Effect of *Sophora Davidii* Skeels and *Pennisetum Sinese* Roxb Intercropping Systems on Soil Nutrients and Evaluation of Comprehensive Fertility

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**Abstract.** In this study, field experiments were used to set three cropping patterns: *Sophora davidii* Skeels monocropping pattern, *Pennisetum sinese* Roxb monocropping pattern, *S. davidii* and *P. sinese* intercropping pattern to explore the effect of different cropping patterns on soil nutrients and fertility. The results showed that the soil moisture content under different cropping patterns in the 0-30cm soil layer was as follows: *S. davidii* and *P. sinese* intercropping > *P. sinese* monocropping > *S. davidii* monocropping, and there were significant differences between different cropping patterns in the same soil depth (*P* <0.05); soil pH increased gradually with the increasing depth in soil, and the difference between different cropping patterns in the same soil depth was significant (*P* <0.05); *S. davidii* and *P. sinese* intercropping 0-10 cm soil layer of organic matter, total nitrogen, total phosphorus, available nitrogen and available phosphorus were significantly higher than that of *S. davidii* and *P. sinese* monocropping (*P* <0.05); In the 0-20cm soil layer, the ammonium nitrogen in *P. sinese* monocropping pattern was significantly higher than that in *S. davidii* and *P. sinese* monocropping (*P* <0.05); In the 0-20cm soil layer, the ammonium nitrogen in *P. sinese* monocropping pattern was significantly higher than that in *S. davidii* monocropping and *S. davidii* and *P. sinese* intercropping, while in the 20-30 cm soil layer, intercropping were significantly higher than that in the monocropping (*P* <0.05); in the 0-30cm soil layer, *S. davidii* monocropping pattern was significantly higher than *P. sinese* monocropping and *S. davidii* and *P. sinese* intercropping (*P* <0.05) (except for that of the *P. sinese* monocropping 10-20 cm). The quality of soil integrated fertility index (FQI) showed that the rank of FQI value in the 0-30 cm soil layer was as follows: *S. davidii* and *P. sinese* intercropping > *S. davidii* monocropping > *P. sinese* monocropping. These findings suggest that the *S. davidii* and *P. sinese* intercropping could effectively improved 0-30 cm soil comprehensive fertility.
1. Introduction
Intercropping can make use of the "spatial difference" and "time difference" formed by different plants during the growth process to fully utilize the production potential of light, heat, water, gas and other resources, and effectively improve the agricultural ecological environment. Studies have shown that intercropping can promote the utilization of deep soil water and increase plant yield. At the same time, it can also promote the uptake of nitrogen, phosphorus, potassium and trace elements by plants [1-3]. Reasonable intercropping can effectively alleviate competition between plants and improve the utilization of soil resources, so as to achieve the goals of mutual benefit and reciprocity, increasing yield and efficiency.

_Pennisetum sinese_ Roxb, also known as king grass, is a perennial, high-yielding, high-quality forage grass of the grass family Pennisetum. However, with the continuous cropping of _P. sinese_, soil organic matter, total nitrogen, available phosphorus, and available potassium content will gradually decrease [4-5]. In view of the characteristics of strong asexual reproduction ability and strong invasion of _P. sinese_, materials about suitable legumes for intercropping with _P. sinese_ have not been reported. Therefore, the interplanting of _Sophora davidii_ (Franch.) Skeels, a leguminous shrub with broad adaptability, high protein content, and strong nitrogen fixation capacity, is selected for intercropping with _P. sinese_. It is hoped that the soil micro-ecological environment can be effectively improved, so as to extend the continuous cropping and planting life of _P. sinese_, reduce the input of pesticides and fertilizers, and achieve the goal of improving both economic and ecological benefits.

At present, there are no reports about the intercropping between _S. davidii_ and _P. sinese_, especially the influence of _S. davidii_ and _P. sinese_ intercropping on soil. Therefore, this experiment intends to study the changes of soil nutrients in the 0-30 cm soil layer under the _S. davidii_ and _P. sinese_ intercropping, to explore the effects of _S. davidii_ and _P. sinese_ intercropping on soil nutrients, and to evaluate soil fertility to provide a reference for the ecological cultivation of forage and the continuous improvement of soil in karst areas.

2. Materials and methods

2.1. Overview of the study area
Field experiments were conducted at the experimental farm of Guizhou Grass Industry Research Institute, Dushan County, Qiannan Prefecture, Guizhou Province. The soil in the test area in this area were yellow soil. The physical and chemical properties of the soil in the 0-30 cm soil layer before the experiment were as follow: organic matter content was 18.70 g·kg⁻¹, pH was 7.17, total nitrogen content was 1.21 g·kg⁻¹, total phosphorus content was 0.53 g·kg⁻¹, total potassium content was 13.74 g·kg⁻¹, fast-acting potassium content was 108.0 mg·kg⁻¹, effective phosphorus content was 21.6 mg·kg⁻¹ and alkaline nitrogen content was 50.2 mg·kg⁻¹.

2.2. Experimental design
The test grass species were _P. sinese_ and Panjiang _S. davidii_ (510) (Guizhou Institute of Pratacultural). Using random block design, there are 3 cropping patterns of _S. davidii_ monocropping, _P. sinese_ monocropping and _S. davidii_ and _P. sinese_ intercropping, each treatment was repeated 3 times, a total of 9 plots, each plot area was 65 m². The planting density of single and intercropping was 1 plant /m². The ecological conditions and field management measures of each treatment were consistent.

2.3. Index measurement
The conventional agrochemical analysis method [6] was used to determine the water content, pH, organic matter, available nitrogen, available phosphorus, available potassium, total nitrogen, total phosphorus, total potassium, ammonium nitrogen and nitrate nitrogen of the test soil samples.
2.4. Data processing

Data processing and statistical analysis were performed using Microsoft Excel 2003 and SPSS 23.0 statistical software. Use the membership model to calculate the membership of each indicator, and use the principal component analysis (PCA) to reduce the soil fertility index to obtain the principal component factor, and obtain the weight and load of each indicator in each principal component. The soil fertility quality index \(FQI\) of different soil depths was calculated, and the level of this index was used as the basis for evaluating the comprehensive soil fertility [7].

\[
FQI = \sum_{j}^{m} K_{j} \left[ \sum_{i=1}^{n} \omega_{i} Q(x_{i}) \right]
\]  

In the formula: \(Q(x_{i})\) represents the degree of membership of each soil attribute; \(\omega_{i}\) represents the weight vector of each soil attribute; \(n\) represents the number of evaluation indicators; \(m\) represents the number of selected principal components; \(K_{j}\) represents the number of the \(j\)th principal component variance contribution rate.

3. Results and analysis

3.1. Effects of different cropping patterns on soil nutrients

Under three different cropping patterns, soil water content showed a trend of rising first and then falling with the increase of soil depth. The \(S.\davidii\) monocropping and \(S.\davidii\) and \(P.\sinese\) intercropping 10-20cm both had significantly higher water content than the other two (\(P<0.05\)). The order of soil water content in the 0-30cm soil layer was as follows: \(S.\davidii\) and \(P.\sinese\) intercropping > \(S.\davidii\) monocropping, and there were significant difference between different cropping patterns in the same soil depth (\(P<0.05\)). The soil pH of the three cropping patterns showed a gradually increasing trend with the increase of soil depth (\(P<0.05\)), and the difference between different cropping patterns at the same soil depth was significant (\(P<0.05\)). The \(S.\davidii\) monocropping was the highest, \(P.\sinese\) monocropping was the lowest.

Under three different cropping patterns, the contents of soil organic matter, available phosphorus, available potassium, total nitrogen, and nitrate nitrogen all gradually decreased with the increase of soil depth. The soil organic matter, total nitrogen, total phosphorus, available nitrogen and available phosphorus in the 0-10cm layer of \(S.\davidii\) and \(P.\sinese\) intercropping were significantly higher than those in the two monocropping systems (\(P<0.05\)). The available potassium of \(S.\davidii\) monocropping 0-30cm was significantly higher than that of the other two cropping patterns (\(P<0.05\)).

The soil ammonium nitrogen in the 0-20cm soil layer, the \(P.\sinese\) monocropping was significantly higher than the \(S.\davidii\) monocropping and the \(S.\davidii\) and \(P.\sinese\) intercropping, and in the 20-30cm soil layer, the intercropping showed significantly higher than the monocropping (\(P<0.05\)). The \(P.\sinese\) monocropping 10-20cm treatment group except.
### Figure 1. Effects of different cropping patterns on soil nutrients

Note: Different capital letters indicate significant differences between different soil depths in the same planting method, and different lowercase letters indicate significant differences between different soil depths in the same soil layer, P<0.05. B indicates *S. davidii* monocropping; H indicates *P. sinese* monocropping; J indicates *S. davidii* and *P. sinese* intercropping. The same below.

#### 3.2. Comprehensive evaluation of soil fertility under different cropping patterns

For the determination of soil indexes by using membership function and principal component analysis (PCA) calculation for three cropping patterns soil integrated fertility index (FQI). The results showed that the soil FQI of the *S. davidii* and *P. sinese* intercropping was significantly higher than *P. sinese* monocropping and *S. davidii* monocropping in the 0-30cm soil layer (P<0.05), and the soil fertility of different soil layers showed the following order: *S. davidii* and *P. sinese* intercropping > *S. davidii* monocropping > *P. sinese* monocropping. The above shows that *S. davidii* and *P. sinese* intercropping could effectively improved the comprehensive soil fertility of 0-30cm soil layer.

| Soil organic matter (g·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|-------------------------------|--------|---------|---------|
| 0%                            | B      | H       | J       |
| 5%                            |        |         |         |
| 10%                           |        |         |         |
| 15%                           |        |         |         |
| 20%                           |        |         |         |
| 25%                           |        |         |         |

| Soil available nitrogen (g·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.05                            |        |         |         |
| 0.1                            |        |         |         |
| 0.15                           |        |         |         |
| 0.2                            |        |         |         |
| 0.25                           |        |         |         |

| Soil available phosphorus (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|-------------------------------------|--------|---------|---------|
| 0%                                  | B      | H       | J       |
| 20                                  |        |         |         |
| 40                                  |        |         |         |
| 60                                  |        |         |         |
| 80                                  |        |         |         |
| 100                                 |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 5                                  |        |         |         |
| 10                                 |        |         |         |
| 15                                |        |         |         |
| 20                                |        |         |         |
| 25                                |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.5                               |        |         |         |
| 1                                 |        |         |         |
| 1.5                               |        |         |         |
| 2                                 |        |         |         |
| 2.5                               |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.05                            |        |         |         |
| 0.1                            |        |         |         |
| 0.15                           |        |         |         |
| 0.2                            |        |         |         |
| 0.25                           |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.5                              |        |         |         |
| 1                               |        |         |         |
| 1.5                             |        |         |         |
| 2                               |        |         |         |
| 2.5                             |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.05                            |        |         |         |
| 0.1                            |        |         |         |
| 0.15                           |        |         |         |
| 0.2                            |        |         |         |
| 0.25                           |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.5                              |        |         |         |
| 1                               |        |         |         |
| 1.5                             |        |         |         |
| 2                               |        |         |         |
| 2.5                             |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.05                            |        |         |         |
| 0.1                            |        |         |         |
| 0.15                           |        |         |         |
| 0.2                            |        |         |         |
| 0.25                           |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.5                              |        |         |         |
| 1                               |        |         |         |
| 1.5                             |        |         |         |
| 2                               |        |         |         |
| 2.5                             |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.05                            |        |         |         |
| 0.1                            |        |         |         |
| 0.15                           |        |         |         |
| 0.2                            |        |         |         |
| 0.25                           |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.5                              |        |         |         |
| 1                               |        |         |         |
| 1.5                             |        |         |         |
| 2                               |        |         |         |
| 2.5                             |        |         |         |

| Soil available kalium (mg·kg⁻¹) | 0-10cm | 10-20cm | 20-30cm |
|---------------------------------|--------|---------|---------|
| 0%                              | B      | H       | J       |
| 0.05                            |        |         |         |
| 0.1                            |        |         |         |
| 0.15                           |        |         |         |
| 0.2                            |        |         |         |
| 0.25                           |        |         |         |
4. Conclusion

(1) Under three different cropping patterns, the soil pH gradually increased with the increase of soil layer depth (P<0.05), and there were significant differences between different cropping patterns in the same soil layer depth (P<0.05). The S. davidii monocropping was the highest, and P. sinese monocropping was the lowest. The order of soil moisture content in the 0-30cm soil layer was as follows: S. davidii and P. sinese intercropping>P. sinese monocropping>S. davidii monocropping, and there were significant differences between different cropping patterns in the same soil layer depth (P<0.05).

(2) The contents of soil organic matter, available phosphorus, available potassium, and total nitrogen and nitrate nitrogen decreased gradually with the increase of soil depth. The soil organic matter, total nitrogen, total phosphorus, available nitrogen and available phosphorus in 0-10 cm layer of S. davidii and P. sinese intercropping were significantly higher than those in the two monocropping systems (P<0.05). The available potassium of S. davidii monocropping 0-30cm was significantly higher than that of the other two cropping patterns (P<0.05).

(3) Soil ammonium nitrogen in 0-20 cm soil layer, P. sinese monocropping was significantly higher than S. davidii monocropping and S. davidii and P. sinese intercropping, whereas in 20-30 cm soil layer, characterized by intercropping was significantly higher than monocropping (P<0.05). The S. davidii monocropping was significantly higher than P. sinese monocropping and S. davidii and P. sinese intercropping (P<0.05) (except for that of the P. sinese monocropping 10-20 cm treatment group).

(4) The results of soil comprehensive fertility quality index(FQI) showed that the FQI value of S. davidii and P. sinese intercropping were significantly higher than that of P. sinese monocropping and S. davidii monocropping in the 0-30cm soil layer (P<0.05). Moreover, the soil fertility of different soil layers was ranked as: S. davidii and P. sinese intercropping>S. davidii monocropping>P. sinese monocropping. These findings suggest that S. davidii and P. sinese intercropping could effectively improve soil comprehensive fertility in 0-30cm soil layer.

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