# The Approach and Practice for the Cultivation of Nitrogen-Saving and High-yielding of Super Hybrid Rice

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- The Nitrogen-saving issue in Super-High-yielding cultivation of rice
- Approaches for the nitrogen-saving and high-yielding cultivation of super Hybrid Rice

1. Study and practice of the nitrogen-saving and high-yielding cultivation

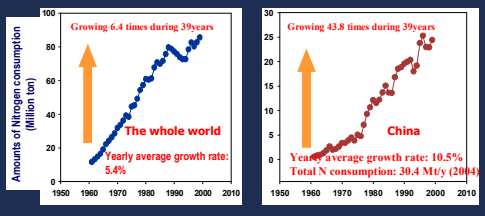
# 1. The Nitrogen-saving issue in Super-High-yielding cultivation of rice

## Hybrid rice made great contribution to Chinese food security

- Basic Chinese situation
  - population: about 1.3 billion
  - population rate: 22% of world's
  - arable land rate: 9% of world's
- China became self-sufficient in basic food for the first time in modern history
- Tremendous accomplishment in last century, the innovation of HYBRID RICE, made by Prof. Yuan Longping

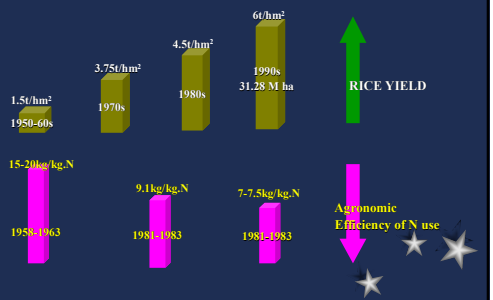
Using 9% of the world's arable land
Feeding 22% of world's population

## Question 1: Arable land in China: 9%, but nitrogen consumption: 33.7%




Key issues to be resolved for super high-yielding rice cultivation:
Environmental friendly
Resource-saving as well as
High-yielding and profit

## The continuous increase of rice yield last 50 years in China but decrease of the efficiency of N use



## Question 2: higher N rate result in higher yield?

Tab 1. Yield response with N application in different N experiments

| Varieties | Highest yield（t/ha） | Purity N applied （kg/ha） | Data originated |
|---|---|---|---|
| Wujin9728 | 8.98 | 375.0 | Feng Tao et al |
| 9746 | 11.32 | 300.0 | Ye Huabing et al |
| Wuxianggen14 | 8.93 | 300.0 | Luo Jianjun et al |
| Xieyou9019 | 8.90 | 300.0 | Ruan Xinming et al |
| Sanyou63 | 9.54 | 170.1 | Liu Lijun et al |
| 9915 | 9.34 | 141.5 | Liu Lijun et al |
| Liangyou 293 | 12.14 | 231.0 | Demonstration plot |
| Liangyoupeijiu | 12.26 | 255.0 | Demonstration plot |

High yielding cultivation results in higher nitrogen application:

- Single cropping of rice: 226 kg/ha
- Double cropping of rice: 185 kg/ha
- National average: >200 kg/ha
- World's average: 90 kg/ha(FAO, 2002)

Problem: 33.6% households consume excessive N at >250 kg/ha (CAU,2005)

## Question 3: Face to next super high yielding?

Yield of Super HR: 10.5t/ha → 12t/ha → 13.5kg/ha

N amount applied: 202.5kg/ha → 240~270kg/ha → >300??Kg/ha

Table The yield and amounts of N application for Super hybrid rice demonstration

| year | location | Hybrid varieties | Yield (t/ha) | N amount (kg/ha) | marks |
|---|---|---|---|---|---|
| 2004 | HUNAN | Liangyou293 | 12.15 | 231 | designed |
| 2002 | HUNAN | Liangyoupeijiu | 12.26 | 255 | Less measure for |
| 2003 | HAINAN | Liangyou293 | 12.40 | 420 | Sandy soil |

How much quantity N could meet a new target of 13.5 t/ha?
What are the worse effects unknown by high N cultivation?

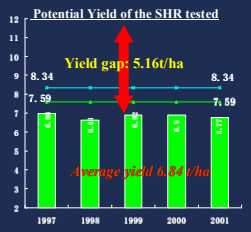
World's Yield record: 17.1 t/ha(1999)
New record: 19.3 t/ha(2006)
Above 12t/ha in an area of 8 ha at Longshan county in 2002

## Question 4: Face to the great yield gap on large scale?

- The yield of super hybrid rice in test area of Hunan province: 12t/ha
- The average yield of single-cropping rice in Hunan: only 6.84t/ha
- Yield gap: 5.16 t/ha
- The possible target of rice production on the large scale in order to accelerate the healthy development and application of the super HR:

  Yield increased by 0.75-1.5 t/ha

  The average yield increased up to 7.59-8.34t/ha

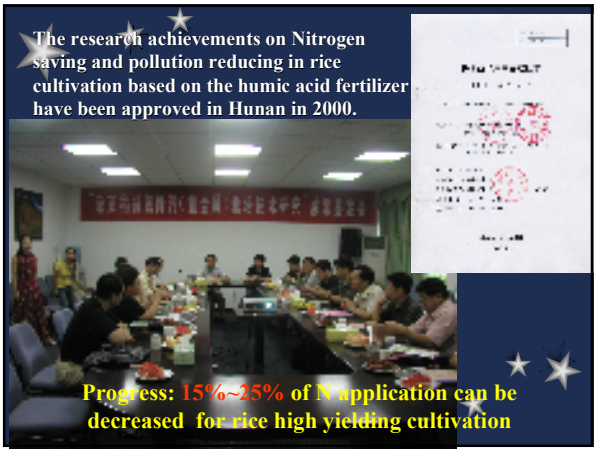



How to shorten the yield gap of rice production on the large scale ?
What is the corresponding nitrogen-saving techniques for Super HR?

## The idea of nitrogen-saving technique

- high efficiency of nitrogen use (rice variety, slow release fertilizer and relative techniques)
- less nitrogen application
- High-yielding and profit
- Environmental friendly

The research achievements on Nitrogen saving and pollution reducing in rice cultivation based on the humic acid fertilizer have been approved in Hunan in 2000.





Progress: 15%~25% of N application can be decreased for rice high yielding cultivation

Progress : Developed the materialized technical product---- Special component fertilizer of lower-N, suitable P & higher P, and new recommendation: 142.5-187.5 kg/ha for the super HR rice cultivation based on the balanced fertilization

## 2. Approaches for the nitrogen-saving and high-yielding cultivation of super Hybrid Rice

### 1) Genetic potential

- Key indicators for Breeding program as a two-way choice :
  - yield potential and wide adaptation
  - Agronomic efficiency of N utilization
- Good new varieties selected perform not only lower nitrogen toleration but higher yield and wide adaptation

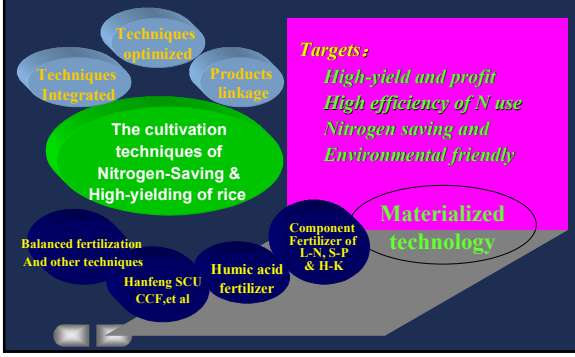
### 2) Management technical potential

- Adopt different advanced techniques and skills of fertilizer managements
- a balanced fertilization and the site-specific nutrient management (SSMN)

### 3) Materialized technology potential

- Merge special techniques into special kinds of fertilizers
- New component fertilizer with designed lower-N, suitable P and higher K based on method of the balanced fertilization
- Hanfeng SCU and CCF based on the slow-release techniques

### The system of cultivation techniques of Nitrogen-Saving & High-yielding of rice




## 3. Study and practice of the nitrogen-saving and high-yielding cultivation

### 3.1 the differences between genotypes in nitrogen response of super hybrid rice

| Year of 2006 | | | Year of 2007 | |
|---|---|---|---|---|
| | varieties | N treatments | varieties | N treatments |
| 1. | Zhun S/1243 | A、90 kg/hm² B、180 kg/hm² | 1. Zhun S/1243 | A、0 kg/hm² B、90 kg/hm² C、180 kg/hm² |
| 2. | 58S/2469 | | 2. 58S/2469 | |
| 3. | Long liangyou No 1 | | 3. Long liangyou No 1 | |
| 4. | C-liangyou 343 | | 4. C-liangyou 343 | |
| 5. | 58s/3218 | | 5. Zhun S/187 | |
| 6. | 1161S/2469 | | 6. Liangyoupeiji u | |
| 7. | Anlong3S/aixun 6 | | | |
| 8. | peiai64S/1243 | | | |
| 9. | Y-liangyou No1 | | | |
| 10. | C-liangyou 87 | | | |
| 11. | Liangyoupeijiu | | | |
| 12. | Keyou 21 | | | |
| 13. | 58S/747 | | | |

**Yielding differences between different genotypes of super hybrid rice varieties**

| | varieties | yield(t/hm²) N1 | yield(t/hm²) N2 | N1 to N2 (%) | test P<0.05 | test P<0.01 | type |
|---|---|---|---|---|---|---|---|
| 2006 | Zhun S/1243 | 10.475 | 10.268 | 2.02 | NO | | I |
| | 58S/2469 | 9.561 | 9.343 | 2.33 | NO | | |
| | Long liangyou No 1 | 9.183 | 9.687 | -5.20 | NO | | |
| | C-liangyou 343 | 9.473 | 10.147 | -6.65 | NO | | |
| | 58s/3218 | 9.417 | 10.287 | -8.46 | Significant | NO | II |
| | 1161S/2469 | 8.447 | 9.177 | -7.96 | Significant | NO | |
| | Anlong3S/aixun 6 | 8757 | 9.726 | -9.96 | Significant | NO | |
| | pciai64S/1243 | 8.658 | 9.777 | -11.45 | Significant | NO | |
| | Y-liangyou No1 | 9.198 | 10.376 | -11.36 | Significant | NO | |
| | C-liangyou 87 | 9.378 | 11.046 | -15.10 | | Significant | III |
| | liangyoupeijiu | 8.405 | 10.140 | -17.11 | | Significant | |
| | Keyou 21 | 7.770 | 9.483 | -18.06 | | Significant | |
| | 58S/747 | 8.276 | 11.135 | -25.69 | | Significant | |
| 2007 | Zhun S/1243 | 11.299 | 10.937 | 3.20 | NO | | I |
| | C-liangyou 343 | 10.855 | 11.070 | -1.98 | NO | | |
| | Zhun S/187 | 10.472 | 10.766 | -2.81 | NO | | |
| | 58S/2469 | 10.277 | 11.290 | -9.86 | Significant | | II |
| | Guang S-1/P117 | 10.486 | 11.069 | -5.56 | Significant | | |
| | Liangyoupeijiu | 9.182 | 10.388 | -13.13 | Significant | | |

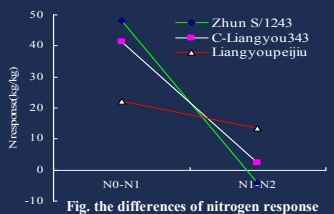



**Fig. the differences of nitrogen response between super rice hybrids(2007)**

N rate Note: N0: no nitrogen application, Ck, N1: 90kg/hm2; N2: 180kg/hm2

N response Results:

- Lower-nitrogen-tolerate type varieties(zhunS/1243 and C-Liangyou343)
  - N0 to N1: very strong
  - N1 to N2: Weak & negative
- Nitrogen-favorite type (Liangyoupeijiu)
  - N0 to N1: Stronger
  - N1 to N2: Strong also

## 3.2 Nitrogen-saving effect of humic acid fertilizer

6 treatments in 2 hybrid rice varieties at 3 replications, the results as follows:

- BF treatments under nitrogen-saving conditions (minus N 15% to 25%) yielded more significantly than No BF treatments
- Under nitrogen saving 15%, BF treatment yielded the same as 180kg/ha
- No obvious different between BF or no BF under higher N (180kg/ha)
- under nitrogen-saving condition (153~225kg/ha), BF treatment increased
  - the effective panicle: +2.9%~6.3%
  - spikelets per panicle +2%~9.3%
  - filled spikelets: +0.5~2.9 percentage

Table 2、The effects of nitrogen-saving of the humous fertilizer, Black Fertilizer

| varieties | treatments | Pure Nitrogen (kg/ha) | Yield (t/ha) |
|---|---|---|---|
| Fengyou 299 | No BF+ NS 25% | 135 | 6.61Cc |
| | BF+ NS 25% | 135 | 6.95Bb |
| | No BF + NS 15% | 153 | 6.92Bb |
| | BF + NS15% | 153 | 7.30Aa |
| | No BF + Full N | 180 | 7.25Aa |
| | NF + Full N | 180 | 7.24Aa |
| T-you 207 | No BF+ NS 25% | 135 | 6.76Cc |
| | BF+ NS 25% | 135 | 7.08Bb |
| | No BF + NS 15% | 153 | 7.11Bb |
| | BF + NS15% | 153 | 7.47Aa |
| | No BF + Full N | 180 | 7.45Aa |
| | NF + Full N | 180 | 7.41Aa |

## 3.3 Effect of balanced fertilization and nitrogen-saving of component fertilizer lower N, suitable P & high K

6 treatments in different ecological locations, at 3 replications within 2 years, the results as follows:

- In high yielding rice cropping area, it can gain maximum yield under applying high level nitrogen but lower rate of the output to cost
  - → nitrogen level >180.0 kg/ha , rate of output to cost <10.0.
- In high yielding rice cropping area, treatments of Nitrogen-reducing (from 10% to 40%) can obtain higher yield , that means that the excessive nitrogen is not good for high yield, but a waste of nitrogen resource and deteriorates the environment

Tab 3. Effect of component fertilizer of lower N, suitable P & high K,( in 2004-2005)

| Treatments | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 |
|---|---|---|---|---|---|---|---|---|---|
| Location | Total N | 124.5 | 106.5 | 142.5 | 123.75 | 141.75 | 187.5 | 206.25 | 0 |
| | Total NPK | 334.5 | 274.5 | 394.5 | 291.75 | 351.75 | 440.1 | 497.25 | 0 |
| Liling, Hunan | Yield | 9.15 | 8.40 | 9.66 | 8.80 | 9.60 | 10.35 | 10.41 | 5.85 |
| | output to input | 13.60 | 10.21 | 9.92 | 12.40 | 11.17 | 9.68 | 9.02 | |

In medium-, high- yielding rice cropping area:

- Liangyou 293 do not always output high yield under higher level of nitrogen application, Lower N level obtained higher yield .
- There are no significant differences in between different N levels, and nitrogen saving by reducing the total amount of nitrogen can achieve the higher productivity and higher efficiency of N use. So that the Nitrogen recommendation for farmers can be 135 kg/ha to 180 kg/ha.
- The higher nitrogen level ,the lower ratio of output to cost
  - → nitrogen level >145.0 kg/ha , ratio of output to cost <10.0.

Tab 3. Effect of component fertilizer of lower N, suitable P & high K, in 2004-2005)

| Treatments | | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 |
|---|---|---|---|---|---|---|---|---|---|
| Location | Total N | 124.5 | 106.5 | 142.5 | 123.75 | 141.75 | 187.5 | 206.25 | 0 |
| | Total NPK | 334.5 | 274.5 | 394.5 | 291.75 | 351.75 | 440.1 | 497.25 | 0 |
| Xiang Xiang, Hunan | Yield | 9.57 | 9.11 | 9.83 | 9.35 | 9.59 | 9.64 | 9.18 | 7.85 |
| | output to input | 11.63 | 13.54 | 10.10 | 13.18 | 11.15 | 9.01 | 7.96 | |

## 3.4 The nitrogen-saving Effect of slow-release fertilizer

### 3.4.1 The differences of yield and nitrogen utilization between slow-release fertilizers

Fertilizers:

- SCU (sulfur coated urea)
- CCF (coated component fertilizer)
- Urea
- Ck (no nitrogen application)

Treatments:

- NE: equal nitrogen application at 180kg/ha
- NS: nitrogen application at 135kg/ha

Place and years: at the standing plots/field of 2 years' continuous experiment in Changsha, China in 2006 and 2007

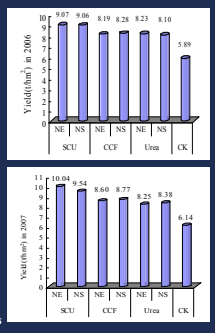



Fig.3. The yield differences between slow-release fertilizers and nitrogen applications

## Comparison of nitrogen use efficiencies of different fertilizer treatments

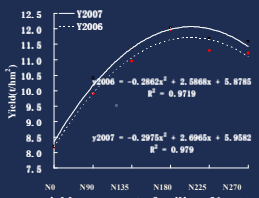
| Year | Treatment | | PE (kg/kg) | $N^-/N^+$ | AE (kg/kg) | $N^-/N^+$ | RE(%) | $N^-/N^+$ | PFP (kg/kg) | NHI | NGPE (kg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | SCU | $N^-$ | 40.07a | +12.37 | 23.44a | +38.37 | 58.5a | +23.16 | 67.10a | 0.66a | 49.60a |
| | | /$N^+$ | 35.66b | | 16.94bc | | 47.5b | | 48.40c | 0.64a | 47.06bc |
| | CCF | $N^-$ | 33.78b | +11.82 | 16.68b | +29.3 | 49.4b | +15.69 | 61.30b | 0.57b | 47.51b |
| | | $N^+$ | 30.21cd | | 12.90cd | | 42.7d | | 43.70c | 0.56b | 45.59c |
| | Urea | $N^-$ | 31.19c | +5.55 | 13.36bc | +18.76 | 42.8d | +12.34 | 60.00b | 0.56b | 46.44bc |
| | | $N^+$ | 29.55d | | 11.25d | | 38.1e | | 44.40c | 0.55b | 44.59c |
| | SCU/ | $N^-$ | | +28.47 | | +75.45 | | +36.68 | | | |
| | Urea | $N^+$ | | +20.68 | | +50.58 | | +24.67 | | | |
| 2007 | SCU | $N^-$ | 42.16a | +1.64 | 25.16a | +20.9 | 59.7a | +18.92 | 70.65a | 0.67a | 51.11a |
| | | $N^+$ | 41.48a | | 20.81b | | 50.2b | | 53.56c | 0.63b | 49.42ab |
| | CCF | $N^-$ | 37.63b | +20.88 | 19.45bc | +42.18 | 51.7b | +17.77 | 64.93b | 0.62bc | 47.53bc |
| | | $N^+$ | 31.13cd | | 13.68d | | 43.9cd | | 45.88d | 0.59c | 46.35c |
| | Urea | $N^-$ | 29.96d | +0.91 | 13.59d | +23.88 | 45.4c | +23.04 | 62.11b | 0.56cd | 46.76c |
| | | $N^+$ | 29.69d | | 10.97d | | 36.9e | | 43.98d | 0.55d | 45.88c |
| | SCU/ | $N^-$ | | +40.72 | | +85.13 | | +31.49 | | | |
| | Urea | $N^+$ | | +39.71 | | 89.69 | | +36.04 | | | |

Note: PE: Physiological efficiency; AE: Agronomic efficiency; RE: Recovery efficiency; PFP: Partial factor productivity; NHI: Nitrogen harvest index; NGPE: Nitrogen grain production efficiency

## 3.4.2 The optimized nitrogen rate and diminishing marginal yield analysis

### 1) The optimized nitrogen rate

- The highest yields appeared at same rate of 180kgN.ha-1. Over or less this rate, Y-you No 1 also yielded less.
- The N application increased from N135 to N225 and N270 by 66.7% ~ 100%, but the yield in N225 and N270 was little higher by only 2.1%~3.2%.



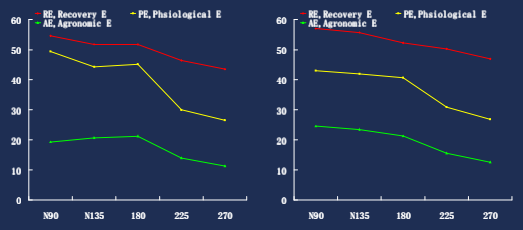

yield response to fertilizer N rate

### 2) diminishing marginal yield analysis

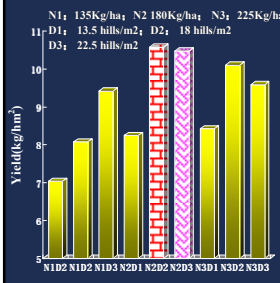
- When N rate at $X_{2006}$=217.3 kg/hm2 & $X_{2007}$ 214.0kg/hm2, then, the maximum yield: $Ymax_{2006}$=11.50t/hm2，$Ymax_{2007}$=11.85t/hm2。
- When the best economic yield at Y2006=11.30t/hm2，Y2007=11.67t/hm2,then The best economic N rate: X2006=165.0 kg/hm2 & X2007=167.30kg/hm2

**The N quantity decreased by about 30% but yield only less 1.5%～1.7%**

## Effeciency of Nitrogen use




## 3.4.3 The ratio of NPK under slow release fertilizer N



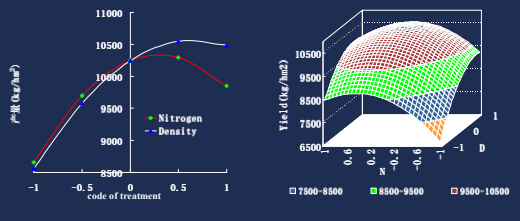

**The highest yield appeared at the medium N with medium or higher desity(N2D2，N2D3)**

Yield component and interaction effect between fertilizer N and density（2007）

| treat | Effective panicle (/m²) | Spike-lets | filled | SSR (%) | Grain weight (g) |
|---|---|---|---|---|---|
| N1D1 | 183.0d | 186.2c | 149.9c | 80.5b | 24.8b |
| N1D2 | 201.0c | 195.3ab | 166.8b | 85.4a | 25.1ab |
| N1D3 | 220.0b | 199.3a | 175.0a | 87.8a | 25.3a |
| N2D1 | 205.0c | 194.0b | 168.0ab | 86.6ab | 25.2ab |
| N2D2 | 211.0bc | 198.2a | 178.4a | 90.0a | 25.4a |
| N2D3 | 247.0a | 199.9a | 179.9a | 90.0a | 25.6a |
| N3D1 | 199.0c | 201.4a | 157.9b | 78.4b | 25.4a |
| N3D2 | 223.0b | 197.2ab | 162.5b | 82.4ab | 25.8a |
| N3D3 | 238.0a | 196.5ab | 162.5b | 82.7ab | 25.8a |
| N | * | * | * | NS | NS |
| Density | * * | NS | * * | * * | NS |
| N×D | * * | NS | * * | * | NS |

**Yield component can be optimized under medium nitrogen treatment**

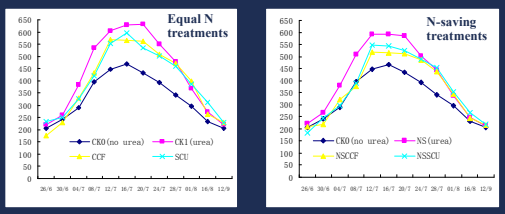
## The main effect and interaction effect between fertilizer N and density




**The negative interaction effect between fertilizer N and density indicate indicated the density contribute more yield than fertilizer N under nitrogen saving technique。**

## 3.5 The other important characters of the nitrogen-saving technique

### 3.5.1 Stable process of tillerring and healthy population construction




The effects on the tillering dynamics of different slow-release fertilizers

**SCU & CCF(Equal N or N-saving): Tillering initiates slowly, increase stably and no panicle difference. Urea initiates tillering fast in the early stage and promote much higher maximum tillers than that of release fertilizer**

## The effects on the tillers and panicles between different slow-release fertilizers

Variety, Y-you No 1

| Treatments | SCU | | CCF | | Common urea | |
|---|---|---|---|---|---|---|
| | NS | NE | NS | NE | NS | NE |
| Maximum tillers (per $m^2$) | 546.9 | 594.5 | 517.7 | 570.6 | 590.9 | 633.3 |
| Effective Panicles (per $m^2$) | 267.0 | 310.9 | 243.3 | 261.6 | 246.9 | 270.8 |
| Effective Panicles rate (%) | 48.83 | 52.31 | 46.99 | 45.84 | 41.80 | 42.76 |

1） SCU：HanFen SCU，$N_2$ $P_2$ K=37：0：0；2） CCF：$N_2$ $P_2$ K=15：8：12；
3） NE：N 187.5kg/ha; NS: 130 kg/ha (30% N-saving).

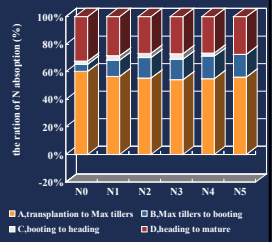
1. The maximum tillers were less SCU treatments than common urea, but the effective panicles conversely;
2. Under N-saving 30%, SCU treatments get the same panicles as full common urea.

Conclusion: the NUE. of SCU is higher that of common urea.

## 3.5.2 Nitrogen supply and absorption delay

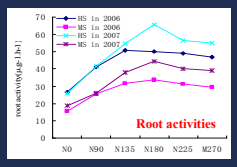
1） the differences between slow release fertilizer (left) and different N rate (right)

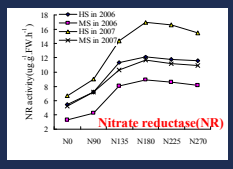
| treatment | SCUN- | SCUN | CCFN- | CCFN | UreaN- | UreaN |
|---|---|---|---|---|---|---|
| A (%) | 46.31 | 46.78 | 54.51 | 55.90 | 68.30 | 64.13 |
| B (%) | 20.09 | 20.14 | 16.45 | 16.78 | 11.97 | 12.96 |
| C(%) | 3.47 | 3.09 | 1.76 | 1.05 | 0.61 | -0.09 |
| D (%) | 30.13 | 29.99 | 27.27 | 26.27 | 19.12 | 23.00 |
| Total N ($g/m^2$) | 20.08 | 21.16 | 17.95 | 18.57 | 15.89 | 17.54 |

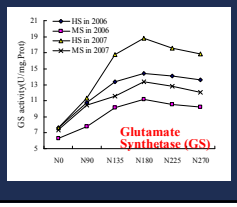


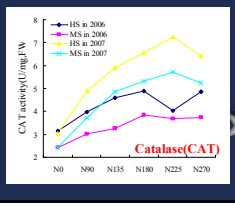

conclusion：1) with a tendency for the slow release fertilizer nitrogen to delay the nitrogen supply and absorption; 2) having a good match for the longer mature stage of super hybrid rice due to very large panicle

## 3.5.3 The difference of the root activity and some enzymatic activities between difference N levels




## 3.5.4 The effects on the diseases and pests of SCU nitrogen-saving cultivation

Table 5 The relationship between different N levels and damages by main pests and diseases

| Levels of N (kg/ha) | leaf folding rate by leaf folder (%) | numbers of Plant hopper per 100 hills (heads) | Sheath blight | |
|---|---|---|---|---|
| | | | Ratio of susceptible plants(%) | Ratio of susceptible hills(%) |
| 0 | 0.89 | 60 | 0.0 | 0.0 |
| 90 | 4.44 | 440 | 8.0 | 20 |
| 135 | 8.22 | 1640 | 16.0 | 20 |
| 180 | 10.44 | 1620 | 27.0 | 40.0 |
| 225 | 15.33 | 2180 | 35.0 | 40.0 |
| 270 | 26.00 | 2380 | 45.0 | 40.0 |

1) The more nitrogen, the more pests and diseases;
2) 0 to 90 kg/ha, both pests and diseases are under protection; 90 kg/ha to 135 kg/ha, there is a deadly turnaround point.
3) Nitrogen-saving can apparently reduces harmful pests

# Thank you

# 中秋快乐！