Interactive comment on “Obtaining more benefits from crop residues as soil amendments by application as chemically heterogeneous mixtures” by Marijke Struijk et al.

Response to Anonymous Referee #1 (RC1)

General comments

This manuscript reports the results of a full-factorial field experiment, carefully conducted to examine the short-term effects of different mixtures of crop residues on lettuce crop yield and soil respiration, aggregate stability, bulk density, and organic C, N, P, K and Mg contents. The authors found significant non-additive increases in soil available N and soil organic matter contents with the application of a straw-compost mixture (stronger effects than those of straw and compost applied separately) 44 days after the application of the amendments. The topic is important to improve management strategies for crop residues, and the results are well discussed in general. However, some aspects detailed below would need to be clarified before publication (especially aspects related to the first hypothesis and the methodology).

Thank you for the thorough and detailed review of our manuscript. Please see below for our responses to each of your comments by line number.

Specific comments and technical suggestions

L. 13. “(i.e. mixture 6= sum of the parts)” is not needed

We agree to remove this from the sentence so that it now reads:

> *“Mixing high C:N ratio with low C:N ratio amendments may result in greater carbon use efficiency and non-additive benefits in soil properties ~~(i.e. mixture ≠ sum of the parts)~~.”*

L. 47. “(mixture > sum of the parts)” is also redundant and not needed.

We agree to remove this from the sentence so that it now reads:

> *“Synergistic non-additive mixing effects are frequently observed, i.e. decomposition of the mixture is greater than would be predicted from the rate of decomposition of individual litter types ~~(mixture > sum of the parts)~~, especially when the litters are chemically heterogeneous (Pérez Harguindeguy et al., 2008; Wardle et al., 1997)”*

L. 64. What “other soil properties” are the authors referring to?

Since the sentence prior to this one only makes reference to C and N we agree with the point that the reviewer has highlighted and agree to revise the following sentence:

> *“These experiments suggest that non-additivity in decomposition rates and changes to other soil properties could go hand-in-hand.”*

so that is now reads:

> *"These experiments suggest that non-additivity in decomposition rates and changes to soil C and N dynamics could go hand-in-hand"*

L. 113-115. The authors hypothesized that faster decomposition of the mixtures would result in higher soil respiration and greater levels of SOM. To fairly test this hypothesis, it would be necessary to differentiate between SOM and amendment organic matter, and this study fails to do so (SOM measurements included amendment organic matter).In other words, it is not possible to tell how much of the OM added with the amendment has been transformed into SOM.
This is true. However, in this study we assume that in each block the SOM levels measured in the control plots are representative of the levels found if no amendments are added.

L. 134. Is +-0.8 a standard error? Why only for straw?
Due to the low density of straw, several buckets had to be weighed out to add up to a rate equivalent to 10 t/ha straw. Woodchips and compost are more dense and were much easier to accurately weigh out. The range of actual straw application rates was within the range of 9.2 t ha^{-1} and 10.8 t ha^{-1}, hence 10±0.8 t ha^{-1}. We will rephrase this for clarity as follows:

> *"… and 10±0.8 t ha^{-1} straw (equivalent to 9.2±0.8 t ha^{-1} dry matter;* ***± indicates inclusive range of the straw application rate****)."*

L. 134. More information about the amendments would be very useful, especially about the preparation of the compost (stability and maturity).
The compost was not made under laboratory conditions specifically for the experiment. It was prepared by the farm and they have many years of experience preparing compost with their residues. Our primary objective was to combine low C/N ratio residues and high C/N ratio residues readily available on-site. Following the standard practice of the farm, the raw materials (as mentioned in line 153) were collected and mixed on 26 March and composted for 52 days prior to use in the experiment on 17 May when the amendment mixtures (straw-compost and woodchip-compost) were prepared. The amendment mixtures were then left for another 26 days prior to field application, allowing some further maturation of the compost. We have no stability data of the compost, but observed that the compost appeared to be well rotted (see the photograph in Fig. 1b in the manuscript).

L. 137-139. "roughly twice". Did the authors consider this error (and those of the application of the individual amendments) when evaluating additive effects?
Thank you for pointing this out. We suggest that the word "roughly" can be removed because it results from the range of application rates addressed in the previous comment (line 134).

L. 140. To what depth were the residues incorporated in the soil profile?
After application the residues were incorporated with a power harrow, which mixes the residues with the soil in the top ~15 cm. It may be worthwhile to note that the power harrow does not invert the soil, so the residues were not buried but mixed.

L. 140. Was the "fresh" compost (l. 134) mature enough for sowing just the day after its application?
As indicated above in line 134, we followed the farm's experience in using compost at their farm and fitted the experiment in their regular procedure of using compost. Our main interest in using the compost was not related to its maturity but the high N content of this residue (see Table 3). The term 'fresh' in the context used in l. 134 refers to the mass (20 t ha^{-1}) being the fresh weight, as opposed to the dry weight (7 t ha^{-1}). To avoid confusion, we propose to remove the word 'fresh' from this sentence so that it now reads:

> *Application rates of the different amendments were 20 t ha^{-1} ~~fresh~~ compost (equivalent to 7 t ha^{-1} dry matter), 13.3 t ha^{-1} woodchips (equivalent to 8.7 t ha^{-1} dry matter) and 10±0.8 t ha^{-1} straw (equivalent to 9.2±0.8 t ha^{-1} dry matter).*

L. 150. Table 2 can be moved to supplementary information.
Since Table 2 contains baseline soil data that are not essential to understand the findings of this work, we agree to move it to the Supplement.

L. 151. How long was the composting process? Did you perform any maturity or stability test? What was the average size of the straw and woodchip amendments?
The composting process took 52 days. No maturity or stability tests were performed. The straw was in stalks of about 10-40 cm and the woodchips were about 1.5 x 1.5 x 0.5 cm. The straw was taken from a well-mixed pile.

L. 182. LOI at 430ºC instead of 500ºC as above for residue characterization. Why?
Because the initial soil samples were analysed at the University of Reading, according to our standard in-house protocol, while the later samples were analysed at a commercial laboratory (NRM) according to their standard protocol.

L. 233. The text "some of which were statistically significant (Table 5). Most notably…"is too vague. Only the effects on available N and SOM were significant. Please reword for clarity.
The sentences that follow the quoted text contain further detail about those effects that were significant. Since this was unclear, we suggest to rephrase the paragraph as follows:

> *"Both compost-residue mixtures resulted in a non-additive increase in lettuce yield, available and potentially mineralisable N, available Mg, SOM, and soil respiration, but not in available K (hypothesis 1) some of which were statistically significant, **as further specified below** (Table 5). Most notably, we observed greater available N and SOM levels in soils to which a mixture of residues was applied, compared to the available N and SOM levels in treatments receiving only individual residue amendments. The straw-compost mixture resulted in a significant ($T = 4.022$, $p = 0.014$) non-additive increase in SOM of 13.10%, and while the woodchip-compost mixture did not result in statistically significant non-additivity ($T = 0.954$, $p = 0.205$), it did result in a positive non-additive increase in SOM of 6.73%."*

L. 252-254. I agree with the statement that "measurements from residue-mixture treatments cannot be directly compared to individual-residue treatments." Hypothesis 1, however, is

stated as "faster decomposition of residue mixtures will result in a higher soil respiration rate in the short term, as well as the release of greater levels of soil available nutrients (N, P, K, Mg) and SOM compared to individual residues." Please reword to clarify.
H1 predicts a non-additive increase in soil respiration, but this was not the case. It is different from directly comparing treatments, as the treatments were set up to enable calculation of non-additive effects, not to compare individual treatments.

To clarify we will reword the hypothesis (L. 114) so that it reads:

> *"In particular, we hypothesised faster decomposition of residue mixtures to result in a higher soil respiration rate in the short term, as well as the release of greater levels of soil available nutrients (N, P, K, Mg) and SOM compared to* ***what would be expected by combining the effects of*** *individual residues (hypothesis 1)"*

L. 281 and S3. How were these percentages calculated and on which assumptions? Soil cores used for nutrient analysis were collected to 20-cm depth, whereas bulk density was measured on separate 10-cm-depth soil cores (and the authors still need to specify to what depth the residues were incorporated).
Thank you for pointing out incomplete calculations. The revised calculations are as follows and will be included in the relevant section of the Supplement:

First the mass of nutrients applied per plot was calculated, using the application rate of each residue (kg residue/plot) and the amount of each nutrient in the residues (mg nutrient/kg residue):

$$Nutrients\ applied\ (mg\ plot^{-1}) = Reisude\ applied\ to\ each\ plot\ (kg\ plot^{-1}) \times nutrient\ content\ of\ reisdues\ (mg\ kg^{-1})$$

Then, using the plot volume to 20 cm depth 0.2 m × 6 m × 2 m = 2.4 m3/plot) and the bulk density (g/m3), assuming the bulk density is representative of the top 20 cm and assuming nutrients from the residues applied remained in the top 20 cm of the soil (the sampling depth), we calculated the amount of nutrients added per g of soil via the residues (mg nutrients/g soil) as:

$$Nutrient\ application\ rate\ (mg\ g^{-1}) = \frac{Nutrients\ applied\ (mg\ plot^{-1})}{Area\ of\ the\ plot\ (m^3)} / Bulk\ density\ (g\ m^{-3})$$

Then the difference between the amount of nutrients measured in each plot and the average amount of nutrients measured in the control plots was calculated as:

$$Nutrient\ increase\ (mg\ g^{-1}) = Nutrients\ in\ treatment\ plot\ (mg\ g^{-1}) - nutreints\ in\ control\ plot\ (mg\ g^{-1})$$

Then we determined the increase in soil available nutrients (relative to control) as a proportion of the amount of nutrients added to the soil via residue amendments:

$$Increase\ in\ available\ soil\ nutrients\ (\%) = \frac{Nutrient\ increase\ (mg\ g^{-1})}{Nutrient\ application\ rate\ (mg\ g^{-1})} \times 100\%$$

L. 312. Again hypothesis 1. Here decomposition is measured in terms of soil respiration, so how can it be that faster decomposition of an organic input compared to another results in higher soil respiration and greater levels of soil organic matter at the same time?

Soil samples were sieved to 2 mm before measurements of SOM or respiration were made. Therefore, the > 2 mm pieces of the amendments themselves, although organic, do not directly contribute to the measurement of either SOM, or respiration. We therefore hypothesise that greater respiration and SOM in the residue mixture treatments (compared to single residue treatments) is because the > 2 mm pieces in the residue mixture treatments are decomposed faster and more of the carbon associated with these pieces becomes live microbial biomass, dead microbial necromass, or the products of microbial respiration. We hypothesise that the treatments with only one residue applied decomposed more slowly and so more of the carbon in these samples remains in pieces that are > 2 mm and do not contribute to the SOM or respiration measurements. This hypothesis is related to the understanding that most SOM is derived from microbial processing and the fact that microbes operate at a certain CUE (carbon use efficiency - the fraction of carbon assimilated from organic matter additions to the soil system compared to C losses to the atmosphere via microbial respiration).

L. 322. Do you mean that the Solvita burst method is not accurate enough? Please clarify.

We are not criticizing the accuracy of the Solvita burst method. We are instead acknowledging that the method may not be entirely representative of respiration in the field because (1) samples are removed from the field, (2) sample size is very small, and (3) chunks of residues greater than the sieve mesh are sieved out. Soil respiration may be different when measured under field conditions and in un-sieved condition. Moreover, the small sample size may not be representative of the whole soil plot. We can clarify this in line 322 as follows:

> *"Moreover, our soil respiration measurements were taken by the Solvita burst method, on soil samples removed from the field and sieved to* ***2*** *mm* ***removing parts of residues and other organic matter greater than 2 mm****, which may not have been a good representation of the respiration from a soil mixed with crop residues at various stages of decomposition."*

L. 322. You mentioned above that soils were sieved to 2 mm, and here that they were sieved to 4 mm. Please clarify.

Thank you for pointing this out. We have double-checked this and the 4 mm is a mistake. It should be 2 mm. Thank you for spotting this.

L. 364-365. Organic amendments could stimulate native soil organic matter mineralization while increasing total soil organic matter content. Why not?

Indeed, we agree that organic amendments could stimulate the mineralisation native SOM (priming). However, in line 364-365 we are comparing the SOM level in the straw-compost treatment to the control treatment, rather than assessing the non-additive effect which involves the individual amendment treatments.

We will clarify this by revising as:

> *"Even in the straw-compost treatment, the SOM level was very close to that of the control treatment, suggesting* ***net*** *mineralisation of native SOM* ***as a result of the residue amendment*** *was negligible"*

Table 5 could be moved to supplementary information.

We would be happy to move Table 5 to the Supplement.

We hope we have responded to these comments in a satisfactory manner.