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# Characteristics of N and P Loss in the Soil of Purple Sloping Farmland at Different Fertilization Levels*

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**Abstract**: Using the "Winter Wheat-Summer Maize" model and the plot runoff monitoring method, we studied the characteristics of nitrogen and phosphorus loss in the soil sediment of purple sloping farmland under five conditions, including control, combined manure/fertilizer application, chemical fertilizer, high intensity chemical fertilizer, and cross ridge farming. The results showed that the nutrient content of the surface soil increased, to some extent. Furthermore, the nutrients were enriched in the sediment for all groups. The degree of sediment nutrient enrichment of cross ridge farming was less great compared to longitudinal farming. For the combined manure/fertilizer application, the ratio of effective nutrients was larger than that of total nutrients; whereas, for the chemical fertilizer group, the ratio of effective nutrients was significantly smaller. At all fertilization levels, sediment loss only accounted for 0.34% ~6.21%. 78.80% ~84.83% of the total phosphorus loss occurred in the sediment, and the phosphorus loss was largely in the sediment. The relative loss factor of nitrogen was the largest for the chemical fertilizer group, followed by the cross ridge farming group, the high intensity chemical fertilizer group, and the combined manure/fertilizer application group. The relative loss factor of phosphorus was the largest for the high intensity chemical fertilizer group, followed by the cross ridge farming group, the chemical fertilizer group, and the combined manure/fertilizer application group.

**Key words**: purple soil; sloping farmland; fertilization level; rainfall; sediment; *N* and *P* loss

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In China, purple soil is widely distributed in Yunnan, Guizhou, Hunan, Zhejiang, Jiangxi, Jiangsu, and, particularly, Sichuan. Purple soil is characterized by a short development time and strong physical weathering, by which a large amount of loose detritus with weak cementation capability can easily form. Moreover, the purple soil distribution areas are usually high mountains with rich and focused precipitation (e. g. frequent rainstorms), and thus have serious soil erosion [1-3]. In addition, these areas are mostly conventional agricultural production areas, and nitrogen and phosphorus fertilizers have been widely used in these areas. Hence, the agricultural pollution in these areas is mainly caused by excessive nitrogen and phosphorus fertilizer, inappropriate fertilizer ratios, and soil erosion. The loss of nitrogen and phosphorus in the sloping farmland of purple soil areas has received wide attention [4-6]. Yu et al[7]. suggested that nitrate loss is the major cause of nitrogen loss in dry arable soil. Yuan et al[8]. found that the loss of nitrogen and phos-

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phorus is mostly focused in the rainy months of May, June, and August. Based on this finding, they suggested that rainfall is both the driving force and the carrier of nutrient loss in soil. In the present study, using the "Winter Wheat-Summer Maize" model, we studied the characteristics of nitrogen and phosphorus loss in the farmland soil sediment of 15° purple slopes under different fertilization conditions. Our study provides scientific evidence for designing appropriate fertilization systems and subsequently reducing pollution caused by fertilizer runoff.

# 1 Materials and Methods

## 1.1 Materials and experimental design

The study area (106°24′20″E, 29°48′42″N) is located in the mountain farm of Southwest University in Chongqing City. The area is 15° sloping farmland on the west side of a hill. The area has a subtropical monsoon climate with annual precipitation of 1 100 mm, average annual temperature of 18.3 ℃, and annual sunlight of 1 270 hours. The soil in this area is purple clay with medium productivity, and has the local name of Shaximiao purple soil.

A representative area was selected in the study area, divided into 15 runoff plots (5 groups with 3 replicates for each group). The plots had an area of 32 $m^2$ (8 m×4 m). Runoff plot setting is shown in Fig. 1 The plots were separated with cement ridges to prevent the diffusion of water and nutrients. The cement ridges had a width of 20 ~ 30 cm, with a 30 cm underground part and a 20 cm above ground part. The runoff pool had brick or cement walls with a designed volume of 1.8 $m^3$ (1.5 m×1.2 m×1.0 m). A groove was dug near the runoff pool along the 4 m sideline, and a "V" shape runoff inlet was set in the center of the groove. The height of the runoff inlet was the same for all plots.

Fig. 1 Runoff plot setting

<table>
<tr><td colspan="7">Protective role</td></tr>
<tr><td rowspan="2">Protective row</td><td>Control<br>T0</td><td>Combined<br>manure/fertilizer<br>application<br>T1</td><td>Chemical<br>fertilizer<br>T2</td><td>High intensity<br>chemical fertilizer<br>T3</td><td>Cross ridge<br>T4</td><td rowspan="2">Protective row</td></tr>
<tr><td>Plot 1</td><td>Plot 2</td><td>Plot 3</td><td>Plot 4</td><td>Plot 5</td></tr>
</table>

## 1.2 Sampling and analysis

1.2.1 *Precipitation acquisition* An automatic precipitation meter was used to record the intensity of each rainfall.

1.2.2 *Soil sample acquisition* Before the experiment, samples of soil at depths of 0 ~ 20 cm and 20 ~ 40 cm were collected from the study area and mixed to calculate the baseline value of soil productivity. After the experiment, 0 ~ 20 cm soil samples were collected from each plot using the diagonal mixing method. For each plot, a 1 kg soil sample was collected to measure the content of total *N*, total *P*, total *K*, and their effective components.

1.2.3 *Acquisition of runoff water and sediment* During rainfall, the runoff was measured first. Following that, a clean bamboo pole was used to fully mix the runoff water, and water samples were collected at different sites and depths, put into cleaned water bottles, and labeled. Each sample had two bottles with a volume of more than 500 mL, of which one was used for analysis and the other one was stocked. After the runoff became clear, the upper clear water layer was discharged. The sediment at the bottom of the runoff pool was collected and weighed. The runoff pool was cleaned with water for future use. The collected water samples were directly used for the measurement of total *N* and total *P*. After filtering with quantitative filter paper and 0.45 μm membrane, the water samples were measured for the contents of soluble *P*, nitrate, and ammonia, or stocked at −20℃ for future measurement.

1.2.4 *Sample analysis* Soil nutrient content was measured using routine agricultural analytical methods. The nutrient content of the water and sediment samples was measured as follows: nitrate was measured using phenol disulfonic acid spectrophotometry (GB/T7480-87), ammonia was measured using indophenol blue colorimetry (GB17378.4), total *N* was measured using the persulfate oxidation - UV spectrophotometry method (GB11894-89), total *P* and soluble *P* were measured using the persulfate digestion - molybdenum blue method (GB11893-89).

### 1.3 Data analysis

Data analysis and creation of figures were performed using Excel 2003 software, SPSS10.0 software and DPS software.

## 2 Results and Analysis

### 2.1 Nutrient content of surface soil under different fertilization conditions

Slope surface soil is directly involved in rainfall erosion and soil erosion. To prevent soil degradation and improve land productivity, it is critical to analyze the changes in the nutrient content of surface soil to better understand the effects of the fertilization mode on the speed of soil degradation.

To study the dynamic distribution of soil nutrients under different fertilization conditions, we compared the nutrient content of 0 ~ 20 cm soil before and after the fertilization experiment in multiple plots. The contents of different types of nutrients in the surface soil are shown in Tab. 1.

As shown in Tab. 1, the nutrient content of the surface soil increased under all fertilization conditions except *T*0, indicating that fertilization can indeed improve soil fertility and prevent soil degradation. The orders of increase of different nutrients were as follows: 1) total *N*, *T*3>*T*1>*T*4>*T*2 (i.e. high intensity chemical fertilizer > combined manure/fertilizer application > cross ridge farming > chemical fertilizer; 2) effective *N*, *T*4 > *T*3 > *T*1 > *T*2; 3) total *P*, *T*3 > *T*4 = *T*2 > *T*1 (note: *T*1 showed a reduced nutrient content compared to the control group); 4) soluble *P*, *T*3>*T*4>*T*1>*T*2.

Comparing the average degree of fertilization-induced nutrient increase, we found that total *N* showed the largest increase, followed by effective *N*, and soluble *P*, while total *P* failed to show any obvious increase.

### 2.2 Characteristics of sediment *N/P* loss under different fertilization conditions

2.2.1 *Sediment N/P content under different fertilization conditions* A large number of surface soil nutrients are lost with sediment due to the surface runoff on sloping land, which not only results in the siltation of rivers and lakes and subsequently the contamination of water, but can also reduce the thickness of soil tillage and the productivity of soil. The loss of soil nutrients is significantly affected by the slope fertilization mode.

Tab. 1 Comparison of nutrient content in surface soil (0 ~ 20 cm) under different fertilization conditions

| | | Total *N*/($g \cdot kg^{-1}$) | Effective *N*/($mg \cdot kg^{-1}$) Nitrate | Ammonia | Sum | Total *P*/($g \cdot kg^{-1}$) | Soluble *P*/($mg \cdot kg^{-1}$) |
|---|---|---|---|---|---|---|---|
| Before experiment | | 0.76 | 19.51 | 24.19 | 43.70 | 0.68 | 18.29 |
| | T0 | 0.72 | 18.47 | 19.83 | 38.30 | 0.58 | 17.10 |
| After experiment | 19.60 | T1 | 1.01 | 20.07 | 23.79 | 43.86 | 0.64 |
| | 18.19 | T2 | 0.86 | 20.26 | 23.57 | 43.83 | 0.68 |
| | 21.98 | T3 | 1.15 | 20.26 | 24.01 | 44.27 | 0.74 |
| | 20.60 | T4 | 0.90 | 20.27 | 24.87 | 45.14 | 0.68 |

Tab. 2 Nutrient enrichment ratio of sediment on different fertilization levels

| Group \ Enrichment ratio | Total *N* | Effective *N* Nitrate | Effective *N* Ammonia | Total *P* | Soluble *P* |
|---|---|---|---|---|---|
| T0 | 1.079 | 0.999 | 0.988 | 1.088 | 1.050 |
| T1 | 1.013 | 1.390 | 1.590 | 1.029 | 1.230 |
| T2 | 1.710 | 1.009 | 1.007 | 1.250 | 1.046 |
| T3 | 2.120 | 1.013 | 1.002 | 1.544 | 1.022 |
| T4 | 1.118 | 0.998 | 0.983 | 1.147 | 0.988 |

A number of studies have suggested that soil erosion can result in the enrichment of nutrients in the sediment, which can be described by the enrichment ratio, namely, the percentage of sediment nutrients in the total surface soil nutrients. As shown in Tab. 2, the enrichment ratio was 1.079 ~ 2.120 for total *N*, 0.998 ~ 1.390 for nitrate, 0.983 ~ 1.590 for ammonia, 1.029 ~ 1.544 for total *P*, and 0.988 ~ 1.230 for soluble *P*. The results indicated that all types of nutrients were enriched in the sediment. The order of the average enrichment ratio was as follows: total *N* (1.408) > total *P* (1.212) > *ammonia* (1.114) > *nitrate* (1.082) > soluble *P* (1.067), indicating that in purple sloping farmland, total *N* and total *P* were the easiest to lose during runoff, followed by ammonia, nitrate, and soluble *P*.

Under different fertilization conditions, the regularities of nutrient enrichment in the sediment differed, as follows: 1) in the *T0* group (control), the total *N*, total *P*, and soluble *P* were enriched, to some extent, while they were not significantly enriched under other fertilization conditions; 2) in the *T1* group (combined manure/fertilizer application), the total *N*, total *P*, effective *N* (i. e. ammonia, nitrate), and soluble *P* all were enriched, and the latter two nutrients showed a higher enrichment ratio, indicating that under this fertilization mode, the effective nutrients in the surface soil were easily lost compared to the total nutrients.

Analysis of nutrient enrichment ratios for *T2*, *T3*, and *T4* revealed that in all three groups, the total nutrients showed higher enrichment ratios compared to the effective nutrients. This is probably because in these groups only chemical fertilizer was used, which, unlike manure, cannot promote the formation of soil granule aggregates or adjust the ratio of air and water in the soil. Further analysis revealed that the nutrient enrichment ratio also differed among different fertilization modes. Compared to *T2*, *T3* showed obvious changes in the enrichment ratios of total nutrients but not effective nutrients. These observations indicated that for the chemical fertilizer group, higher amounts of fertilizer could enhance the loss of total nutrients but not effective nutrients in the sediment. Compared to *T3*, *T4* showed decreases in all types of nutrients, indicating that cross ridge farming can reduce the loss of nutrients in the sediment compared to longitudinal farming.

2.2.2 *Amount of sediment N/Ploss under different fertilization conditions* The amount of sediment *N/P* loss was calculated as the product of the sediment amount and the average nutrient content in the sediment (Tab. 3).

Tab. 3 Nutrient loss by sediment-carrying

| Group \ Amount of loss | Total N /($kg \cdot hm^{-2}$) | Effective *N* /($kg \cdot hm^{-2}$) Nitrate | Ammonia | Sum | effective/ total/% | Total *P* /($kg \cdot hm^{-2}$) | Soluble *P* /($kg. hm^{-2}$) | effective / total/% |
|---|---|---|---|---|---|---|---|---|
| T0 | 0.337 6 | 0.008 0 | 0.009 8 | 0.017 9 | 5.29 | 0.304 7 | 0.007 9 | 2.59 |
| T1 | 0.099 5 | 0.003 5 | 0.005 0 | 0.008 5 | 8.52 | 0.288 2 | 0.009 3 | 3.21 |
| T2 | 0.210 7 | 0.003 2 | 0.004 0 | 0.007 1 | 3.39 | 0.350 0 | 0.007 9 | 2.25 |
| T3 | 0.125 9 | 0.001 5 | 0.001 9 | 0.003 4 | 2.73 | 0.432 3 | 0.007 7 | 1.78 |
| T4 | 0.035 3 | 0.000 8 | 0.001 0 | 0.001 8 | 5.09 | 0.321 2 | 0.007 4 | 2.32 |

The *T0* groups (control) showed the highest loss of total *N*, nitrate *N*, and ammonia, which were 0.3 376 $kg \cdot hm^{-2}$, 0.0 080$kg \cdot hm^{-2}$, and 0.0 098$kg \cdot hm^{-2}$, respectively. Furthermore, the loss of total *P* and soluble *P* of *T0* was not the lowest among the five groups, indicating that fertilization could not increase the nutrient loss in the sediment. As the nutrient loss was determined by both the nutrient content and the sediment amount, this result was probably caused by the largest amount of sediment of *T0*, which in turn was induced by its low degree of vegetation coverage. In addition, the different loss extents of *N* and *P* indicated that the mechanisms underlying the loss of these two types of nutrients were also different.

The *T1* group (combined manure/fertilizer application) showed the lowest loss of total $N$ and total $P$, which were 0.0995kg. $hm^{-2}$ and 0.2882 kg. $hm^{-2}$, respectively. However, the percentages of effective $N$ and $P$ were the largest, which were 8.52% and 3.21%, respectively, indicating that under the condition of combined manure/fertilizer application, effective nutrients can be more easily lost compared to total nutrients.

Comparing $T2$, $T3$, and $T4$, we found that $T4$ showed the lowest loss of nutrients in the sediment, indicating that cross ridge farming can reduce the loss of nutrients compared to longitudinal farming. Furthermore, $T3$ showed less loss of all nutrients than $T2$, indicating that increasing the fertilizer amount might not result in enhanced nutrient loss, which could be determined by the degree of the vegetation coverage. In addition, comparing the ratio between the effective nutrients and total nutrients, we found that under all fertilization conditions, the loss of effective $P$ was always less than that of effective $N$.

2.2.3 *Comparison of runoff N/P loss under different fertilization conditions* It has been widely accepted that runoff erosion and sediment carrying are two major causes for the soil nutrient loss of purple sloping farmland. However, the main carrier and the dominant pathway of nutrient loss have remained controversial. Wang et al[9]. analyzed the watershed rainfall, runoff and sediment nutrient content in the purple soil areas of Sichuan Province, and found that runoff was the major pathway for nutrient loss in purple soil. Fu et al. [10] studied the regularities of nutrient loss under different rainfall and slope conditions in the purple soil areas of the Three Gorges Reservoir using an indoor rainfall simulation device, and found that sediment was the predominant carrier for nutrient loss, and runoff also had some effects. Huang et al[11]. suggested that in the purple soil areas of the Three Gorges Reservoir, the $N$, $P$ and K loss of slope soil were mainly caused by sediment loss, and the <0.02 mm aggregates and < 0.002 mm clay were the major carriers of nutrient loss.

In the present study, we also compared the amount of runoff and sediment nutrient loss under different fertilization conditions, As shown in Tab. 4, under all fertilization conditions, $T2$ showed the highest loss of total $N$ in runoff and sediment, which was 22.576 kg · $hm^{-2}$ · a, followed by $T3$ (12.387kg · $hm^{-2}$ · a), $T4$ (10.515kg · $hm^{-2}$ · a), $T1$ (6.1595kg · $hm^{-2}$ · a), and $T0$ (5.441kg · $hm^{-2}$ · a). These results indicated that fertilization resulted in an increase in the loss of total $N$ in sloping farmland. Also, combined manure/fertilizer application can reduce $N$ loss compared to application only of chemical fertilizer. Furthermore, cross ridge farming can reduce $N$ loss compared to longitudinal farming. In addition, increasing the amount of fertilizer might not increase $N$ loss.

Tab. 4 Comparison of nitrogen loss in runoff and sediment under different fertilization conditions

| | Runoff/(kg · $hm^{-2}$ · $a^{-1}$) | | | | Sediment/(kg · $hm^{-2}$ · $a^{-1}$) | | | | Ratio of total N loss/% | | Total loss/(kg · $hm^{-2}$ · $a^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total $N$ | Nitrate | Ammonia | $(N+A)/T$(%) | Total $N$ | Nitrate | Ammonia | $(N+A)/T$(%) | Runoffloss | Sedimentloss | Total $N$ | Nitrate | Ammonia |
| $T0$ | 5.102 9 | 1.766 9 | 1.304 8 | 60.2 | 0.337 6 | 0.008 0 | 0.009 8 | 5.29 | 93.79 | 6.21 | 5.440 5 | 1.774 9 | 1.314 7 |
| $T1$ | 6.060 1 | 2.049 7 | 1.513 5 | 58.8 | 0.099 5 | 0.003 5 | 0.005 | 8.52 | 98.38 | 1.62 | 6.159 5 | 2.053 2 | 1.518 5 |
| $T2$ | 22.365 6 | 3.493 2 | 2.301 2 | 25.91 | 0.210 7 | 0.003 2 | 0.004 | 3.39 | 99.07 | 0.93 | 22.576 3 | 3.496 4 | 2.305 2 |
| $T3$ | 12.261 | 4.065 5 | 3.132 6 | 58.71 | 0.125 9 | 0.001 5 | 0.001 9 | 2.73 | 98.98 | 1.02 | 12.387 | 4.067 | 3.134 5 |
| $T4$ | 10.480 1 | 2.155 8 | 2.083 1 | 40.45 | 0.035 3 | 0.000 8 | 0.001 | 5.09 | 99.66 | 0.34 | 10.5154 | 2.156 6 | 2.084 1 |

Under all fertilization conditions, the loss ratio of nitrate and ammonia in the total $N$ was 40.45% ~ 60.2% for runoff, and a much lower 2.73% ~ 8.52% for sediment. Furthermore, runoff accounted for 93.79% ~ 99.66% of total $N$ loss (5.102 9 ~ 22.365 6 kg · $hm^{-2}$ · a), while sediment only accounted for 0.34% ~ 6.21% (0.0353% ~ 0.3376 kg · $hm^{-2}$ · a). These results indicated that in purple sloping farmland, runoff accounted for most of the *N* loss under all fertilization conditions, which is consistent with the findings of Wang et al. [9].

The results in Tab. 4 also show that compared to *T0* (control), the loss of all types of nitrogen in runoff increased under all fertilization conditions. In detail, the nutrient loss increased by 0.19 ~ 3.38 fold for total N, 0.16 ~ 1.30 fold for nitrate, and 0.16 ~ 1.40 fold for ammonia. However, the *N* loss decreased in sediment under all fertilization conditions. The nutrient loss decreased by 0.60 ~ 8.51 fold for total *N*, 1.28 ~ 9.00 fold for nitrate, and 0.96 ~ 8.8 fold for ammonia. The discrepancy between runoff and sediment indicated that fertilization can increase runoff *N* loss while decreasing sediment *N* loss. This could be because fertilization can promote the growth of plant roots, which in turn can consolidate the soil and enhance the permeability of the soil. As a result, the *N* loss in the sediment would be decreased. Meanwhile, fertilization can increase the N content in the surface soil, and runoff can cause the loss of the unabsorbed *N*, resulting in increased *N* loss in the runoff.

As shown in Tab. 5, under all fertilization conditions, the loss ratio of soluble *P* in the total *P* was 4.99% ~ 8.22% for runoff, and a lower 2.46% ~ 4.21% for sediment. Furthermore, runoff only accounted for 15.17% ~ 21.20% of total *P* loss (0.054 5 ~ 0.116 3 $kg \cdot hm^{-2} \cdot a$), while sediment accounted for 78.80% ~ 84.83% (0.288 2 ~ 0.432 3 $kg \cdot hm^{-2} \cdot a$). These results indicated that in purple sloping farmland, sediment accounted for more than 80% of the *P* loss under all fertilization conditions. Hence, sediment was the major pathway for *P* loss. However, runoff *P* loss was also important, because the ratio of soluble *P* loss was larger for runoff than for sediment. This result is consistent with that reported by Wang et al. [9], but differs from that of Fu et al. [10]. Further study is required to elucidate the discrepancy.

Based on the amount of *N* and *P* loss under different fertilization conditions, we calculated the relative loss of *N* and *P* under different fertilization conditions and their loss coefficients (Tab. 6).

Tab. 5 Comparison of phosphorus loss in runoff and sediment under different fertilization conditions

| | Runoff / ($kg \cdot hm^{-2} \cdot a^{-1}$) | | | Sediment / ($kg \cdot hm^{-2} \cdot a^{-1}$) | | | Ratio of total *P* loss /% | | | Total loss/ ($kg \cdot hm^{-2} \cdot a^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total *P* | Soluble*P* | *S/T*/% | Total *P* | Soluble*P* | *S/T*/% | RunoffLoss | Sedimentloss | Total *P* | Soluble*P* | *S/T*/% |
| *T0* | 0.054 5 | 0.004 2 | 7.71 | 0.304 7 | 0.007 9 | 2.59 | 15.17 | 84.83 | 0.359 2 | 0.012 1 | 3.37 |
| *T1* | 0.071 8 | 0.005 9 | 8.22 | 0.288 2 | 0.009 3 | 3.21 | 19.94 | 80.06 | 0.360 0 | 0.015 2 | 4.21 |
| *T2* | 0.082 | 0.004 7 | 5.73 | 0.350 0 | 0.007 9 | 2.25 | 18.98 | 81.02 | 0.432 0 | 0.012 6 | 2.91 |
| *T3* | 0.116 3 | 0.005 8 | 4.99 | 0.432 3 | 0.007 7 | 1.78 | 21.20 | 78.80 | 0.548 6 | 0.013 5 | 2.46 |
| *T4* | 0.075 6 | 0.004 3 | 5.69 | 0.321 2 | 0.007 4 | 2.32 | 19.05 | 80.95 | 0.396 8 | 0.011 7 | 2.96 |

Tab. 6 Nitrogen and phosphorus loss and coefficients under different fertilization conditions

| | Fertilizer amount / ($kg \cdot hm^{-2}$) | | Absolute loss amount / ($kg \cdot hm^{-2}$) | | Absolute loss coefficient /% | | Relative loss amount / ($kg \cdot hm^{-2}$) | | Relative loss coefficient /% | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | *P* | Total *N* | Total *P* | Total *N* | Total *P* | Total *N* | Total *P* | Total *N* | Total *P* |
| *T0* | 0 | 0 | 5.441 | 0.359 | | -- | -- | -- | -- | -- |
| *T1* | 413 | 165 | 6.160 | 0.360 | 1.491 | 0.218 | 0.719 | 0.001 | 0.174 | 0.000 5 |
| *T2* | 413 | 165 | 22.576 | 0.432 | 5.466 | 0.262 | 17.136 | 0.073 | 4.149 | 0.044 1 |
| *T3* | 619.5 | 247.5 | 12.387 | 0.549 | 1.999 | 0.222 | 6.946 | 0.189 | 1.121 | 0.076 5 |
| *T4* | 413 | 165 | 10.515 | 0.397 | 2.546 | 0.240 | 5.075 | 0.038 | 1.229 | 0.022 8 |

As shown in Tab. 6, the absolute loss coefficient of *N* was 1.491% ~ 5.466%, and the relative loss coefficient of *N* was 0.174% ~ 4.419%, which lies between the observations of Si et al. (10% ~ 20%) and

Zhang et al. (2.5% ~6.1%) [12-13]. For $P$, the absolute loss coefficient was 0.218% ~0.262%, and the relative loss coefficient was 0.000 5% ~0.076 5%, which is lower than the data obtained from the farmland in Fuling, Chongqing and from the Loess Plateau. Further study is required to elucidate the discrepancy.

The loss coefficient differed among different types of $N$. In the case of some amount of $N$ and $P$ fertilization, the combined manure/fertilizer application showed the lowest loss coefficients of $N$ and $P$. The absolute loss coefficients were 1.491% for $N$ and 0.218% for $P$, and the relative loss coefficients were 0.174% for $N$ and 0.000 5% for $P$. The sole chemical fertilizer application showed the highest loss coefficients of $N$ and $P$. The absolute loss coefficients were 5.466% for $N$ and 0.262% for $P$, and the relative loss coefficients were 4.419% for $N$ and 0.044 1% for $P$. Cross ridge farming showed intermediate loss coefficients. The absolute loss coefficients were 2.546% for $N$ and 0.240% for $P$, and the relative loss coefficients were 1.229% for $N$ and 0.028 8% for $P$. These results indicated that the combined manure/fertilizer application can reduce the loss of $N$ and $P$ compared to the sole fertilizer application, and cross ridge farming can reduce the loss of $N$ and $P$ compared to longitudinal farming. The higher amount of fertilization (50% higher) led to absolute loss coefficients of 1.999% for $N$ and 0.222% for $P$, and relative loss coefficients of 1.212% for $N$ and 0.0765% for $P$. Compared to the standard-amount fertilizer application, the absolute loss coefficient was reduced 3.467% for $N$ and 0.04% for $P$, and the relative loss coefficient was reduced 3.028% for $N$ while it increased 0.032 4% for $P$, which could be related to the fertilization amounts of $N$ and $P$.

## 3 Conclusions

Through the experiments, we found the regularities of nutrient loss in the sediment of purple sloping farmland to be as follows:

1) Comparing the nutrient content of the surface soil before and after the experiment, the nutrient content increased under all fertilization conditions except T0, indicating that fertilization can indeed promote the productivity of soil and prevent the degradation of soil, which benefits the growth of crops.

2) Comparing the average nutrient content of sediment, nutrient enrichment occurred under all fertilization conditions. The enrichment ratio was 0.998 ~2.120, which is consistent with previous studies. However, the degree of nutrient enrichment differed under different fertilization conditions. For the control group, total $N$, effective $N$ and soluble $P$ were all enriched, with enrichment ratios similar to other groups. For the combined manure/fertilizer application, all types of nutrients were enriched, and the enrichment ratios of effective nutrients (effective $N$ and soluble $P$) were larger than those of total nutrients. For the sole fertilizer application, the enrichment ratios of total nutrients were significantly higher than those of effective nutrients, and the higher amount of fertilizer can increase the enrichment ratio of total nutrients but not effective nutrients. Cross ridge farming led to reduced enrichment ratios of all types of nutrients, compared to longitudinal farming.

3) Under all fertilization conditions, the sediment-carried nutrient loss was 0.035 3 ~0.337 6 $kg \cdot hm^{-2}$ for total $N$, and 0.288 2 ~0.432 3 $kg \cdot hm^{-2}$ for total $P$. The control group showed the highest loss, while the cross ridge farming groups showed the lowest loss. The combined manure/fertilizer application showed the highest loss ratio of effective nutrients in the total nutrients, which were 8.52% and 3.21%, respectively.

4) Under all fertilization conditions, the total amount of $N$ loss was 5.441 ~22.576 $kg \cdot hm^{-2} \cdot a$, in which runoff accounted for 93.79% ~99.66% and sediment only accounted for 0.34% ~6.21%. In nutrient loss caused by runoff, effective nutrients accounted for 40.45% ~60.2%, and the $N$ loss largely occurred in runoff. The total amount of $P$ loss was 0.359 ~0.549 $kg \cdot hm^{-2} \cdot a^{-1}$, in which runoff accounted for 15.17% ~21.20% and sediment accounted for 78.80% ~84.83%. The $P$ loss largely occurred in sedi-

ment, but the *P* loss caused by runoff showed a higher ratio of soluble *P* compared to the sediment *P* loss.

5) Under all fertilization conditions, the *N* loss showed an absolute loss coefficient of 1.491% ~ 5.466% and a relative loss coefficient of 0.174% ~ 4.419%, the *P* loss showed an absolute loss coefficient of 0.218% ~0.262% and a relative loss coefficient of 0.000 5% ~0.076 5%.

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