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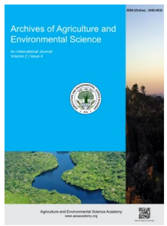

ORIGINAL RESEARCH ARTICLE

# Effect of biochar and nitrogen on soil characteristics, growth and yield of radish (*Raphanus sativus* L.) at Paklihawa, Rupandehi condition of Nepal

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**ABSTRACT**

An experiment on effect of biochar and nitrogen on soil characteristics, growth and yield of radish (*Raphanus sativus* L.) was conducted at Institute of Agriculture and Animal Science (IAAS), Paklihawa, Rupandehi, from November 2019 to February 2020. The experiment was laid in Randomized Complete Block Design with two factors: nitrogen and biochar, each factor having four levels (biochar: 0 t/ha, 5 t/ha, 10 t/ha and 15 t/ha and nitrogen: 0 kg/ha, 50 kg/ha, 100 kg/ha, 200 kg/ha), resulting in sixteen treatment combinations. Biochar application was found to be effective in improving soil bulk density, pH, soil organic matter and soil nitrogen and potassium content. Application of nitrogen fertilizer (200 kg/ha) and biochar (15 t/ha) alone, and in combination, showed significantly higher root dry matter (15.83 gm, 16.63 gm and 20.57 gm), biological yield (80 t/ha, 63.75 t/ha, and 95.75) and root yield (26.74 t/ha, 24.06 t/ha and 30.32 t/ha). In comparison to the sole effects of the highest dose of nitrogen fertilizer (200 kg/ha) and the highest dose of biochar (15 t/ha), their combined application showed the increased yield in radish root by 13.38% and 26.01%, respectively, indicating that the combined effect of biochar and nitrogen is more productive for the growth and yield in radish crop as compared to the sole effect of nitrogen and biochar.



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## INTRODUCTION

Soil fertility depletion, alike in several other countries, has been identified as a major challenge in crop production system in Nepal. Soil erosion, reduced soil organic matter, nutrient mining and indiscriminate use of fertilizers are the major factors engendering the depletion (Tripathi, 2019). Apart from this, crop residue burning, a conventional practice common in Terai belt of Nepal, done after the harvest of the crop as residue management technique has led to the decline in soil nitrogen content, soil moisture content, disturbance in soil micro flora and fauna and increase in soil potassium content; exacerbating the soil health (Bhattarai *et al*., 2015). Therefore, proper soil management techniques, addressing such issues, are essential to maintain soil sustainability; Biochar seems to be one of them. Biochar is defined as stable carbon-rich product obtained through the pyrolysis (temperature ranging from 300-1000 °C) of biomass under limited or no supply of oxygen. It can be prepared from a variety of biomass including crop residues, manures, forest residues and green wastes pyrolyzing at different conditions at different scales i.e. from large scale industries to domestic level at home (Yaashikaa *et al*., 2020). The concept of biochar is not novel in agriculture. From past centuries, records of using charcoal and slash and burn technique in agriculture had been observed extensively. However, an indigenous soil practice known as Terra Preta de Indio, also known as Amazon Dark Earth - an anthropogenic soil created by native population inhabited in Amazon is considered to be its major inspiration. Enriched with black carbon (a major constituent of biochar) along with other essential nutrients present, the soil captivated the researchers regarding its use in the restoration of soil fertility and enhancement of crop productivity leading to its myriad of studies (Glaser *et al*., 2001; Zhang *et al*., 2012). Today, it is gaining more popularity because of its contribution towards soil management, sustainable agriculture development and carbon sequestration (Woolf *et al*., 2010; Chen *et al*., 2019). When incorporated in soil, it has been reported that biochar leads to the improvement in physical and chemical properties of soil (Adekiya *et al*., 2020), immobilization of toxic metals, leaching prevention, and enhancement in soil microbial activities (Sousa and Figueiredo, 2016), resulting in the improvement in crop yield. The performance of biochar is even more productive when applied with other nutrient sources (Wang *et al*., 2014; Ding *et al*., 2017). A number of studies have reported the efficient usage of nitrogenous fertilizer, when it is co-applied with biochar. Badu *et al*. (2019) observed the increase in grain yield in maize by 213% relative to the control, when biochar at 10 t/ha was applied along with nitrogen fertilizer at 45 kg N/ha. Similarly, the increment in grain yield (t/ha) in rain-fed rice by 78% and by 83 % along with the increment in test weight (gm) by 16% and by 13% in oxic-paleustaif and oxic-paleustult soil respectively has been observed, on application of rice husk biochar with nitrogen fertilizer (Oladele *et al*., 2019).

Nitrogen is the most important macro nutrient for the growth and development of plants. In developing country like Nepal, farmers rely heavily on urea as nitrogen source. However, the application is not capable of maintaining yield increment because larger portion of those fertilizer becomes unavailable from root zone due to nitrogen volatilization and leaching (Utomo *et al*., 2012). On top of that, the untimely availability and the price inflation of the fertilizer are other problems faced by those economically challenged farmers. The combine application of biochar with nitrogen fertilizer could be one of the best solutions to these problems. However, a very few studies have been conducted in Nepal regarding this. So, the objective of this study is to observe and assess the effectiveness of combined application of biochar and nitrogen fertilizer on soil characteristics and growth and yield of radish crop. We hypothesized that combination of biochar with nitrogen fertilizer would significantly improve yield in radish as compared to nitrogen fertilizer alone through improvement in soil properties and prevention of nitrogen leaching from soil.

## MATERIALS AND METHODS

### Experimental site

The research was carried out at Agronomy farm of Paklihawa Campus, Institute of Agriculture and Animal Science, located at Siddharthanagar Municipality of Rupandehi district of Nepal. The site lies 110m above sea level and is located at the latitude of 27° 30' 0 North and longitude of 83°27' 0 East. The research study continued from November 2019 to February 2020. The physio-chemical properties of soil of experimental site before the conduct of research is shown in Table 1.

### Experimental detail

The experiment was two factorials, laid out in a randomized complete block design, replicated three times. Altogether, there were forty-eight plots with size of 1 × 1.4 $m^2$. The treatment consisted of four levels of rice husk biochar: 0, 5, 10 and 15t/ha and four levels of nitrogen fertilizer (Urea- 46% N): 0, 50, 100 and 200 kg/ha, combined to form sixteen treatments: (i) $N_0B_0$ (ii) $N_0B_5$ (iii) $N_0B_{10}$ (iv) $N_0B_{15}$ (v) $N_{50}B_0$ (vi) $N_{50}B_5$ (vii) $N_{50}B_{10}$ (viii) $N_{50}B_{15}$ (ix) $N_{100}B_0$ (x) $N_{100}B_5$ (xi) $N_{100}B_{10}$ (xii) $N_{100}B_{15}$ (xiii) $N_{200}B_0$ (xiv) $N_{200}B_5$ (xv) $N_{200}B_{10}$ (xvi) $N_{200}B_{15}$. The biochar was prepared by burning rice husk in a closed perforated stainless-steel drum covered with an air-tight lid, maintaining anaerobic condition. The whole process took around 6 to 8 hours.

### Cultivation practice adopted

The field was ploughed with tractor drawn cultivator followed by rotavator. Plots were prepared according to the layout plan. Biochar was applied ten days prior to sowing on the basis of treatment allocated to the respective plots. Right after three days of biochar application, FYM was applied to the field at the rate of 1500kg/ha. Fertilizer was added to the soil before sowing at the rate of 180:60 kg PK/ha in the form of single super phosphate and potash, whereas nitrogen fertilizer (urea) was applied at two splits: first split broadcasted before sowing and second split at 30 days after showing, on the basis of treatment allocated to the respective plots. The healthy, disease and insect free, vigorous and good quality seed of radish variety, Minnow Early was used for sowing. Seed was primed overnight with lukewarm water to facilitate rapid and uniform germination. Seed was sown by line sowing method at depth of 2 cm maintaining row to row distance of 20 cm and plant to plant distance of 22 cm. Mulching was done with straw for 5 days. Thinning was done to maintain required plant population and to facilitate root development. Optimum soil moisture was maintained in the field by applying required irrigation. Weeding and earthing up was carried out at the time of top dressing, at 30 days after sowing.

**Table 1.** Physio-chemical properties of soil prior to application of treatment.

| Soil Parameters | Values |
|---|---|
| Total N (%) | 0.107 |
| Exchangeable $K_2O$ (kg/ha) | 206.98 |
| Organic matter (%) | 1.71% |
| pH | 6.6 |
| Bulk density (g/cc) | 1.54 |

**Table 2.** Methods of laboratory analysis.

| Parameters | Analysis methods |
|---|---|
| Soil pH | Portable pH meter |
| Soil organic matter | Walkley and Black (1934) |
| Soil total nitrogen | Kjeldhal method |
| Soil available Potassium | Flame Photometer |
| Soil bulk density | Core Sampler |

### Soil and plant analysis

For soil test, samples, representative of the entire field, were collected making Z-shape prior to biochar application at the depth of 20 cm. From those collected samples, a composite sample was made for laboratory analysis. Furthermore, to analyze the performance of the applied treatments, final soil samples were collected from biochar (alone) treated plots, after crop harvest. The samples were then dried in shade, ground and sieved through 2 mm sieve and then subjected to determine their nutrient status. Their nutrient status was determined using following methods as shown in Table 2.

### Statistical analysis

Ten plants were selected using simple random sampling from each plot for collecting data regarding various parameters such as root diameter, root dry matter, root yield and biological yields. Data were statistically analyzed following analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) using R-Studio The significant difference among treatment means was compared by the least significant difference (LSD) at 5% level of probability.

## RESULTS AND DISCUSSION

### Soil properties

**Soil bulk density:** The statistical analysis revealed significant reduction on soil bulk density on application of rice husk biochar (Table 3). The reduction was from 1.54 g/cc at control treatment (0 t/ha) to 1.42 g/cc, 1.30 g/cc and 1.28 g/cc at 5 t/ha, 10 t/ha and 15 t/ha respectively. As the amount of biochar was increased, the soil bulk density was observed to be decreased. Our study was consistent with a number of studies. Githinji (2014) reported that the bulk density of soil decreased from 1.325 to 0.363 g $cm^{-3}$, when treated with biochar. Abrishamkesh *et al.* (2015) observed that with the application of rice husk biochar on alkaline soil, the bulk density of soil was decreased from 1.39 to 1.14 g $cm^{-3}$. Biochar is highly porous in nature and has low bulk density. Hence, on incorporating into the soil, dilutes the mineral fractions of soil reducing its bulk density (Pratiwi and Shinogi, 2016; Tomasz *et al.*, 2016).

**Soil pH:** No significant effect of treatment was observed on soil pH with the application of biochar. However, a slight increment in pH from 6.6 (at control treatment) to 7.4 (at 15 t/ha biochar) was observed (Table 3). Sousa and Figueiredo (2015) found slight increase in pH from 6.20 to 6.55 on application of sewage sludge biochar. Ghorbani and Amirahmadi (2018), in their experiment, has also reported that application of biochar has led to increase in soil pH. This increment is attributed to the alkaline nature of biochar; as it contains ash of carbonates and phosphates (Chen *et al.*, 2019).

**Soil organic matter:** Result showed the slight increment in soil organic matter content from 1.71 % at control treatment to 2.16% at 15 t/ha biochar application (Table 3). Timilsina and Khanal (2017) found that the application of biochar in soil has led to the increase in organic matter content in soil from 1.165% to 2.915% and concluded that the organic carbon content is positively co-related with the application rate of biochar. Charred biomass contains up to 80% carbon by weight (Mašek, 2013), sequestering about 50% of initial carbon in soil as compared to biomass subjected to direct burning and biological decomposition (Lehmann *et al.*, 2006).

**Soil nitrogen:** Biochar had significant effect on soil nitrogen content. The maximum soil nitrogen content (0.199%) was recorded at the highest dose of biochar (15 t/ha), followed by 0.145% at 10 t/ha, 0.123% at 5 t/ha and 0.107% at control treatment (0 t/ha) (Table 3). Timilsina and Khanal (2017) found that different doses of biochar when added to soil, soil nitrogen content increased. The highest nitrogen content (12 g/kg) was found at 20 Mg/ha biochar application and lowest was found in the soil without biochar application. The observed increment in nitrogen content might be due to the reduction in the leaching of nitrogen from soil involving several mechanisms: absorption of N through ion exchange and removal of $NH_3$ via adsorption (Clough *et al.*, 2013).

**Soil potassium:** Biochar application increased soil potassium content from 206.98 kg/ha at control treatment (0 t/ha) to 268.8 kg/ha at 5 t/ha, 339.58 kg/ha at 10 t/ha and 373.09 kg/ha at 15 t/ha (Table 3). Timilsina and Khanal (2017) found that increased rates of biochar application resulted in increased available potassium content in soil with highest soil potassium (12.3 mg/kg) at 20 Mg/ha biochar and lowest at 0 Mg/ha biochar application. Such result could be attributed to high ash content in biochar (Abrishamkesh *et al.*, 2015).

**Table 3.** Effect of different doses of biochar on physio-chemical properties of soil.

| Biochar | Bulk density (g/cc) | pH | Organic matter % | Nitrogen content % | Potassium content (kg/ha) |
|---|---|---|---|---|---|
| 0 t/ha | $1.54^{a}$ | $6.6^{a}$ | $1.71^{b}$ | $0.107^{b}$ | $206.98^{b}$ |
| 5 t/ha | $1.42^{ab}$ | $7.24^{a}$ | $1.80^{ab}$ | $0.123^{b}$ | $268.8^{ab}$ |
| 10 t/ha | $1.30^{b}$ | $7.34^{a}$ | $1.90^{ab}$ | $0.145^{ab}$ | $339.58^{a}$ |
| 15 t/ha | $1.28^{b}$ | $7.4^{a}$ | $2.16^{a}$ | $0.199^{a}$ | $373.09^{a}$ |
| SEm(±) | 0.047 | 0.254 | 0.120 | 0.016 | 12.304 |
| LSD(α=0.05) | 0.16 | 0.88 | 0.42 | 0.55 | 127.44 |
| CV | 5.95% | 6.16% | 10.97% | 19.22% | 21.46% |
| Grand Mean | 1.38 | 7.15 | 1.90 | 0.14 | 297.11 |

Note: Treatment means followed by different letter(s) are significantly different from each other based on DMRT at 5% level of significance.

**Table 4.** Combined effect of Biochar and Nitrogen fertilizer on yield components of radish.

| Biochar (t/ha) | Nitrogen (kg/ha) | Root length (cm) | Root diameter (cm) | Root dry matter (gm) | Biological yield (t/ha) |
|---|---|---|---|---|---|
| 0 | 0 | $14.9^{k}$ | $2.71^{j}$ | $3.87^{m}$ | $20.75^{g}$ |
| 0 | 50 | $16.8^{j}$ | $2.93^{i}$ | $6.17^{klm}$ | $30.5^{fg}$ |
| 0 | 100 | $18.1^{hi}$ | $3.13^{h}$ | $8.47^{ijk}$ | $37.25^{ef}$ |
| 0 | 200 | $19.4^{efg}$ | $3.39^{fg}$ | $12.1^{fgh}$ | $37.25^{ef}$ |
| 5 | 0 | $15.7^{k}$ | $3.32^{g}$ | $5^{lm}$ | $30^{fg}$ |
| 5 | 50 | $18.6^{gh}$ | $3.42^{fg}$ | $9.74^{hij}$ | $35.25^{ef}$ |
| 5 | 100 | $19.6^{efg}$ | $3.50^{efg}$ | $13.1^{efg}$ | $42.25^{de}$ |
| 5 | 200 | $20.4^{cde}$ | $3.58^{def}$ | $15.27^{cde}$ | $50.25^{cd}$ |
| 10 | 0 | $17.1^{ij}$ | $3.56^{def}$ | $7.43^{jkl}$ | $52^{cd}$ |
| 10 | 50 | $19.7^{defg}$ | $3.63^{de}$ | $13.27^{efg}$ | $56^{c}$ |
| 10 | 100 | $20.9^{bcd}$ | $3.74^{bcd}$ | $16.47^{bcd}$ | $70.75^{b}$ |
| 10 | 200 | $22.0^{b}$ | $3.89^{b}$ | $18.6^{ab}$ | $72^{b}$ |
| 15 | 0 | $18.9^{fgh}$ | $3.67^{cde}$ | $11.03^{ghi}$ | $69.5^{b}$ |
| 15 | 50 | $20.0^{def}$ | $3.75^{bcd}$ | $14.27^{def}$ | $74.25^{b}$ |
| 15 | 100 | $21.3^{bc}$ | $3.87^{bc}$ | $17.47^{bc}$ | $80.25^{b}$ |
| 15 | 200 | $23.2^{a}$ | $4.24^{a}$ | $20.57^{a}$ | $95.75^{a}$ |
| Sem(±) | | 0.39 | 0.065 | 0.9036 | 3.75 |
| LSD(α=0.05) | | 1.13 | 0.187 | 2.61 | 10.85 |
| CV | | 3.55% | 3.2 | 12.99% | 12.21 |
| Grand Mean | | 19.16 | 3.525 | 12.05 | 53.375 |

Note: Treatment means followed by different letter(s) are significantly different from each other based on DMRT at 5% level of significance.

## Yield and yield components

The effect of biochar and nitrogen fertilizer alone on yield and yield components (root length, root diameter, dry matter and biological yield) of radish crop is shown in the Table 4. It was observed that the individual effect of nitrogen fertilizer and biochar, each had significant effect ($p < 0.05$) on the crop. The highest root diameter (3.90 cm), root length (20.8 cm), root dry matter (15.83 gm), biological yield (80 t/ha) and root yield (26.74 t/ha) were recorded at highest dose of nitrogen fertilizer (200 kg/ha), whereas the control treatment (0 kg/ha nitrogen fertilizer) gave the lowest root diameter (3.04 cm), root length (17.3 cm), root dry matter (7.65 gm), biological yield (31.5 t/ha) and root yield (15.11 t/ha). Similarly, the highest dose of biochar (15 t/ha) gave the highest root diameter (3.78cm), root length (21.3 cm), root dry matter (16.63 gm), biological yield (63.75 t/ha) and root yield (24.06 t/ha), whereas the lowest root diameter (3.32 cm), root length (16.6 cm), root dry matter (6.83 gm), biological yield (33 t/ha) and root yield (16.8 t/ha) was recorded at control treatment (0 t/ha biochar applied).

In our study, biochar alone increased the root yield in radish by 12%, 31.2% and 43% at 5 t/ha, 10 t/ha and 15 t/ha respectively as compared to the control treatment (0 t/ha). As the application dose increased, the yield in crop also increased. Our findings are at consistent with several studies: Timilsina and Khanal (2017) reported the increment in biomass yield from 36.94 Mg/ha to 63.2 Mg/ha, in root yield from 25.50 Mg/ha to 46.83 Mg/ha and in shoot yield from 11.44 Mg/ha to 16.38 Mg/ha on radish crop, on application of biochar at the rate of 20 Mg/ha as compared to control treatment (0 t/ha). Hien *et al.* (2017) also observed the positive response of biochar with the increment in fresh weight by 47.2% in radish and 14.2% in carrot at an application of biochar at the rate 4%. This positive effect is mainly associated to the improved soil physio-chemical properties. Biochar reduces soil bulk density, increase soil pH and enhances the nutrient availability in soil. The reduction in soil bulk density facilitates the better root penetration and development in root and tuber crops (Adekiya *et al.*, 2020). Furthermore, the enhancement in nutrient availability improves the nutrients uptake in plants, resulting in the improvement in crop yield.

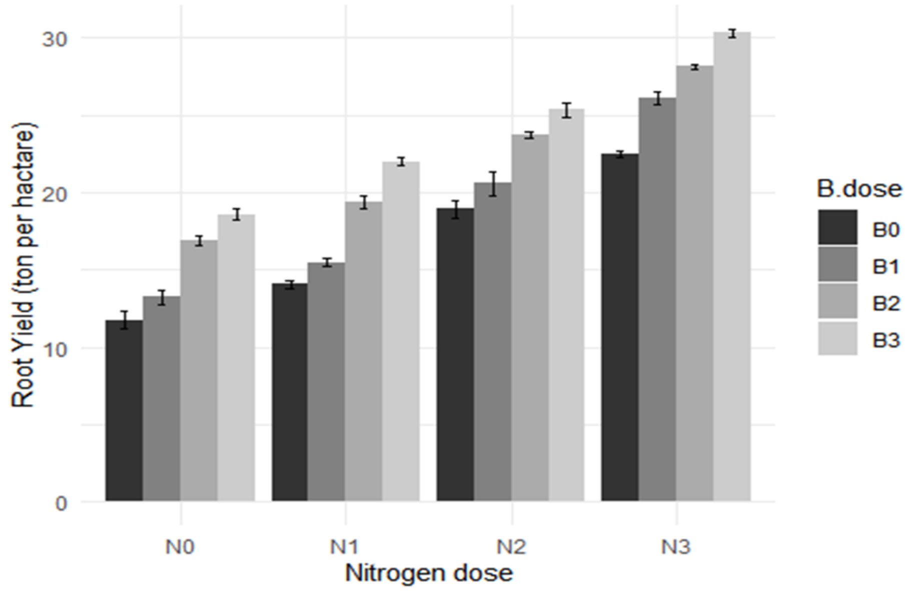


**Figure 1.** *Combined effect of Biochar and Nitrogen fertilizer on root yield of radish.*

The interaction between biochar and nitrogen had more pronounced effect as compared to their sole effects. The interaction of nitrogen fertilizer at dose 200 kg/ha with biochar at dose 15 t/ha gave the maximum values of root diameter (4.24 cm), root length (23.2 cm), root dry matter (20.57 gm), biological yield (95.75 t/ha) and root yield (30.32 t/ha) whereas the control treatment (0 kg/ha nitrogen fertilizer and 0 t/ha biochar) gave the lowest root diameter (2.71 cm), root length (14.9 cm), root dry matter (3.87 gm), biological yield (20.75 t/ha) and root yield (11.73 t/ha). Hence, on comparison, it was found that the application of nitrogen fertilizer at 200 kg/ha and biochar at 15 t/ha increased the yield in radish root by 13.38%, 37%, 71% and 91% as compared to sole effect of nitrogen fertilizer at 200 kg/ha, 100 kg/ha, 50 kg/ha and 0 kg/ha respectively and by 26.01%, 37.63%, 61% and 87% as compared to sole effect of biochar at 15 t/ha, 10 t/ha, 5 t/ha and 0 t/ha respectively.

Our finding is in agreement with several other studies. Mete *et al.* (2015) observed the enhancement in seed yield by 370%, 284% and 477% and biomass production by 318%, 312% and 274% for three different varieties of soyabean, when biochar was co-applied with nitrogen fertilizer. Oladele *et al.* (2019) reported that the rice husk biochar when supplemented with nitrogen fertilizer, enhanced the grain yield (t/ha) in rain-fed rice by 78% and by 83% along with increment in test weight (gm) by 16% and by 13% in oxic-paleustaif and oxic-paleustult soil respectively. This is due to the fact that biochar improves the nitrogen use efficiency of the crop, when supplemented with nitrogen fertilizer. Yu *et al.* (2018) observed the higher level of nitrogen in soil when nitrogen fertilizer was applied with biochar rather than nitrogen fertilizer alone. As biochar absorbs nitrogen through ion exchange, reduced ammonia volatilization through adsorption, it reduces nitrogen leaching in soil (Clough *et al.*, 2013), enhancing the availability of nitrogen in soil and thus increases the plant nitrogen uptake. Nitrogen is the most important constituents of protein, nucleic acids, chlorophyll, enzymes, etc. and contributes towards cell division, cell elongation, synthesis of amino acids, chlorophyll (Poudel *et al.*, 2018).

## Conclusion

The interaction of biochar and nitrogen fertilizer had significant effects on the yield and yield components of radish crop. The performance of the crop was synchronized well with the increase in application rate of biochar and nitrogen. Biochar application significantly reduced soil bulk density, increased soil pH, nitrogen content, potassium content and soil organic matter. Through adsorption and ion exchange mechanism of nitrogen, it reduced nitrogen leaching from soil, resulting in highest root yield (30.32 t/ha) at 200 kg/ha nitrogen fertilizer and 15 t/ha biochar, which was 13.38% greater as compared to sole performance of 200 kg/ha nitrogen fertilizer. In conclusion, the combined application of nitrogen fertilizer and biochar have the potential to enhance the productivity of radish crop. It could be a sustainable solution for the farmers to minimize the nitrogen loss from the soil, thereby minimizes the extra cost of nitrogen fertilizer. However, series of similar research, multi-seasonal research and its trial on different soil type needs to be conducted for its confirmation, before recommending to farmers.



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