



Comparative Effect of Various Organic Extracts Coated Urea Fertilizer on the Release Pattern of Ammonium and Nitrate in the Soil at Different Time Intervals

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Abstract

The losses of nitrogen (N) fertilizer applied to the soil microenvironment reduce its efficiency. Different strategies like the use of polymer coating and chemical nitrification inhibitors had been employed to reduce N losses. But these chemical nitrification inhibitors are very expensive. Thus, a study was conducted to investigate the effects of different concentrations of *Parthenium* extract, neem oil, and acidulated cow dung compost extract on N dynamics in the soil. Three concentrations of *Parthenium* extract (5, 10, and 15%) and neem oil (1, 2, and 3%) were coated on urea granules using a polymer as the binding agent. Three pH (2, 4, and 6 pH) based acidulated cow dung compost extracts were also coated on urea granules in the same pattern. These coated fertilizers and uncoated urea were applied in jars filled with soil (100 g per jar) at the rate of 1 g of fertilizer per jar. One treatment was kept as control (without fertilizer). Treatments along three replications were arranged according to the completely randomized design. Results depicted that all coating materials caused the release of N consistently from applied fertilizers compared to uncoated treatment. In addition, percent nitrified N was also reduced significantly in coated treatments in comparison to the uncoated urea and control treatments. However, the level of concentration effect was not obvious as lower concentrations of these extracts and oil also performed almost equal to that of higher concentrations in inhibiting nitrification process.

Keywords *Parthenium* extract · Neem oil · Acidulated cow dung compost extract · Polymer · Coated urea · N dynamics · Nitrification inhibition · Consistent N release

1 Introduction

The increasing population demands healthy food with more production of crops for which plant nutrients are vitally essential. Chemical-based inorganic fertilizers are of prime importance under soil management strategies to enhance the quality and quantity of agricultural outputs (Itelima et al. 2018). Nitrogen (N) plays an important role in plant growth and development as a prime mineral nutrient. Higher plants require large amounts of N for physiological and biochemical processes that lead to a higher quality of produce and

increased yield. Low organic matter contents and several other factors are responsible for the deficiency of N in Pakistani soils. According to an estimate, 78–79% N is present in the atmosphere but it is in an inert gas. Thus, technical nutrient management practices are required (Leghari et al. 2016; Zhang et al. 2021). In modern agriculture, large amounts of N fertilizers are applied for higher production, but less than 50% of these applied fertilizers are utilized by the crops (Zhang et al. 2020). Recently, different strategies had been employed to enhance the efficiency of N fertilizers (Yaseen et al. 2021).

However quick hydrolysis of urea releases plant-available forms of N in the soil suddenly after exposure to moisture in the presence of the urease enzyme. Firstly, NH_4^+ is formed which is a plant available form and immobile in the soil (Lei et al. 2018). Excessive application of N fertilizer at an early stage of the plant induces low use efficiency of applied fertilizer because this excess fertilizer got lost via volatilization, nitrification, denitrification, and runoff (Jain and Abrol 2017;

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Anas et al. 2020). To reduce such losses, different strategies had been employed like the 4-R strategy (i.e., considering the right source, right rate, right time, and the right place for fertilizer application), split application of urea and controlled-release urea (Tao et al. 2018; Freedman 2018; Yaseen et al. 2016; Noor et al. 2017). Biodegradable polymer coated urea slows the release kinetics of available forms of N in the soil (Beig et al. 2020). Thus slow-release N fertilizers are very crucial to reduce the losses of N to the environment and groundwater. But N released in the form of NH_4^+ in the soil got converted to the nitrate form via nitrification process if not up-taken by the plants indicating nitrification as a less desirable process (Lasisi et al. 2019).

To overcome the nitrification losses from agricultural activities, different nitrification inhibitors had been used in recent years (Byrne et al. 2020). But commercial nitrification inhibitors are much more expensive for small farmers (Hatano et al. 2019). On the other hand, organic extracts and oils are much more cost-effective and good nitrification inhibitors in comparison to commercial nitrification inhibitors. As neem oil could reduce nitrification losses more effectively than the lower dose of dicyandiamide (Opoku et al. 2014). *Parthenium hysterophorus* is a well-known invasive weed with plenty of negative roles as agricultural, medicinal, and environmental hazards (Kaur et al. 2014). In addition to its other roles, its plant extract is a very good nitrification inhibitor (Mahmood et al. 2014). Kanchan and Jayachandra (1981) also showed that root and leaf extract of *Parthenium hysterophorus* effectively reduced the *Nitrosomonas* and *Nitrobacter* population in the soil resulting in inhibited nitrite production. Low pH also contributes to the inhibition of the nitrification process (Rose et al. 2020). Yet no study was conducted to coat such naturally occurring waste material extracts, especially *Parthenium* and cow dung extract to manage the nitrogen use efficiency. Thus based on these studies, it is clear that coating of organic extracts mixed with the polymer on urea could be beneficial for N management. In this way, an additional benefit of optimization of organic extracts will also be achieved. Thus, it was hypothesized that polymer mixed neem oil, *Parthenium* extract, and acidulated cow dung compost extract may reduce the nitrification losses of nitrogen in addition to the slow release of available N from urea fertilizer. So, in the present study, the effect of polymer mixed neem oil, *Parthenium* extract, and acidulated cow dung compost extract coated urea is compared with the uncoated urea for N release, NH_4^+ , and NO_3^- concentrations in the soil and percent nitrified N at different time intervals.

2 Materials and Methods

A laboratory experiment was performed at Soil Fertility and Plant Nutrition Laboratory (SFPNL), Institute of Soil and Environmental Sciences (ISES), University of Agriculture, Faisalabad (UAF) to investigate the comparative effect of neem oil, *Parthenium* extract, and acidulated cow dung compost extract coated urea on nitrification potential and N release kinetics. Three replications of each treatment were designed according to the completely randomized design (CRD). The treatment plan was consisted of the following:

- Three concentrations of neem oil (1, 2, and 3%)
- Three concentrations of *Parthenium* extract (5, 10, and 15%)
- Three pH based cow dung extracts (2 pH, 4 pH, and 6 pH)
- Positive control (uncoated urea)
- Negative control (without fertilizer)

Urea coating with *Parthenium* extract, neem oil, and acidulated cow dung extracts was carried out in SFPNL, ISES, UAF. Neem oil was extracted by using a solvent extraction method (Puri 1999), while *Parthenium* extract was collected by following Anteneh and Mendesil method (Netsere and Mendesil 2011). A 10% Cow dung compost (with different pH) extract was collected from the Soil and Environmental Microbiology Laboratory, ISES, UAF. Oil and organic extracts were coated on urea granules with polymer as a binding agent. To avoid any contamination, controlled Laboratory conditions were maintained for all activities. Shade drying of coated urea was done and stored at room temperature (25 °C).

The experiment was conducted in the incubator by using disposable cups (250 cm³), and each cup was filled with 100 g soil after determining the physicochemical properties of the soil (Table 1). In all the cups, field capacity was maintained after saturation percentage measurement. Urea fertilizer was added in cups at the rate of 1 g in each cup (having 460 mg N). After the addition of soil, fertilizer, and water, the weight of cups was maintained at an interval of 24 h with distilled water. The whole experiment was carried out at 25 ± 1 °C and NH_4^+ and NO_3^- were measured after 20, 40, and 60 days of incubation through the indophenol blue method and phenoldisulphonic acid method, respectively (Keeney and Nelson 1989). Sum of NH_4^+ and NO_3^- was taken to determine cumulative nitrogen (N), while nitrate to ammonium ratio, percent nitrified N, and N release efficiency (Tong et al. 2018) were calculated by using the following formulas:

$$\text{Nitratetoammoniumratio} = \frac{\text{NitrateNinthesoil}}{\text{AmmoniumNinthesoil}}$$

Table 1 Pre-analysis of soil for physicochemical properties

Physical properties	Unit	Values
Sand	%	48.03 ± 2.03
Silt	%	27.90 ± 1.45
Clay	%	24.07 ± 1.13
Texture	-	Sandy loam
Saturation Percentage	%	31 ± 1.3
Chemical properties	Unit	Values
ECe	dSm ⁻¹	2.01 ± 0.58
pHs	—	7.78 ± 0.76
CEC	cmol _c kg ⁻¹	14.1 ± 0.88
Ca ²⁺ + Mg ²⁺	me L ⁻¹	9.93 ± 0.7
SO ₄ ⁻²	me L ⁻¹	8.65 ± 0.65
Cl ⁻¹	me L ⁻¹	11.69 ± 1.01
HCO ₃ ⁻¹	me L ⁻¹	2.38 ± 0.56
CO ₃ ⁻²	me L ⁻¹	0.29 ± 0.03
Organic matter	%	0.68 ± 0.02
Soluble Na	me L ⁻¹	15.65 ± 1.2
Extractable P	mg kg ⁻¹	7.20 ± 0.95
Soluble K	me L ⁻¹	0.03 ± 0.002

Note: %, percent; dSm⁻¹, desisiemens per meter; cmol_ckg⁻¹, centimoles charge per kilogram; me L⁻¹, milliequivalents per liter; mg kg⁻¹, milligram per kilogram

$$\text{Percent Nitrified} = \frac{\text{Nitrate N}}{\text{Ammonium N}} \times 100$$

$$\text{N release efficiency (\%)} = \frac{(\text{Cumulative N in fertilizer pot} - \text{cumulative N in unfertilized pot})}{\text{Amount of N applied}} \times 100$$

All collected data were analyzed according to completely randomized design (CRD) with factorial arrangements following Fisher's analysis of variance (Steel et al. 1997). The mean comparison was done with the Tuckey HSD test.

3 Results

3.1 Ammonium Concentration in the Soil

Ammonium concentration in the soil was significantly controlled by all three types of extracts used for coating the urea fertilizer (Table 2). Uncoated urea gave the highest concentration of ammonium in the soil at the first interval that was significantly reduced at later intervals. While in the case of coated fertilizers, ammonium concentration showed an opposite trend as ammonium concentration was lower at the first interval, but this release was increased at later intervals. In the case of coated fertilizers, the release was maximum at the second interval in all types of coating materials, even differences were non-significant between organic amendments but in close view, *Parthenium* extract and acidulated cow dung extract showed slightly higher release than neem oil. At the third interval, release of ammonium was reduced in comparison to the second interval but still, release was significantly higher in coated fertilizers than uncoated fertilizer. Ammonium release was higher at a lower concentration of organic amendments but was reduced with an increase in

Table 2 Ammonium concentrations in the soil at 20, 40, and 60 days intervals

Treatment	NH ₄ concentration (mg kg ⁻¹)		
	1st interval (20 days)	2nd interval (40 days)	3rd interval (60 days)
Negative control (without fertilizer)	1.71 ± 0.03 n	0.75 ± 0.03 n	0.4 ± 0.06 n
Positive control (Uncoated fertilizer)	1429.3 ± 5.2 b	433.2 ± 2.89 l	246.1 ± 2.31 m
5% <i>Parthenium</i> extract coated urea	628.7 ± 3.47 k	1532 ± 4.05 a	1355.8 ± 5.78 c
10% <i>Parthenium</i> extract coated urea	629.8 ± 3.47 k	1532.6 ± 5.2 a	1248.9 ± 5.78 d
15% <i>Parthenium</i> extract coated urea	630.9 ± 2.89 k	1530.9 ± 3.47 a	1090.4 ± 5.2 g
1% neem oil coated urea	629.8 ± 2.31 k	1530.4 ± 2.31 a	1153.5 ± 4.62 e
2% neem oil coated urea	629.3 ± 2.31 k	1529.8 ± 4.05 a	1123.9 ± 5.78 f
3% neem oil coated urea	629.3 ± 2.89 k	1528.1 ± 3.47 a	678.9 ± 4.05 j
2 pH acidulated cow dung compost extract coated urea	630.4 ± 2.89 k	1528.1 ± 2.89 a	1060 ± 5.2 h
4 pH acidulated cow dung compost extract coated urea	630.9 ± 1.73 k	1532.6 ± 2.89 a	948.4 ± 4.05 i
6 pH acidulated cow dung compost extract coated urea	623.1 ± 1.73 k	1532.6 ± 2.31 a	688.4 ± 2.89 j

Note: Data are mean ± standard error; means with different statistical letters are significantly different at 5% probability level according to Tukey HSD test

the concentration. Ammonium release was only lower after concentration increased in the third interval.

3.2 Nitrate Concentration in the Soil

The uncoated urea showed maximum nitrate concentration at the first interval that was lowered at latter intervals but still higher in comparison to the coated treatments. In coated fertilizer treated jars, nitrate concentration was significantly lower in comparison to uncoated urea. At latter intervals, the concentration of nitrate was slightly increased in coated treatments but still lower in comparison to uncoated urea showing the inhibition of the nitrification process in the soil.

Among concentrations of organic amendments, lower concentrations showed more reliable results. Among the type of organic amendments, acidulated cow dung extract showed slightly higher nitrate concentration in the soil, while other amendments showed slightly lower concentrations (Table 3).

3.3 Cumulative N Concentration in the Soil

Table 4 showed that the concentration of cumulative N was significantly lower in the coated treatments in comparison to the uncoated treatment at the first interval. While the release was increased with time in coated treatments but decreased in uncoated treatment. All organic amendments performed almost equally in N release, though acidulated cow dung extract coated urea showed a slight increase in

Table 3 Nitrate concentrations in the soil at 20, 40, and 60 days intervals

Treatment	NO ₃ concentration (mg kg ⁻¹)		
	1st interval (20 days)	2nd interval (40 days)	3rd interval (60 days)
Negative control (without fertilizer)	1 ± 0.29 n	0.48 ± 0.02n	0.5 ± 0.06 n
Positive control (Uncoated fertilizer)	1176 ± 5.78 a	837.5 ± 4.05 b	310.5 ± 4.05 k
5% <i>Parthenium</i> extract coated urea	272.75 ± 3.47 l	383.5 ± 2.89 fg	403.5 ± 3.47 e
10% <i>Parthenium</i> extract coated urea	374.5 ± 3.47 g	349.75 ± 4.05 i	405.25 ± 4.05 e
15% <i>Parthenium</i> extract coated urea	275.25 ± 2.89 l	353.5 ± 3.47 hi	477.5 ± 4.05 c
1% neem oil coated urea	273.5 ± 2.31 l	371.2 ± 3.47 gh	432.75 ± 2.89 d
2% neem oil coated urea	378.25 ± 1.73 fg	319.75 ± 3.47 jk	403.75 ± 4.05 e
3% neem oil coated urea	302.75 ± 1.16 k	396 ± 3.47 ef	440.5 ± 2.89 d
2 pH acidulated cow dung compost extract coated urea	336 ± 1.73 ij	486 ± 4.05 c	402.75 ± 3.47 e
4 pH acidulated cow dung compost extract coated urea	339 ± 2.31 i	406.75 ± 3.47 e	492.5 ± 4.05 c
6 pH acidulated cow dung compost extract coated urea	449 ± 3.47 d	205.25 ± 2.31 m	492 ± 4.05 c

Note: Data are mean ± standard error; means with different statistical letters are significantly different at 5% probability level according to Tukey HSD test

Table 4 Cumulative N concentrations in the soil at 20, 40, and 60 days intervals

Treatment	Cumulative N concentration (mg kg ⁻¹)		
	1st interval (20 days)	2nd interval (40 days)	3rd interval (60 days)
Negative control (without fertilizer)	2.71 ± 0.25 t	1.23 ± 0.05 t	0.9 ± 0.1 t
Positive control (Uncoated fertilizer)	2605.3 ± 10.98 a	1270.7 ± 6.03 l	556.6 ± 5.57 s
5% <i>Parthenium</i> extract coated urea	901.45 ± 0.00 r	1915.5 ± 6.03 c-e	1759.3 ± 8.09 g
10% <i>Parthenium</i> extract coated urea	1004.3 ± 6.94 p	1882.35 ± 8.03 ef	1654.15 ± 8.55 h
15% <i>Parthenium</i> extract coated urea	906.15 ± 5.78 r	1884.4 ± 6.01 e	1567.9 ± 8.03 i
1% neem oil coated urea	903.3 ± 0.00 r	1901.7 ± 5.04 de	1586.25 ± 6.57 i
2% neem oil coated urea	1007.55 ± 4.05 p	1849.55 ± 6.51 f	1527.4 ± 8.55 j
3% neem oil coated urea	932.05 ± 4.05 r	1924.1 ± 6.01 cd	1119.4 ± 6.03 n
2 pH acidulated cow dung compost extract coated urea	966.4 ± 1.16 q	2014.1 ± 6.03 b	1462.75 ± 7.56 k
4 pH acidulated cow dung compost extract coated urea	969.9 ± 0.58 q	1939.35 ± 5.51 c	1440.9 ± 7.01 k
6 pH acidulated cow dung compost extract coated urea	1072.1 ± 5.2 o	1737.85 ± 4 g	1180.4 ± 6.03 m

Note: Data are mean ± standard error; means with different statistical letters are significantly different at 5% probability level according to Tukey HSD test

the N release. At the last interval, N release was decreased in all treatments but the decrease in the release was significantly more in uncoated treatment than coated treatments. It was also observed that lower concentrations of organic extracts gave more trustworthy results as cumulative N release was lower at the first interval but increased at the second interval and this release was more in comparison to higher concentrations, even at third interval release was higher with lower concentrations.

3.4 Nitrate to Ammonium Ratio

Nitrate to ammonium ratios given in Fig. 1 depicted that nitrate to ammonium ratio was higher in both control treatments. While in organic extracts and oil-coated fertilizer treatments, nitrate to ammonium ratios were significantly lower in comparison to treatments without extracts. Though at all intervals nitrate to ammonium ratio was higher in uncoated urea treatment, the highest ratio was observed at the second interval. In coated treatments, nitrate to ammonium ratios were higher at the first and last interval in comparison to second intervals. Among extracts, non-significant results were seen between *Parthenium* extract, neem oil, and acidulated cow dung extract, though acidulated cow dung showed a slightly higher ratio.

3.5 Percent Nitrified N (%)

Figure 2 illustrated the percent nitrified N for all treatments at all intervals. These results clearly stated that the nitrification process was significantly reduced with the use of organic extracts coated urea in comparison to treatments not receiving extracts. Though all the extracts performed significantly to lower the nitrification process, the results of *Parthenium* extract were much better. Among the concentrations of these extracts, all concentrations showed significant results, even lower concentrations also performed equally to that of higher concentrations.

3.6 N release Efficiency (%)

N release efficiency was highest at the first interval for uncoated urea but it was reduced significantly at latter intervals and even at 60 days interval, its release efficiency was just 12% (Fig. 3). In the case of coated treatments, release efficiency was lower at the first interval but at the second interval, it was increased significantly. At the third interval, a slight decline was seen in N release efficiency by the coated treatments but the release was still much higher than uncoated treatment. Among different types of coating

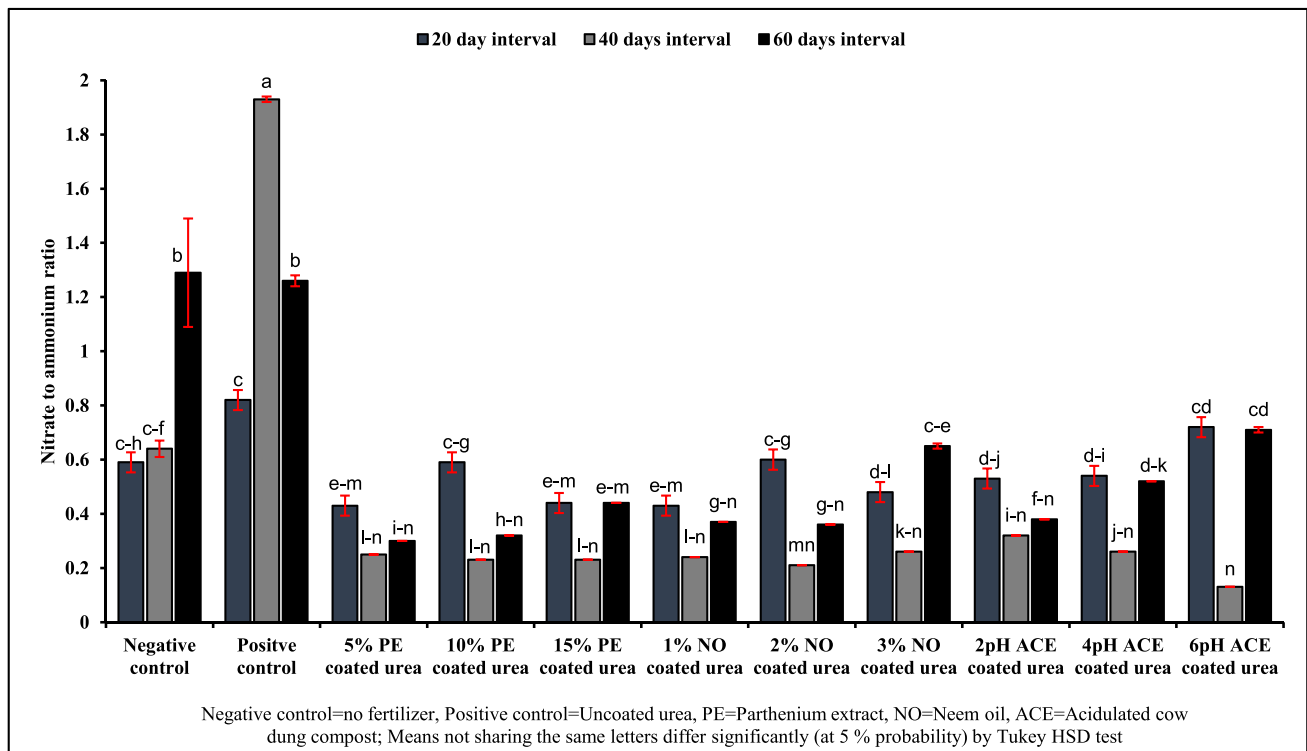


Fig. 1 Nitrate to ammonium ratios for treatments at 20, 40, and 60 days interval. Negative control, no fertilizer; Positive control, uncoated urea; PE, *Parthenium* extract; NO, neem oil; ACE, acidu-

lated cow dung compost; Means not sharing the same letters differ significantly (at 5% probability) by Tukey HSD test

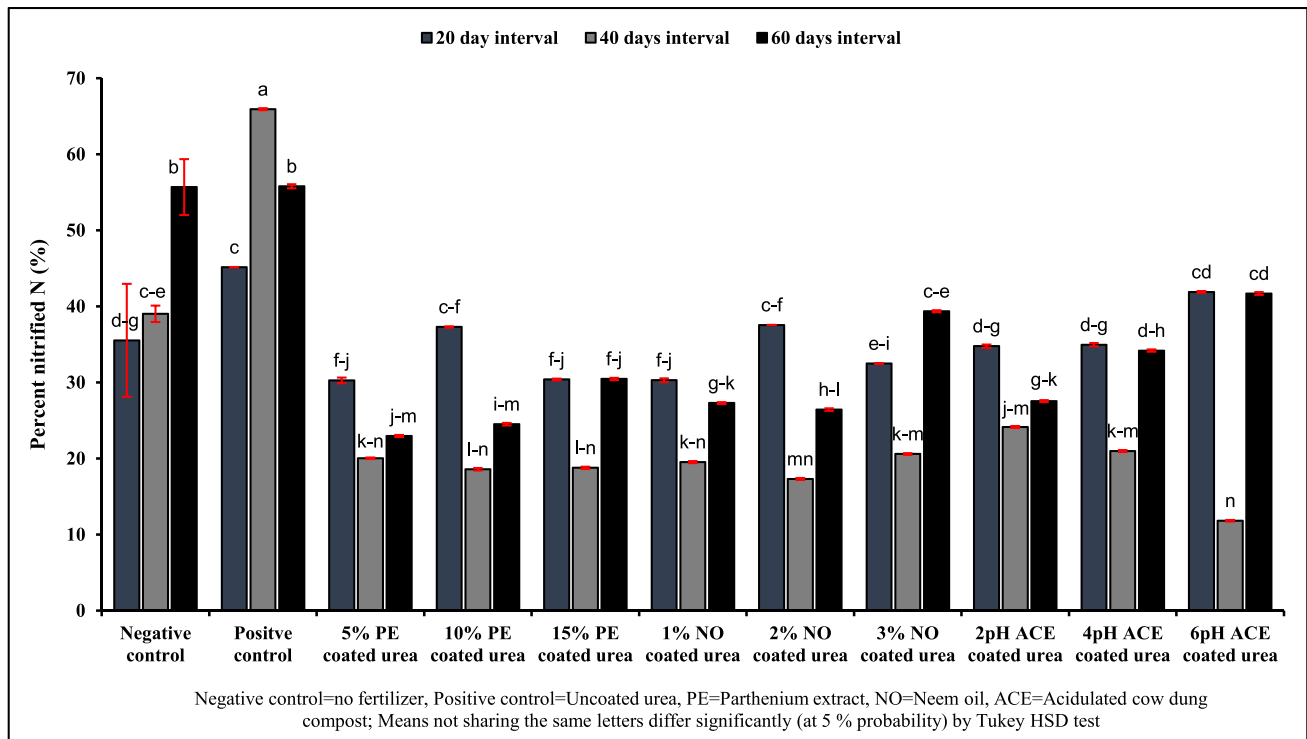


Fig. 2 Percent nitrified N (%) for treatments at 20, 40, and 60 days interval. Negative control, no fertilizer; Positive control, uncoated urea; PE, *Parthenium* extract; NO, neem oil; ACE, acidulated cow

dung compost; Means not sharing the same letters differ significantly (at 5% probability) by Tukey HSD test

materials, N release efficiency was slightly higher in *Parthenium* extract coated urea than other coating materials.

4 Discussion

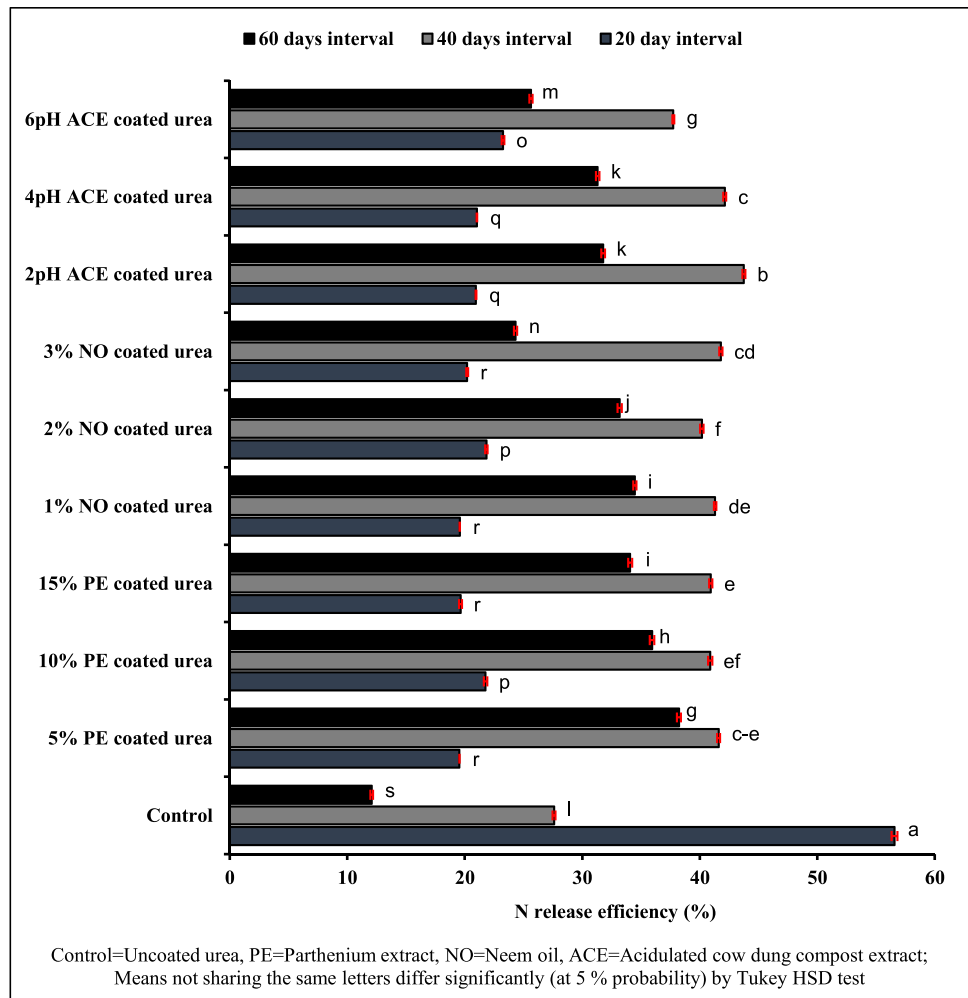
The use of chemical fertilizers is a basic commodity in today's agricultural systems (Yan et al. 2020). Specifically, nitrogen (N) fertilizers are much important as nitrogen is an essential macronutrient for all plants (Li et al. 2021). But with the addition of N fertilizer in the soil, several problems originate, as much of the applied N is lost via nitrification and subsequent denitrification processes (Belete et al. 2018; Van Eerd et al. 2017). It is stated in many studies that applied N undergoes several interactions with loss pathways, chemical reactions, soil microbes, and plant roots (Castellano-Hinojosa et al. 2019; Abbas et al. 2020). On oxidation, by the nitrifying bacteria, ammonium first converts to nitrite then to nitrate in two consecutive steps. During this process, nitrogen might be lost as nitrous oxide or nitrite form (Zhu et al. 2021). The final product of this reaction is NO_3^- which might also be lost via nitrate leaching or denitrification process resulting in groundwater, surface water, and atmospheric contamination (Wang et al. 2019). Thus, it is very crucial to control the nitrogen dynamics in the soil. A

laboratory experiment was conducted at SFPN, ISES, UAF to check the effect of polymer mixed organic extracts and oil-coated urea on the N release efficiency, percent nitrified N, and respective ammonium and nitrate concentrations in the soil.

Results depicted that the ammonium concentration was much higher in comparison to nitrate concentration in all treatments at all intervals possibly due to the presence of amide N in urea fertilizer. Each urea molecule contains two amide groups; these amide groups could easily be converted to ammonium form on hydrolysis of urea. While conversion to nitrate requires more time to stay in the environment, nitrate formation requires ammonium to be formed first for the process of nitrification. Our results are in line with the findings of Sigurdarson et al. (2018) who reported the conversion of urea to ammonia and carbonic acid upon hydrolysis. That ammonia is further converted to ammonium, as ammonia is an unstable product.

Furthermore, our outcomes on nitrate to ammonium ratio and percent nitrified N demonstrated the reduced nitrification process in the organic extracts and oil-coated urea treatments as compared to the uncoated urea. The reduction in nitrification might be due to the nitrification inhibiting compound present in these organic amendments (Wu et al. 2017; Plaimart et al. 2021), as *Parthenium* extract contain

Fig. 3 N release efficiency (%) of coated and uncoated fertilizers at 20, 40, and 60 days interval. Control, uncoated urea; PE, parthenium extract; NO, neem oil; ACE, acidulated cow dung compost extract; Means not sharing the same letters differ significantly (at 5% probability) by Tukey HSD test



parthenin, phenolics, and terpenes that are having nitrification inhibiting potential (Chandrasena and Narayana 2018). Similarly, neem oil contains melacin to inhibit the nitrification process (Savich and Novik 2021). Anyhow, acidulated cow dung compost extract at low pH also reduced percent nitrified N that could be due to its low pH character, as low pH is itself a nitrification inhibitor. With a decrease in pH, nitrification reduces and even ceases below pH 6 (Fumasoli et al. 2017). It was observed in the present study that low concentrations of these extracts and oil reduced nitrified N percentage in consistence with that of higher concentrations. Thus, 5% *Parthenium* extract, 1% neem oil, and 2 pH acidulated cow dung compost extract were found sufficient for this purpose in consistence with the findings of Kumar et al. (2011) who reported a decline in net nitrification and enhanced nitrogen use efficiency in lowland irrigated rice with lower concentration of neem oil. They reported that 500 mg kg⁻¹ neem oil was found sufficient for coating on urea granules to reduce nitrification process and to enhance nitrogen use efficiency of rice.

Our findings showed that all the coating materials significantly reduced the N release efficiency by lowering the release of ammonium, nitrate, and cumulative N in the soil in comparison to uncoated urea at earlier intervals. Though an increase in release efficiency was seen at latter intervals from coated urea, that was not much higher, while in uncoated urea the release of N was significantly lowered at latter intervals than the first interval. That trend could be due to the reason that coating material acts as a physical barrier against the counter-ions and water molecules allowing only a limited amount to be passed through very small pores on its surface. This character of coating material usually slows the process of nutrient release from the fertilizer granule. In a similar study, Trinh et al. (2015) established a model to state the release kinetics of N from coated urea which clearly described that the release of N was lower in coated fertilizer than uncoated.

Overall, all coating materials behaved almost equally in controlling the release of plant-available N in consistence with the crops N demand. As early seedlings require a small amount of available N but at latter plant stages, the

established plants require more N. Antimicrobial characteristics of the extracts and oil might lower the degradation process of polymer coated on the fertilizer granule to control the N release. So, this controlled release might be a consequence of this trait. In line with our findings, Shivay et al. (2016) reported that sulfur coated urea slowed the N release due to its antimicrobial properties. Among organic extracts and oil, *Parthenium* extract performed relatively better than all others. It might be due to the allelochemicals present in *Parthenium* extract that could act as inhibitors for nearby plants and microbial populations. Thus, a prominence concerning nitrification inhibition and controlled release of N than other organic amendments would be a consequence of these allelochemicals. In a similar manner, Shafiq et al. (2020) reported allelopathic effects of *Parthenium*. Thus, based on the above discussion, it is clear that using polymer mixed *Parthenium* extract, neem oil, and acidulated cow dung compost extract for coating on urea could helpfully enhance the nitrogen use efficiency in addition to the eradication of these waste materials in a positive way.

5 Conclusion

Based on our findings we concluded the organic extracts coated fertilizers have the potential to control and release N effectively, especially the *Parthenium* extract, neem oil, and acidulated cow dung compost extract. Our results provided new insight on urea coating by these extracts that could reduce nitrification chances and supply ammonium consistently which is essential for field crop demand. Future research should focus on clarifying the mechanism of biochemical interaction, assessing the contribution of respective microbial populations to the long-term nitrogen in the soil.

6 Data Availability Statement

All data of this manuscript is available from the corresponding author on request.

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Declarations

Conflict of Interest The authors declare no competing interests.

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