\*

钱晨晨[1,2], 王淑彬[1,2], 杨滨娟[1,2], 黄国勤[1,2**]

(1.                                                330045; 2.                                                    330045)

**：为综合评价紫云英与氮肥配施对早稻干物质生产及氮素吸收利用的影响, 筛选紫云英等量翻压条件下, 较适宜的施氮水平, 以冬闲常规施氮[150 kg(N)·hm$^{-2}$]处理为对照, 在翻压紫云英 22 500 kg·hm$^{-2}$ 条件下, 设置 90 kg(N)·hm$^{-2}$、120 kg(N)·hm$^{-2}$、150 kg(N)·hm$^{-2}$ 和 180 kg(N)·hm$^{-2}$ 4 个施氮水平, 研究紫云英和施氮量对早稻干物质生产及氮素吸收利用的影响。结果表明: 紫云英与氮肥配施各处理的干物质积累量均高于对照, 其中紫云英配施氮肥 90 kg(N)·hm$^{-2}$ 和 120 kg(N)·hm$^{-2}$ 的干物质积累量最多, 分别达 9.65 t·hm$^{-2}$ 和 9.97 t·hm$^{-2}$, 比对照分别增加 11.18%和 14.86%。各处理在水稻播种—分蘖期及抽穗—灌浆期干物质积累量较大, 占成熟期干物质量的 19.26%~24.77%和 45.23%~52.75%, 这两个生育阶段是干物质主要积累时期。紫云英与氮肥配施各处理的氮素积累量均高于对照, 增幅为 6.95%~18.68%。氮素干物质生产效率和氮收获指数均以紫云英配施 90 kg(N)·hm$^{-2}$ 处理最高, 比其他处理分别增加 3.94%~14.08%和 6.65%~14.90%。紫云英配施氮肥有利于提高早稻的干物质积累量和氮素利用率, 其中以紫云英配施氮肥 90 kg(N)·hm$^{-2}$ 和 120 kg(N)·hm$^{-2}$ 效果较优, 可实现减氮增效目的, 是较理想的施肥模式。

**：紫云英; 氮肥; 早稻; 干物质; 氮素吸收

**：S551+.9; S511.3+1          **：A          **：1671-3990(2017)04-0563-09

# Effect of combined application of Chinese milk vetch and nitrogen fertilizer on nitrogen uptake, utilization and dry matter accumulation in early rice[*]

QIAN Chenchen[1,2], WANG Shubin[1,2], YANG Binjuan[1,2], HUANG Guoqin[1,2**]

(1. Research Center on Ecological Science, Jiangxi Agricultural University, Nanchang 330045, China;
2. Colleges and Universities Union of Ecology in Jiangxi Province, Nanchang 330045, China)

**Abstract:** This study evaluated the effect of combined application of Chinese milk vetch (*Astragalus sinicus* L.) and different levels of nitrogen (N) fertilizer on dry matter accumulation and N use efficiency of early rice in order to determinate the suitable N level under application of Chinese milk vetch. Field treatments were set with four N application levels (90 kg·hm$^{-2}$, 120 kg·hm$^{-2}$, 150 kg·hm$^{-2}$ and 180 kg·hm$^{-2}$) under 22 500 kg·hm$^{-2}$ Chinese milk vetch using the winter fallow field with general

N fertilizer level (150 kg·hm⁻²) as the control. In the experiment, Chinese milk vetch was planted in winter and incorporated into soil in spring before early rice transplant, while N fertilizer was applied as base fertilizer, tillering fertilizer and heading fertilizer with 5∶3∶2 rate. The rice plants were sampled at tillering, booting, heading, filling and maturity stages of the early rice. Dry matter weight and N content were assayed, and the relative indexes were calculated. The results showed that all N application treatments had higher dry matter accumulation than the control. Specifically, the treatments with Chinese milk vetch combined with 90 kg(N)·hm⁻² and 120 kg(N)·hm⁻² increased dry matter (9.65 t·hm⁻² and 9.97 t·hm⁻²) respectively by 11.18% and 14.86% compared to the control. Dry matter accumulation increased with duration of growth and peaked twice, one at sowing–tillering stage (19.26%–24.77%) and the other at heading–filling stage (45.23%–52.75%). The combined application of Chinese milk vetch and N fertilizer supported N integration that was beneficial to rice growth. The amounts of N accumulation of early rice treated with Chinese milk vetch and N fertilizer were higher than the control, with increases of 6.95%–18.68%. Among the treatments, that of Chinese milk vetch combined with 90 kg(N)·hm⁻² had the highest production efficiency of dry matter and N harvest index, with respective increases of 3.94%–14.08% and 6.65%–14.90% over other treatments. The results indicated that combined application of Chinese milk vetch with 90 kg(N)·hm⁻² or 120 kg(N)·hm⁻² was satisfactory because they reduced N fertilizer and increased N use efficiency at the same time, which was the ideal fertilization model for the study area.

**Keywords:** Chinese milk vetch; Nitrogen fertilizer; Early rice; Dry matter; Nitrogen uptake

(*Astragalus sinicus* L.)　　　　　　　　　　K₂O 120 kg·hm⁻²)

，

[1-3]　　　　　　　　，

，　　　　　　　　　　，

，　　　　　　　　　　　　　（　　　　　　　　）　　，

，　　　　　　　，

180 kg·hm⁻²，

75%，　　　　　　　300 kg·hm⁻²[4-5]

[6]

[7]

，　　　　　　，　　　　　　，

，　　　　　　　　，

，

## 1　材料与方法

### 1.1

2014　10　　　2015　7
(28°46′N, 115°55′E)

4.79×10¹³ J·hm⁻²，　　　　　1 852 h，

≥0 ℃　　　6 450 ℃，　　　　17.1~17.8 ℃，

1 624 mm

，

pH 5.59，　　　29.48 g·kg⁻¹，　　　2.17 g·kg⁻¹，

38.69 mg·kg⁻¹，　　　　12.22 mg·kg⁻¹，

30.31 mg·kg⁻¹

[8-9]　　　　[10]

，

60%~80%　　　　　　　（

：N 150 kg·hm⁻²　P₂O₅75 kg·hm⁻²　K₂O 120 kg·hm⁻²)，

10%~59%

[11]

，

8.5%~

17.4%　　[12]　　25

### 1.2

，

[150 kg(N)·hm⁻²]　　（　　A），

22 500 kg·hm⁻²（　　　　　　：

3.9%~7.8%　　　26.7 g·kg⁻¹，　2.1 g·kg⁻¹，　20.1 g·kg⁻¹)　　　，

[13]　　，

20%(　　　　：N 150 kg·hm⁻²　P₂O₅ 75 kg·hm⁻²

90 kg(N)·hm$^{-2}$(　　B)　120 kg(N)·hm$^{-2}$(
C)　150 kg(N)·hm$^{-2}$(　　D)　180 kg(N)·hm$^{-2}$(
E)4　　，　5　　，　　　3　　，15
　　，　　　　　16.5 m$^2$(5.5 m×3 m)，
　　　，
'　　　　'，2014　10　4　　，2015　4
3　　　　　　　'　　458'，2015
3　27　　，4　29　　，7　28
　3　，　　　325　　　　　（　N
46%），　　　　　（　P$_2$O$_5$ 12%），
（　K$_2$O 60%）　　　　　　　，
(P$_2$O$_5$)50 kg·hm$^{-2}$，　(K$_2$O)120 kg·hm$^{-2}$，
　；　　　　：　　：　=5：3：2
　　　　5~7 d　　　，
1~2 cm

**1.3**
**1.3.1**
　　　(2015　6　1　)　　　(6
14　)　　(6　25　)　　　(7　6　)
(7　25　)
5　(　　　　)，　　　　(
)　　　，105 ℃　　　30 min，80 ℃
　　[14]
　：
　　　=　　　　－
　　　　　　　　(1)
　　　=　　　　/
×100%　　　　(2)

=　　　　/
×100%　　　(3)
**1.3.2**
　　　　　　　　，
H$_2$SO$_4$-H$_2$O$_2$　　，
　　　　　　　[15]　　：
=　　　×　(4)
(NDMPE)=
/　(5)
(NHI)=　　／
(6)

**1.4**
Microsoft
Excel 2010，　　SPSS 17.0

**2　结果与分析**

**2.1**
**2.1.1**
　　　　1　，
(*P*>0.05)　　　，
C
(*P*<0.05)　　，　　B　C
D　　　　A　E　(*P*<0.05)
，　　B　C
A(*P*<0.05)，　　　16.77%　17.02%
，　　B　C　D
A(*P*<0.05)，　　C　　A　E　　(*P*<0.05)

表 1　各处理对早稻主要生育期群体干物重的影响
Table 1　Effects of different treatments on dry matter weight of population at main growth stages of early rice　　t·hm$^{-2}$

| Treatment | Tillering stage | Booting stage | Heading stage | Filling stage | Maturity |
|---|---|---|---|---|---|
| A | 2.15±0.12a | 2.62±0.05c | 3.78±0.09b | 8.05±0.24b | 8.68±0.14c |
| B | 1.95±0.06a | 3.06±0.06b | 4.45±0.04a | 9.40±0.15a | 9.65±0.27ab |
| C | 1.92±0.14a | 3.58±0.17a | 4.66±0.13a | 9.42±0.42a | 9.97±0.24a |
| D | 2.09±0.07a | 3.04±0.16b | 4.54±0.12a | 8.81±0.46ab | 9.44±0.29ab |
| E | 2.16±0.09a | 2.70±0.04bc | 3.78±0.02b | 8.58±0.17ab | 9.10±0.06bc |

A:　　　+150 kg(N)·hm$^{-2}$; B:　　　+90 kg(N)·hm$^{-2}$; C:　　　+120 kg(N)·hm$^{-2}$; D:　　　+150 kg(N)·hm$^{-2}$; E:　　　+180 kg(N)·hm$^{-2}$
　3　　　　±　；　　　　　　　(*P*<0.05)　A: winter fallow with 150 kg(N)·hm$^{-2}$ application in early rice; B: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; C: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; D: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; E: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice . Values in the table are mean ± SE of 3 replicates. Different lowercase letters in the same column mean significant differences at 0.05 level.

**2.1.2**
（　2），　　　　　——　　　　——
　　　　，

表 2　各处理早稻主要生育阶段干物质积累量和比例

Table 2　Dry matter accumulation and its ratio in main growth stages of early rice under different treatments

| Treatment | Sowing–tillering stage | | Tillering–booting stage | | Booting–heading stage | | Heading–filling stage | | Filling–maturity stage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DMA (t·hm$^{-2}$) | RTDM (%) | DMA (t·hm$^{-2}$) | RTDM (%) | DMA (t·hm$^{-2}$) | RTDM (%) | DMA (t·hm$^{-2}$) | RTDM (%) | DMA (t·hm$^{-2}$) | RTDM (%) |
| A | 2.15±0.12a | 24.77 | 0.47±0.11b | 5.41 | 1.16±0.11ab | 13.36 | 4.27±0.30a | 49.19 | 0.63±0.27a | 7.27 |
| B | 1.95±0.06a | 20.21 | 1.11±0.12ab | 11.50 | 1.39±0.06ab | 14.40 | 4.95±0.13a | 51.30 | 0.25±0.40a | 2.59 |
| C | 1.92±0.14a | 19.26 | 1.66±0.28a | 16.65 | 1.08±0.17b | 10.83 | 4.77±0.44a | 47.84 | 0.55±0.27a | 5.52 |
| D | 2.09±0.07a | 22.15 | 0.95±0.09b | 10.06 | 1.50±0.04a | 15.89 | 4.27±0.34a | 45.23 | 0.63±0.18a | 6.67 |
| E | 2.16±0.09a | 23.74 | 0.54±0.13b | 5.93 | 1.08±0.03b | 11.87 | 4.80±0.19a | 52.75 | 0.52±0.14a | 5.71 |

A:　　　+150 kg(N)·hm$^{-2}$; B:　　　+90 kg(N)·hm$^{-2}$; C:　　　+120 kg(N)·hm$^{-2}$; D:　　　+150 kg(N)·hm$^{-2}$; E:　　　+180 kg(N)·hm$^{-2}$
DMA:　　　　　　　　　　; RTDM:　　　　　　　　　　3　　　±　　;
(P<0.05)　A: winter fallow with 150 kg(N)·hm$^{-2}$ application in early rice; B: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; C: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; D: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; E: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice. DMA: amount of dry matter accumulation at the growth stage; RTDM: ratio of dry matter accumulation to total accumulation in the growth stage. Values in the table are mean ± SE of 3 replicates. Different lowercase letters in the same column mean significant differences at 0.05 level.

　　　　　，　　　　　　　　　　　　　　　　　　，　46.50%，　　　　A　E
　　　　19.26%~24.77%　45.23%~52.75%，(P<0.05)，　　　　7.83　　　　　　4.75
　　　　(P>0.05)　　　　—　　　　　　　　　　　　　　　　　　　　　　　，
C　　　　　　　　　　　，　　　　A　D　E　　　　，　　　　　　　(P<0.05)，
(P<0.05);　　　—　　　，　　　D　　　　　　A　　　　，　41.33%;　　　　D
　，　　　　　　C　E(P<0.05)，　　　38.89%;　　　，　14.00%，　A　B　E　　　(P<
　—　　　　　　　　　　　　　0.05)
(P>0.05)　　　　　　　　　　　　　　　，　　　　　　　　　　　，
**2.1.3**　　　　　　　　　　　　　　　18.50%~ 23.50%　　　　64.50%~68.67%
　　　　　　　　　　　(　3)　，　　　D　　　，　　　C
　　　　　　　　，　　(P<0.05);　　　B　A　C　D
　　　　　　　　C　　(P<0.05)

表 3　各处理早稻中、后期干物质在茎鞘、叶片和穗的分配情况

Table 3　Dry weight ratios of stem-sheath, leaf, panicle at middle and late stages of early rice under different treatments　　%

| Treatment | Ratio of stem-sheath | | | Ratio of leaf | | | Ratio of panicle | | |
|---|---|---|---|---|---|---|---|---|---|
| | Heading stage | Filling stage | Maturity stage | Heading stage | Filling stage | Maturity stage | Heading stage | Filling stage | Maturity stage |
| A | 38.67±0.33c | 28.00±0.58a | 22.00±0.58a | 41.33±0.33a | 18.00±0.00a | 11.67±0.67bc | 20.00±0.58ab | 54.00±0.58a | 66.33±0.33bc |
| B | 43.33±0.67ab | 27.67±1.67a | 20.67±1.20a | 36.67±0.33c | 21.66±2.67a | 10.67±0.33c | 20.00±1.00ab | 50.67±4.33a | 68.67±0.89a |
| C | 46.50±1.44a | 26.25±1.25a | 20.75±0.75a | 35.00±0.41d | 17.75±0.75a | 13.25±0.48ab | 18.50±1.71b | 56.00±1.87a | 66.00±0.71bc |
| D | 43.50±0.50ab | 26.50±0.50a | 21.50±0.50a | 33.00±0.00e | 19.00±0.00a | 14.00±0.00a | 23.50±0.5a | 54.50±0.50a | 64.50±0.50c |
| E | 41.75±0.75bc | 28.50±0.87a | 20.25±0.25a | 38.25±0.63b | 18.50±0.29a | 12.00±0.41bc | 20.00±1.29ab | 53.00±1.00a | 67.75±0.25ab |

A:　　　+150 kg(N)·hm$^{-2}$; B:　　　+90 kg(N)·hm$^{-2}$; C:　　　+120 kg(N)·hm$^{-2}$; D:　　　+150 kg(N)·hm$^{-2}$; E:　　　+180 kg(N)·hm$^{-2}$
　3　　　　　±　　;　　　　　　　　　　　　　　　(P<0.05)　A: winter fallow with 150 kg(N)·hm$^{-2}$ application in early rice; B: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; C: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; D: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; E: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice . Values in the table are mean ± SE of 3 replicates. Different lowercase letters in the same column mean significant differences at 0.05 level.

**2.1.4**

　　　　4　，　　　B

　　　　　　　　　　，　　　C　，

E　　　　　，　D　3　　　　　　　A，

　　　　　　（*P*>0.05）

　　　，

　　　　　　　　　　　　，　　　　　　　，

　　，

**2.2**

**2.2.1**

　　　1　，

　　　　　　　　　　　，

　　　　　　　　　　（*P*>0.05）

　　D　　　　　　　，

　　　　　　C　　　　　　　　，

　　　A，

B(*P*<0.05)

### 表 4　各处理早稻干物质的转运
Table 4　Dry matter transformation of early rice under different treatments

| Treatment | Dry matter exportation from stem-sheath and leaf (t·hm$^{-2}$) | Output percent of dry matter from stem-sheath and leaf (%) | Apparent conversion rate (%) |
|---|---|---|---|
| A | 0.11±0.01c | 3.31±0.07c | 2.20±0.06c |
| B | 0.54±0.01a | 15.17±0.43a | 9.41±0.08a |
| C | 0.41±0.02b | 10.79±0.43b | 7.17±0.10b |
| D | 0.12±0.01c | 3.46±0.08c | 2.39±0.12c |
| E | 0.09±0.01c | 2.98±0.10c | 1.66±0.07d |

A:　　　+150 kg(N)·hm$^{-2}$; B:　　　+90 kg(N)·hm$^{-2}$; C:　　+120 kg(N)·hm$^{-2}$; D:　　+150 kg(N)·hm$^{-2}$; E:　　　+180 kg(N)·hm$^{-2}$　　　3　　　　　±　　　；　　　(*P*<0.05)　A: winter fallow with 150 kg(N)·hm$^{-2}$ application in early rice; B: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; C: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; D: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; E: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice. Values in the table are mean ± SE of 3 replicates. Different lowercase letters in the same column mean significant differences at 0.05 level.
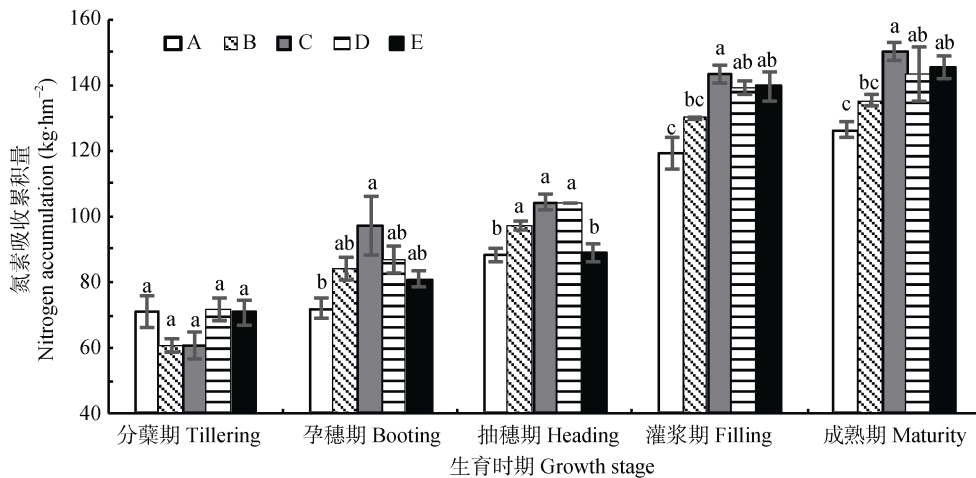


### 图 1　各处理早稻主要生育阶段氮素累积量
Fig. 1　Nitrogen accumulations at main growth stages of early rice under different treatments

A:　　　+150 kg(N)·hm$^{-2}$; B:　　　+90 kg(N)·hm$^{-2}$; C:　　　+120 kg(N)·hm$^{-2}$; D:　　　+150 kg(N)·hm$^{-2}$; E:　　+180 kg(N)·hm$^{-2}$　　　　　　　　　(*P*<0.05)　A: winter fallow with 150 kg(N)·hm$^{-2}$ application in early rice; B: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; C: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; D: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; E: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice . Different lowercase letters mean significant differences at the same growth stage at 0.05 level.

**2.2.2**　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　，

　　　5　，　　　　　　　　　　　　　　　　　　B　　　　　　　　　　　　　；

　　　　　　　　　，　　　　　　　　　　　　　　　　　　；　　　　　　，

　　　　　　　　　　　　　　　　　　　　　　E　　　　　　　(*P*<0.05)

　　　　　　　，　　C　D　E　　　　　　　　　，　　C　　　　　　　　B(*P*<0.05);

B(*P*<0.05),　　　　　　　　　　　　　　，　　　　　　　　　，　　D　　　　　　　B(*P*<0.05);

表 5 各处理早稻成熟期茎、叶、穗的氮素养分含量及吸收量

Table 5 Nitrogen contents and uptakes of stem-sheath, leaf, panicle at maturity stages of early rice under different treatments

| Treatment | Total nitrogen content (%) | | | Nitrogen uptake (kg·hm$^{-2}$) | | |
|---|---|---|---|---|---|---|
| | Stem-sheath | Leaf | Panicle | Stem-sheath | Leaf | Panicle |
| A | 1.14±0.13ab | 2.08±0.15a | 1.45±0.04bc | 21.67±1.97ab | 21.03±1.24ab | 83.60±1.49b |
| B | 1.01±0.04b | 1.83±0.15a | 1.45±0.00bc | 19.96±0.93b | 19.16±1.70b | 95.96±2.20a |
| C | 1.36±0.03a | 1.81±0.07a | 1.41±0.02c | 33.48±5.64a | 23.73±1.58ab | 92.68±2.77a |
| D | 1.34±0.11a | 1.87±0.02a | 1.50±0.03b | 27.52±3.63ab | 24.29±0.58a | 91.33±4.02a |
| E | 1.43±0.10a | 2.03±0.06a | 1.57±0.01a | 26.61±1.99ab | 21.92±0.73ab | 96.80±1.05a |

A: +150 kg(N)·hm$^{-2}$; B: +90 kg(N)·hm$^{-2}$; C: +120 kg(N)·hm$^{-2}$; D: +150 kg(N)·hm$^{-2}$; E: +180 kg(N)·hm$^{-2}$

3 ± ; (P<0.05) A: winter fallow with 150 kg(N)·hm$^{-2}$ application in early rice; B: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; C: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; D: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; E: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice . Values in the table are mean ± SE of 3 replicates. Different lowercase letters in the same column mean significant differences at 0.05 level.

, 4

A(P<0.05)

**2.2.3**

6 ,

(NDMPE) ,

B

, 3.94%~14.08%

(NHI)

,

61.83%~71.04%, B

表 6 各处理早稻的氮素干物质生产效率**(NDMPE)**和氮收获指数**(NHI)**

Table 6 Nitrogen dry matter production efficiency (NDMPE) and nitrogen harvest index (NHI) of early rice under different treatments

| Treatment | NDMPE (kg·kg$^{-1}$) | NHI (%) |
|---|---|---|
| A | 68.73±4.31a | 66.19±1.08bc |
| B | 71.44±3.08a | 71.04±1.45a |
| C | 66.52±2.87a | 61.83±1.35c |
| D | 65.95±7.97a | 63.80±1.43bc |
| E | 62.62±1.84a | 66.61±1.08b |

A: +150 kg(N)·hm$^{-2}$; B: +90 kg(N)·hm$^{-2}$; C: +120 kg(N)·hm$^{-2}$; D: +150 kg(N)·hm$^{-2}$; E: +180 kg(N)·hm$^{-2}$

3 ± ; (P<0.05) A: winter fallow with 150 kg(N)·hm$^{-2}$ application in early rice; B: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; C: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; D: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice; E: Chinese milk vetch plantation in winter and incorporation in spring combined with 90 kg(N)·hm$^{-2}$ application in early rice . Values in the table are mean ± SE of 3 replicates. Different lowercase letters in the same column mean significant differences at 0.05 level.

(P<0.05), E ,

, B

, 71.44 kg·kg$^{-1}$ 71.04%

**3 讨论与结论**

, [16] [13] ,

22 500 kg·hm$^{-2}$ , 100% (N 150 kg·hm$^{-2}$ P$_2$O$_5$ 75 kg·hm$^{-2}$ K$_2$O 120 kg·hm$^{-2}$) , ;

20%, 18.8%, 40%~60% , [17] :

[18] , , 18.8%~26.9% , ,

120 kg·hm$^{-2}$ — , 10.01% [19] , , , 150 kg·hm$^{-2}$ 180 kg·hm$^{-2}$ 90 kg·hm$^{-2}$ 120 kg·hm$^{-2}$ , , ,

[20] ,            ,
,
,
,                                   ,
,
[21]          [22]

,                      ,
[23]

,
,
[24]

,
,
,
[25]               ,
,
[26]
7%~18%                         [27]

,

,
,                      ,
6.95%~18.68%,
120 kg·hm$^{-2}$
[28]     [29]

,
,                ,
,
,                    [30]
,            [11]
,
,                          ,

,
90 kg·hm$^{-2}$     120 kg·hm$^{-2}$            ,
,

## 参考文献  References

[1] Zhou C H, Zhao Z K, Pan X H, et al. Integration of growing milk vetch in winter and reducing nitrogen fertilizer application can improve rice yield in double-rice cropping system[J]. Rice Science, 2016, 23(3): 132–143

[2]          ,         ,          ,     .
                              [J].                          ,
2014, 33(5): 7–12
Guo X Y, Song X H, Liu C Z, et al. Effects of *Astragalus sinicus* manure application and chemical fertilizer dosage on growth, yield and economic efficiency of rice[J]. Journal of Mountain Agriculture and Biology, 2014, 33(5): 7–12

[3] Lee C H, Park K D, Jung K Y, et al. Effect of Chinese milk vetch (*Astragalus sinicus* L.) as a green manure on rice productivity and methane emission in paddy soil[J]. Agriculture, Ecosystems & Environment, 2010, 138(3/4): 343–347

[4] Peng S B, Huang J L, Zhong X H, et al. Challenge and opportunity in improving fertilizer-nitrogen use efficiency of irrigated rice in China[J]. Agricultural Sciences in China, 2002, 1(7): 776–785

[5] Peng S B, Tang Q Y, Zou Y B. Current status and challenges of rice production in China[J]. Plant Production Science, 2009, 12(1): 3–8

[6]          ,          .                                   [J].
                     , 2014, 45(2): 116–122
Zhao H W, Sha H J. Recent research on fertilizer-nitrogen use efficiency in paddy flied of China[J]. Journal of Northeast Agricultural University, 2014, 45(2): 116–122

[7] Roelcke M, Han Y, Schleef K H, et al. Recent trends and recommendations for nitrogen fertilization in intensive agriculture in eastern China[J]. Pedosphere, 2004, 14(4): 449–460

[8]          ,          ,          ,     .
                              [J].              , 2011, 31(16):
4542–4548
Gao J S, Cao W D, Li D C, et al. Effects of long-term double-rice and green manure rotation on rice yield and soil organic matter in paddy field[J]. Acta Ecologica Sinica, 2011, 31(16): 4542–4548

[9]          ,          ,          ,     .
                              [J].                 , 2013,
44(2): 409–413
Liu C Z, Liu X F, Li B Y, et al. Effects of applying Chinese milk vetch with different amounts of chemical fertilizer on soil nutrients, aggregation and rice yield[J]. Chinese Journal of Soil Science, 2013, 44(2): 409–413

[10]          ,          ,          ,     .
                              [J].
                 , 2011, (4): 79–82
Xie Z J, Xu C X, Xu Z L, et al. Effects of applying mineral fertilizer reasonably on the availability of soil nutrient and yields of rice under applying equivalent green manure[J]. Soil and Fertilizer Sciences in China, 2011, (4): 79–82

[11]          ,          ,          .
                              [J].                 , 2014, 51(4): 888–896
Wang J H, Cao K, Zhang X. Effects of incorporation of Chinese milk vetch coupled with application of chemical fertilizer on nutrient use efficiency and yield of single-cropping late rice[J]. Acta Pedologica Sinica, 2014, 51(4): 888–896

[12]          ,          ,          ,     .
                              [J].                     , 2011,

44(3): 516–523

Hou H Q, Liu X M, Liu G R, et al. Effect of long-term located organic-inorganic fertilizer application on rice yield and soil fertility in red soil area of China[J]. Scientia Agricultura Sinica, 2011, 44(3): 516–523

[13]　　　　，　　　　，　　　　，　　．
　　　　　　　　　　　　　　　[J].　　　　　　　，
2010, 22(10): 13–14

Xu C X, Xie Z J, Xu Z L, et al. Effects of applying mineral fertilizer reasonably on nutrient absorption and dry matter accumulation of early rice under applying equivalent *Astragalus sinicus*[J]. Acta Agriculturae Jiangxi, 2010, 22(10): 13–14

[14]　　　　，　　　　，　　　　，　　．
　　　　　　　　[J].　　　　　　，2015, 42(21): 1–5

Li X L, Feng Y H, Wang X Y, et al. Effects of different nitrogen application amounts on dry matter characteristics of mechanized transplanted hybrid indica[J]. Guangdong Agricultural Sciences, 2015, 42(21): 1–5

[15]　　　　，　　　　，　　　　，　　．
　　　　　　　　[J].　　　　　　　，2013, 35(1):
13–17

Zhou C H, Pan X H, Wu J F, et al. Effects of different cropping patterns on early rice yield and nitrogen absorption and utilization[J]. Acta Agriculturae Universitatis Jiangxiensis, 2013, 35(1): 13–17

[16]　　　　，　　　　，　　　　，　　．
　　　　　　　　　　[J].　　　　　　　，
2015, 36(6): 1091–1098

Tang H M, Cheng A W, Xu Y L, et al. Effects of long-term mixed application of organic and inorganic fertilizers on dry matter accumulation and yield of rice in double cropping rice fields[J]. Research of Agricultural Modernization, 2015, 36(6): 1091–1098

[17]　　　　，　　　　，　　　　，　　．
　　　　　　　　　　[J].　　　　　，2004, 35(2):
199–202

Yang C M, Yang L Z, Yan T M, et al. Effects of nutrient regimes on dry matter production and nutrient uptake and distribution by rice plant[J]. Chinese Journal of Soil Science, 2004, 35(2): 199–202

[18]　　　　，　　　，　　　　，　　．
　　　　　　　　　　[J].　　　　　　　，2013,
44(5): 10–13

Jiang B W, Li H, Wang C H, et al. Effect of mixed application of organic-inorganic fertilizers on dry matter accumulation and translocation of rice[J]. Journal of Northeast Agricultural University, 2013, 44(5): 10–13

[19]　　　　，　　　，　　　．
　　　　　　　　　　[J].　　　　　　，2016,
29(3): 579–583

Nie J, Shi L L, Qiu J R, et al. Effects of organic manure

application combined with chemical fertilizers on dry matter production and yield of rice[J]. Southwest China Journal of Agricultural Sciences, 2016, 29(3): 579–583

[20]　　　　，　　　，　　　，　　．
　　　　　　　　　　[J].　　　　　　，2013, 41(7):
2945–2947

Tang S, Wang Y Q, Cao W D, et al. Effects of N-release from *Astragalus sinicus* in different applied conditions[J]. Journal of Anhui Agricultural Sciences, 2013, 41(7): 2945–2947

[21]　　　　．
　　　　　　　　[D].　　　：　　　　　　，2013

Zhu B. Effects of nitrogen application on yield, dry matter-accumulation and remobilization, N-uptake and utilization of double-cropping rice[D]. Nanchang: Jiangxi Agricultural University, 2013

[22]　　　　，　　　，　　　，　　．
　　　　　　　　　[J].　　　　　　　，2009,
37(4): 1641–1643

Zhao T J, Feng Y H, Han G G, et al. Effects of different N application rate on the matter accumulation and translocation of transplanted hybrid rice under No-tillage condition[J]. Journal of Anhui Agricultural Sciences, 2009, 37(4): 1641–1643

[23]　　　　，　　　，　　　．
　　　　　　　　[J].　　　　　　　，2016, 49(13):
2561–2571

Yang X Y, Liu X H, Han X R. Effect of nitrogen application rates in different fertility soils on soil N transformations and N use efficiency under different fertilization managements[J]. Scientia Agricultura Sinica, 2016, 49(13): 2561–2571

[24]　　　　，　　　，　　　，　　．
　　　　　　　　[J].　　　　　　　，2015, 29(3):
190–195

Liao Y L, Lu Y H, Xie J, et al. Effects of combined application of controlled release nitrogen fertilizer and Chinese milk vetch on yield and nitrogen nutrient uptake of early rice[J]. Journal of Soil and Water Conservation, 2015, 29(3): 190–195

[25]　　　　，　　　，　　　，　　．
　　　　　　　　　[J].　　　，2010, 42(3): 467–472

Yao W Q, Qin J T, Zhang J G, et al. Effects of different patterns of fertilization on rice nutrient use in Jinxian County of Jiangxi Province[J]. Soils, 2010, 42(3): 467–472

[26]　　　　．　　　　　　　　　　　　[J].
　　　　　　，2001, 23(3): 262–266

Shang Y F. Influence of organic-inorganic compound fertilizers on nitrogen recovery in paddy rice[J]. Journal of Southwest Agricultural University, 2001, 23(3): 262–266

[27]　　　　，　　　，　　　，　　．
　　　　　　　　[J].　　　　　　　，2009, 20(3):
624–630

Zhang X L, Meng L, Wang Q J, et al. Effects of

organic-inorganic mixed fertilizers on rice yield and nitrogen use efficiency[J]. Chinese Journal of Applied Ecology, 2009, 20(3): 624–630

[28]　　．　-
　　　　　[D]．　　：　　　　，2012
Li H. Study of the application of organic-inorganic fertilizer on the nutrient accumulation of rice and nitrogen use efficiency[D]. Harbin: Northeast Agricultural University, 2012

[29]　　．　　-
　　　　　　　[D]．　　：　　　，2008

Meng L. Effects of application of organic-inorganic mixed fertilizers on the yields of rice grains and nitrogen use efficiency and soil nitrogen supply[D]. Nanjing: Nanjing Agricultural University, 2008

[30]　　　，　　，　　．
　　　　　　　——SSNM[J]．　　　：
　，2003, 29(1): 67–70
Wang G H, Zhang Q C, Huang C Y. SSNM — A new approach to increasing fertilizer N use efficiency and reducing N loss from rice fields[J]. Journal of Zhejiang University: Agriculture & Life Sciences, 2003, 29(1): 67–70