We sincerely thank the reviewer for the constructive comments and suggestions, which helped us to substantially improve our manuscript. Please find the point-to-point responses (blue) to the comments (black) as listed below.

Reviewer 1

Comment 1: I wonder whether authors could extract Ca_2-P and Olsen-P properly. I agree that the potential limitation of the sequential extraction methods as described in p. 8. Line 18-20 but I think that authors have to refer to the difference between Ca_2-P and Olsen-P in Introduction or Materials and methods. Although both of them are extracted with $NaHCO_3$, Ca_2-P is classified into moderate-cycling IP and Olsen-P into labile-P. Moreover, the concentration of Ca_2-P and Olsen-P in each treatment are really similar (Fig.3 a,b and Fig. 5 a,b) and they are significantly positively correlated each other (r= 0.63 and 0.53 in Table 3). I wonder if authors extracted almost same chemical properties. Refer difference between Ca_2-P and Olsen-P in terms of chemical compounds. If they are chemically similar compounds, Ca_2-P should be eliminated from Moderate-cycling IP when SEM were built.

Response: Thanks for the comment. And we agree with the reviewer's comment that Ca_2-P and Olsen P are chemically similar. The description about the difference between Ca_2-P and Olsen-P was added in the Introduction section as "Soil Olsen P could be directly absorbed and utilized by plants, which includes all water-soluble P, some of the absorbed and soluble IP, and mineralizable organic P (Tang et al., 2009; Cao et al., 2012). Ca_2-P, chemically similar to Olsen P, includes water-soluble P, citrate-soluble P, and partially surface-adsorbed P (Shen et al., 2004; Zhao et al., 2019)" (P. 4 Lines 23-24). Therefore, we defined Ca_2-P as labile IP and Olsen-P as available P (P. 4 Lines 16-19). And the SEM has been reanalyzed by eliminating Ca_2-P from moderate-cycling IP, where it was defined as the labile IP in the SEM modeling.

Reference cited:

Shen, J., Li, R., Zhang, F., Fan, J., Tang, C., Renfenl, Z.: Crop yields, soil fertility and phosphorus fractions in response to long-term fertilization under the rice monoculture system on a calcareous soil, Filed Crop Res. 86, 225-238.
Tang, X., Ma, Y., Hao, X., Li, X., Li, J., Huang, S., Yang, X.: Determining critical

values of soil Olsen-P for maize and winter wheat from long-term experiments in China, Plant Soil, 323:143-151.

Cao, N., Chen, X., Cui, Z., Zhang, F.: Change in soil available phosphorus in relation to the phosphorus budget in China, Nutr. Cycl. Agroecosyst, 94: 161-170, 10.1007/s10705-012-9530-0, 2012.

Zhao, F., Zhang, Y., Dijkstra, F. A., Li, Z., Zhang, Y., Zhang, T., Lu, Y., Shi, J., and Yang, L.: Effect of amendments on phosphorous status in soils with different phosphorous levels, Catena 172, 97-103.

Comment 2: I have some concern about SEM. At first, how do the authors handle N addition effects when making SEM? There is no description about that. Second, the description "Moderate-cycling IP was mainly regulated by plant biomass" (e.g. p.2 line 14-15) sounds strange. In this study, plant biomass is also affected by soil IP. Finally, not only IP but Organic P also affects TP because the percentage of each IP fraction to total P (TP) is less than 50%. Organic P (TP-TIP) fraction accounts large part of TP and must have great effects on TP in this study. Author should explain these three points and reanalyze them.

Response: Thanks for the constructive suggestions. We revised the manuscript according to all the suggestions as mentioned above. First, N and P addition effects have been incorporated into the SEM (please see Fig. 6), which was described in the Statistical analysis section as "Structural equation models (SEM) were built to clarify direct and indirect N and P addition effects on soil P fractions through the changes in plant P uptake and soil pH" (P. 11 Lines 7-8). Second, we replaced the parameter of plant biomass with plant P uptake in the SEM, because the plant P uptake intensity (amount) instead of plant biomass can directly affect soil P dynamics. Third, we fully agree with the point that soil organic P has great effects on TP and we tried to add the soil organic P into the SEM. However, there are multiple collinearities (variance proportions = 0.97) between soil organic P and soil TP resulting in the failure of the SEM. Thus, we added the correlation between organic P and TP to illustrate the significant contribution of organic P to TP in Table 3.

Comment 3: I have serious concern about description in Results section of this study. This paper has several mistakes in the Results section. Some description in Results do not correspond to the relevant Table and Figure. Some specific comments are written

below.

Response: We have addressed these concerns in the following responses to specific comments.

Specific comments

p.4 line 16-18: It may be appropriate to show which fraction of inorganic P increased in the previous study.

Response: Thanks for the comment. We have added the information of which inorganic P fractions increased in the previous study as "In a previous study it was found that long-term application of $Ca(H_2PO_4)_2$ increased soil IP fractions (Al-P, Fe-P, Ca_2-P, Ca_8-P and O-P) and total P (TP) concentrations in a calcareous soil (Wang et al. 2010)" (P. 5 Lines 22-24).

p. 6 line 4-7 (2nd hypothesis): I cannot understand how hypothesis 2 was derived. I particularly do not understand why authors hypothesized that recalcitrant P would be higher with KH_2PO_4 addition than with $Ca(H_2PO_4)_2$ addition. I think that it takes much time to form recalcitrant P from labile-P. Authors should add explanation about chemical properties of recalcitrant IP with introducing previous studies.

Response: Thanks for the comment. We hypothesized that recalcitrant P would be higher with KH_2PO_4 addition than with $Ca(H_2PO_4)_2$ addition, because more soluble KH_2PO_4 can convert into labile and moderate-cycling IP fractions faster and consequentially promoting the formation of recalcitrant IP fractions. We agree that it takes much time to form recalcitrant P from labile P, but the time should be shorter for KH_2PO_4 addition than $Ca(H_2PO_4)_2$. Here, hypothesis 2 has been clarified as "addition of soluble KH_2PO_4 would be more efficient in increasing soil labile IP, moderate-cycling IP fractions, recalcitrant P fractions and total P (TP) than less-soluble $Ca(H_2PO_4)_2$, because of faster conversion of KH_2PO_4 into labile and moderate-cycling IP fractions and consequentially promoting the formation of recalcitrant fractions" (P. 7 Lines 9-14). We have added chemical properties of soil recalcitrant IP in the introduction section as "Soil recalcitrant IP is relatively stable and unavailable for plants, which is mainly converted from the fixation of labile and moderate-cycling IP (Shen et al., 2004; Zhao et al., 2019)" (P. 4 Line 25-P. 5 Line 1).

We hope this information would help to support the 2nd hypothesis.

Reference cited:

Shen, J., Li, R., Zhang, F., Fan, J., Tang, C., Renfenl, Z.: Crop yields, soil fertility and phosphorus fractions in response to long-term fertilization under the rice monoculture system on a calcareous soil, Filed Crop Res. 86, 225-238, 10.1016/j.fcr.2003.08.013, 2004.

Zhao, F., Zhang, Y., Dijkstra, F. A., Li, Z., Zhang, Y., Zhang, T., Lu, Y., Shi, J., and Yang, L.: Effect of amendments on phosphorous atatus in soils with different phosphorous levels, Catena, 172, 97-103, https://doi.org/10.1016/j.catena.2018.08.016, 2019.

p.4 line 16-20: These two sentences introduce the previous studies which results were opposite. The connection of them is not good. I think that these two sentences should change to "Some previous study showed that~~~ and other one showed that ~~~. "

Response: Thanks for the helpful suggestion. This sentence has been corrected accordingly (P. 5 Line 22- P. 6 Line 1).

It may be appropriate to explain how large three species of plants (*Stipa baicalensis, Leymus chinensis* and *Carex duriuscula*) are occupied per area if authors have some data. Is there difference of dominant ratio among treatments?

Response: As suggested, we calculated and analyzed the relative biomass proportion of the three species (shown in P. 8 Lines 2-6) which showed no difference among P addition rates but significantly increased with N addition. The data for relative proportion of the three dominant species has been listed in the following table.

Table Sum of the relative biomass (%) of three dominant plant species (*Stipa baicalensis*, *Leymus chinensis* and *Carex duriuscula*) as affected by P addition type and rate without and with N addition, respectively.

P rate (kg P ha^{-1} yr^{-1})	KH_2PO_4		$Ca(H_2PO_4)_2$	
	Without N	With N	Without N	With N
0	61.07±6.75	82.16±4.31	61.07±6.75	82.16±4.31
20	65.35±8.34	80.73±5.62	54.56±4.77	81.21±4.62
40	63.94±6.83	83.15±7.56	67.16±6.61	85.06±3.96
60	73.61±2.77	83.37±6.00	50.29±7.12	89.05±3.25
80	67.39±6.89	89.23±2.30	59.60±6.28	91.92±2.22
100	74.75±5.86	72.43±9.92	65.07±3.30	83.11±5.30

p.9 line 3-5 and p.10 line 11 and other: "P uptake" should be replaced by another word (i.e. the biomass-weighted P concentration). In this study, authors just determined the concentration of P in plant body not the P uptake.

Response: We thank the reviewer for the suggestion. But here we calculated the amount of P uptaken by the three dominant species via multiplying P concentration by plant biomass (P. 10 Lines 13-15). It's not biomass-weighted P concentration which is determined via multiplying P concentration by plant biomass proportion.

Explain about dataset authors have. According to Materials and methods, authors used 110 plots in total including replication, which means that 0 kg P ha^{-1} yr^{-1} treatments are overlapped between KH_2PO_4 and $Ca(H_2O_4)_2$ fertilization. Although most of their data looks same among KH_2PO_4 and $Ca(H_2O_4)_2$ fertilization when 0 kg P were added but some are different. For example, soil pH is almost same between N treatment when 0 kg KH_2PO_4 were added (Fig. 1e) but there is difference between N treatment when 0 kg $Ca(H_2O_4)_2$ were added. Explain why some data are difference when 0 kg P were added as seen in soil pH.

Response: Sorry for the confusion. In the field experiment, we have 5 replicate control plots for both KH_2PO_4 and $Ca(H_2O_4)_2$ fertilization. In our previous version, we forgot to overlap the control plots between KH_2PO_4 and $Ca(H_2O_4)_2$ fertilization for soil pH. But it is correct for all the other parameters. Now, we have corrected and reanalyzed the data of soil pH (Fig. 1e, f).

p.10 line 21-23: Unclear, explain more in detail

Response: Thanks for the comments. This sentence mainly explained the interactive $P_r \times N$ and $P_t \times P_r \times N$ effects on soil Al-P. It has been clarified into "For instance, Al-P concentration was higher with KH_2PO_4 addition than $Ca(H_2PO_4)_2$ at P addition level of 60 kg P ha^{-1} yr^{-1} when N was not added, but it was higher for P addition levels of 60, 80 and 100 kg P ha^{-1} yr^{-1} when N was added" (P. 12 Lines 5-8).

Results 3.3 and 3.4: There are many faults. Relevant Figure and Table does not show the result which are written in manuscript. First of all, it is strange that there are two

"3.3" section. Specific comments are below.

Response: Sorry for the confusion. We have changed the second 3.3 to 3.4 and changed 3.4 to 3.5. Responses for all the specific comments are listed below.

p.11 line 10-13: Fig 4a, b and Table S2 does not show the results as described in manuscript. I think authors should replace "0, 40, 100" by "20, 60, 80" according to Table S2. Moreover, Table S2 just shows whether there is difference of soil IP fraction between types of added P compounds (KH_2PO_4 and $Ca(H_2O_4)_2$) or not but it does not show which is higher or lower between them. However, Table S2 does not coincide with Fig.4a and b. For example, Table S2 shows that soil Ca_{10}-P are significantly different (Student t-test, $p<0.01$) between KH_2PO_4 and $Ca(H_2PO_4)_2$ addition when 0 kg P were added but they look no different in Fig 4a and b. I think something is wrong and authors should reconfirm the dataset and reanalyze them.

Response: We thank the reviewer for pointing this out. We checked all the data and presented Table S2 with means ± standard error in order to show which P type was higher. According to Table S2, we replaced 0, 40 ,100 by 40, 60, 100. We feel really sorry that we mistakenly did not present the data from the same control of KH_2PO_4 addition as $Ca(H_2PO_4)_2$ in Table S2 in our previous version (but the data of 0 kg P presented in Figure 4 were correct) (same correction mentioned for soil pH data). This has been corrected in the current version where we now used the data from the same control plots.

p.11 line 14-16: There is no asterisk in Fig. 4d. I cannot judge whether there is significant difference between Without N and N addition at 60 and 80 kg P ha^{-1} yr^{-1}.

Response: Sorry for the confusion. We added the asterisks in Fig. 4d.

p.11 line18-20: Unclear, explain more in detail. What about O-P for 0 kg P ha^{-1} yr^{-1} treatment with N addition? Table S2 shows the significant difference between KH_2PO_4 and $Ca(H_2PO_4)_2$ addition ($p<0.05$).

Response: We thank the reviewer for pointing this out. We feel sorry for our mistake in presenting the data from control plots. The O-P concentration should be the same in the control plots for KH_2PO_4 and $Ca(H_2PO_4)_2$ addition, as we used the same control

plots for the two P types as described in the Material and Method section. This has been corrected.

p.12 line 3-4: Fig. 5d does not show that results. Soil TP with $Ca(H_2PO_4)_2$ does not increase with increasing P addition when N was added.

Response: Thanks for the observation. This sentence has been corrected into "KH_2PO_4 addition increased soil TP irrespective of N addition, while $Ca(H_2PO_4)_2$ addition only increased soil TP without N addition".

p.12 line 7-8: There are no results which indicate correlation between TP and moderate-inorganic IP (Fe-P, Al-P, Ca_2-P, Ca_8-P) in Table 3.

Response: Thanks so much for the observation. We added the correlation between soil TP and moderate-cycling IP (Al-P, Fe-P and Ca_8-P) in Table 3.

p.13 line 1: "applied P was immobilized mainly into inorganic forms" sounds strange. "Immobilization" is the conversion of inorganic materials to organic ones.

Response: As per suggestion, we replaced the word "immobilized" with "fixed" (P. 14 Line 15).

Add "soil" before each P fraction. Some are already added but I think that authors should unify the expression about soil IP fraction.

Response: We agree with the reviewer and have added "soil" before each P fractions in the manuscript.

Is the term "recalcitrant inorganic phosphorus" used commonly?

Response: Yes, we found some references about recalcitrant IP. In this study, we defined Ca_{10}-P and O-P as the recalcitrant IP which is insoluble and unavailable for plants. Miller et al (2001) introduced that most soil P exists in recalcitrant minerals and forms soil recalcitrant phosphate with the depletion of primary minerals. In addition, Lawrence et al (2001) also proposed the conversion of recalcitrant inorganic phosphorus into other P forms.

Reference cited:
Miller, A., Schuur, E., Chadwick, O.: Redox control of phosphorus pools in Hawaiian

montane forest soils, Geoderma, 102: 0-237, 10.1016/s0016-7061(01)00016-7, 2001.

Lawrence, D and Schlesinger, W.: Changes in soil phosphorus during 200 years of shifting cultivation in Indonesia, Ecology, 82: 2769-2780, 10.2307/2679959, 2001.

p.15 line 13: not "P demand" but "concentration of P in plant" as pointed out above.

Response: It's not "concentration of P in plant", because plant P uptake (g P per m^2) was calculated via multiplying plant P concentration (g P kg^{-1} biomass) by plant biomass (g m^{-2}).

p. 15 line 3-6: The sentence is wordy.

Response: Thanks for the comments. We reanalyzed the SEM and clarified the description into "The decrease in soil pH contributed to the increase in labile P with $Ca(H_2PO_4)_2$ addition (Fig. 6b)" (P. 16 Lines 20-21) according to the SEM model.

Conclusion: I think that authors should suggest how to fertilize P and N appropriately on grassland ecosystems to maintain plant productivity in Conclusion based on the results of this study.

Response: Thanks for the constructive suggestion. This information has been added in the Conclusion section as "Overall, P fertilization is necessary for promoting productivity and sustainable management of grasslands by maintaining soil P availability and pools under scenarios of ecosystem N enrichment" (P. 19 Lines 23-25).

Technical corrections

p.3 line 17 and other: Olsen P => Olsen-P

Response: As per suggestion, we replaced "Olsen P" with "Olsen-P".

p.4 line17: inorganic P => IP

Response: As per suggestion, we replaced "inorganic P" with "IP".

p.7 line 1: phosphorus => P

Response: As per suggestion, we replaced "phosphorus" with "P".

Caption of Fig. 7: moderate-cycling P => moderate-cycling IP

Response: As per suggestion, we replaced "moderate-cycling P" with "moderate-cycling IP" in Fig. 7 caption.

Fig. 4c: Replace lowercase letters (i.e. a, b) by capital letters (i.e. A, B).

Response: As suggested, we replaced lowercase letters (i.e. a, b) by capital letters (i.e. A, B) in Fig 4c.

Fig. 5a: The vertical axis labels of Fig. 3a and c and the horizontal axis labels of Fig. 5a are written in bold type and they should be changed.

Response: Thanks for the observation. We have corrected the vertical axis labels of Fig. 3a and c and the horizontal axis labels of Fig. 5a.

Fig. 6: Explain what the width of arrows means.

Response: We thank the reviewer for pointing this out. The width of arrows is proportional to the strength of the relationship, which has now been explained in the figure caption.

Fig. S1 and 2: Replace "N0" and "N10" by "Without N" and "N addition." The terms "N0" and "N10" are not used in the main manuscript.

Response: Thanks, we have replaced "N0" and "N10" with "Without N" and "N addition" in Fig. S1 and Fig. S2.

I recommend that authors use consistent color for "Without N" and "N addition" in figures for easy understand. In current manuscript, white bar represents "Without N" in the bar graph, whereas white dot represents "N addition" in the scatter plots. Red fitted line represents "Without N" in Fig. 1c, d and "N addition" in Fig. 2, 3.

Response: Thanks for pointing this out. We have corrected the dot figures for consistency using white and black colors to represent "Without N" and "N addition", respectively. Moreover, black and red lines were fitted for "Without N" and "N addition" treatments, respectively.