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Furrow Application of Lime on Growth and Yield of Potato in Acid Soils of North Bank Plain Zone of Assam, India

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ABSTRACT

A research experiment was successfully conducted at farmers' field in potato (*Solanum tuberosum* L.) during the year 2022 - 23 by application of lime to ameliorate the soil acidity for better production of potato in three villages of Lakhimpur District of Assam. There were 3 Technologies i.e. (TO-1: Lime @ 2 – 4 q/ha + 50% Recommended Dose of Fertilizer (RDF) that is NPK @ 60:50:50 kg/ha, TO-2: RDF (NPK@ 60:50:50 kg/ ha)and TO-3: Farmers Practice). The experiment was conducted in total area of 0.3 ha following randomized block design. The outcomes revealed that application of lime @ 2 – 4 q/ha in furrows + 50% RDF (NPK@ 60:50:50 kg/ha) gave higher yield of 93.7 q/ha and in farmers practice it gave 74.2 q/ha having B:C ratio of 2.33 and 2.10, respectively. With the integration of lime and chemical fertilizers the soil nutrient status improved as compared to the plot receiving only chemical fertilizers and to the Farmers practice. So, application of lime in furrows @ 2 – 4 q/ha and 50% RDF (NPK@ 60:50:50 kg/ha) is economical and profit oriented for small land holding farmers of that region and maintaining the soil acidity in Lakhimpur district of Assam.

***Key words**: Farmers Practice, Lime, Potato, Soil Nutrient Statusand Yield*

Introduction

Potato (*Solanum tuberosum L.*) as we all know is called 'poor man's friend'is one of the important agricultural crop all over the world. Globally the potato production is found to be 376.0 million tons with India producing 54 million tonnes (Food and Agriculture Organization, 2021). The potato production in Assam is 1072780 tonnes (2017). Potato is considered to be the commonly grown tuber crop having calories in high amount and rich source of starch. Limited rainfall, lack of irrigation facilities, diseases and pests and poor agronomic practices, in terms of poor nutrient management lead to decline in productivity of the district. The greatest need of nutrients in vegetative stage and tuber formation

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stage in case of early varieties. The deficiency of it leads to decrease in production of the tubers and its quality (Laboski *et al.,* 2007). Nurmanov *et al.* (2019) told that N, among all other essential element is required for proper yield and increase in dry matter yield. Deficiency of nitrogen causes poor yields, while overdose of N application results in leaching, excess vegetation, low quality tubers and drastic reduction in production due to defoliation (Goffart *et al.,* 2008). Singh *et al.* (2011) told that phosphorus shows a beneficial effect as it increases the development of the roots, enhances the uptake of nitrogen, tuber formation and its development. Potato, since it is a heavy feeder of nutrients requires higher potassium because it helps in proper development of roots and leaves, and it also protects the plant from diseases (Adams *et al.,* 2014). Abbas *et al.* (2012) told that the release of carbon dioxide through the process of mineralizationleads to the activation of nutrients and make them available to the plants. Soil acidity is one of the primary constraint which has led to reduction in crop yield through-out the world (Singh and Swami, 2020). In India, one-third of the cultivated land is acidic.48 to 49 Mha is occupied by acid soils out of 142 Mha of arable land. Again, 25 Mhais having pH below 5.5 and 23 Mhashow pH between 5.6 to 6.5 (Mandal, 1997). High rainfall leads to high soil acidity in Northeastern India. 65% of the area of North Eastern India suffers from high soil acidity having pH below 5.5 in (Sharma and Singh, 2002). Nutrients become unavailable which leads to its deficiency (phosphorus, calcium, magnesium, molybdenum) and low productivity of major crops. So, to increase productivity managing soil acidity is very much required. Combined use of balanced inorganic fertilizers along with lime will improve the soil physical properties and also increase the yield of the crops (Saha *et al.,* 2010; Swami *et al.,* 2020). Lazarevic *et al.* (2014) told that potatoes growwell in low pH acidic soils, even well in pH is below 5. Agricultural limestone is the best acid neutralizer for improving soil pH of soils having pH less than 5.5 in potato cultivation (Das, 2018). Microbial activities can be enhanced with lime application as it will make available most of nutrients which were in fixed forms.Production of potatoes for commercial purposes is basically based on the application of mineral fertilizers. Due to lack of awareness on balanced application of fertilizers and lime in potatoof the district, the aim of the study was to examinethe effects of lime application in furrows along with synthetic/chemical fertilizers to manage the soil acidity problem in the district and also to increase the production.

Materials and Methods

North Bank Plain Zone – At A Glance

North Bank Plain Zone (NBPZ) is located as its name implies in the Northern bank of Brahmaputra river. NBPZ is one of the six agroclimatic zones of Assam. Darrang, Udalguri, Sonitpur, Lakhimpur and Dhemaji are 5 districts of Assam which comes under NBPZ. The NBPZ is located between 91°22′E to 95°20′E longitude and 26°41′N to 27°48′N latitude. Geographical area ofthis zone is1431536 ha which 18% of the total area of Assam is. Lakhimpur District has a Geographical Area of 2,27,700 ha, Forest Area of 24,887 ha, Non cultivable area of 46,669 ha, Fallow land of 13,122 ha, Total Cultivable Area of 1,37,747 ha, Net Sown Area of 1,23,625 ha, Total Cropped Area of 2,17,223 ha and Cropping intensity of 175.7%. The area has got sub-tropical climate of hot and humid summer and cool winter. Receiving annual rainfall from 1951 to 2843 mm per annum. July receives highest rainfall in a year.

There are five large Agro – Ecological Zones (AEZ) of Lakhimpur District. They are AEZ I – Foot hills, AEZ II – Medium land with high rainfall, AEZ III – Low land with lower elevations sand deposit, AEZ IV- Deep water with lower elevations, AEZ V – Sand and silt deposited deep water areas (Regional Agricultural Research Station, North Lakhimpur, Assam Agricultural University, 2014). In Lakhimpur district pH of 5.1-5.5 which is strongly acidic, 5.6-6.0 (medium acid soils)and pH of 4.5 – 5 that is very strongly acid soil covering 40.15, 22.00 and 21.33 per cent, respectively is found. Only 9.22, 3.46, 2.11, 1.25 and 0.48 per cent soils having pH 6.1-6.5 (slightly acidic), 7.4 -7.8 (mildly alkaline), extremely acid (<4.5) and moderately alkaline (7.9-8.4) in soil reaction, respectively in the district. Medium soil organic carbon was predominant in the district covering 37.18 per cent area followed by high (24.59%), low (22.38%), very high (10.18%) and very low (5.67%) status of organic carbon. Major parts of the district comprised of available nitrogen (64.46%) in medium range followed by (25.26%) which is low, then (9.22%) which is in very low range and (1.06%) in the high range. About 48.70 per cent soils comprise of medium range in available phosphorus, 35.93% of the soil show deficiency in phosphorus, 14.41% show low phosphorus and high phosphorus range of 0.96% is predominant in the district. Potassium in medium range covering 42.07% area followed by 26.8% in low range, 11.14% in very low range, 10.57% in high range and 9.41% is very high range is predominant in the soils of the district. Again, sulphur is in the medium range covering 45.55 % followed by 31.99% which is in the high range, 13.74% in very high range, 8.45% in low range in the district (Regional Agricultural Research Station, North Lakhimpur, Assam Agricultural University, 2014).

Study Area

The research experiment covers three villages namely Podumoni, Pukhuripuria, 2 No. Rangajan of Lakhimpur district. The criteria of selecting the above three villages is because most of the farmers in these areas are potato growers and severe acidity is the major problem leading to low production and productivity of the potato crop. The experiment was conducted to study the effect of lime in growth and yield of potato crop which will ultimately help to generate more income from increased production of potato crop in Lakhimpur district of Assam. The study area covered under each village is 0.10 ha and total area is0.3 ha. Three technologies viz. TO-1: Lime @ 2 – 4 q/ha + 50% RDF (NPK@ 60:50:50 kg/ha), TO-2: RDF (NPK@ 60:50:50 kg/ha)and TO-3: Farmers Practice were taken. Randomized Block Design was followed which was replicated in three different villages and atthree different farmers fields during the year 2022 - 2023. Potato variety which is locally grown in these villageswas used for conducting the experiment. Before implementing the experiment all three farmers of three different villages were trained properly on soil fertility management and proper potato cultivation.

Soil Sampling

To know the actual nutrient levels of the experimental sites representative composite soil samples were collected randomly from the field before sowing of potato and fertilizer application from the three different locations. The depth of soil sampling was (0-15cm). The initial soil status of the soil samples are analysed in Soil Science Laboratory of Krishi Vigyan Kendra, Lakhimpur, Assam Agricultural University and are given in (Table 1) which was collected before planting of the crop. The soil was found to be acidic and sandy. Again after harvest of the potato crop, soil samples were drawn from 0-15 cm depth from three technologies viz: TO-1: Lime @ 2 – 4 q/ha + 50% RDF (NPK@ 60:50:50 kg/ha), TO-2: RDF (NPK@ 60:50:50 kg/ha)and TO-3: Farmers Practice of three different locations. Soil Sample collection was done in early morning hours.

Soil Analysis

The collected soil samples from three different locations were analyzed. Soil pH (Glass electrode pH meter method by Jackson, 1973), organic carbon (Walkley and Black, 1934 rapid titration method), available nitrogen (Alkaline permanganate method by Subbiah and Asija, 1956), available phosphorus (Bray and Kurtz, 1945 method), available potassium (Flame photometer method by Jackson, 1973) was evaluated before and after harvest of the crop from three different locations of three different farmers fields.

Economics Calculated

The economics and the cost benefit analysis were also evaluated at the end of the experiment for the benefit of the farmers from the formulas given below:

Gross Cost (Rs/ha) = expenses incurred for agronomic operations in terms of labour, farm machinery and input costs like (seeds, fertilizers, irrigation, pesticides and FYM).

Gross Return (Rs/ha) = Yield of the crop X Sale Price of the crop

Net Return (Rs/ha) = Gross Return – Gross cost

Benefit: Cost ratio = Gross Return / Gross Cost.

Results and Discussion

The weather data during the crop season are given

Table 1. Initial Soil Status of the Experimental Sites.

pH	Organic Carbon (%)	Available Nitrogen (Kg/ha)	Available Phosphorus (Kg/ha)	Available Potassium (Kg/ha)
4.90	0.74	310.29	21.4	152.40

in (Figure 2). The amount of rainfall was highest in the month of February 2023 that is 75.2 mm and during the month of November 2022 there was hardly any rainfall (Assam Agricultural University – Zonal Research Station, North Lakhimpur, 2022 - 23).

Yield and Yield Attributing Traits

The results in (Table 2) showed that application of lime along with synthetic fertilizers lead to proper growth and production of potato as compared to the plot receiving no lime (TO-2) and (TO-3) that is Farmers practice. The highest plant height (51.20 cm) and tuber yield of (93.7 q/ha) were obtained in the plot TO-1: Lime @ 2 – 4 q/ha + 50% RDF (NPK@ 60:50:50 kg/ha). Again, it was observed that lowest plant height (39.9 cm) and tuber yield (74.2 q/ha) were recorded in the plot TO-3: Farmers Practice. The exchangeable base cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na+) got increased with lime application and chemical fertilizers which ultimately lead to increase in the yield by reducing the concentrations of acidic cations like Iron, Aluminium and hydrogen. Lime application improves plant root growth, makes nutrients available to the plants and gives higher crop yields by overcoming Fe and Al toxicity. This collaborates with the findings of (Bordoloi, 2021) and (Ejigu *et al.*, 2023). Findings are also in agreement with (Harelimana, 1990) who reported that lime is effective in increasing potato yield in Southern acidic soils of Rwanda (Cifu *et al.*, 2004) observed similar results in case of increase wheat yields with lime application which was due to decrease in exchangeable aluminium and iron and the increase in soil pH, organic matter and soil available nutrients. The findings are also similar with the findings of (Liu *et al.*, 2020), who reported that with lime application there was substantial increase in crop production which was also due to reduction of exchangeable aluminium and iron, increase in soil pH and increase in concentrations of basic nutrients like calcium, magnesium and potassium (Getachew *et al.*, 2017) told that addition of lime increased the response of crops to applied phosphorus fertilizer which would otherwise be unavailable to the plants as a result of fixation of phosphorus in acid soils. Similarly, (Kreismane *et al.*, 2016) reported that liming decreases the emission of nitrogen oxide) which improves the nitrogen use efficiency and production. The findings are also related to the findings of (Olego *et al.*, 2021) who reported thatapplication of lime improves aluminium toxicity, improves root growth, uptake of water and nutrients from soiland higher yields.

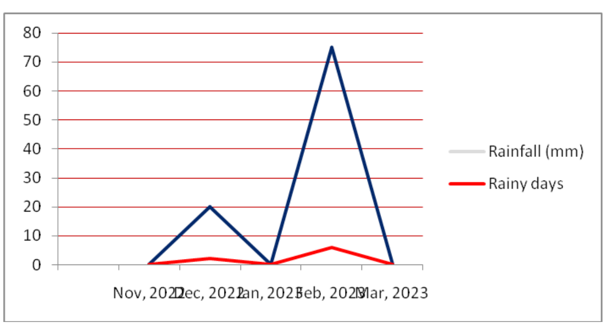

Fig. 2. Rainfall Data during the crop period (2022 -23)

Table 2. Effect of lime application on Yield and Plant Height of potato (Variety – Local).

Technology	Plant Height (cm)	Yield(q/ha)
TO-1	51.2	93.7
TO-2	46.8	88.2
TO-3	39.9	74.2
Grand Mean	45.95	85.37
CV (%)	0.07	0.68
SE.M	0.01	0.33
LSD (0.05)	0.07	1.31

Soil Chemical Properties

Application of lime affected the chemical properties of soil as well. In (Table 3) it has been observed that TO–1 that is Lime @ 2 – 4 q/ha + 50% RDF (NPK@ 60:50:50 kg/ha)showed highest pH value of 5.56, highest Organic Carbon (%) of 0.86, highest available NPK of 383.48 kg/ha, 32.6 kg/ha and 165.75 kg/ha respectively and lowest was observed in TO -3 that is farmers practice.The results suggests that lime application is related with pH. The increase in soil pH is due to precipitation of exchangeable iron and aluminium as insoluble hydroxides of iron and aluminium and increase in concentrations of exchangeable cations like calcium, magnesium, potassium. This collaborates with the findings of (Garbuio *et al.*, 2011). Similarly, (Fageria, 1989b) reported an increase of soil phosphorus due to release of phosphorus ions from iron and aluminium oxides, which are responsible of phosphorus fixation. The findings are also related with the findings of (Nurlaeny *et al.*, 1996) that phosphorus is deposited as insoluble iron and aluminium phosphates which becomes unavailable to the plants. But lime reverse the scenario and increase the soil phosphorusreported that acidic soils are deficient in phosphorus and significant portions of applied phosphorus are immobilized due to precipitation. Presence of basic cations like calcium and magnesium leads to increase in soil pH and reduction of soil exchangeable acidity (Frageria *et al.*, 2007) and the anions present in lime are able to exchange hydrogen ions from exchange sites to form water and carbon dioxide. The cations occupy the space which is left behind by hydrogen ions on the exchange leading to increase in soil pH (Caires *et al.*, 2006) reported the responses of pH to application of lime in tropical soils in various parts of the world and in Ethiopia it was reported by (Alemayehu, 1999) and (Beyene, 1987). (Antoniadis *et al.*, 2015) and (Muchaonyerwa *et al.*, 2020) reported that application of lime increased soil available phosphorus due to increased soil pH, decreased iron and aluminumions and reduction in fixation of phosphorus. Moreover, liming increased the contents of available nutrients and soil organic matterdue to greater addition of organic inputs from crop residues and plant roots (Antoniadis *et al.*, 2015). The soil organic carbon increased due to increase in microbial activities which speeds up the process of mineralization, which again leads toincrease in phosphorus availability and other nutrients in soil (Qaswar *et al.*, 2020).

Correlation relationship between yield and soil parameters as affected by lime

In (Table 4) it has been observed that a linear positive relationship between the yield and available phosphorus (r=0.999*). The unavailable phosphorus was made available with application of lime because adding lime reduces soil acidity which increases soil pH and ultimately increases the yield of the crop. The soil pH is positively significantly correlated with available nitrogen (r=1.000* *). The yield of the crop was correlated positively with pH (r=0.886), organic carbon (r=0.483), available nitrogen (r=0.892) and available potassium (r=0.981). This is because addition of lime increases the availability of nutrients, which would otherwise be strongly limited by low soil pH. An increase in soil pH as a result of liming increases microbial activity, resulting in increased decomposition of soil organic matter. The decomposition resulted in increased mineral nitrogen and phosphorus (Biasi *et al.*, 2008; Garbuio *et al.*, 2011; Persson *et al.*, 1989).

Economic Indices of Potato Crop

The data in (Table 5) reflects that highest net return of (Rs. 1,08,971 / ha) was observed in TO-1: Lime @ 2 – 4 q/ha + 50% RDF (NPK@ 60:50:50 kg/ha). Conversely, in TO -3 that is in farmers practice net return of (Rs.78,000 per ha) was observed which is lowest as compared with the lime treated plot. The results also revealed that average cost of cultivation was significantly lower in farmers practice as compared to the lime treated plot. The B-C ratio was significantly higher in TO-1: Lime @ 2 – 4 q/ha + 50% RDF (NPK@ 60:50:50 kg/ha) that is 2.33.

Table 3. Effect of lime on chemical properties of soil.

Technology	pH	Organic Carbon (%)	Available Nitrogen (Kg/ha)	Available Phosphorus (Kg/ha)	Available Potassium (Kg/ha)
TO-1	5.56	0.86	383.48	32.6	165.75
TO-2	5.10	0.76	336.20	30.1	159.26
TO-3	4.91	0.79	315.55	21.9	151.54
Grand Mean	5.19	0.80	345.08	28.2	158.85

Table 4. Correlation Analysis of Yield with Soil Parameters as affected by lime.

	Yield	pH	Organic Carbon	Avail. Nitrogen	Avail. Phosphorus	Avail. Potassium
Yield	1.000					
pH	0.886	1.000				
Organic Carbon	0.483	0.834	1.000			
Avail. Nitrogen	0.892	1.000**	0.827	1.000		
Avail. Phosphorus	0.999*	0.861	0.437	0.867	1.000	
Avail. Potassium	0.981	0.960	0.645	0.963	0.969	1.000

Table 5. Economic Analysis of different technologies of Potato crop (Variety: Local).

Technology	Yield (q/ha)	Gross Cost (Rs/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
TO-1	93.7	80,429	1,89,400	1,08,971	2.33
TO-2	88.2	78,400	1,76,400	98,000	2.25
TO-3	74.2	70,400	1,48,400	78,000	2.10

Conclusion

The present study shows that furrow application of lime is more effective to mitigate acidic soils as it increases the soil pH, increases the yield, increases the soil organic carbon and also enhances the nutrient availability. Furrow application of lime is more effective in mitigating soil acidity, that enhances available nutrients and crop yields as compared to broadcasting of lime. Highest yield of potato was attained with application of Lime @ 2 – 4 q/ha + 50% RDF (NPK@ 60:50:50 kg/ha). We can conclude that application of lime infurrows @ 2 – 4 q/ha was found to be economical and profit oriented for small land holding farmers in the area.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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