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Effect of soil amendments and potassium on performance of rapeseed (*Brassica campestris* L.) and soil properties

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ABSTRACT

A *pot experiment was conducted during rabi season, 2024 in the Department of Soil Science, SAS, Nagaland University Medziphema, to the study effect of soil amendments and potassium on performance of rapeseed and soil properties. The experiment with four soil amendments (A_0-control, A_1-5% LR, A_2-2.5 t biochar ha^{-1} and A_3-5% LR + 2.5 t biochar ha^{-1}) and 4 levels of potassium (K_0- control, K_{20}- 20, K_{40}-40 and K_{60}- 60 kg K_2O ha^{-1}) was carried out in complete randomized design with three replications. Results revealed that application of soil amendments significantly enhanced the growth, yield attributes, yield, nutrient content and nutrient uptake in rapeseed. Application of A_3-(5% LR + 2.5 t biochar ha^{-1}) significantly increased the seed yield to an extent by 50.8% and stover by 21.5% over control. Application of potassium significantly enhanced the growth, yield attributes, yield, nutrient content and nutrient uptake of rapeseed. Application of 60 kg K_2O ha^{-1} gave significantly higher yield over rest of the treatments. Soil amendments application significantly increased the soil pH, porosity, available NPK, exchangeable Ca^{2+}, SMBC, dehydrogenase, acid phosphatase and decreased that of acidity component of soil viz exchangeable acidity, exchangeable Al^{3+}, exchangeable H^+ and total potential acidity. Potassium application significantly increased the available N and K contents of post-harvest soil.*

Keywords: Rapeseed, soil amendments, potassium, yield, nutrient uptake, soil properties

INTRODUCTION

Oilseed crops play an important role in the Indian agriculture. Rapeseed (*Brassica campestris* L.) is a major oilseed crop that is traditionally grown in entire the country because of its high adaptability to conventional farming systems. Rapeseed contributes 31% to edible oil production in the country, followed by soybean (26%) and groundnut (25%) (Bhagat *et al.,* 2022). In India, Uttar Pradesh, Rajasthan, Madhya Pradesh, Haryana, Punjab, Orissa, Assam, Bihar, Gujarat and West Bengal are the states in where it is grown. Globally, India continues to be rank 2nd after Canada in acreage (19.81%) and rank 4th after Canada, European Union and China in terms of production (10.37%). During 2019-20 it was grown on 6.86 million ha in India, with a production of 9.12 million tonnes and a productivity of about 1329 kg ha^{-1}. In Nagaland, rapeseed is cultivated over an area of 15,070 ha, with a production of 15,978 metric tons (Nagaland Statistical Handbook, 2023). Soil acidity is a major agricultural issue in Nagaland that has a negative impact on crop productivity, either directly or indirectly (Poji *et al.,* 2017). The fertility of such acidic soils is exceedingly low, resulting in poorer yields from crops planted in such soils. Therefore, it is advisable to supply the required dose of lime to the soil to sustain its fertility and productivity. Lime is a major means of ameliorating soil acidity because it has a very strong acid-neutralizing capacity, which can effectively remove existing acids. Liming raises the soil pH and causes Al and Mn to move from the soil solution back into solid (non-toxic) chemical forms. Biochar is an organic material that is rich in carbon produced by biomass heating in the presence of low or no oxygen. Several advantages of using biochar for soil correction include an increase in water holding capacity and nutrient retention, improved soil fertility and agrarian productivity and an inordinate increase in soil pH.

Potassium (K) is the third most important plant nutrient required in high amounts by plants. It also plays a role in charge balancing osmotic adjustment and enzyme activation in plant cells. It is highly mobile in plants because it is not the structural part of plant tissue but is present in ionic form in plants. Potassium is also a quality

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element because it improves the quality of agricultural products. Potassium also develops resistance to different environmental stresses and can mitigate biotic and abiotic stresses that develop immunity in plants (Rawat *et al.,* 2022). Potassium is one of the principal plant nutrients that improve crop yield, productivity and quality. Potassium is an essential plant macronutrient that plays a key role in the synthesis of cells, enzymes, proteins, starch, cellulose and vitamins; nutrient transport and uptake; conferring resistance to abiotic and biotic stresses; and enhancing crop quality. Keeping all the above facts in view, the present investigation was conducted during the *rabi* season of 2024 to study the impact of soil amendments and potassium on performance of rapeseed and soil properties.

MATERIALS AND METHODS

A pot experiment was conducted at School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus, during October to March 2024 with rapeseed (Var. TS 38) as test crop. The experimental site is situated at 25˚43.923' to 25˚50.569' North latitude and 93˚37.645' to 93˚55.202' East longitude at an elevation of 310 meters above mean sea level. The soil of experimental field was sandy clay loam in texture with pH 5.02, EC 0.16 dSm^{-1}, organic carbon 7.35 g kg^{-1}, soil available N, P & K status 225, 25 & 155 kg ha^{-1}, and exchangeable Ca^{2+} & Mg^{2+} 1.55 & 0.50 $cmol(p^+)kg^{-1}$. Exchangeable Al^{3+}, H^+ & acidity 1.41, 0.81 & 2.30 $cmol(p^+)kg^{-1}$ respectively and total potential acidity 12.6 $cmol(p^+)kg^{-1}$. The SMBC, DHA and APA of experimental soil were 165.97 µg g^{-1} soil, 2.70 µg TPF g^{-1} hr^{-1} and 266.0 µg PNP $g^{-1}hr^{-1}$. Four levels of soil amendments viz Control (A_0), 5% LR (A_1), 2.5 t biochar ha^{-1}(A_2) and 5% LR + 2.5 t biochar ha^{-1}(A_3) and four levels of potassium viz Control (K_o), 20 kg K_2O ha^{-1} (K_{20}), 40 kg K_2O ha^{-1} (K_{40})60 kg K_2O ha^{-1}(K_{60}) were tested in completely randomized design (CRD) with three replications. The 25 X 30 cm earthen pots, used for experiment, were cleaned and kept in sun light for 2 days for drying. The stubbles and stone present in the soil were removed. Then the collected soil @ 15 kg pot^{-1} was filled in the pots. Recommended dose of nitrogen and phosphorus (60:30 kg ha^{-1}) were supplied through urea and single superphosphate, respectively. Half dose of nitrogen and full dose of phosphorus was applied as basal application at sowing time. Rest half dose of nitrogen was applied at 30 DAS. Soil amendments and potassium levels applied according to the treatments. 5% LR was supplied through $CaCO_3$ and potassium was supplied through muriate of potash. The 5 seeds pot^{-1} was sown at a depth of 1.5 cm. After 15 days of sowing three plants were maintained in each pot. Time to time hand weeding was done and for controlling the biting and chewing type insects, neem oil was sprayed in the in the crop. Pots were irrigated as and when required. Crop was harvested at maturity stage. After threshing the seeds were separated out and cleaned manually. Data on plant height, primary & secondary branches per plant, siliqua per plant, seeds per siliqua, test weight, seed and stover yield were recorded. Nitrogen content in plant samples was determined by Kjeldahl method. Phosphorus, potassium, calcium and magnesium content in plant samples were determined in di-acid (HNO_3-$HClO_4$) digestion by using standard procedures as advocated by Jackson (1973). Nutrient uptake was calculated by multiplying grain and stover yields with their respective nutrient contents. Total nutrient uptake was calculated by summation of nutrient uptake in seed and stover. Oil content in seed samples was estimated by Soxhlet extraction method. The pH, EC, organic carbon, available N, P & K content in post-harvest soil were determined by using standard procedures (Singh *et al.,* 2019). For available P, soil samples were extracted with Bray P-1 extractant (Bray and Kurtz, 1945) and phosphorus content in soil extract was determined as described by Jackson (1973). Exchangeable calcium and magnesium were determined by versenate method. The exchangeable Al^{+3}, exchangeable H^{+1}, exchangeable acidity and total potential acidity were determined using standard methods (Baruah and Barthakur, 1997). Soil Microbial biomass carbon (SMBC) was determined by fumigation extraction method (Vance *et al.,* 1987), dehydrogenase enzyme activity (DHA) by 2,3,5-triphenyl tetrazolium chloride technique (Casida, 1977) and acid phosphatase activity (PHA) by p-nitrophenyl phosphate method (Tabatabai and Bremner 1969). Recorded data was analyzed statistically to compare the treatment effects.

RESULTS AND DISCUSSION

Effect on plant growth

Plant height significantly affected due to different soil amendments at 30, 60 DAS and at harvest as compared to control (Table 1). The maximum plant height (34.38, 85.24 and 94.34 cm) was recorded under treatment A_3 (5% LR +2.5 t Biochar ha^{-1}) followed by A_2 (2.5 t Biochar ha^{-1}) and A_1 (5% LR). Combined application of lime and biochar (A_3) produced 7.5 and 5.0% more plant height over sole application of lime and biochar, respectively. Number of primary and secondary branches per plant significantly affected due to application of different soil amendments and potassium. Maximum number of primary and secondary branches per plant recorded under treatment A_3 (5% LR + 2.5 t Biochar ha^{-1}) at 30 and 60 DAS. The synergistic effect of lime and biochar likely improved soil pH, reduced aluminium toxicity and enhanced nutrient availability, leading to improved shoot development. Biochar role in enhancing soil structure and moisture retention, along with lime's acid-neutralizing capacity, might have created a favourable rhizosphere for root and shoot proliferation. Similar result was reported by Purkaystha *et al.* (2025). Plant height of rapeseed significantly affected due to application of potassium at 30, 60 DAS and at harvest as compared to control. The maximum plant height (35.39, 87.95 and 97.24 cm) was recorded under the treatment K_{60}. The application of 60 kg K_2O ha^{-1} improved plant height by 16.7% at harvest over control (K_0). Maximum primary and secondary branches per plant were also observed under the treatment K_{60}. The progressive rise in primary branches with increasing potassium levels indicates its direct influence on vegetative growth, while the lowest values in control (K_0) reflect nutrient deficiency stress. It can be attributed to potassium's vital role in enhancing cell division, enzyme activation and assimilate translocation. Furthermore, adequate potassium availability improves water use efficiency, strengthens plant structure and promotes the development of lateral shoots, resulting in increased branching (Odyuo *et al.,* 2015; Lu *et al.,* 2016).

Table 1: Effect of soil amendments and potassium levels on growth, yield and oil content of rapeseed

Treatment	Plant height (cm)			Primary branches $plant^{-1}$		Secondary branches $plant^{-1}$		No. of siliqua $plant^{-1}$	No. of seeds $siliqua^{-1}$	Test weight (g)	Seed yield (g pot^{-1})	Stover yield (g pot^{-1})	Oil content (%)
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	30 DAS	60 DAS						
Soil amendments													
A_0 (Control)	31.78	77.16	85.47	1.72	3.48	2.35	5.40	124.12	12.45	4.18	10.16	23.53	32.30
A_1 (5% LR)	32.02	79.45	87.74	1.83	3.67	2.83	6.05	130.88	13.25	4.38	11.07	25.51	33.50
A_2 (2.5 t biochar ha^{-1})	33.00	81.42	89.79	2.03	4.01	3.63	6.45	133.86	13.99	4.42	12.07	26.93	34.90
A_3 (5% LR + 2.5 t biochar ha^{-1})	34.38	85.24	94.34	2.41	4.33	3.95	7.92	139.19	14.75	4.46	15.33	28.61	36.12
SEm±	0.59	1.88	2.18	0.05	0.06	0.03	0.10	1.69	0.36	0.12	0.51	0.49	0.15
CD (P=0.05)	1.71	5.40	6.27	0.15	0.18	0.08	0.28	4.87	1.04	NS	1.45	1.40	0.42
Potassium levels													
K_0	31.46	75.10	83.26	1.65	3.46	2.43	5.18	126.87	12.73	4.32	10.25	24.50	33.45
K_{20}	31.86	79.21	87.48	1.82	3.73	2.70	5.90	132.15	13.57	4.34	12.13	25.58	34.21
K_{40}	32.47	81.02	89.36	2.06	3.97	3.53	6.77	133.71	13.94	4.37	12.39	26.60	34.35
K_{60}	35.39	87.95	97.24	2.45	4.33	4.10	7.98	135.33	14.20	4.41	13.87	27.90	34.81
SEm±	0.59	1.88	2.18	0.05	0.06	0.03	0.10	1.69	0.36	0.12	0.51	0.49	0.15
CD (P=0.05)	1.71	5.40	6.27	0.15	0.18	0.08	0.28	4.87	1.04	NS	1.45	1.40	0.42

Effect on yield attributes, yield and oil content

Number of siliquas per plant and number of seeds per siliqua of rapeseed significantly affected due to different soil amendments as compared to control (Table 1). The maximum number of siliquas per plant (139.19) and seeds per siliqua (14.75) recorded under treatment A_3 (5% LR + 2.5 t Biochar ha^{-1}) followed by A_2 (2.5 t Biochar ha^{-1}) and A_1 (5% LR). Irrespective of treatments, the seed yield varied from 10.16 to 15.33 g pot^{-1}. The maximum seed and stover yields (15.33 & 28.61 g pot^{-1}) obtained under treatment A_3 (5% LR + 2.5 t Biochar ha^{-1}). A critical examination of data revealed that 5% LR lime application did not increase seed yield significantly over control. While sole biochar application improved seed yield significantly over control (A_0). Combined application of lime and biochar (A_3) increased seed and stover yields by 50.8 & 21.6%, respectively in comparison to control. It was also observed that combined application of lime and biochar (A_3) improved seed yield by 38.4% and 27.0% over sole application of lime (A_1) and biochar (A_2), respectively. Hence combined application of lime and biochar found more beneficial than sole application for acidic soils of Nagaland. It can be attributed to improved soil structure, pH balance and nutrient availability, which enhanced overall plant growth and productivity. The synergistic effect of lime and biochar created favourable conditions for root development, nutrient uptake and efficient translocation of assimilates to the developing seeds. Similar results have also been reported by Lalhruaizeli *et al.* (2017). Irrespective of treatments, the oil content in seeds ranged from 32.30 to 36.12%. Oil content of rapeseed crop was significantly affected due to different soil amendments as compared to control. The maximum oil content (36.12%) was recorded under treatment A_3 (5% LR + 2.5 t Biochar ha^{-1}). The combined application of lime and biochar likely corrected soil acidity, boosted microbial activity and improved nutrient uptake, particularly of elements like sulphur and potassium that are vital for oil biosynthesis (Liu *et al.,* 2022). The maximum number of siliquas per plant (135.33) and seeds per siliqua (14.20) recorded under the treatment K_{60} (60 kg K_2O ha^{-1}). Seed and stover yields of rapeseed significantly affected due to application of potassium as compared to control and highest values obtained under the treatment K_{60}. The K_{60} level of potassium increased seed and stover yield to the extent of 35.3 & 13.9% over control. Potassium supply increases cytokinin synthesis and photosynthates, ultimately which increases the seed yield. Furthermore, enhancement in seed yield of rapeseed can be attributed to potassium's essential role in activating various enzymes, facilitating energy transformation and supporting critical biochemical processes for plant growth and development. Oil content of rapeseed significantly influenced due to application of potassium. The maximum oil content was recorded under the treatment K_{60} (60 kg K_2O ha^{-1}) followed by K_{40} and the minimum under control (K_0), respectively. Potassium enhances enzyme activation, improves photosynthate translocation and supports the efficient conversion of assimilates into oil. Additionally, it influences the synthesis of fatty acids and contributes to the development of oil-rich seeds. There was no significant effect on test weight of rapeseed due to different soil amendments and potassium application.

Table 2: Effect of soil amendments and potassium levels on nutrients content and uptake in rapeseed

Treatment	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Calcium content (%)		Magnesium content (%)		Total nutrient uptake (mg pot^{-1})				
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	N	P	K	Ca	Mg
Soil amendments															
A_0 (Control)	2.70	0.31	0.94	0.56	0.62	0.79	0.77	1.47	0.81	1.12	347.7	228.0	249.1	425.0	348.3
A_1 (5% LR)	2.92	0.33	1.01	0.64	0.68	0.85	0.81	1.66	0.83	1.15	408.8	274.9	293.9	512.9	391.5
A_2 (2.5 t biochar ha^{-1})	2.94	0.37	1.05	0.76	0.75	0.90	0.80	1.58	0.82	1.13	455.7	331.6	333.0	521.3	403.6
A_3 (5% LR + 2.5 t biochar ha^{-1})	3.10	0.41	1.10	0.80	0.88	0.91	0.84	1.68	0.86	1.19	595.6	398.5	402.1	608.4	473.1
SEm±	0.02	0.004	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.28	5.50	7.76	7.83	6.62	2.80
CD (P=0.05)	0.07	0.01	0.02	0.06	0.06	0.05	0.04	0.07	NS	NS	15.85	22.35	22.54	19.06	8.07
Potassium levels															
K_0	2.80	0.34	1.01	0.66	0.60	0.82	0.78	1.58	0.80	1.12	371.7	265.3	263.9	467.5	357.2
K_{20}	2.89	0.34	1.02	0.68	0.66	0.86	0.80	1.60	0.82	1.15	441.2	301.3	300.3	508.3	397.8
K_{40}	2.99	0.37	1.03	0.70	0.77	0.88	0.81	1.61	0.84	1.16	469.7	316.9	331.1	528.2	416.9
K_{60}	2.98	0.38	1.04	0.72	0.87	0.89	0.82	1.61	0.85	1.16	525.2	349.4	382.8	563.7	444.4
SEm±	0.02	0.004	0.01	0.02	0.02	0.02	0.02	0.02	0.013	0.28	5.50	7.76	7.83	6.62	2.80
CD (P=0.05)	0.07	0.01	NS	NS	0.06	0.05	NS	NS	NS	NS	15.85	22.35	22.54	19.06	8.07

Effect on nutrient content and uptake

The N, P, K and Ca content in rapeseed seed and stover enhanced significantly with soil amendments application (Table 2). Highest enhancement observed with combine application of lime and biochar (A_3). However, Mg content in seed and stover was not affected significantly with soil amendments. A significant impact of soil amendments observed on nutrient uptake in rapeseed. The data further reveals that maximum nutrient uptake recorded under combine application of lime and biochar (A_3), followed by 2.5 t ha^{-1} biochar application. Total N, P, K, Ca and Mg uptake increased by 71.2, 74.7, 61.4, 43.1 and 35.8% over control, respectively with lime and biochar application (A_3). Improvement of nutrient uptake may be attributed to enhanced nutrient concentration in tissues and biomass yield (seed and stover) with application of biochar and lime (Wan *et al.,* 2023). A significant enhancement in N and potassium content in seed and stover observed with potassium application, while effect on P, Ca & Mg content was insignificant. Maximum nutrient content in seed and stover recorded under K_{60} treatment. Total N, P, K, Ca and Mg uptake in rapeseed significantly improved with potassium application. Highest uptake of these nutrients recorded under K_{60} level of potassium. The K_{60} potassium level increased N, P, K, Ca and Mg uptake to the extent of 41.2, 31.6, 45.0, 20.5 and 24.4% respectively, over control. Increase in nutrient uptake by plants with higher levels of potassium application may be attributed to potassium's vital role in improving nutrients metabolism and translocation within the plant. Potassium application enhanced nutrients content and yield, which ultimately increased nutrients uptake in rapeseed (Kishor *et al.,* 2015).

Table 3: Effect of soil amendments and potassium levels on soil properties

Treatment	Soil pH	EC (dSm-1)	Porosity (%)	Org. carbon (g kg-1)	Acidity components (cmol kg-1)				Available nutrients (kgha-1)			Ex. calcium (cmol kg-1)	SMBC (µg g-1)	Dehydrogenase (µg TPF g-1 hr-1)	Acid phosphatase (µg PNP g-1 hr-1)
					Ex acidity	Ex Al^{3+}	Ex H^+	TPA	N	P	K				
Soil amendments															
A_0 (Control)	5.00	0.18	49.55	7.11	2.43	1.42	1.01	12.5	218	26.4	154	1.51	191.29	3.00	284.71
A_1 (5% LR)	5.11	0.17	48.71	7.32	2.26	1.35	0.91	12.1	232	27.5	159	1.58	192.47	3.24	294.25
A_2 (2.5 t biochar ha^{-1})	5.05	0.18	51.01	7.60	2.28	1.39	0.89	10.9	232	28.8	161	1.56	194.19	3.40	298.15
A_3 (5% LR + 2.5 t biochar ha^{-1})	5.20	0.18	50.89	7.68	2.23	1.30	0.93	9.7	235	29.0	164	1.58	210.49	3.56	302.14
SEm±	0.03	0.008	0.63	0.30	0.03	0.03	0.05	0.31	2.4	0.70	0.58	0.01	1.43	0.01	4.27
CD (P=0.05)	0.09	NS	1.80	NS	0.10	0.08	0.14	0.88	7.0	2.03	1.68	0.03	4.11	0.02	12.29
Potassium levels															
K_0	5.07	0.17	50.12	7.33	2.29	1.33	0.96	10.7	222	26.4	143	1.56	175.61	3.01	290.13
K_{20}	5.10	0.17	50.05	7.43	2.28	1.36	0.92	11.1	231	27.5	156	1.54	193.17	3.15	292.44
K_{40}	5.08	0.18	49.83	7.48	2.30	1.38	0.92	11.5	232	28.9	162	1.56	203.37	3.36	296.15
K_{60}	5.12	0.19	50.17	7.47	2.31	1.39	0.92	11.8	233	28.8	177	1.57	216.28	3.69	300.52
SEm±	0.03	0.008	0.63	0.30	0.02	0.03	0.05	0.31	2.4	0.70	0.58	0.01	1.43	0.01	4.27
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	7.0	NS	1.68	NS	4.11	0.02	NS

Effect on soil properties

Soil amendments significantly increased soil pH & porosity and reduced exchangeable acidity, exchangeable Al^{3+}, exchangeable H^+ and total potential acidity (TPA) of post-harvest soil (Table 3). Highest values of pH and porosity and minimum values of acidity components noted under combined application of lime and biochar (IA_3). Lime and biochar application decreased exchangeable acidity and TPA by 6.5 and 22.4% over control. Combined application of biochar and lime possibly decline in exchangeable acidity and exchangeable aluminium by an increasing CEC, which could bind Al and Fe to the soil exchange sites and thus improved soil acidity (Odyuo and Sharma, 2020). Available N, P, K and Ca enhanced significantly with lime and biochar application. Highest improvement was noted when lime and biochar applied together (A_3). Available N, P, K and Ca enhanced by 7.7, 9.8, 6.4 and 4.6% respectively over control. Although the application of biochar might have reduced the adsorption of phosphate by increasing the soil pH and the precipitation of Al^{3+} and Fe^{3+}. Co-application with lime increased the soil pH much more than biochar alone. This enhanced pH effect explained the superior performance of the biochar–lime co-application in increasing the soil available P (Zhang *et al.,* 2025). Likewise available nutrients, soil microbial biomass carbon (SMBC), dehydrogenase activity (DHA) and acid phosphate activity (APA) significantly increased with application of soil amendments. Highest enhancement was recorded with combined application of lime and biochar, which was 10.0, 18.6 and 6.1% respectively over control. The improvement in microbial activities due to different soil amendments may be attributed to enhanced soil physical and chemical conditions that support microbial growth and activity. The application of lime helps in correcting soil acidity, creating a more favourable pH range for microbial communities. Biochar with its porous structure and high surface area, provides habitat and energy sources for soil microbes (Chen *et al.,* 2021). The EC and organic carbon not affected significantly with soil amendments application. Available nitrogen, potassium, SMBC and DHA increased significantly with potassium application. Maximum enhancement in these parameters recorded under K_{60} level of potassium. The K_{60} potassium level improved potassium content to the extent of 23.7% over control. Potassium application could not show significant effect on other soil properties viz pH, EC, porosity, organic carbon, acidity components, available P & Ca and APA. Increase in available potassium might be attributed to the direct addition of potassium through fertilizers, which enhances the exchangeable potassium pool in the soil. As the rate of potassium application increases, more potassium remains in the available form after meeting the plant's immediate uptake, especially when soil conditions support its retention (Zhang *et al.,* 2025).

From these results, it may be concluded that combined use of lime & biochar and potassium application were found more effective in enhancing growth and yield of rapeseed and improving soil health. Thus, application of 5% LR + 2.5 t biochar ha^{-1} along with 60 kg K_2O ha^{-1} are recommended for getting better yield of rapeseed in acidic soil condition of Nagaland.

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