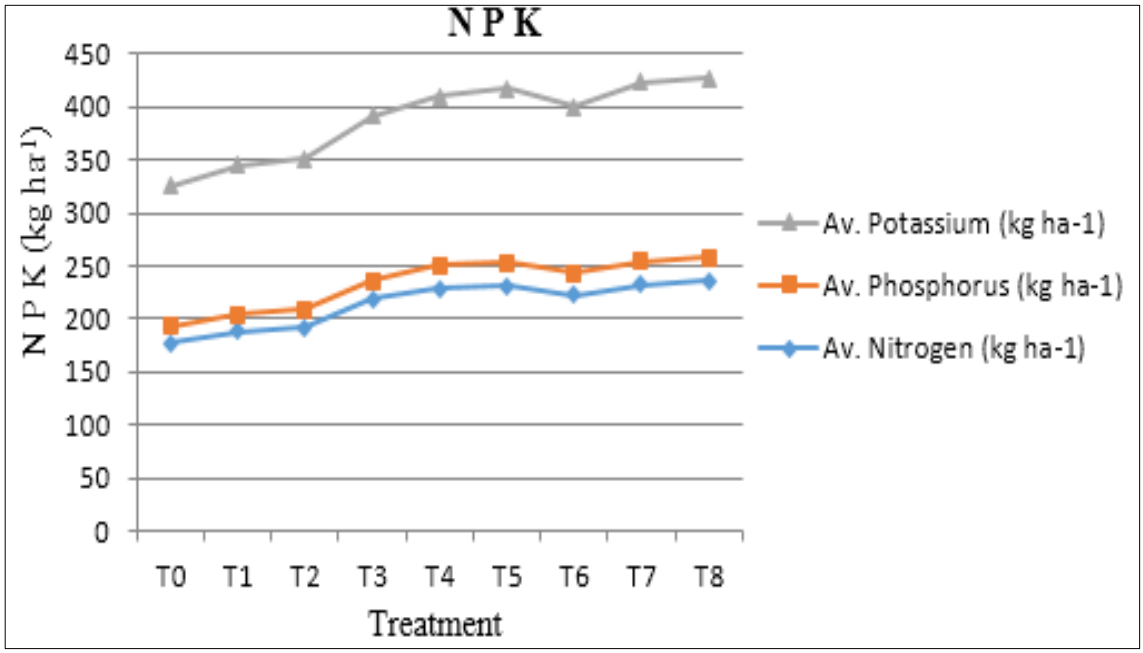

Fig 3: Effect of different levels of N P K(kg ha^{-1}) on post-harvest soil

4. Conclusions

The findings of the experiment concluded that the application of NPK (@ 120 kg ha^{-1}, 100 kg ha^{-1}, 120 kg ha^{-1} and Neem cake @ 1250 kg ha^{-1} had significant effects on the soil, growth and yield of Potato which makes the combined application of NPK and Neem cake a beneficial approach towards an important source of plant nutrients. From economical point of view, the treatment T_8(NPK 100% RDF+ Neem cake 100 kg ha^{-1}) was found to be economically viable in terms of gross return (Rs 325120.00 ha^{-1}). The treatment T_8(NPK 100% RDF+ Neem cake 100 kg ha^{-1})) also recorded as the highest B: C ratio which was (2.7:1).

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