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Photodegradation for Nutrient Management in the Dry Tropics

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ABSTRACT

Nutrient limitation in agriculture is a big problem in many tropical areas. Much research has focused on the optimal use of crop residues in agriculture. Recent work indicates that plant residue decomposition rates, including nutrient release rates can be increased by pre-exposure to sunlight. This has potential as a technology to manipulate nutrient release from residues to match crop demands. The possible development and use of this technology is discussed. There is some evidence that this could increase emissions of trace gases, but the increase is thought to be small. Research needs are discussed.

Keywords: Photodegradation; Tropical Agriculture; Nutrient Management; Greenhouse Gas Balance

1. Introduction

In many tropical regions, particularly Africa, mineral fertilizers are too expensive to be used extensively by most farmers. Efficient use of organic residues as fertilizers is therefore important, and there is a large literature on this topic [1,2]. Particularly high quality plant litter and residues that can release most of their nutrients during peak crop growth are valuable. Attempts to mix different types of residues to manipulate nutrient release rate to much crop demand as closely as possible have been met with varying success.

Several recent studies have indicated that photodegradation, enhancement of decomposition rate caused by exposure to light, may play an important role in plant residue decomposition and in the carbon cycle in semi-arid ecosystems where other climatic factors appear less important [3-9]. These environments are characterized by high radiation levels coinciding with low vegetation cover for at least part of the year, meaning that the degrading litter on the soil surface will be exposed to high radiation. The mechanism for how photodegradation happens is still imperfectly known, but our earlier experiment indicates that photodegradation may work by increasing subsequent microbial decomposition rate in the wet season [10]. Substantial photo-exposure appears to be necessary, as the effect was not found when plant litter was exposed to lower amounts of radiation [10-12]. The mechanism for how photo-exposure affects litter mass loss is insufficiently known, but recent work suggests that it particularly affects the degradation of lignin, the plant compound most resistant to microbial degradation [13]. The effect of photo-exposure on nitrogen mineralization has been less studied, but there is some evidence that this may increase rate of nitrogen as well as carbon release from the litter substantially [5,10]. In particular, the evidence suggests that photo-expose can make at least some of the nitrogen in plant litter mineralize very quickly [10]. It is possible that this is related to degradation of lignin as lignin is an important compound in the plant cell wall, and degradation of this wall could make more easily degradable and nitrogen rich cell components leak out. Not much is known about how photodegradation is affected by other environmental factors. However, there is some evidence that wet litter is broken down faster when exposed to light [14]. Foereid *et al*. [10] also found that temperature alone has some effect on litter decay rate, but the interaction with light is not well known.

This poses the question: Can photo-exposure be used intentionally as a technology to manipulate nutrient release rate from crop residues to match crop demand? In this paper I outline this idea, and discuss research needs to develop the technology.

2. Potential Use of Photodegradation in Agriculture

Photodegradation has until now only been studied as an ecological process, and its role in the carbon cycle [4,9]. However, if rate of nitrogen release can be manipulated by previous exposure to sunlight, this gives new opportunities timing nitrogen release from crop residues and other organic material to crop demand in agriculture. This will be the case everywhere there is a marked dry season and cropped fields are mostly bare and can be used to spread the residues. Furthermore, this offers an opportunity to make "low quality" litter that normally will not release much of its nutrients during the cropping season more useful. Photodegradation could be taken advantage of in agriculture by leaving the residues on the ground for the required amount of time, and them digging them under. How long exposure that is required for various sorts of residues would have to be calibrated through experimentation. However in general it would be expected that the more the nitrogen release rate needs to be increased to match crop demand, the longer the exposure needed, as our earlier experiment showed that the shortest exposure time changed nitrogen release rate much less than the longest exposure time [10].

There is a need to try out this system in the field to assess if the benefits are substantial, and the system needs to be optimized. If a simple relationship between amount of radiation received and nutrient release rate can be found, the optimal exposure time only needs to be tested in a few sites and predictions can be made for other sites. Previous work has shown that a fairly consistent relationship between radiation exposure and carbon mineralization can be developed [9]. There is also evidence that the effect of photo-exposure depends on lignin content [13], meaning that it may also be possible to generalize between litter types. The effect of wavelength distribution is imperfectly known [13], and the length of photo-exposure may have to be calibrated separately for areas with very different wavelength distribution.

In addition, potential drawbacks need to be assessed. One of them is the greenhouse gas balance of the system. Primarily methane release needs to be quantified. There is now ample evidence that both live and dead plant material emit low amounts of methane when exposed to UV radiation [15-17]. This emission is likely to be fairly small, but still needs to quantified. In addition, Foereid *et al*. [10] showed that nitrous oxide emission increases after photo-exposure in an incubation experiment. It is likely that this can be partly or completely mitigated when plants are present to take up the available nitrogen (indeed that is the purpose of the system). However, careful quantifycation of the greenhouse gas balance of the system, as well as assessment of mitigation options is needed.

This idea points to research needs of both basic and applied nature. The mechanism of how photo-exposure increases the release rate of nitrogen is not well understood. It is not merely following the increased carbon release as the timing of nitrogen release is different [10]. This can be studied in laboratory incubations. It also needs to be assessed how photodegradation interacts with temperature and moisture. To make use of the process in agriculture field experiments under realistic conditions are needed. The system needs to be optimized under realistic field conditions. The technology will only viable in areas where agricultural fields are left bare in periods with high radiation, *i.e*. areas with a dry season. Still there will be a range of variation in other climatic factors (temperature and moisture) within those areas, and their interaction with photodegradation needs to be assessed. The greenhouse gas balance of the system also needs to be assessed, as well as potential mitigation options.

3. Conclusion

Taking advantage of the effect of photo-exposure on nutrient release rate has potential for use in agriculture. The exact amount of time litter needs to be exposed to sunlight needs to be calibrated, as well potential effects on greenhouse gas emissions.

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