East Campus \(54 \text{ ha}^2\)  
West Campus \(75 \text{ ha}^2\)
East Campus

China Agricultural University
East Campus
主楼：19000平米
配楼：3400平米
### 年度学科排名

#### 一级学科代码及名称：0828 农业工程

<table>
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<th>排名</th>
<th>百分位</th>
<th>院校名称</th>
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Departments, Majors and Centers

• Departments - 4
  1. Agricultural Engineering
  2. Mechanical Design and Manufacture
  3. Vehicle and Transportation Engineering
  4. Mechatronic Engineering

• Centers - 2
  Ù Mechanical Engineering Training Center
  Ù Technological Innovation Center for Undergraduate Students

• Undergraduate Majors - 6
  Ù Mechanical Design, Manufacture and Automation
  Ù Industrial Design
  Ù Vehicle Engineering
  Ù Agricultural Engineering
  Ù Farm mechanization and Automation
  Ù Measurement and Control Technology and Instruments
# Faculty and staff

<table>
<thead>
<tr>
<th>Faculty and staff in total</th>
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<tr>
<td>Professor</td>
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<tr>
<td>Associate professor</td>
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<tr>
<td>Lecturer</td>
<td>16</td>
</tr>
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</table>

- 18 Part-time Professors
- About 2000 students, include 1424 undergraduates, 159 MSc. students and 296 PhD students
Research Fields

- **Field Operation machinery** (Conservation Tillage, Grain and Forage Mechanization)

- **Intelligent Equipment** (Integration of Automation, Agro Robots)

- **Food Processing Equipment** (include Bio resource Utilization)
Fund Sources

Annual Average Fund 10m USD
Research Platforms

Lab. & Centers

- 生物质能科学与技术国际联合研究中心
- 现代农业装备与设施教育部工程研究中心
- 农业部土壤-机器-植物系统技术重点实验室
- 农业部可再生能源清洁化利用技术重点实验室
- 国家农产品加工技术装备研发分中心
- 农业部河北北部耕地保育科学观测实验站
- 现代农业装备优化设计北京市重点实验室
- 农业部保护性耕作研究中心
- 中国农业大学农业工程研究院
- 中国农业大学中国农业机械化发展研究中心
一. Grain Production
二. Ag Mechanization
三. Tillage
四. Planting
五. Harvesting
Crop Allocation in China

North Cotton Belt

Soybean Belt

Wheat /Corn /Soybean Belt

Rape Seed Belt

Rice Belt

Corn Belt
Different farming system in terms of geography

- One crop a year - North east, North west, inner M
- Two crops a year - Most areas in the middle area
- Multi crops a year - very South area
Maize, Rice, wheat, potato, soybean, ……

Maize is the most important crop for food, animal feed and industrial materials, which leading to its sharp increasing demand in China in the last decade.

increase in terms of acreage
increase in terms of tonnage
1. Major Grain Production In China

Maize production In last decade (2006—1015)

26.97 mha—38.11 mha, increase 41.3%
151.6 mt—224.6, increase 48.1%
<table>
<thead>
<tr>
<th>year</th>
<th>Acreage (million hm²)</th>
<th>Yield (t/hm²)</th>
<th>Output (mt)</th>
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<td>5.17</td>
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<td>2009</td>
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<td>5.26</td>
<td>163.5</td>
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<tr>
<td>2011</td>
<td>33.43</td>
<td>5.73</td>
<td>191.7</td>
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<tr>
<td>......</td>
<td></td>
<td></td>
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<tr>
<td>2016</td>
<td>36.76</td>
<td>5.97</td>
<td>219.55</td>
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<tr>
<td>Rice</td>
<td>30.16</td>
<td>6.86</td>
<td>206.93</td>
</tr>
<tr>
<td>Wheat</td>
<td>24.19</td>
<td>5.32</td>
<td>128.85</td>
</tr>
</tbody>
</table>
1. Major Grain Production In China

**Tree crops total area**

- **Rice**
- **Maize**
- **Wheat**
1. Major Grain Production In China

Tree crops total output

Maize

Wheat

Rice
1. Major Grain Production In China

Cost Vs Benefit

2015年玉米价格市场化，而小麦、稻谷依然实施国家保护价，三大粮食作物的生产效率对比中，玉米的相对生产效率弱势，在亩均生产总成本、亩均产值、亩均净利润等方面的比较上发现玉米的种植效益也在三大作物中处于比较弱势。

张丽娜 博士论文
World Corn production

World corn production statistics:

Total planting areas: 153 million hm²
Total yeild: 792 million ton
Per unit yield: 5.2 t/hm²

(346 kg/mu, China: 382 kg/mu)

Total Yield and Per Unit Yield Map for World Corn (ton/hectare, data source: FAO)
Contradiction

Lower Yield

我国玉米单产的增益速度非常缓慢，平均每公顷35公斤，远低于发达国家（154公斤/公顷·年），更低于阿根廷（244公斤/公顷·年）等发展中国家。玉米增产贡献率的75%以上来自扩大种植面积，25%来自提高单产。
High cost

我国农户玉米生产规模小（平均0.5公顷），生产成本连年攀升，与全球玉米主要出口国的成本差距进一步拉大。以美国为例，2015年美国每亩玉米生产成本为696.8元，亩产量为711.4公斤，而中国每亩玉米生产成本为839.5元，亩产量仅为393公斤。加之价格调整等因素的影响，中国与美国农户玉米种植收入差距巨大。（其中：人工亩成本，中国2007年150元增加到2016年的458元，美国33元基本没有变化）
Contradiction

Week market competitiveness

2015年，我国进口玉米的到岸税后价与国内市场价差虽有所缩小，但仍达每吨600元（实际上各类农副产品都类似）。
Contradiction

Unusual phenomena

1. More output (220mt)
2. More storage (220mt)
3. More importation (3-5mt/Yr)
What measurements?

(1) Other crops

Soybean, peanut
Fruit, Vegetable
Minor grain crops

(feasibility?)
What measurements?

(2) silage

調结构：“镰刀弯”14个省（区）调减330 hm²
“镰刀弯”地区玉米结构调整规划（2016-2020年）
① 关注下游产业
② 最好是订单种植
③ 注重品种的选择
④ 收获质量要求
⑤ 收获机械
## 2. Ag Mechanization In China

### Crop Mech. Level

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<th>plant</th>
<th>harvest</th>
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</table>
Operation difference
Gap of planting technology

US
1958年以前——外槽轮式播种机
1966年——Allis Chalmers首先开发出免耕播种机
1980年——开始推广指夹式精量播种
1980年——引进法国满盛（Monosem）气吸式精量播种并推广应用，极大地促进了精量播种技术的发展。之前美国基本是以机械式或气压式精量播种机为主
1980年后期——基本实现玉米精量播种
2010年初期——电驱式播种机的研发
目前：气力式精量播种机占90%，机械式占10%

China
1960年——外槽轮式播种机
1980年——窝眼式穴播机
2000年——勺轮式精量播种机推广应用
2005年——气力式精播机研发
2010年——引进指夹式玉米精量播种机
2012年——玉米机播水平超过80%
2014年——电驱式播种机的研发
Gap of harvesting technology

美国玉米机收时间坐标

1960年——玉米收获全部实现机械化
但以专用型摘穗脱粒机为主
1967年——国际收获机械公司将静液压驱动技术
应用于联合收获机
1970年——谷物联合收获机加装玉米割台收获籽粒
占70%左右
1977年——国际收获机械公司研发成功纵轴流式联合收获机
1980年——全部实现联合收获机加装玉米割台收获籽粒
Challenges

The production cost is getting higher
—— Labor cost, resources cost
Farmer’s income is relatively getting lower

Technologies need to be develop & extend in China

- Rice planting or transplanting
- Corn harvesting
- Potato planting & harvesting
The Fundamental Solution of Agriculture is Mechanization
## Seven Wonders of the Grain Yield

<table>
<thead>
<tr>
<th>Rank</th>
<th>Factor</th>
<th>Value</th>
<th>Value</th>
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<td>Nitrogen</td>
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<td>Hybrid</td>
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<td>Previous Crop</td>
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<td>6</td>
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<td>7</td>
<td>Growth Regulators</td>
<td>10</td>
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<td>4</td>
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</tbody>
</table>
3. Tillage Machine

Hard Pan 6cm-12cm. Bulk density of 1.52g/cm³ will seriously influence the crop roots development.

Small tractor for long time + shallow rotary tillage, repeated compaction
There are significant deficiencies of “shallow, compact and few” for Chinese cultivated land. The plowing depth becomes shallow. National average plowing depth is 16.5cm, and plowing depth for Northeast China Region is only 15.1cm which is lower than the basic requirement of 22cm and quite different from American plowing depth of 35cm.

The soil hardening is quite serious. The volume-weight most suitable for crop root development is 1.1 ~ 1.3g/cm³. National average surface soil bulk density is 1.38g/cm³.

Domestic and Foreign Corn Industry Technology Development Report 2009
Based on subsoiling, combination of scarification and preparation + cultivation pattern of straw returning to field.

The corn roots grow towards the soil pore space.
loosening combine soil preparation machine

Features:
1. Efficient in work: operation speed: 7-10km/h
2. Big working width: caas(7m), lemken(5-9m/12m)
3. High degree’s automation and tilling depth of automatic adjustment with hydraulic pressure
Scarification equipment – match with no tillage and minimum tillage

Cultivators

Combine operation

Off-set Disks

Cover soil preparation machine

Mulch Finishers
Subsoiler (Min-Till Ripper)
Middle sized hose power tractors are popular

Low traction resistant rippers are needed

Vibration type of ripper

Traction resistance reduced by 13~18%
Comparison of Vibration and non Vibration operation
profile after ripping

Shake ripping field

Non Shake ripping field
Roots underneath
Plowing:

Reversible Plow
Soil fertility (Nitrogen)

Organic Fertilizer + straw returning to field
organic matter content: 4~6% VS 1%

Stable high yield farmland soil
(Corn yield: 17-20 tons/hectare)
Previous crop rotation

(previous crop)

Combination of farming and animal husbandry: one crop one year

Corn + soybean rotation
Fertile land effect
4. Planting machine

Planting challenges for different area in China
North east area

No-till planters are available on state farms
Collective Farmers
Individual Farmers

ridging
North west area

Plastic Film——Laying & Collection
“white pollution”

Status after crop harvesting
How to collect?

By hand?
Or by machine? And When?
And what kind of machine could be available?
A kind of collector
For cotton
For maize
How to plant corn after wheat harvesting?
This is a problem for 2 crop a year area
Burn straw in fields directly
Problems caused due to straw burning in fields

Air pollution and fire disaster
Straw handling
Move straw out of fields manually?
Our Difference

Multiple row seeder

Not work
Seeder

- the sharp angle of colter boot easy to be blocked

After harvesting the wheat, directly sew the corns on the stubble no-tillage fields which cover the wheat straw. Because current wheat output is high, straw is much, the smash is not fine, and the drip is not even, the colter boot is often blocked during seeding with previous some small corn planters.
Artificial thinning: seed-consuming, time-consuming, labor-consuming, injury seedlings, soil nutrient-consuming
Improved planters are not available
planters development

Active cleaner & Inactive roller
Design of the planter
Field experiment
Cleaning results: with & without cleaner
5. Harvesting

Multi purpose combine harvesting machine
Ways of wheat harvesting

1. Manual
2. Reaper
3. Stripper
4. Combine
Ways of corn harvesting

1. Manual
2. Reaper
3. picker
4. Combine
Strong stalk, lodging resistance, no gleanings, strong comprehensive adversity-resistance

- Corn plant height: 240-250cm
- Growing season, the time from sowing to maturity: 109d
- Even ear of wheat, tidy position of ear of wheat, 130-150cm
- Long grain filling stage, and quick dehydration in the later stage
- During harvesting, water content for the grains is reduced to 15%-20%
- Loosen leaf
- Beneficial for mechanical harvesting grains
Experience

- large-scale production and standard plant

Consistent convention planting and line spacing
America: 76cm line spacing (individual 90cm)
Australia: 90cm line spacing
Europe: 75cm line spacing (multiple of 25cm)
Foreign direct threshing harvesting
Foreign direct threshing harvesting

Variety: growing season is short; consistent height of the ear and maturity; loose leaf; do not loss the ear of wheat
Those machines are not very successful in practice in China!
Breeding objectives:

— Long growing period
— High yield
— Suitable for manual
— Tight husk
Easy lodging
Corn seeds very high moisture content

Over 30% in most areas, broken or damaged seeds more than 5%
Corn Harvesting story in China

- Cab
- Elevator
- Peeler
- Header
- Bridge
- Chopper
- Tank
Work Principle of Corn

Picher & Husker
Corn harvester of stalk laying type
Stalk & ear simultaneously
harvester

Functions of cutting, collection, feeding...
Third direction of corn breeding

—Quick later seed dehydration, lax bract

During harvesting, the water content is over 30%, which not only causes grain crashing, but also affects threshing harvester application with most mature and economic technology.

Too compact husks cause threshing loss. High moisture content causes the grain loss.
Huskers
Problems
Harvesting problems in China:

Cultivation mode is diversified, and plant row spacing is different (row spacing of 30cm, 40cm, 50cm, 55cm, 60cm, 65cm, 70cm and 90cm), not beneficial for mechanical operation, specially mechanical harvesting.

Wide & narrow row space purpose: increase production?
It’s suitable for annual operation, but not for machinery!
Inter planting or inter cropping pattern:

One cultivation requirement from the mechanical harvesting – consistent plant row spacing

Plant type and spacing diversity cause hard harvesting.

● The mechanical level of the corn plant is relevantly high, but plant standard level is low.
● The plant mode from every place is diversified, such as: convention planting/relay cropping of Huang-Huai-Hai River, ridge planting of Northeast China Region, big and small row plant in all the places, and row spacing is different in different places (30～75cm). Sometimes, row spacing in the same region has many types, which is inconvenient for the mechanical operation.
direction of corn breeding

—For the breeding for mid early variety, shorten the growth period (type that gradually eliminate the interplating)

**Middle late variety** — We mainly and traditionally plant the middle late variety in China, and extend the growth time to boost the output. Interplating is caused by variety problem.
Problems caused by different row space
Harvester Picture of Different Row Spacing

Every roller has the maximum design feeding volume. If the maximum volume is exceeded, it is easy to be blocked, which cause gleaning loss, and even machine failure.
For mechanical harvesting, insistent row spacing not only increases work difficulty and reduce production rate of the machine, but also increase harvesting loss rate. Are the little narrow row and fully feeding type regarded as development direction?

Under the current condition, rapidest effective measure to improve the domestic mechanical harvesting work level is consistent plant row spacing.
Star wheel ear picking mechanism -
Solve feeding blocking problem
The technical mode for mechanical China’s corn harvesting:

1. Cutting and sunning for corns + artificial ear snapping + straw process mode
2. Artificial cluster harvesting + mechanical straw crushing returning to the field
3. Mechanical ear snapping + combine ha straw crushing returning to the field
4. Stalk harvesting mode
5. Corn silage mode
6. Threshing and harvesting mode
Kernel - silage - stalk - cob - husk

- Tapered screw, non-row-alignment
- Narrow row-spacing corn head
- Full-width chain-type corn head
- Spike reel, non-row-alignment
- Knapsack type, attached with different corn heads
- Peeling / threshing

- Non-row-alignment corn head
- 4/5/6/8/9/12 row
- In-row corn head

As Forage fight with as fuel
Row space experiment results

No more than 5% yield

Harvest loss 9%
In future, domestic mechanical harvesting development road - cross-regional work mode

- For mechanical harvesting, insistent row spacing not only increase work difficulty and reduce production rate of the machine, but also increase harvesting loss rate.
- If we want to develop corn harvesting mechanization, we must adopt similar wheat cross-regional work mode, and consistent row spacing is the key influential factor for realizing cross-regional work.

Under current condition, rapidest measure to improve domestic mechanical harvesting operation level is consistent plant row spacing.
Seeder – harvester match:

Consistent row space and number of the row
Variety——Seed breeding
• Planting pattern
• Corn Seeds Harvesters development—— with high moisture content
Maturity of seed harvest

25% ?

Principle of farm machinery, UC davis, R.A. Kepner
Corn seeds combine harvest trials

Less than 5% in total!

Started from north area by imported combines, over 8% damage
Universalization (equipped with several headers)

But lower cost, vs manual 100 rmb/mu, or 50 rmb/mu vs picker saved!
Results by harvesters or drivers

收获机A
破损率12.3%

收获机B
破损率1.93%
Dryers are needed
Corn seeds combine harvest trials

Center parts (HHH area)

Modified models from wheat combines, over 10% damage
Corn seeds combine harvest trials

Southern area

Modified models from rice combines, over 10% damage
Results
Tangential Cylinder Thresher

New Holland
Axial thresher

CASE

切流脱粒滚筒

轴流脱粒滚筒

精选机构
Combined thresher

Rotary separation

1) Impeller
2) Rotors (independent speed adjustment)
Research progress

Bed stand
Research progress

Feed system

Threshing teeth

\[ T \cos \beta_1 > F_f \sin \beta_1 \]

\[ F_f = T \tan \alpha_1 \]

\[ l_1 = \frac{S}{K} \]

\[ 5 \text{ mm} \leq R \leq 20 \text{ mm} \]

\[ v_0 = \left( 33\pi^5 K^5 F_1(e)^{10} F_2(e) R_e^3 \right)^{\frac{1}{2}} \]

\[ \frac{1000 E^4 m}{1000 E^4 m} \]
Research progress

Cylinder

\[ D = D_1 + 2h \]

\[ n = 60 \frac{v}{\pi D} \]
Separation concave

\[ F = \frac{(T \cos \theta + G)R}{R - h} \]
test on stand bench
Shaking sieve & Blowing system

\[ A_\varphi = R - R_2 \]
\[ Q = \frac{q_0}{\mu\gamma} (m^3 / s) = \frac{q_0}{\mu\rho g} (m^3 / s) \]
\[ H \approx \frac{Q}{Bv} (m) \]
\[ P_d = \frac{\rho v^2}{2} (Pa) \]
\[ P = P_j + P_d \]

外径：\( D_2 = \frac{60}{\pi n} \sqrt{\frac{p_g}{\gamma}} \) 内径：\( D_1 = \zeta D_2 \) 扩展半径：\( R_i = \frac{D_2}{2} + \frac{x}{8} h(x=1,3,5,7) \)
Field experiment

(a) 4LY-5型纵轴流玉米籽粒联合收获机 (b) 设计的低损伤组合式脱粒分离装置

(a) 收获机作业 (b) 未脱净籽粒 (c) 籽粒取样 (d) 破碎籽粒称重

13.73% vs 8.64%
Research progress

- **Materials?**
- **Mechanism?**
Snap Rollers
Grain loss 3-4%
Development trend

◆ big, 30 rows
◆ automation
◆ professional
◆ general
◆ intelligent
◆ ……
Development direction:

Large-scale (power, working width, and feeding)
Latest Progress

Border row lifter mechanism

Upper row lifter mechanism
Opposite row Sensor

Height sensor
New snapping + straw smashing compound operation mechanism: good smashing effect

Shift forward of straw shredding knife
Snapping roller with straw cutting function
◆ The width of the largest combine harvester header is 20m, and operation speed of largest and rapidest harvester Lexion750 is 35km/h.
◆ Adopt the differential mechanism, and make the positioning error of GPS reach about 2cm, and compute the output with temperature, humidity, and flow sensors in real time.
Breeding requirements for mechanization production for corns:

- Density toleration, lodging resistance
- Insect resistance, later strong straw
- Consistent height of the ear
- Mid early variety
- Quick later seed dehydration, lax bract
- Improve seed germination
- Suitable for mechanical operation
Direction of corn breeding

Density tolerance, lodging resistance - later strong straw after growing, and insect resistance in order to reduce the gleaning loss of mechanical harvests
Questions & Discussion
Thanks!