

**Soil mimetic eco-friendly fertilizer gate: Nanoclay reinforced binary carbohydrate for crop
efficiency**

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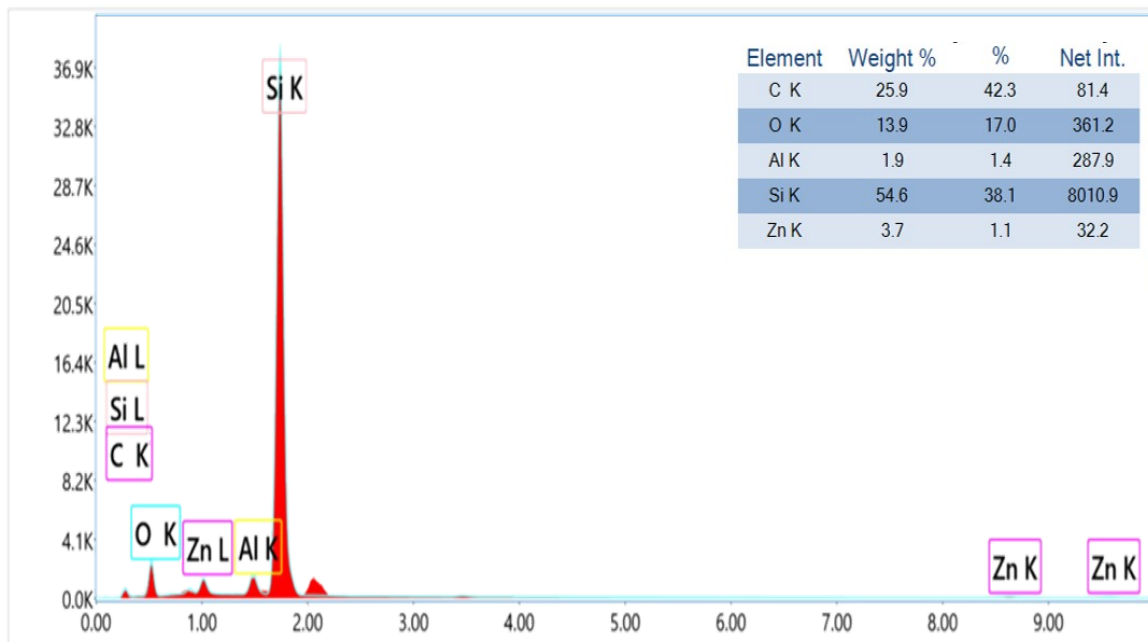


Fig. S1. Graph showing the EDX analysis of SEM image and inset showing the elemental quantification of EDX graph.

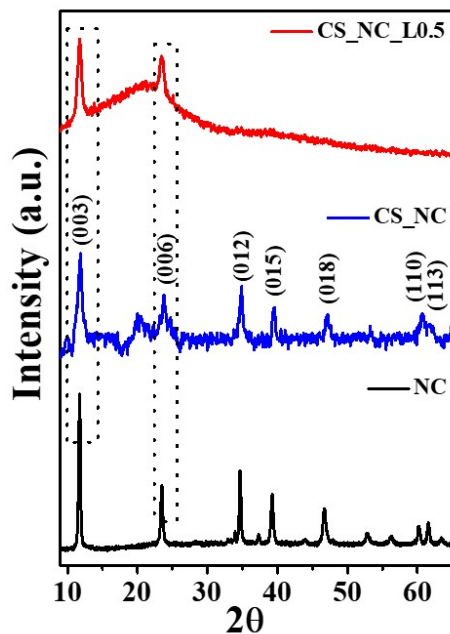


Fig. S2. XRD pattern of NC (normal scan), CS_NC (normal scan) and CS_NC_L0.5 (slow scan).

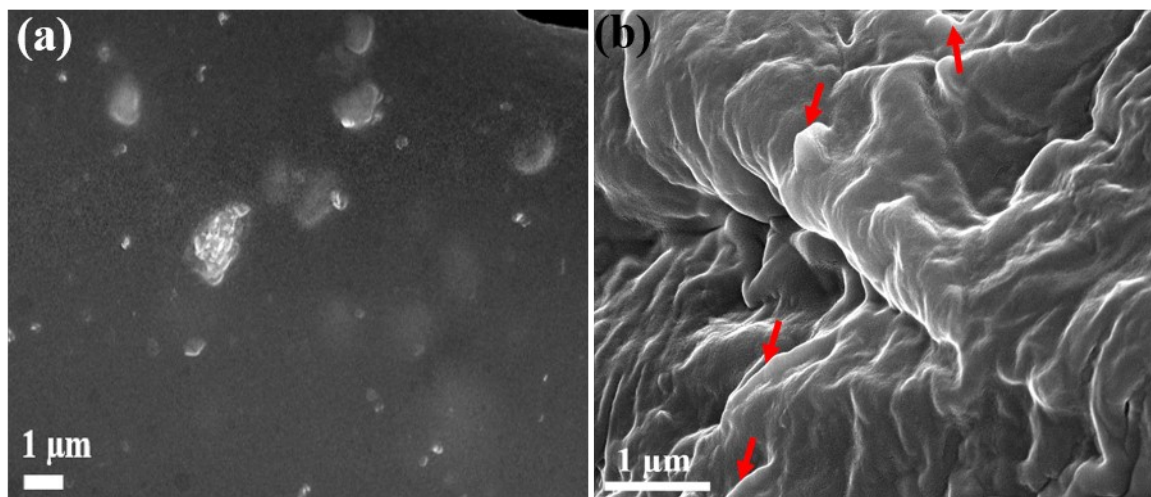


Fig. S3. SEM image showing the surface morphology of CS_NC (a) and CS_NC_L0.5 (b).

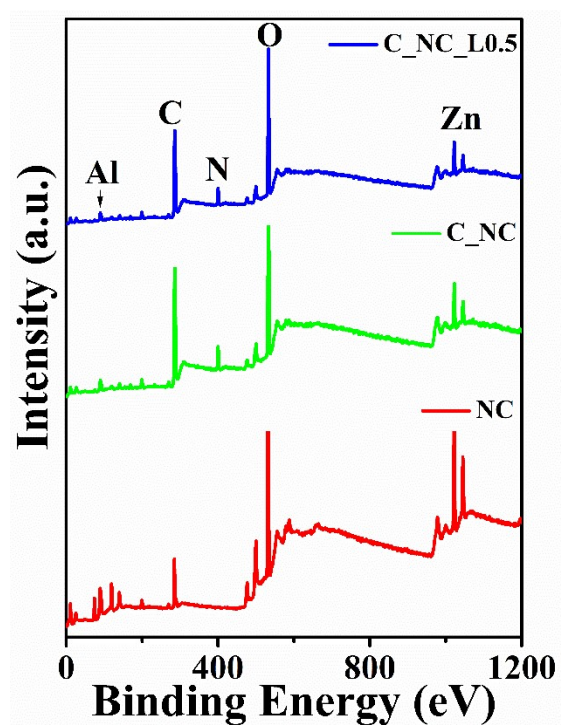


Fig. S4. Graph showing XPS survey spectra of NC, CS_NC and CS_NC_L0.5.

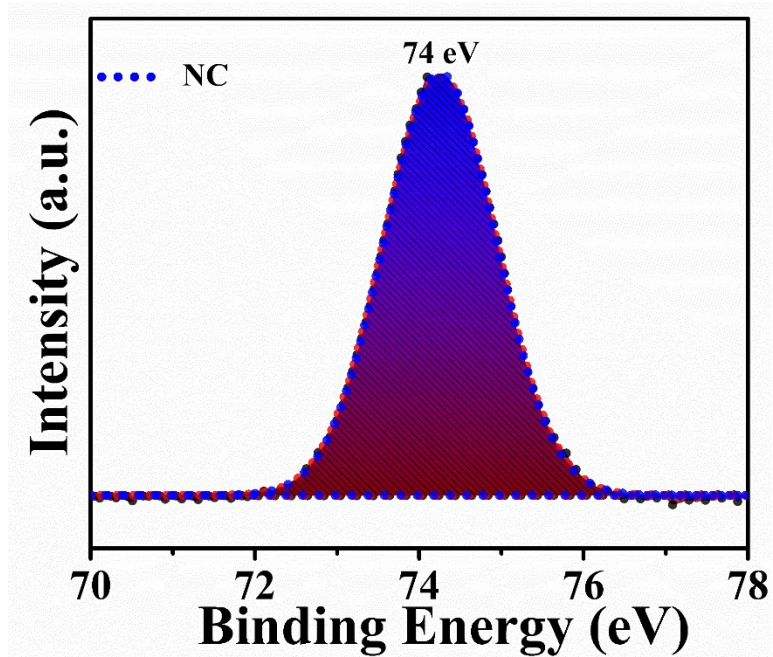


Fig. S5. Graph showing Al2p core level XPS spectra of NC.

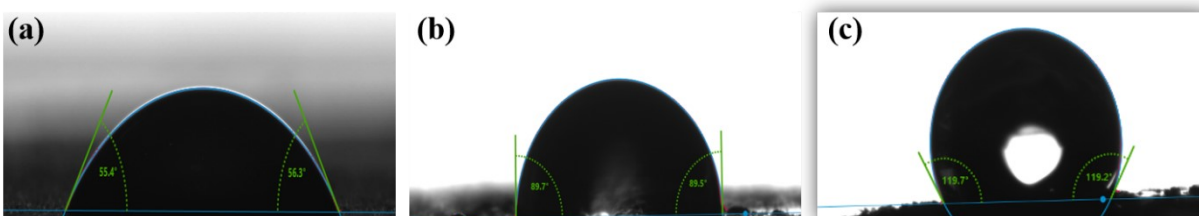


Fig. S6. Image showing water contact angle of (a) NC, (b) CS_NC and (c) CS_NC_L0.5-4L.

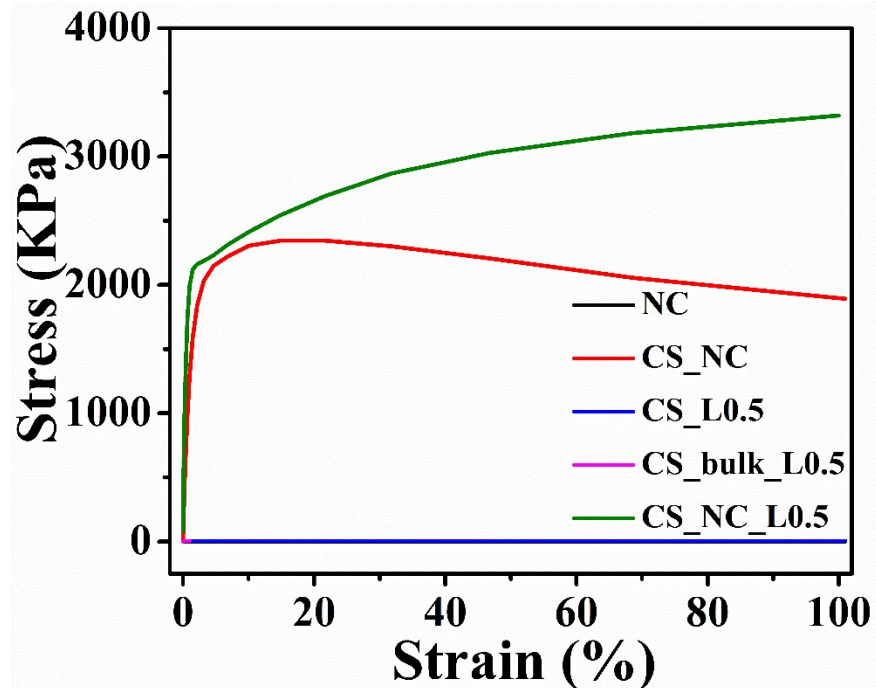


Fig. S7. Graph showing stress-strain curve of NC, CS_NC, CS_L0.5, CS_bulk_L0.5 and CS_NC_L0.5.

Coated pellets	Batch-1 thickness (μm)	Batch-2 thickness (μm)	Batch-3 thickness (μm)	Average thickness (μm)
CP0.5-2L	2.6	2.6	2.6	2.6 ± 0.0
CP0.5-3L	4.6	4	4.9	4.5 ± 0.45
CP0.5-4L	6.9	5.9	6	6.2 ± 0.55

Table. S1. Thickness of the coated MOP pellets

Average thickness values are expressed as in mean \pm SD.

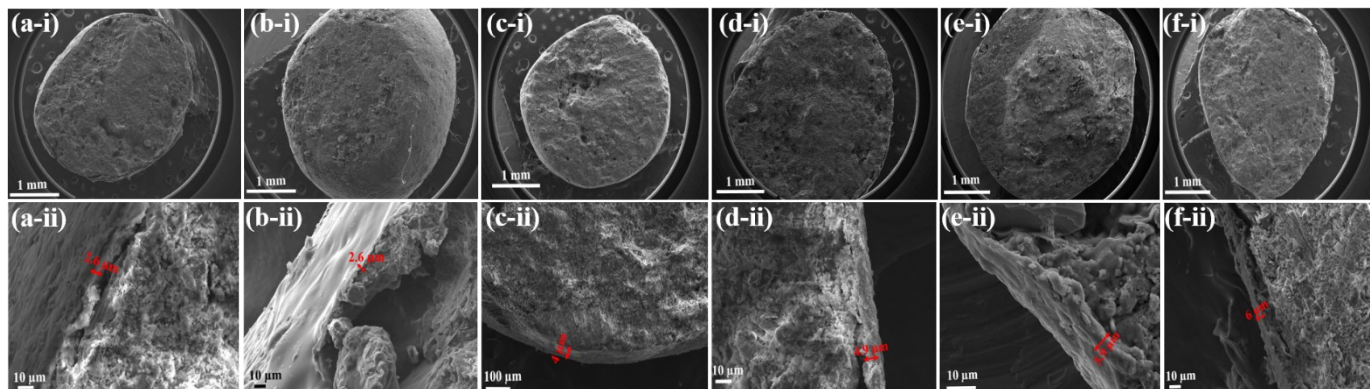


Fig. S8. SEM image showing the cross-section [a-i (batch-2), b-i (batch-3), c-i (batch-2), d-i (batch-3), e-i (batch-2) and f-i (batch-3)] and thickness of [a-i (batch-2), b-i (batch-3), c-i (batch-2), d-i (batch-3), e-i (batch-2) and f-i (batch-3)] CP0.5-2L, CP0.5-3L and CP0.5-4L, marked with the red arrows respectively.

Table. S2. Potassium release behavior of uncoated and coated (CP0.5-2L, CP0.5-3L and CP0.5-4L) MOP pellets in water at different time intervals (0, 10, 20, 30, 40 and 50 days)

Time interval (days)	Control	CP0.5-2L	CP-0.5-3L	CP0.5-4L
0	1.01 ^{af}	0.933 ^{bf}	0.966 ^{bf}	0.91 ^{cf}
10	93.5 ^{ae}	4.78 ^{be}	4.81 ^{be}	4.6 ^{ce}
20	95.5 ^{ad}	11.11 ^{bd}	11.15 ^{bd}	9.41 ^{cd}
30	95.6 ^{ac}	22.08 ^{bc}	22.08 ^{bc}	19.1 ^{cc}
40	95.5 ^{ab}	27.5 ^{bb}	27.4 ^{bb}	26.78 ^{cb}
50	96 ^{aa}	35.2 ^{ba}	35.06 ^{ba}	34.3 ^{ca}

The notations represent the significant variations among the data at $p \leq 0.05$ where 1st notation is for treatments (control, CP0.5-2L, CP0.5-3L and CP0.5-4L) and 2nd notation is for time intervals (0, 10, 20, 30, 40 and 50 days)

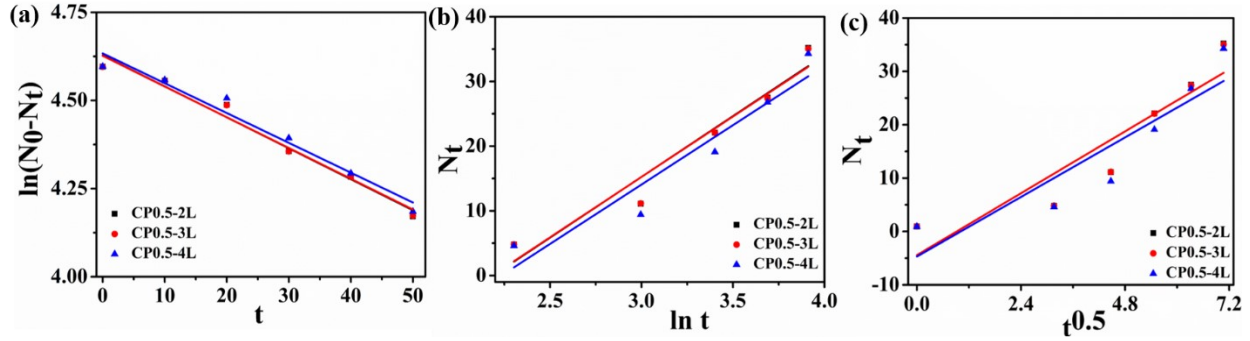


Fig. S9. Graph showing release kinetics of potassium release from coated fertilizers (CP0.5-2L, CP0.5-3L and CP0.5-4L) based on (a) first-order, (b) simple elovich and (c) parabolic diffusion.

Table. S3. Standard errors of estimates (SE), coefficient of determination (R^2) of first-order, simple elovich, parabolic diffusion and kinetics parameters of korsmeyer-peppas model.

Coated fertilizer	First-order		Simple elovich		Parabolic diffusion		Korsmeyer-peppas		
	R^2	SE	R^2	SE	R^2	SE	R^2	SE	n
CP0.5-2L	0.89	0.013	0.84	334.36	0.84	42.09	0.996	0.054	1.26
CP0.5-3L	0.89	0.012	0.85	326.43	0.84	40.75	0.996	0.055	1.25
CP0.5-4L	0.90	0.010	0.84	320.91	0.83	40.85	0.996	0.042	1.29

Table. S4. Increased yield (both biological and economic yield) percentage, NUE and harvest index of different treatments (T1-B-100 and T2-B-75)

Treatment	T1-B-100	T2-B-75
Increased economic yield (%)	13.3 ± 3.0	17 ± 3.3
NUE	2.8 ± 0.04	5 ± 0.19
Increased biological yield (%)	9.9 ± 1.3	14.8 ± 0.93
Harvest index (HI)	14.16 ± 0.23	15.5 ± 0.18

Values are expressed as in mean ± SD and all the data are statistically significant at $p \leq 0.05$.

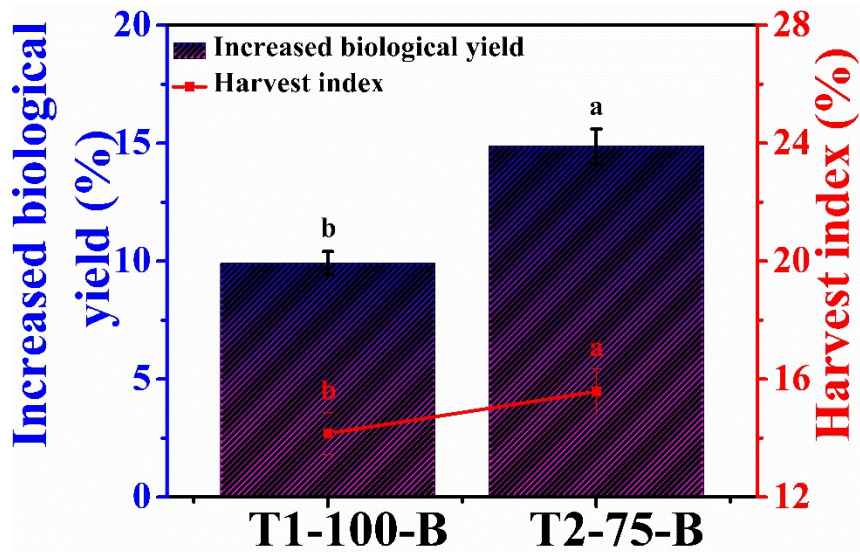


Fig. S10. Graph showing increased biological yield and harvest index of different treatments (T1-B-100 and T2-B-75).

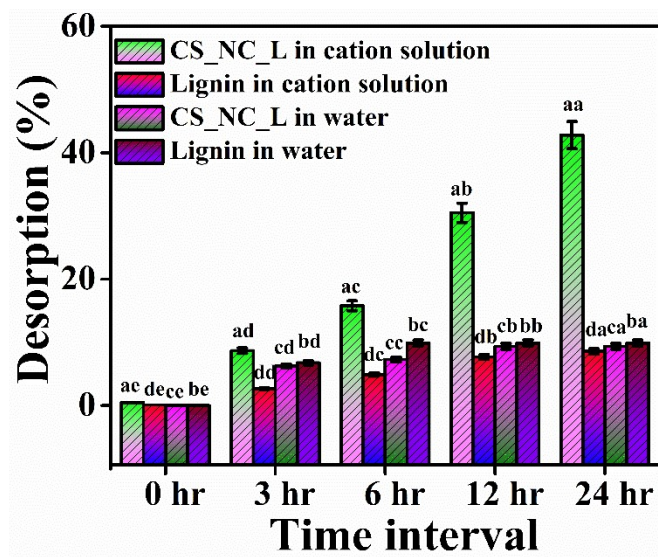


Fig. S11. Graph showing desorption percentage of CS_NC_L and lignin in cationic and water solution at different time intervals (0, 3, 6, 12 and 24 hr).

Table. S5. Roughness of the CS_NC_L0.5 and Lignin before and after laccase treatment

Laccase treated sample	Roughness (nm)
CS_NC_L0.5 (Before)	180 ± 1.2
CS_NC_L0.5 (After)	708.8 ± 28.7
Lignin (Before)	479 ± 3.4
Lignin (After)	3049.2 ± 131.9

Values are expressed in mean ± SD and all the data are statistically significant at $p \leq 0.05$

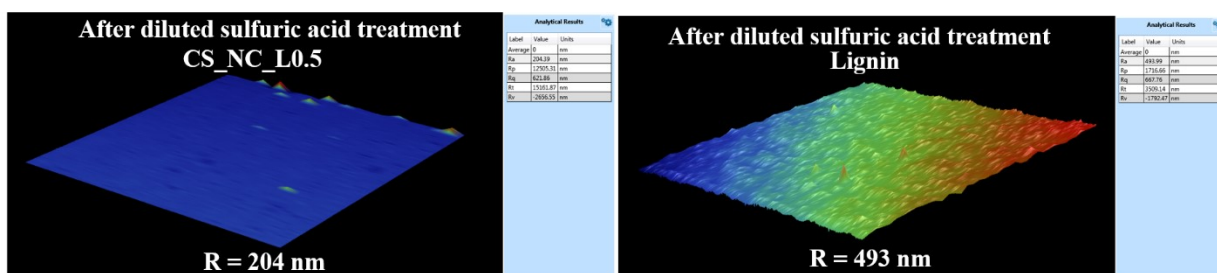


Fig. S12. Surface profilometer image showing the effect of diluted sulfuric acid on the CS_NC_L0.5 and lignin coating.

Table S6. Comparison of life cycle impacts for CS_NC_L coated MOP and GO-polymer latex composite coated KNO₃ to produce 1 kg of potash fertilizer using Greendelta open LCA 2.0.2.

Impact category (unit)	CS_NC_L coated MOP (A)	GO-polymer latex composite coated KNO ₃ (B)	(B)/(A)
Freshwater eutrophication (kg P eq)	1.3847E-10	1.1106E-11	12.4676
Global warming (kg CO ₂ eq)	8.2158E-07	9.0785E-08	9.0497
Human carcinogenic toxicity (kg 1,4-DCB)	4.9079E-08	7.1516E-09	6.8626
Marine eutrophication (kg N eq)	7.3542E-10	2.0934E-11	35.1305
Terrestrial acidification (kg SO ₂ eq)	2.2797E-07	2.3484E-08	9.7076
Terrestrial ecotoxicity (kg 1,4-DCB)	4.8944E-06	3.7628E-07	13.0074
Water consumption (m ³)	9.0597E-08	3.7104E-09	24.4170
Stratospheric ozone depletion (kg CFC11 eq)	1.5252E-07	4.8788E-08	3.1261