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Removal of Atmospheric Nitrous Oxide (N 2 O) Using Photocatalytic Technology Methodology Review

External, R1 Review Round

R #1

December 12, 2023

CONTENT referenced by reviewer's comment *e.g. Section number + paste exact text*	**REVIEWER'S COMMENT** *Please paste the comment from the reviewer*	**AUTHOR'S RESPONSE** *Please describe how the comment was addressed and include new content in quotations*	**Reviewer's Conclusion** [PASSED/ REJECTED *WITH COMMENTS*]
e.g. 2.1 - "approximately 25%	***e.g. Replace** with "adequate"*	*e.g. This was changed to **"The majority of the material must have a moisture content of 25% or less, as measured in the field."***	*PASSED*
The following comments refer to the methodology			

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Reviewer's Blind Review Comments regarding Methodology

Kindly enter your comments based on these questions in the table below. Also, if referencing specific text, please include text excerpt or row/page number from the methodology for ease of reference by the authors. All reviewer comments will remain anonymous unless you choose to be named.

Is the methodology clearly written with adequate detail for implementation?	I feel that the methodology is well written and easy to follow. This is not my expertise, but I could understand the proposed work. However, detail is lacking with respect to the efficiency of the photocatalyst. The report states, *"In reactor-based experiments, it was determined that 1 g of photocatalyst can reduce ambient N2O concentrations by 10% under a set of conditions that are henceforth referred to as standard conditions".* This seems a bit arbitrary, and I can't see any evidence to support this. **This is a major flaw given the nature of the proposed work**. I would have expected to see a lot more detail and possibly suitable references, or reports, to support this statement given that the effectiveness of the whole proposed work hinges on this. RE: Crop Intellect has now provided further details of the experimental work done in collaboration with Ostrava University

	(May 10th with Tica Lubin via email). Additional information about outdoor experiments on May 23rd. The outdoor experiment doesn't provide insight here. Nitrous oxide in the atmosphere varies at a rate greater than observed between the control and the experiments. There are too many factors that were not constrained. For example, air mass origin, boundary layer conditions, and weather (i.e., rainfall) to name but a few. I can not see how an experiment of this type can be used as 'proof' that R Leaf removes N2O.
Is the underlying foundation of the methodology clear?	I believe that the bulk of the underlying methodology is sound in that all aspects have been considered. Most of the principles of this methodology are covered by ISO 14064-2:2019. The math is straightforward and easy to follow. There are presumptions made in the predicative equation and these are clear. I would say that the following assumption is being extra cautious as the levels of N2O will be consistent given the nature of atmospheric mixing. *"Any changes to the baseline N2O concentration are caused by the photocatalyst. For example, if N2O is lost due to reasons other than the photocatalytic breakdown, then the reaction rate will be artificially inflated"*
Is the methodology feasible?	I feel that the practicalities of the methodology are feasible and that the production and application of the product can be achieved. However, to come back to my previous point, this all hinges on the ability of the photocatalyst to remove N2O. I appreciate that this has

	been shown in published studies, but this needs to be shown for the photocatalyst proposed herein. I would also have liked to see more detail on the proposed in situ flux monitoring. The proposal states that, *"A specially designed chamber will be used to assist measurements of the N2O degradation at several points within the project boundary."* This makes it sound very easy, but I feel that this would be a challenge. For example, - What accuracy of measurement is needed to detect N2O breakdown by R Leaf? RE: In our preliminary studies in lab work and limited in field experiments, we anticipate a removal potential of between 1 and 3 ppb. Currently we are using equipments such as LI-COR and GASMET, both of them with a standard deviation between 0.2 and 0.3 ppbs and overall accuracy within ±1-2% of the measured value, depending on calibration and environmental conditions. I do not feel like this is sufficient evidence after reading the reports. - How will the balance between emission from soil and removal by R Leaf be addressed? RE: The baseline N2O levels are measured before the application of R-Leaf. The N2O removal capacity from R-Leaf performance is established through the lab experiments and field trials.

	I do not feel like this is sufficient evidence after reading the reports. - The monitoring data collected from the field will be fed into equations described in the methodology which will account for the on-field parameters, this will give accurate estimation of the balance of N2O removed during the project. Inadequate - Will N2O be removed through denitrification? RE: No, N_2O will not be removed through denitrification in this case. Instead, N_2O will be removed by the photocatalytic reaction happening on the surface of the material (TiO_2). In this process, N_2O is broken down into N_2 (nitrogen gas) and O_2 (oxygen gas), effectively removing it. The photocatalytic reaction involves the absorption of light by the TiO_2 material, which generates electron-hole pairs. These pairs then interact with the N_2O molecules adsorbed on the TiO_2 surface, leading to their decomposition into harmless nitrogen and oxygen gases. This method is particularly effective and environmentally friendly for reducing N_2O emissions. adequate - How will farming practices affect the process? For example, application of fertilizer? It has been shown that N2O emissions are stimulated by rainfall. Therefore, emissions will not be uniform. RE: R-Leaf is able to convert NOx gasses (NO and NO2) into nitrates with data showing a reduction in the use of synthetic fertilizer of up to 50kg on N. This will have a direct impact in farming practices encouraging farmers to

	reduce their use of synthetic inputs, potentially generating savings and potential increased yield. These outcomes are based on more than 3 years of field trials on various crops including cereals, potatoes and various vegetables. Two trials attached (R2308 Wheat field trial S23-509 Winter Wheat (2) and Dyson Trial Report 2023). Regarding uniformity of emissions the IPCC (Intergovernmental Panel on Climate Change) provides guidelines for estimating greenhouse gas emissions, including nitrous oxide (N2O) emissions from synthetic fertilizer use. According to the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, the default emission factor (EF) for N2O emissions from synthetic nitrogen fertilizer application is 1% (0.01) of the nitrogen applied. This means that for every kilogram of nitrogen applied as synthetic fertilizer, approximately 0.01 kilograms (or 10 grams) of N2O is emitted. R-Leaf works on these bases and calculations from IPCC just on the synthetic fertilizer emissions data coming. Overall, taking into account various recognized factors such as rainfall, temperature, fertilizer type and others, there is a potential fluctuation in the low end between 0.2-0.5% and in the high end between 2% and 3% of the N applied. This won't have a great impact in R-Leaf's capacity to remove N2O based on background levels of 330pb of N2O.

	Needs more information
Are there any alternative or additional steps that should be considered?	I feel that Crop Intellect must adequately demonstrate that R-Leaf can remove N2O in the standard conditions they describe. RE: Crop Intellect has performed one experiment in outdoor conditions with positive results. This season, R-Leaf N2O removal capacity will be measured in situ in more than 200 ha of agricultural land in the UK. I feel that this outdoor experiment provides no proof that R Leaf can remove N2O from the air.
Will the proposed processes for data collection and verification achieve the results defined in the methodology?	This section is very thorough and sound.
Do you want to be named in the review? (Expert Reviewers will be anonymous unless you choose to be named)	No

Recommendation

Kindly mark with an X

Accept As Is:	

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Requires Minor Revision:	
Requires Moderate Revision:	
Requires Major Revision:	X
Reject and Re-submit:	
Rejection: (Please provide reasons)	

General/Additional Comments:

Comments not to be sent to Crop Intellect

I have experience in conducting reactor experiments aimed at determining N2O breakdown using photocatalysts. This was done using very sophisticated, accurate and precise instrumentation: this would allow us to detect very small rates of N2O removal. During these experiments, there was no measurable N2O removal for tests using static and flow through chambers. Crop Intellect must adequately demonstrate that R Leaf has this functionality.

Please note that I have not commented on the specifics of the content as I feel that there are some major obstacles to overcome before this becomes important.

Further comments

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After reviewing the documents supplied by Crop Intellect, I am still not convinced that the catalyst can remove N2O from the atmosphere. I feel that the experiments with Ostrava University are fundamentally flawed as the experiments were not conducted under an atmosphere analogous to the real atmosphere. For example, the catalysts were tested under dry conditions in helium. I would like to see the results from tests in real air or artificial air containing ambient levels of N2 and O2 and enough water vapour to replicate a real atmosphere.