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# Urea functionalized multiwalled carbon nanotubes as efficient nitrogen delivery system for rice

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## Abstract

This paper utilized urea functionalized multiwalled carbon nanotubes fertilizer as plant nutrition for rice to understand fully their mechanism of interaction. Surface modification of multiwalled carbon nanotubes was treated by nitric acid at different reflux times. The individual and interaction effects between the design factors of functionalized multiwalled carbon nanotube amount and functionalization reflux time with the corresponding responses of nitrogen uptake and nitrogen use efficiency were structured via the Response Surface Methodology based on five-level central composite design. The urea functionalized multiwalled carbon nanotubes fertilizer with optimized 0.5 weight% functionalized multiwalled carbon nanotubes treated at 21 h of reflux time achieve tremendous nitrogen uptake at 1180 mg/pot and NUE up to 96%. The FT-IR results confirm the formation of acidic functional groups of functionalized MWCNTs and UF-MWCNTs. The morphological observation of transmission electron microscopy shows extracellular regions to be the preferred localization of functionalized multiwalled carbon nanotubes in fresh plant root cells independent of their size and geometry. Penetration into the plant cell results in breaching of graphitic tubular structure of functionalized multiwalled carbon nanotubes with their length being shortened until similar to 50 nm and diameters becoming thinner until less than 10 nm. The capability to agglomerate after translocation into the plant cells alarms potential cytotoxicity effect of functionalized multiwalled carbon nanotubes in agriculture. These work findings have suggested using urea functionalized multiwalled carbon nanotubes for effective nutrient delivery systems in rice plant.

## Keywords

**Author Keywords:** functionalized-MWCNTs; grafted; urea; plant cell; cytotoxicity
**KeyWords Plus:** NANO-ANATASE TIO2; NONHOST RESISTANCE; GROWTH; ARABIDOPSIS; TRANSLOCATION; NANOMATERIALS; TRANSPORTERS; ENHANCEMENT; PATHOGENS; SPINACH

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