中国农业大学草业科学与技术学院
COLLEGE OF GRASSLAND SCIENCE AND TECHNOLOGY

Alfalfa for Better Management of Farm Scale Nitrogen

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Outline

01 Challenges in nitrogen management

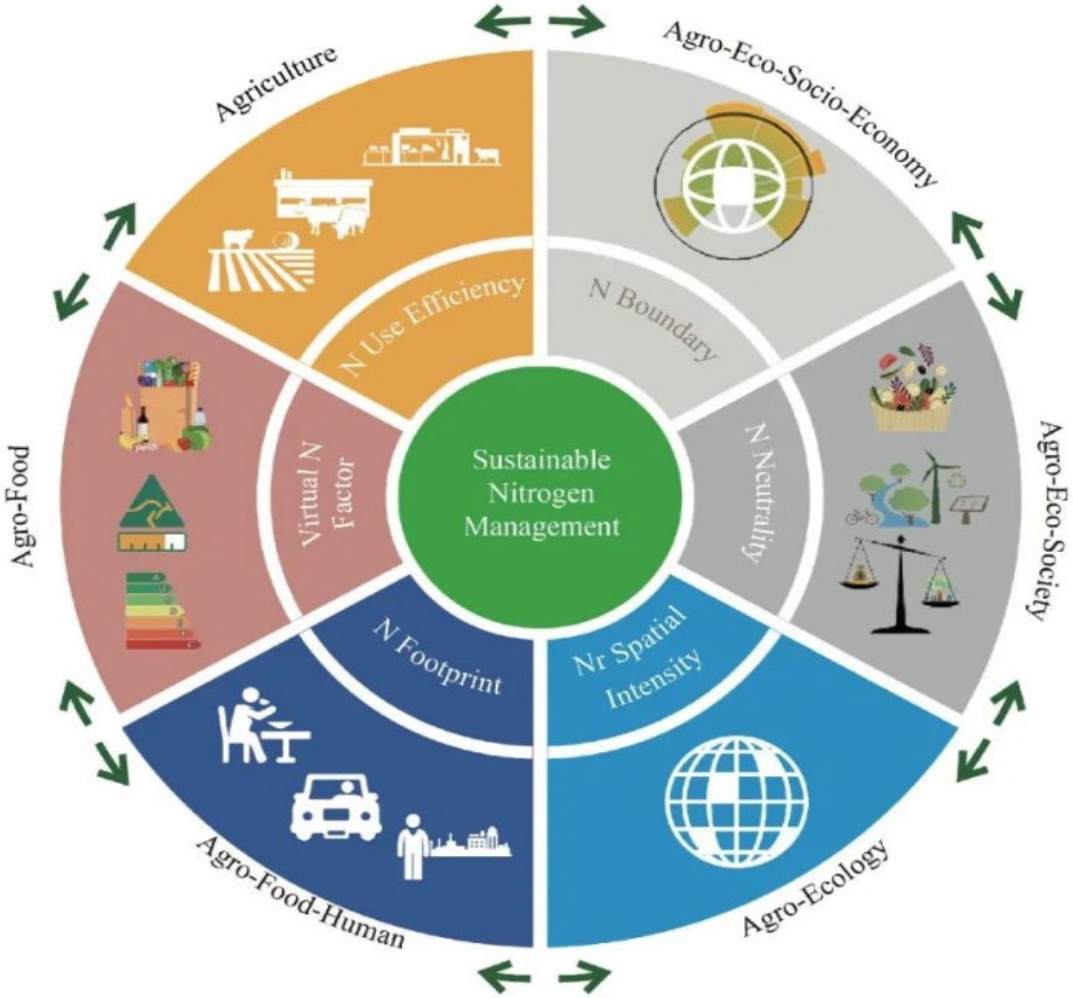
02 Advantages of alfalfa in nitrogen management

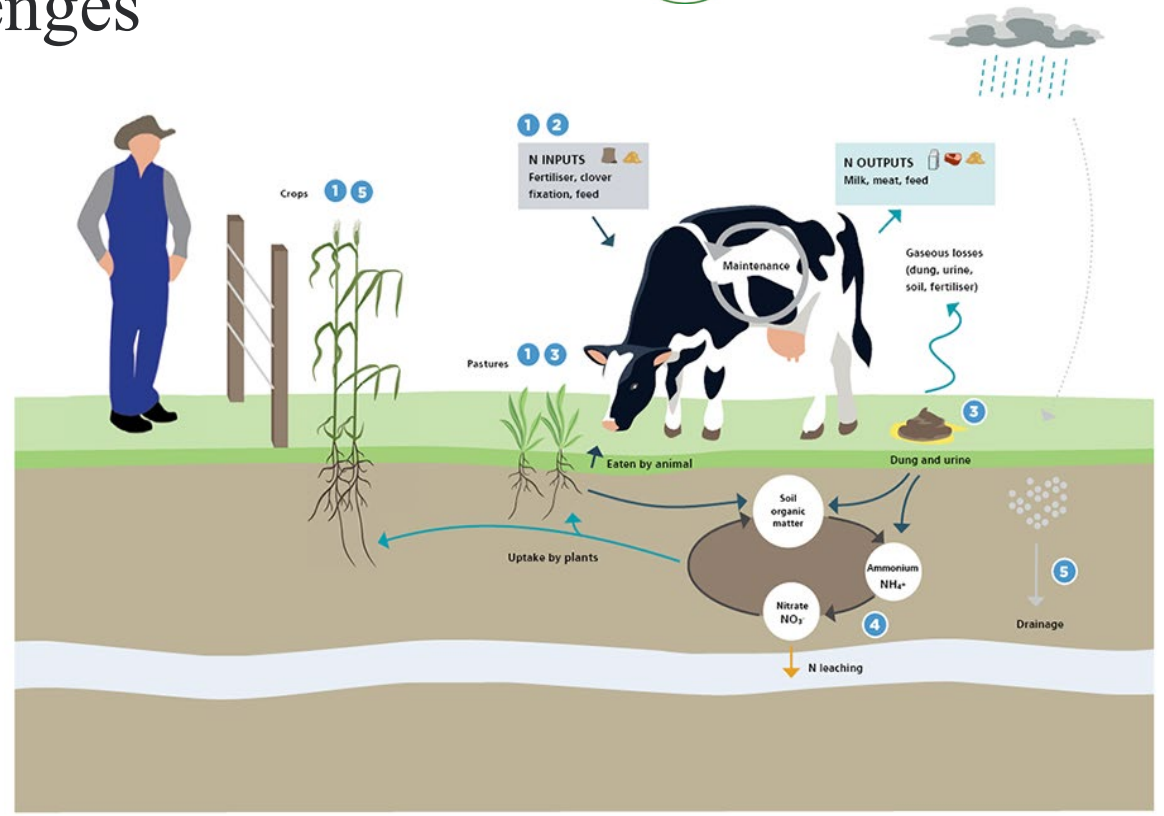
03 The N utilization of alfalfa-silage corn relay intercropping system

04 Conclusion and outlook

Challenges in nitrogen management

Resource and Environment Challenges

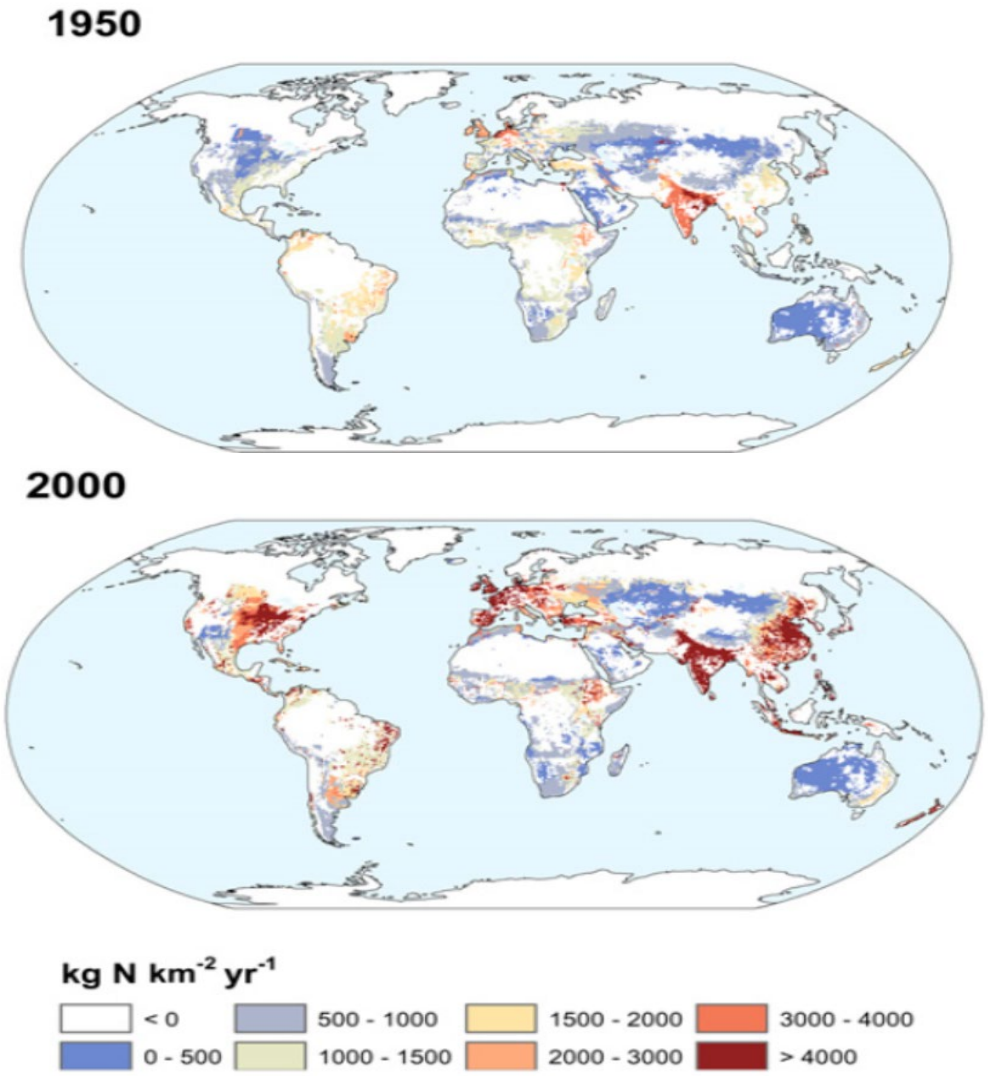


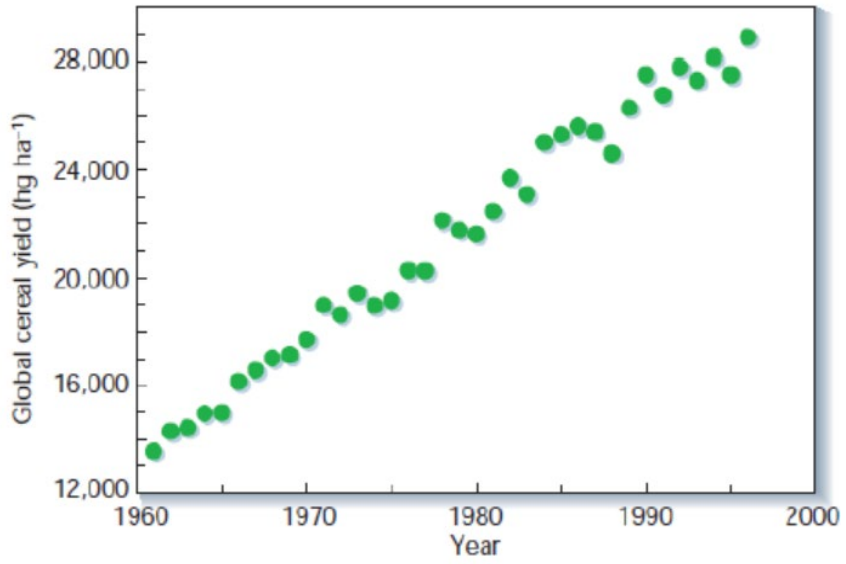


Agricultural production is one of the main ways of nitrogen loss

- Soil acidification,
- Eutrophication and water pollution
- Air pollution
- Biodiversity loss
- Health impacts
- Greenhouse gas emissions
- Climate change

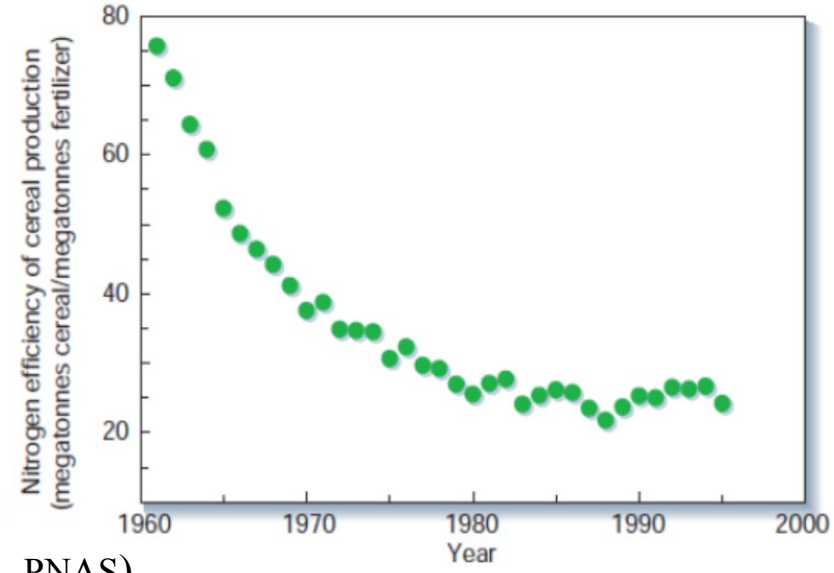
Resource and Environment Challenges





Global cereal yield (1960-2000)

N use



Nitrogen efficiency of cereal production (1960-2000)

Agricultural soil N budget for 2000 (L. Bouwman *et al*, 2013, PNAS)

(Tilman et. al., 2002)

Resource and Environment Challenges in China

Component		Taihu region: Rice	Taihu region: Wheat-south	North China Plain: Wheat-north	North China Plain: Maize
N rate (kg of N per hectare)		300	250	325	263
Recovery rate (%)*		29.6 ± 4.9	18.4 ± 6.3	31.0 ± 3.6	25.5 ± 5.2
Retention rate (%)*		21.7 ± 5.1	28.5 ± 4.6	45.7 ± 5.4	33.9 ± 2.3
Loss pathway	NH_3 volatilization (%)	11.6 ± 4.7	2.1 ± 1.4	19.4 ± 5.2	24.7 ± 5.6
	Leaching out of 1 m soil depth (%)	0.3 ± 0.5	3.4 ± 2.1	2.7 ± 2.6	12.1 ± 8.5
	Denitrification (%)	36.4†	43.5†	0.1 ± 0.04	3.3 ± 1.6

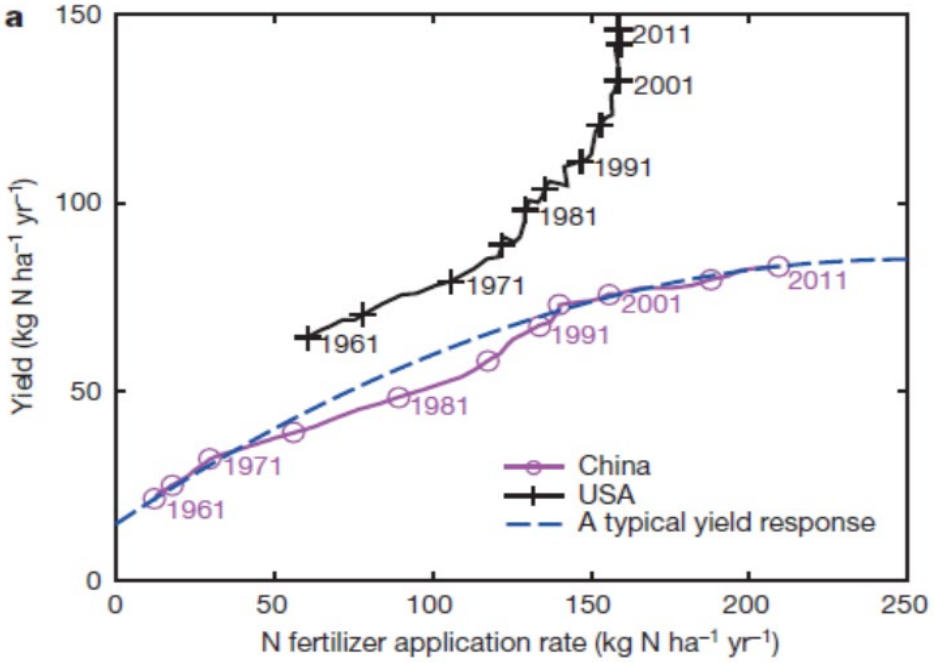
Total fertilizer N loss :

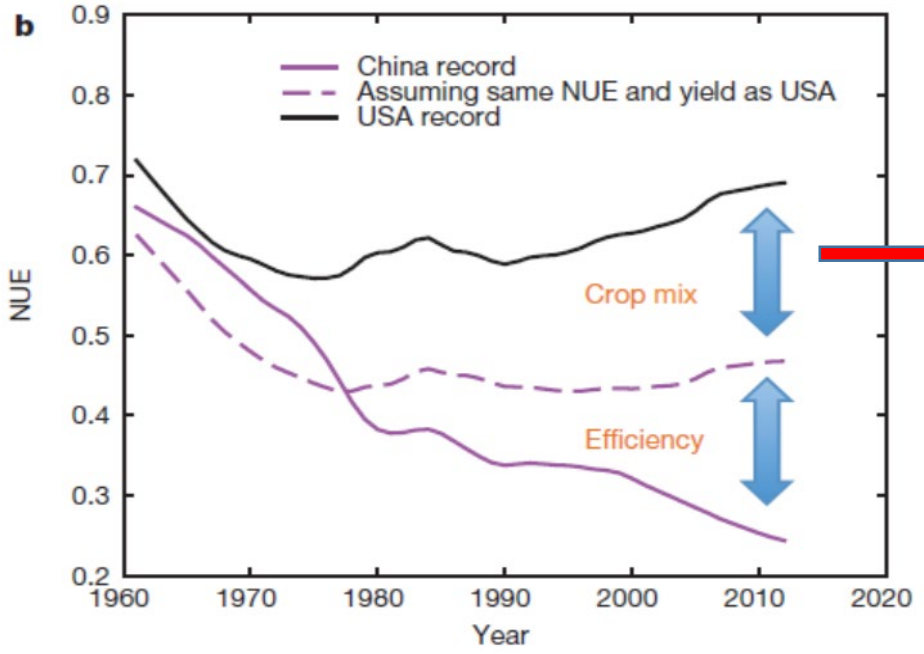
Wheat: 71-155 kg N /ha

Maize: 108 kg N /ha

Rice: 174 kg N /ha

(Ju *et al*, 2009, PNAS)

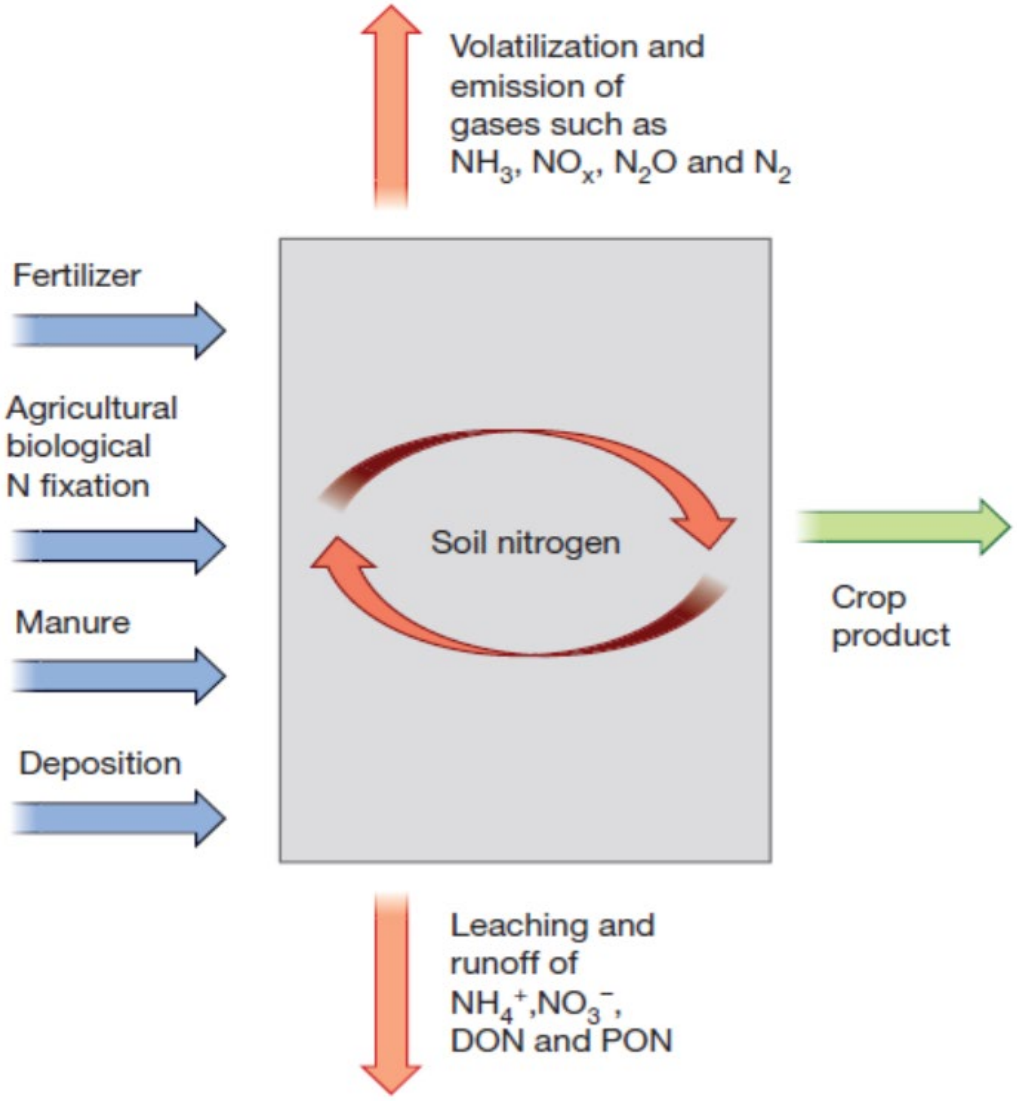




✓ **Diversify cropping system**

(Zhang *et al*, 2015, Nature)

Strategies at farm scale

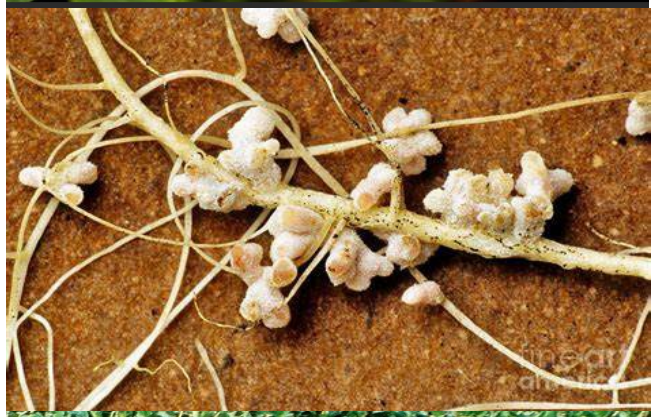


- ✓ Optimized N fertilization
- ✓ Maximize crop N-uptake efficiency
- ✓ Biological nitrogen fixation (BNF)

Advantages of alfalfa in nitrogen management

Alfalfa provides effective solutions for N management

- Forage yield : **10-18 t DM /ha**
- CP yield: **1.9-3.4 t CP /ha**



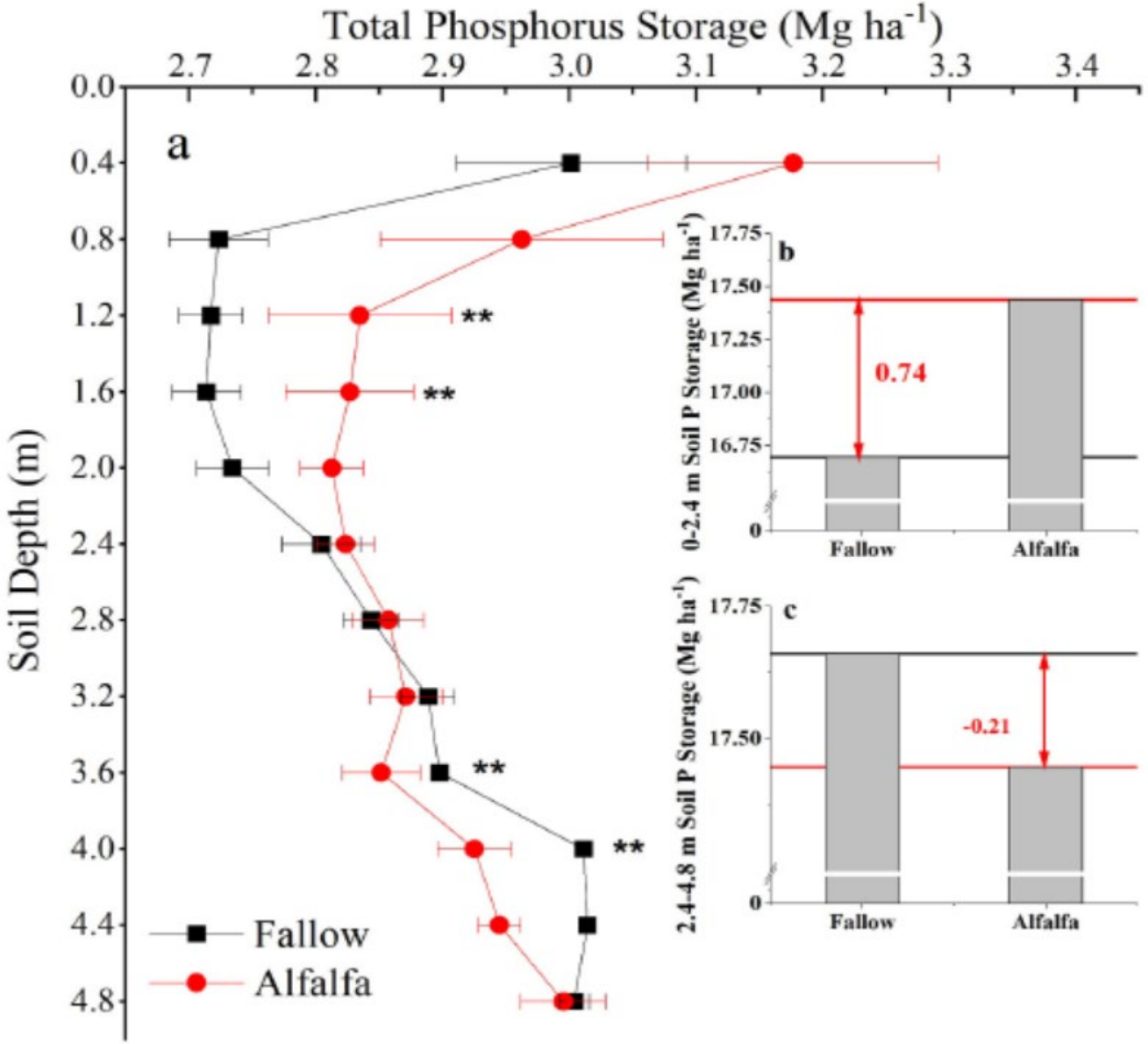
- BNF: **70-400 kg N /ha**

N transfer

Intercropping/ rotation/mulch

- Uptake excess nitrogen

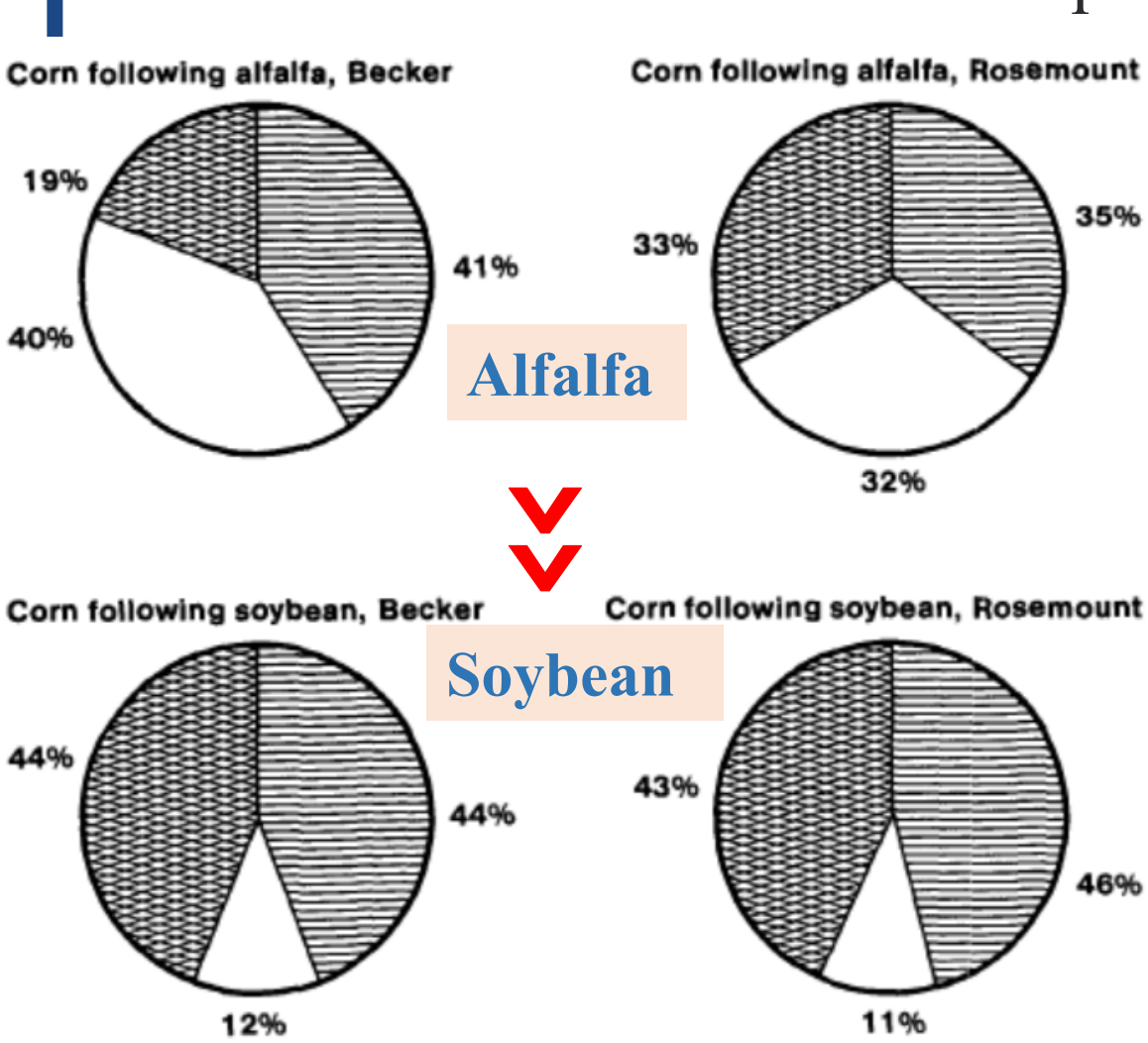
Alleviate P limitation induced by N deposition



The long-term alfalfa establishment drives the soil P redistribution in different forms and could deal with the P-limitation caused by N deposition in the carbonate soil.

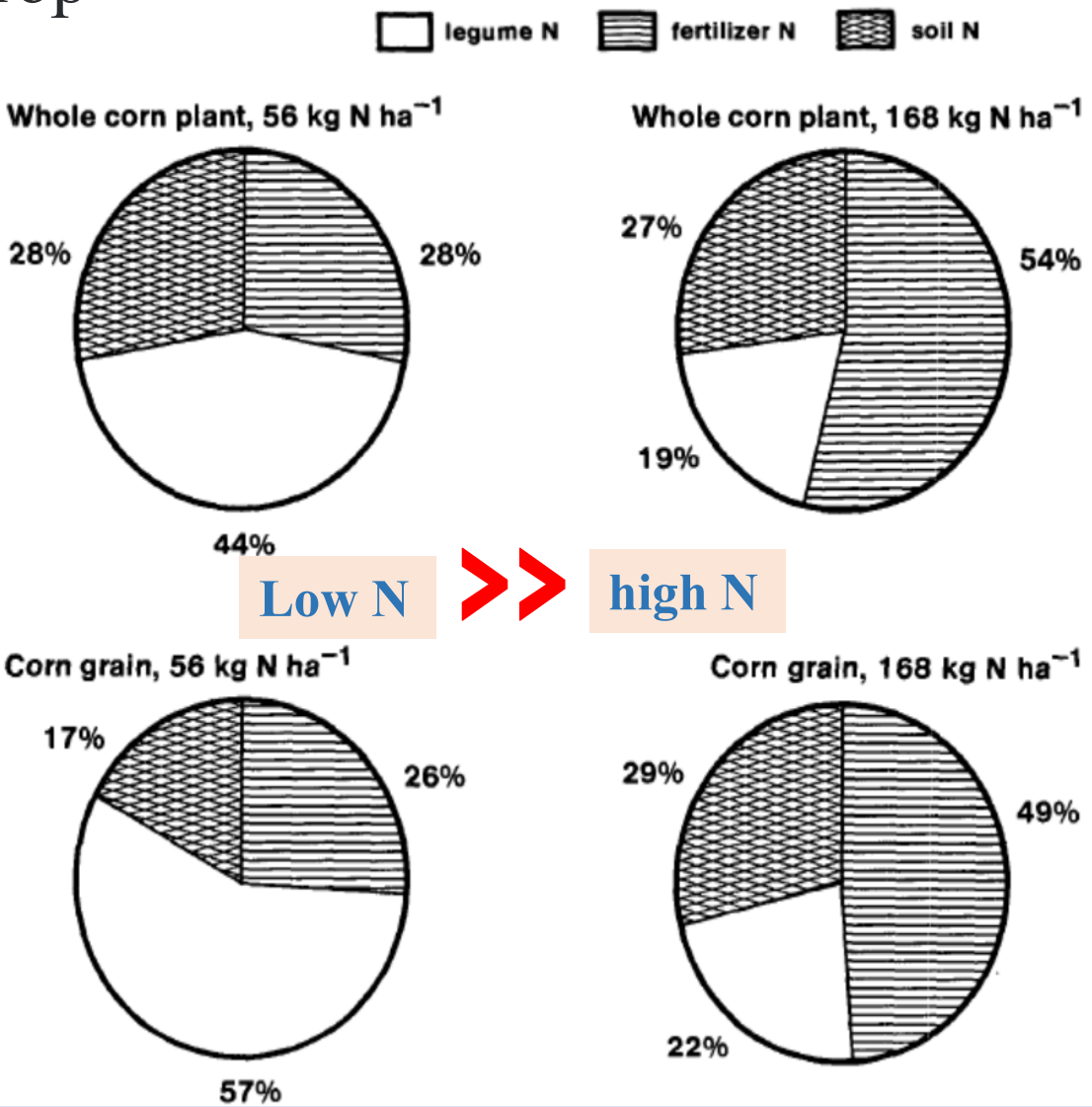
(Song *et al*, 2022, .J. Environ. Manage)

N credits of alfalfa for the subsequent crop



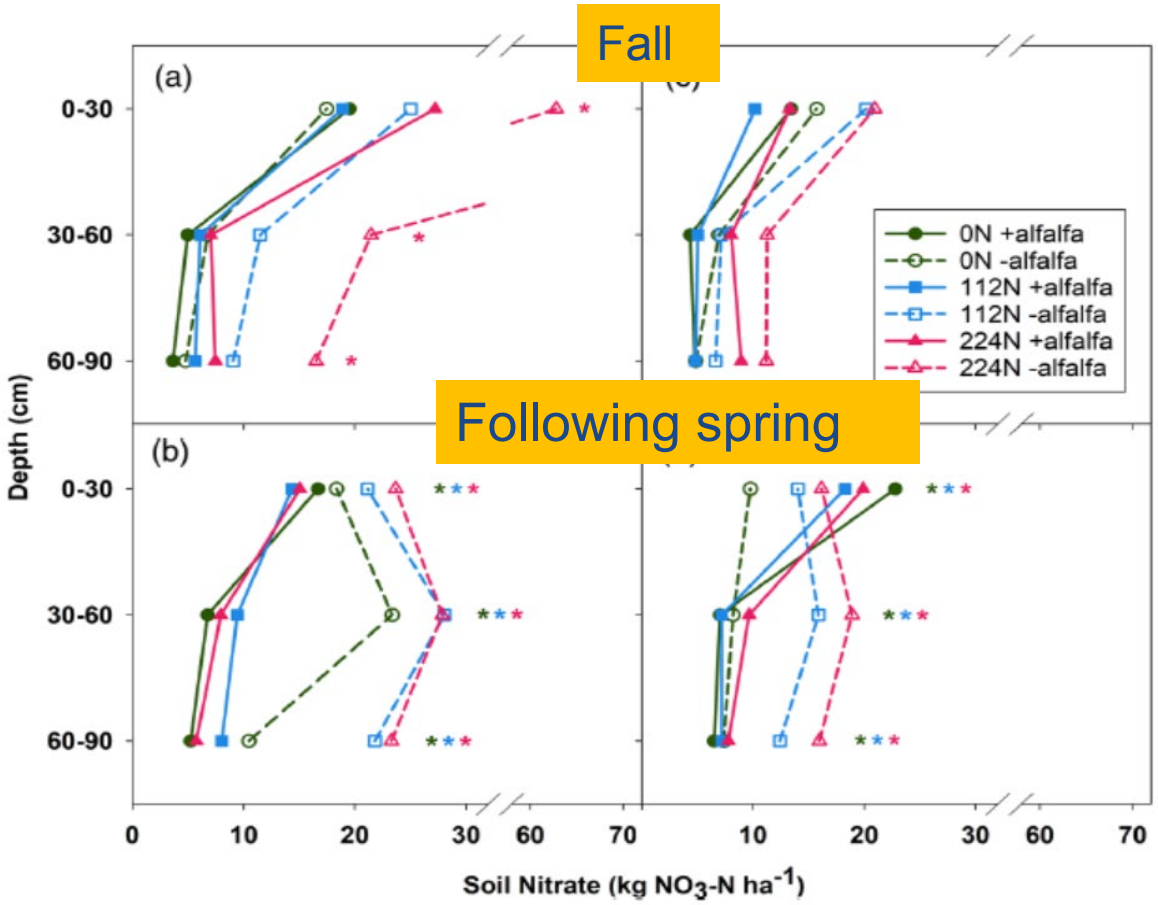
- Alfalfa provided more N than soybean for the subsequent corn

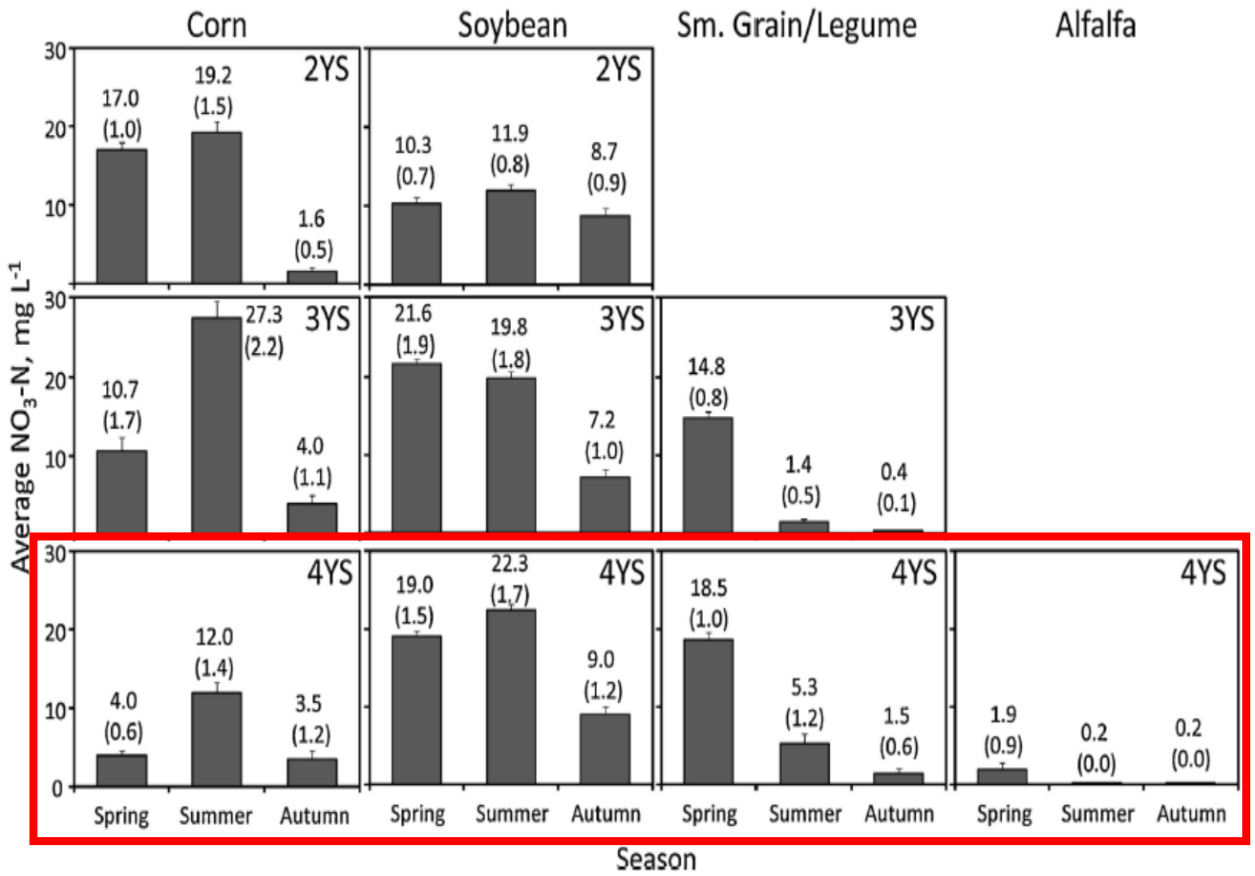
(0. B. Hesterman, *et al*, 1987, Agron. J.)



- Effect of N fertilizer rate on percentages of N in corn derived from legume residue, fertilizer, and soil

Reduce residual soil nitrate and NO_3-N leaching





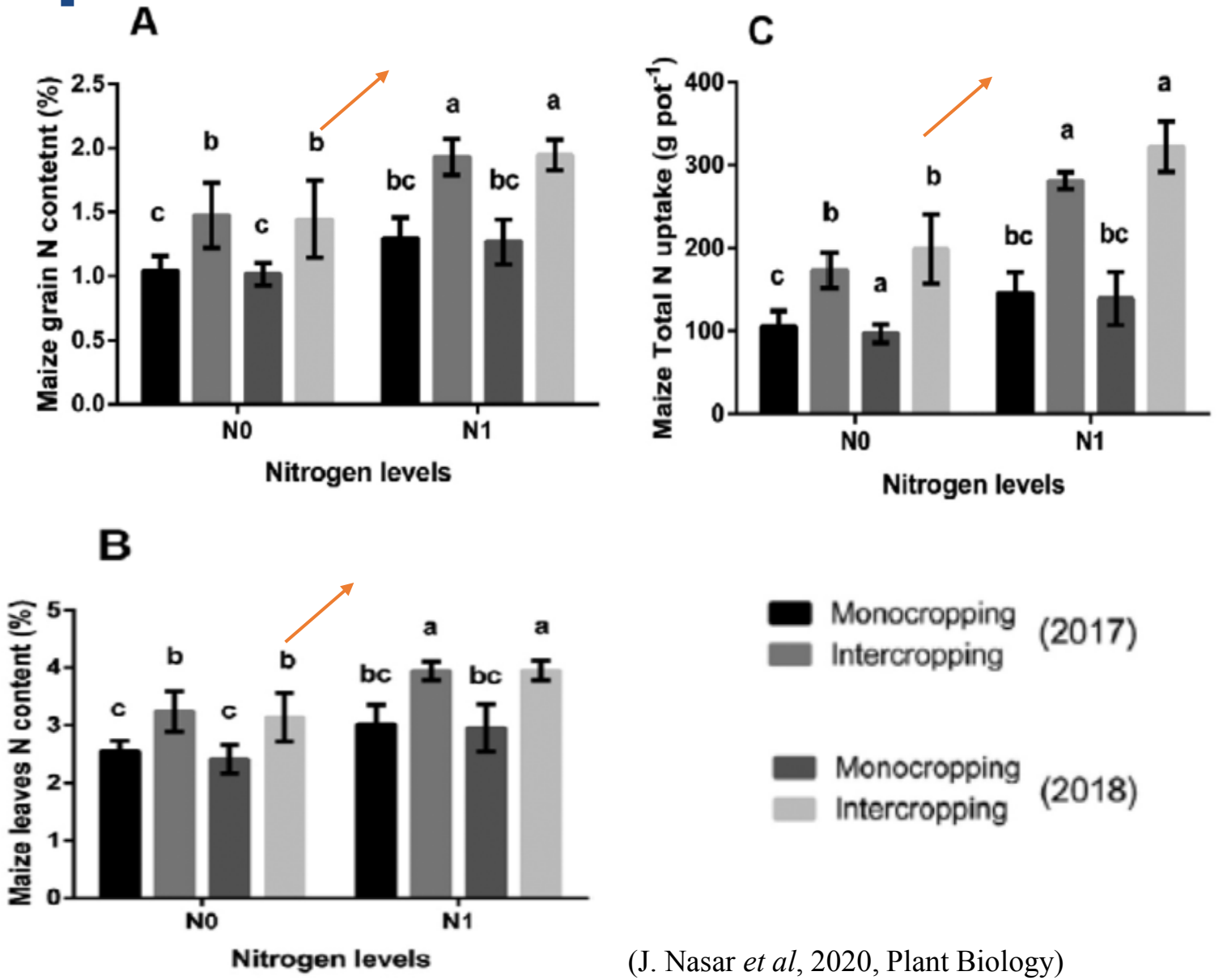
Planting alfalfa with corn reduced NO_3-N content in the soil.(C-C-C-C+A-A-A-A)

(W. Osterholz1 *et al*, 2021, . Agric Environ Lett.)

Rotational systems including alfalfa with annual crops can reduce movement of N below the root zone.

(M. Tomera, *et al*, 2014, . AGEE)

N utilization in intercropping



(J. Nasar *et al*, 2020, Plant Biology)

The grain yield, biomass dry matter of maize crop, maize grain N content, total N uptake, maize leave N content were improved in intercropping with proper N fertilizer.

N fertilizer requirement of pure alfalfa stands in China

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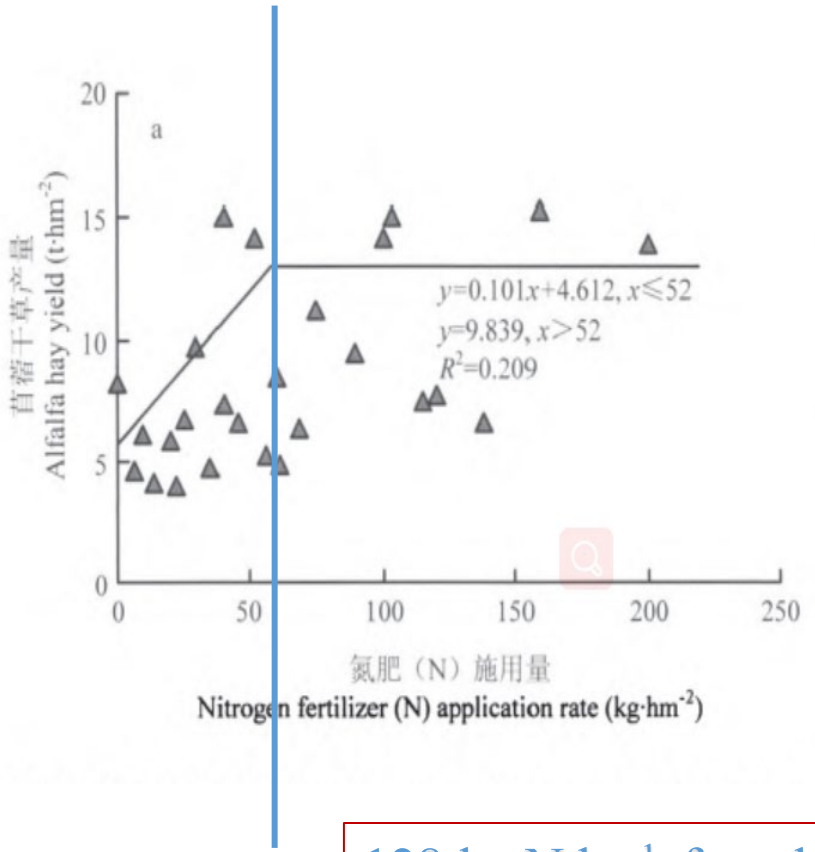


52 kg N ha^{-1} <<

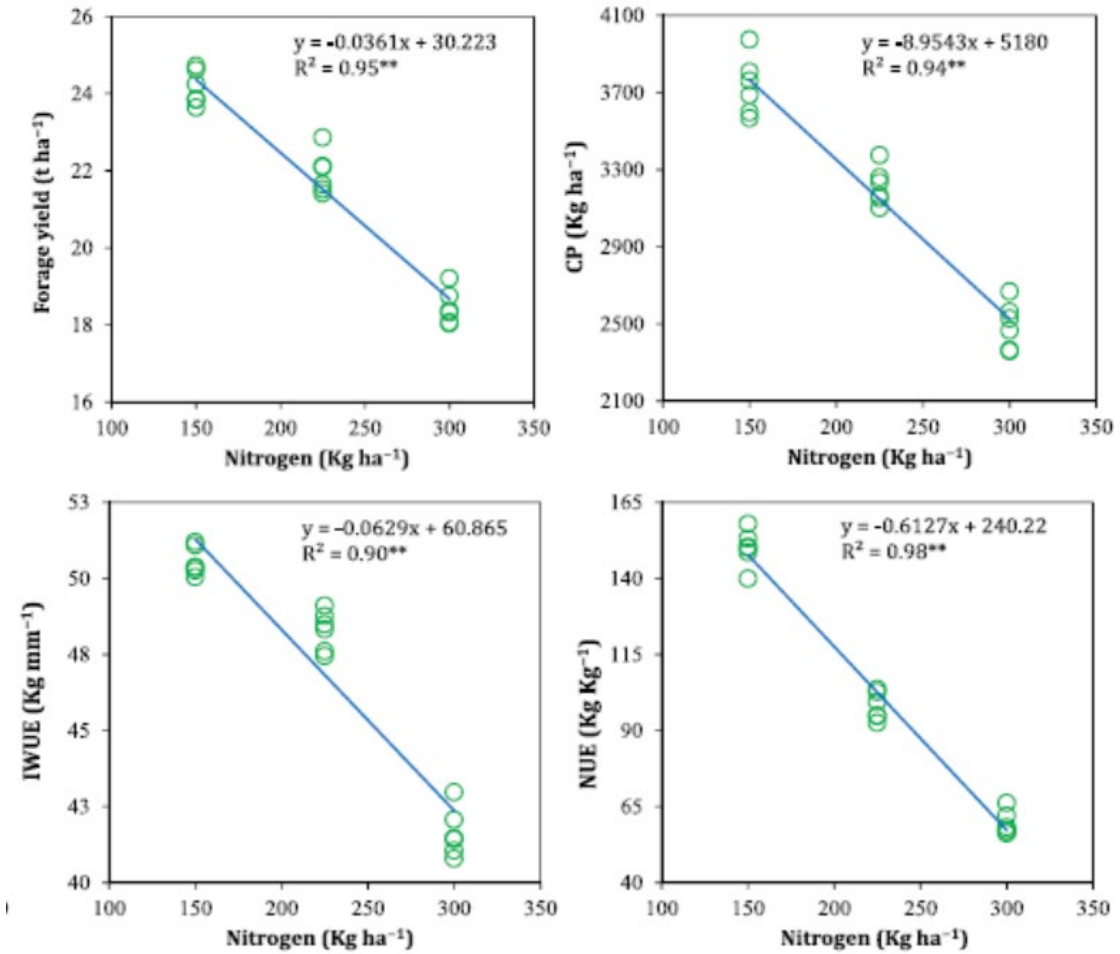
128 kg N ha^{-1} for wheat

158 kg N ha^{-1} for maize

200 kg N ha^{-1} for rice

(Ju *et al*, 2009, PNAS)

(Wei *et al*, 2018, Scientia Agricultura Sin|ca)



Increasing N application resulted in a linear decline in alfalfa forage yield, nutritive quality, irrigation water use efficiency, and N use efficiency.

(M. Kamran *et al*, 2022, Field Crops Res.)

3

The N utilization of alfalfa-silage corn relay intercropping system

- Proper N rate for the system
- N balance of the system

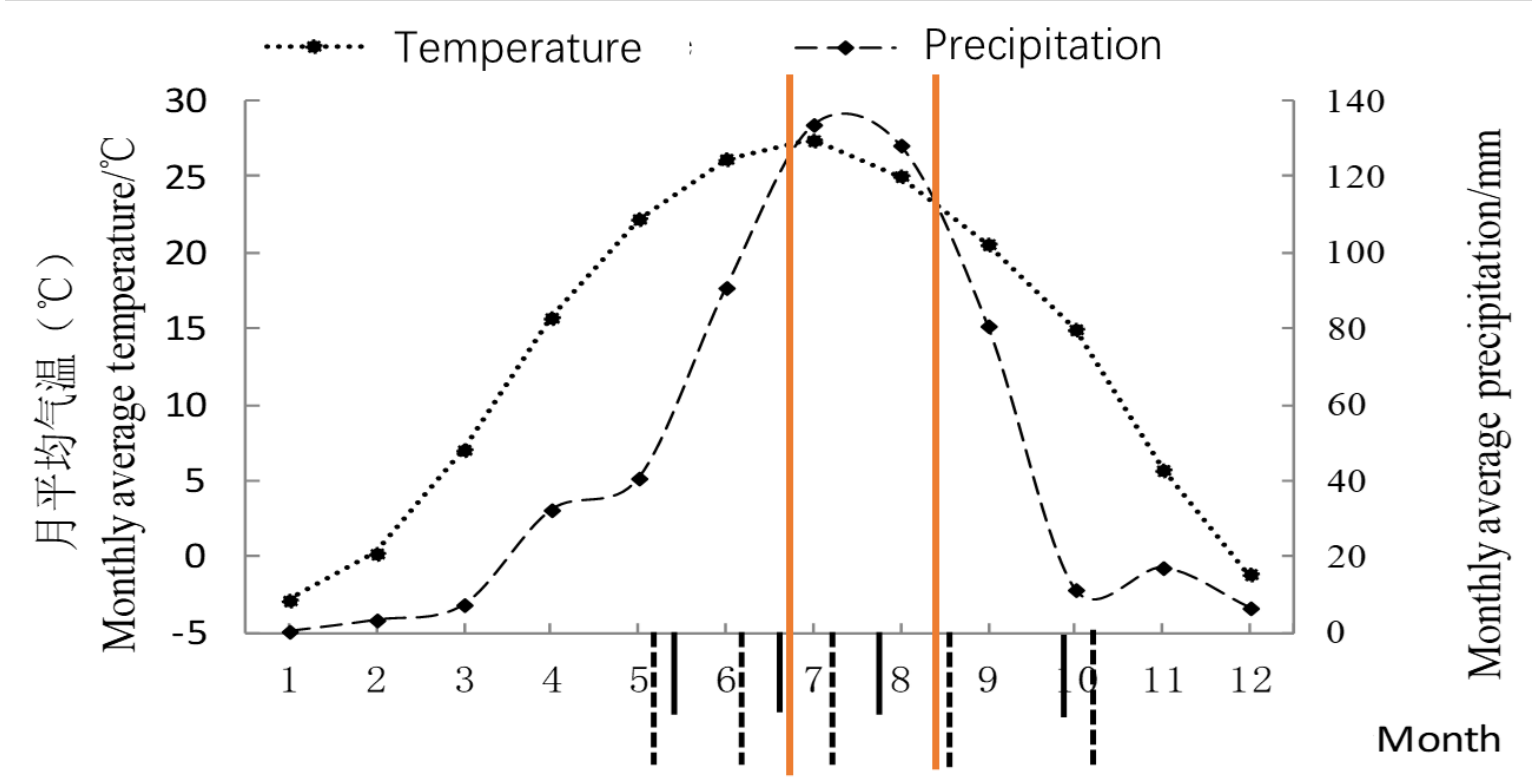
Experiment area

The North China Plain(NCP)

- ✓ **winter cold and summer hot**
- ✓ **monsoon climate**
- ✓ **rain in hot season**

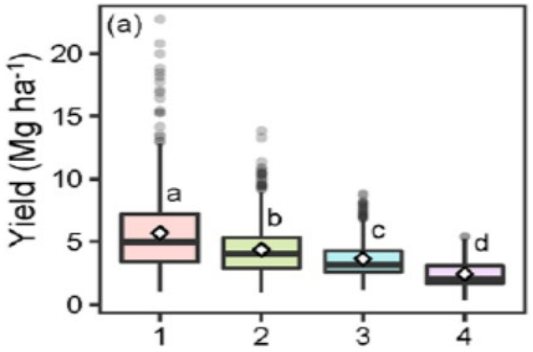
Alfalfa production problems in the NCP

: Harvesting 4 times a year
: Harvesting 5 times a year



- Difficult to dry (30% losses)
- Heavy pests and diseases
- Summer slump
- Waste of heat and rainfall (70%)

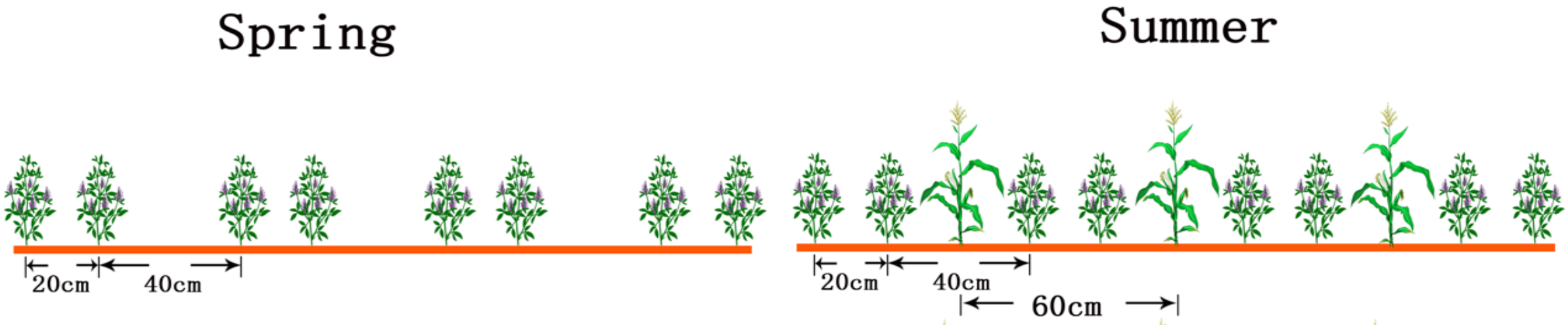
Distribution of alfalfa yield in the NCP



◆ **The yield of 1st and 2nd cuts of alfalfa account for >60% of year total yield.**

Test area	Number of varieties	Test period	1st cut %	2nd cut %	3rd cut %	4th cut %	5th cut %	Percentage of first 2 cuts %
Hebei	11	2003-2005	39.94	22.65	22.25	15.17	--	62.6
Hebei	22	2005-2011	35.76	23.36	24.81	16.07	--	59.12
Hebei	14	2012-2015	31.90	20.61	16.82	18.59	12.09	52.51
Beijing	10	2002-2007	32.00	25.00	25.00	18.00	--	57
Hebei	6	1997-2000	38.40	24.30	22.60	14.70	--	62.7
Henan	42	2001-2005	37.68	24.16	17.42	12.74	8.00	61.84
Henan	18	2004-2006	41.02	24.06	15.49	11.29	8.14	65.08
Shandong	1	2007-2008	40.27	26.85	23.49	9.40	--	67.12
Beijing	8	1998-2000	34.70	20.02	24.72	20.57	--	54.72

Alfalfa-silage corn relay intercropping

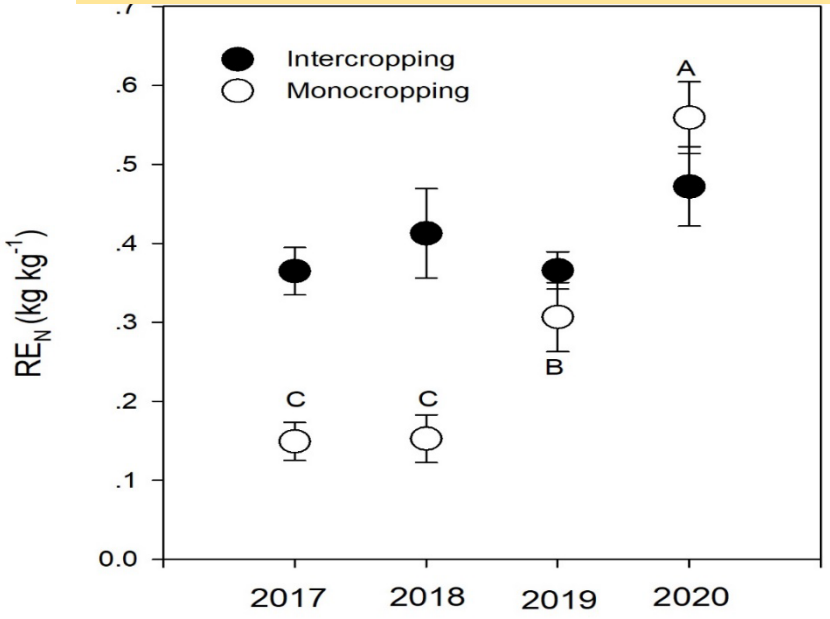


- Maximize the production potential of forages
- Improve the efficiency of land and light resources
- Reduce nitrogen resource consumption and pressure on the environment

DM yield and CP yield of corn

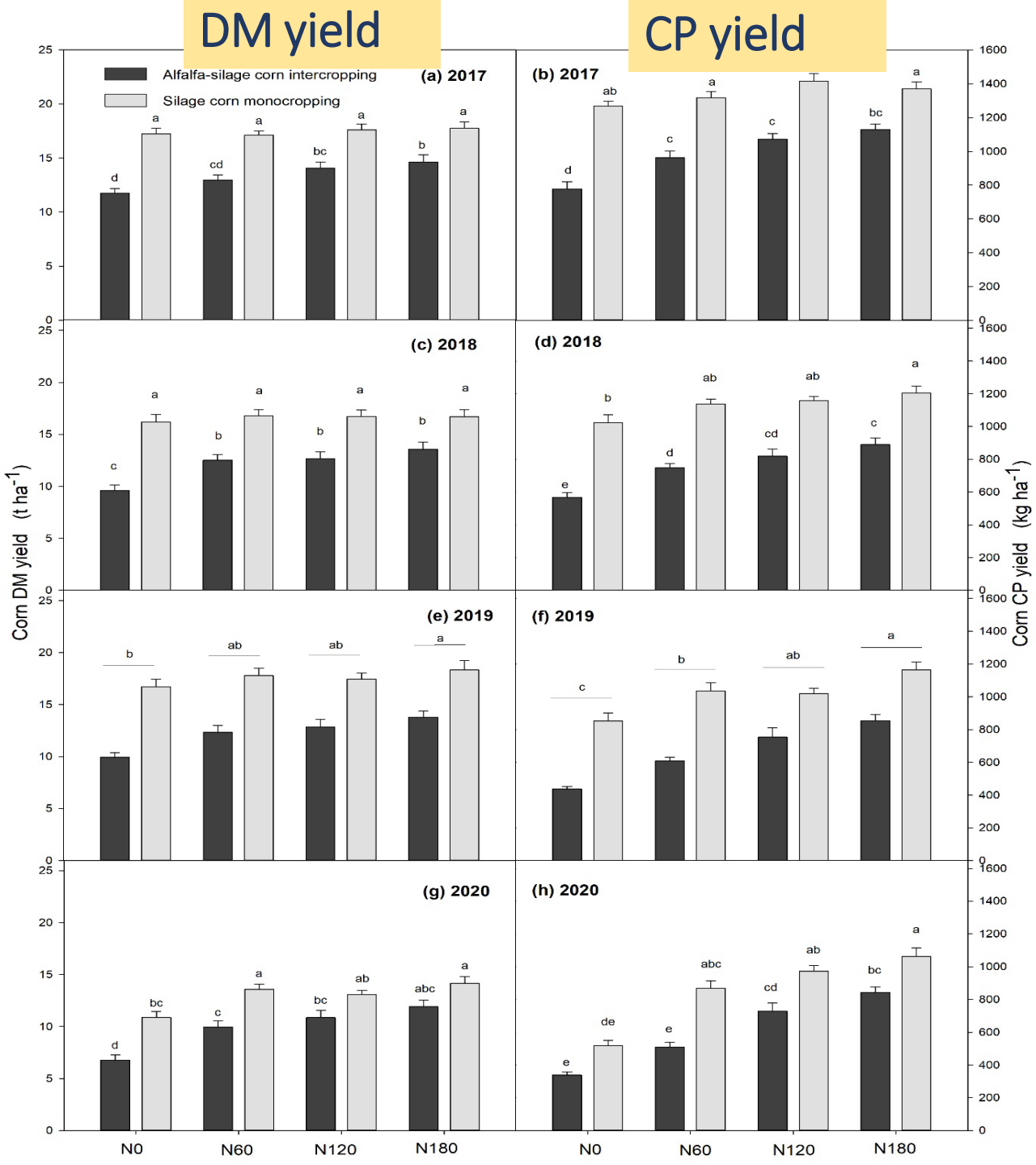
- High environmental N resulted in low N response to solo-seeded corn;
- Alfalfa had strong competition for N;
- N can effectively improve nitrogen nutrition of corn

Nitrogen recovery efficiency



DM yield

CP yield



DM yield and CP yield of alfalfa

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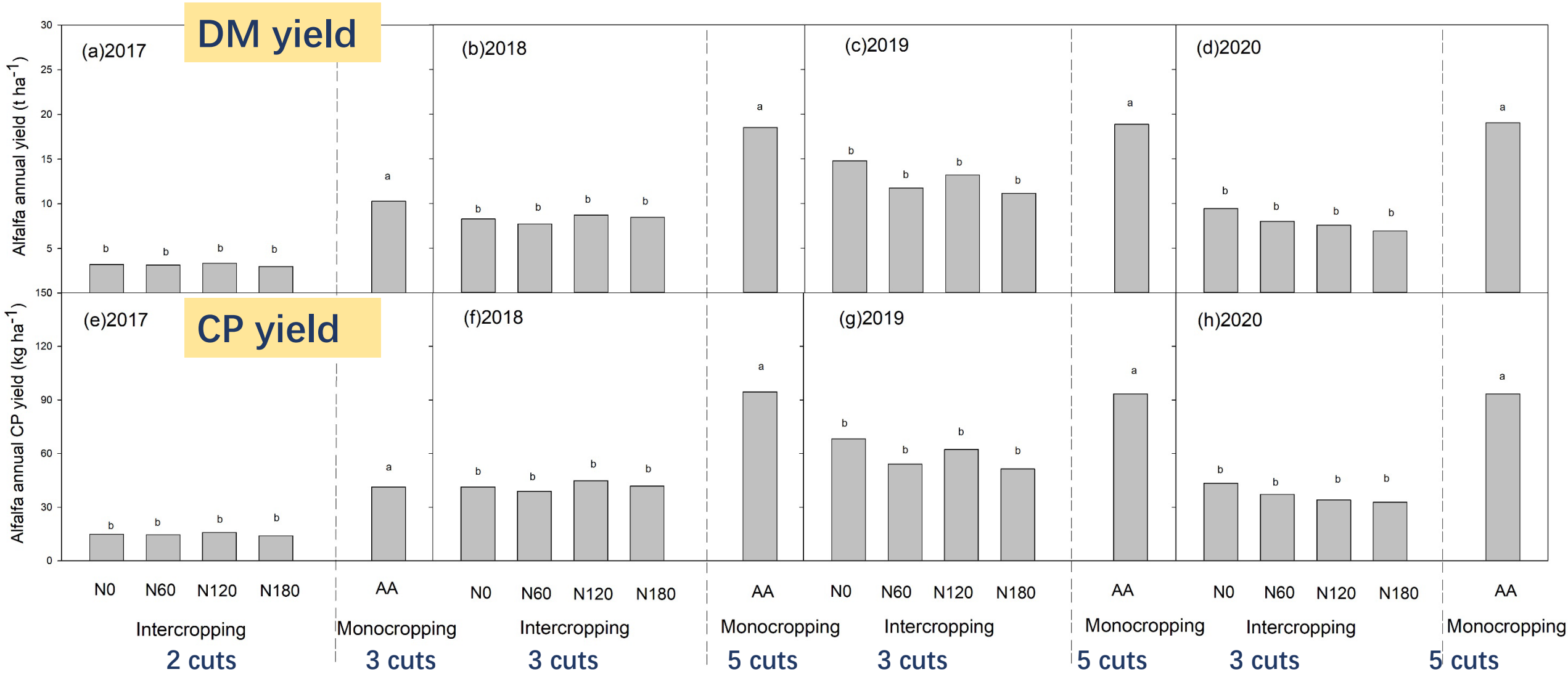
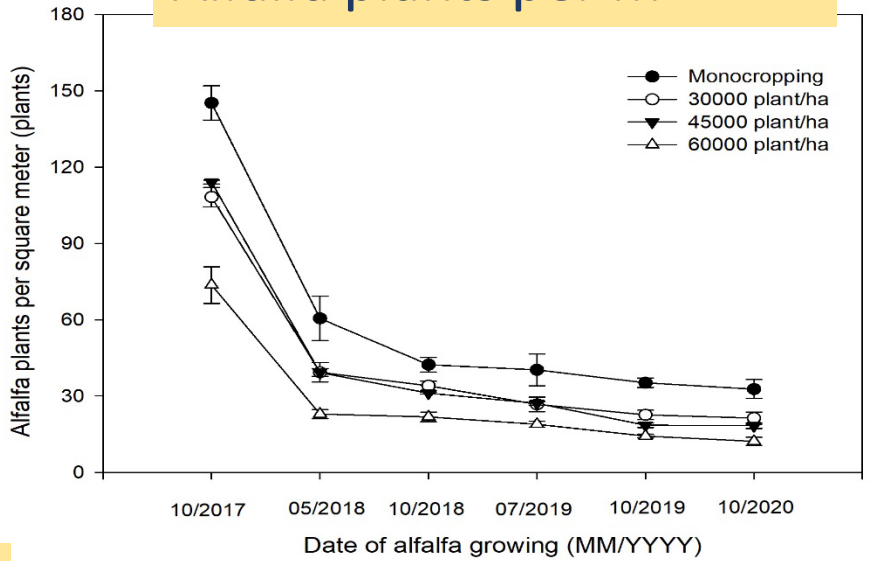
- **Intercropping**: 33%-69% of **yield** reduction
  37%-64% of **CP yield** reduction
- **N fertilizer**: no effect on **alfalfa**



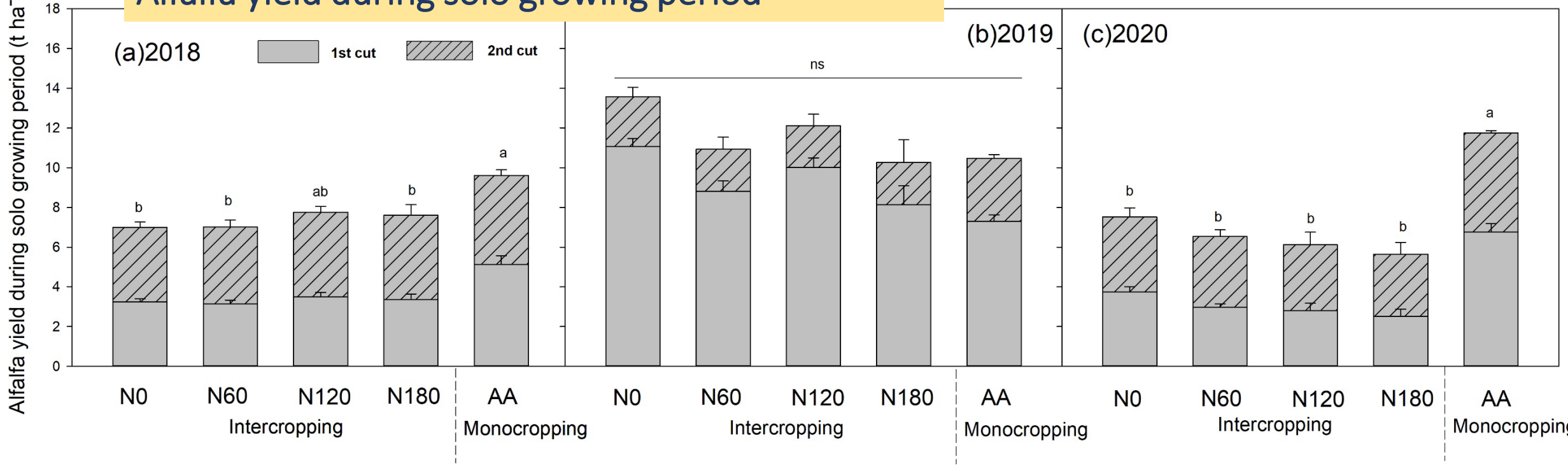
Spring alfalfa production

- **Intercropping**: 30%-55% of **alfalfa plants** reduction
  spring alfalfa production had small differences compared with AA in 2018 and 2019
- **N fertilizer**: no effect on **alfalfa stand**
  no effect on **spring alfalfa production**

Alfalfa plants per m^2



Alfalfa yield during solo growing period



DM yield and CP yield of intercropping system

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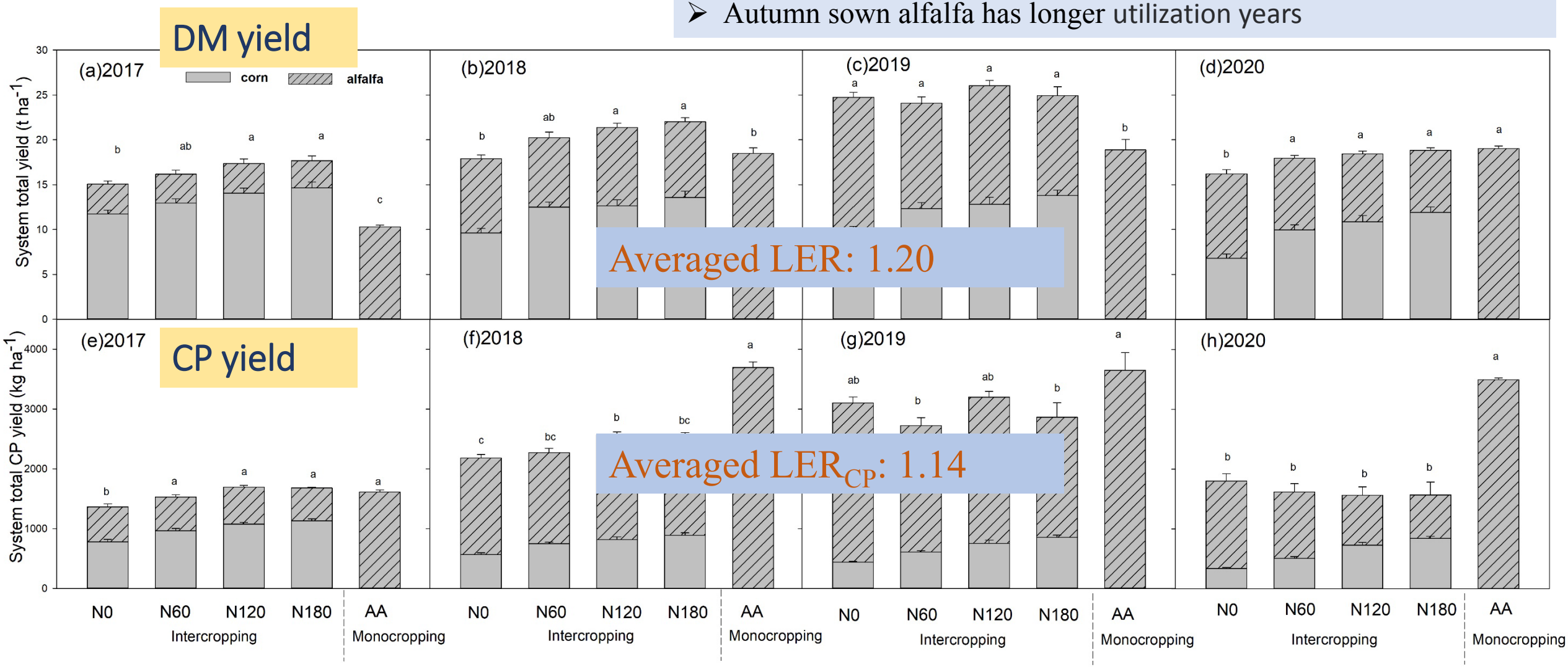
- High land and N use efficiency

- ≥N rate of solo corn of local practice is suggested for the system
- Autumn sown alfalfa has longer utilization years



N balance

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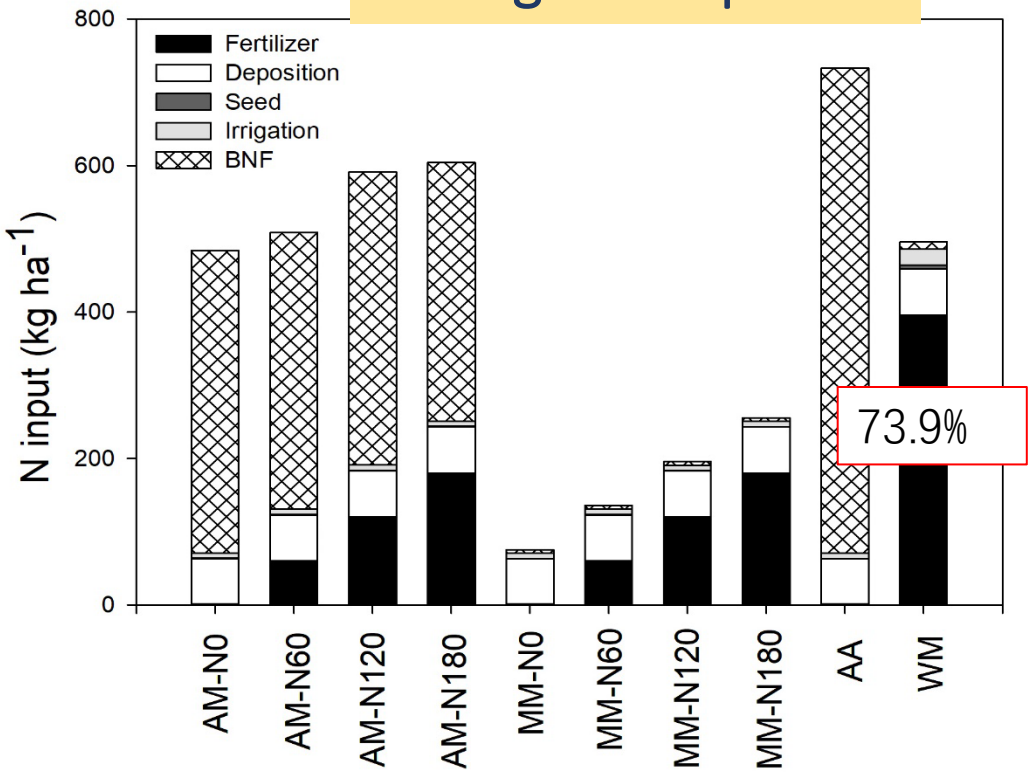
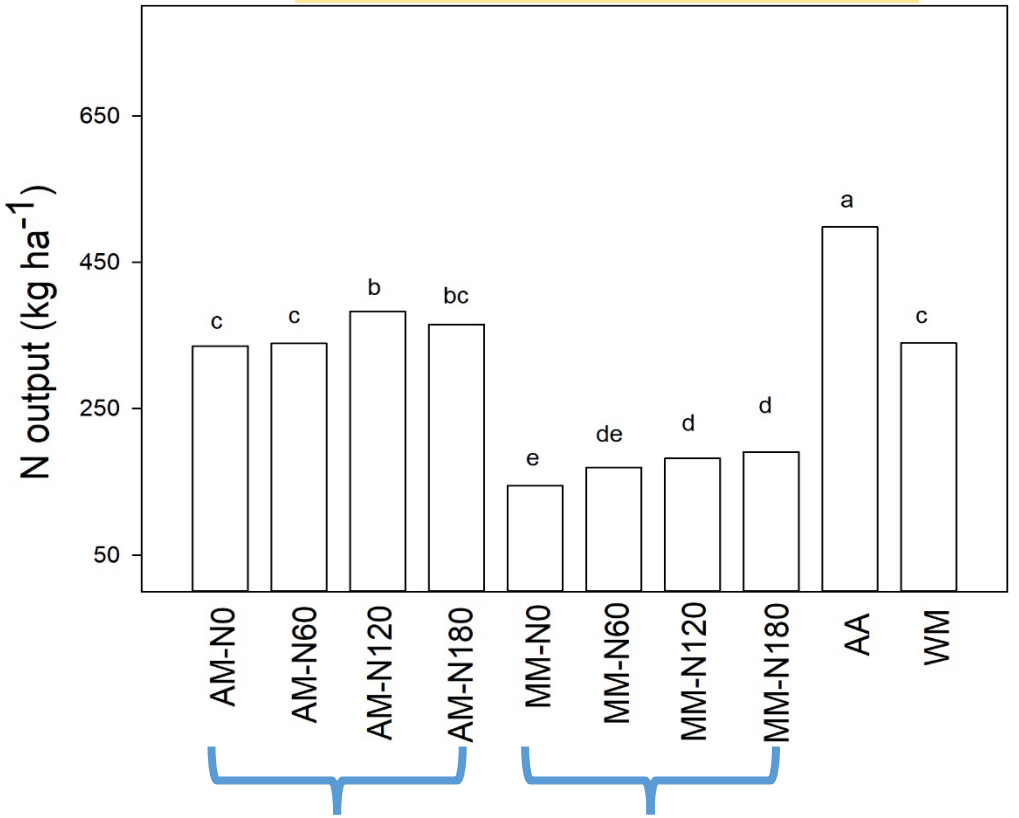
Averaged N input

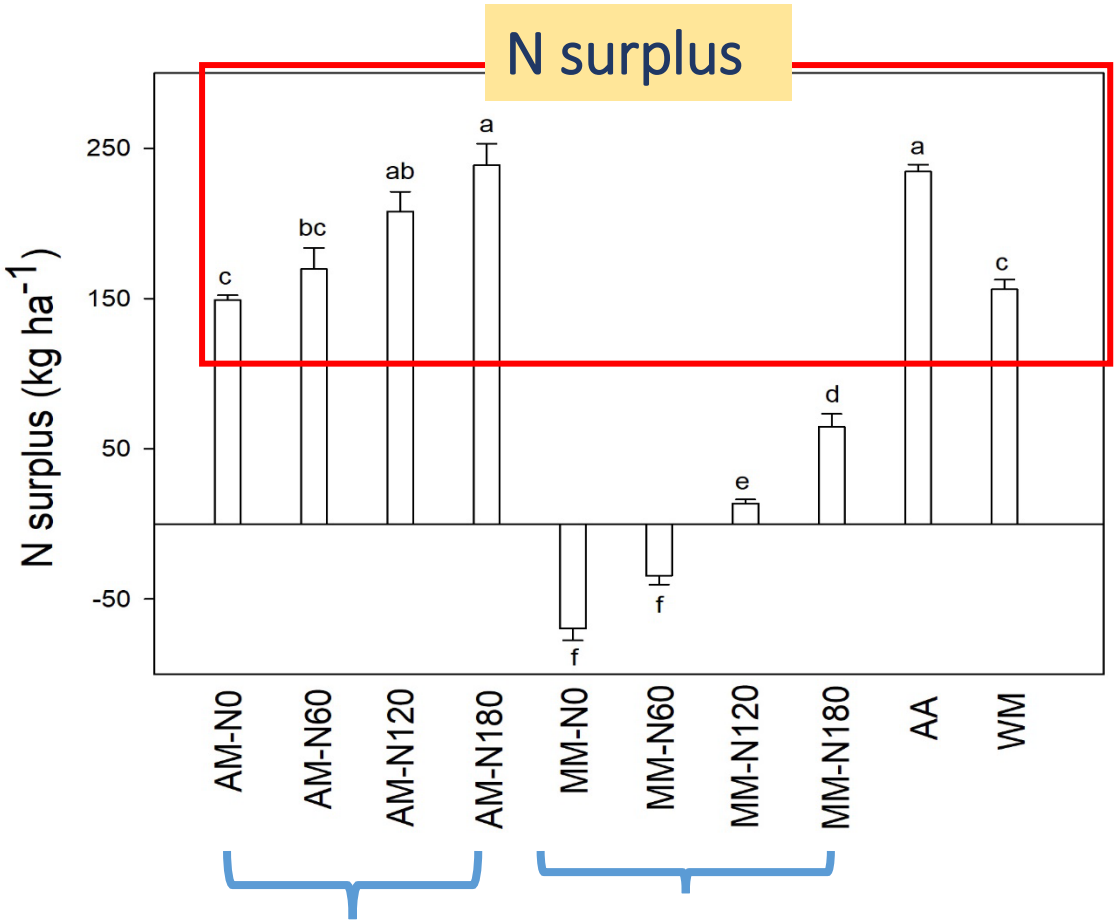


Averaged N output



- N input= Fertilizer + Deposition +Seed + Irrigation + BNF
- $BNF = \left[\alpha \times \frac{Y}{NHI} + \beta\right] \times BGN$ （Anglade， 2015）
- BNF including the underground
- BNF of alfalfa may be overestimated by using the equation

N balance



- **Alfalfa-based systems/winter wheat-summer corn rotation** in the NCP had high N surplus
- Solo-seeded corn with low N rates consumed soil N

The fate of nitrogen?

Ammonia volatilization

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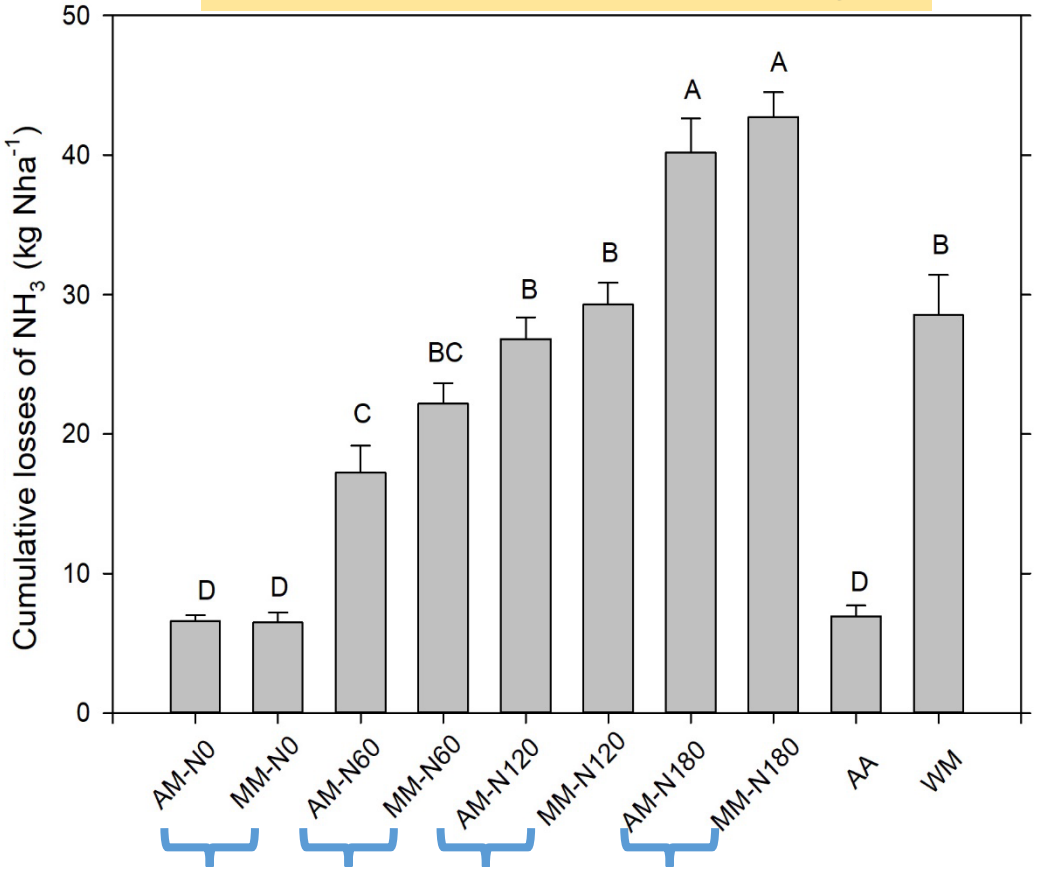
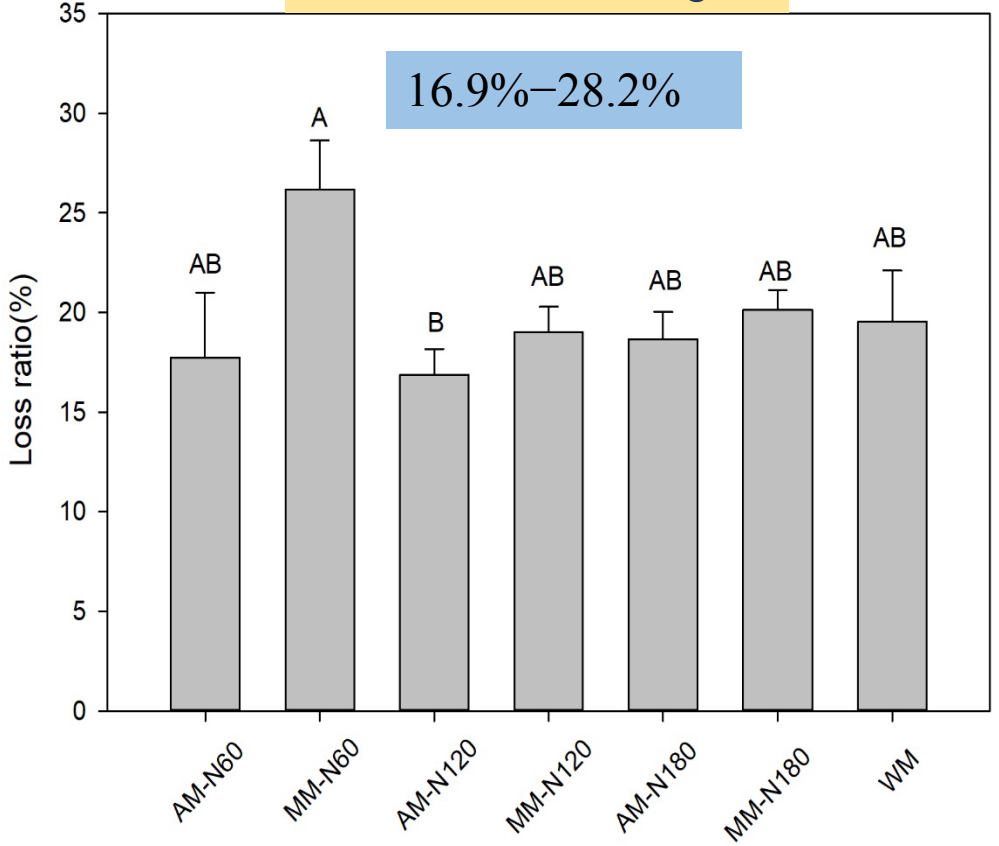
Cumulative losses of NH_3



N0 | N60 | N120 | N180 | Solo alfalfa | Wheat -Corn

Loss rate of NH_3

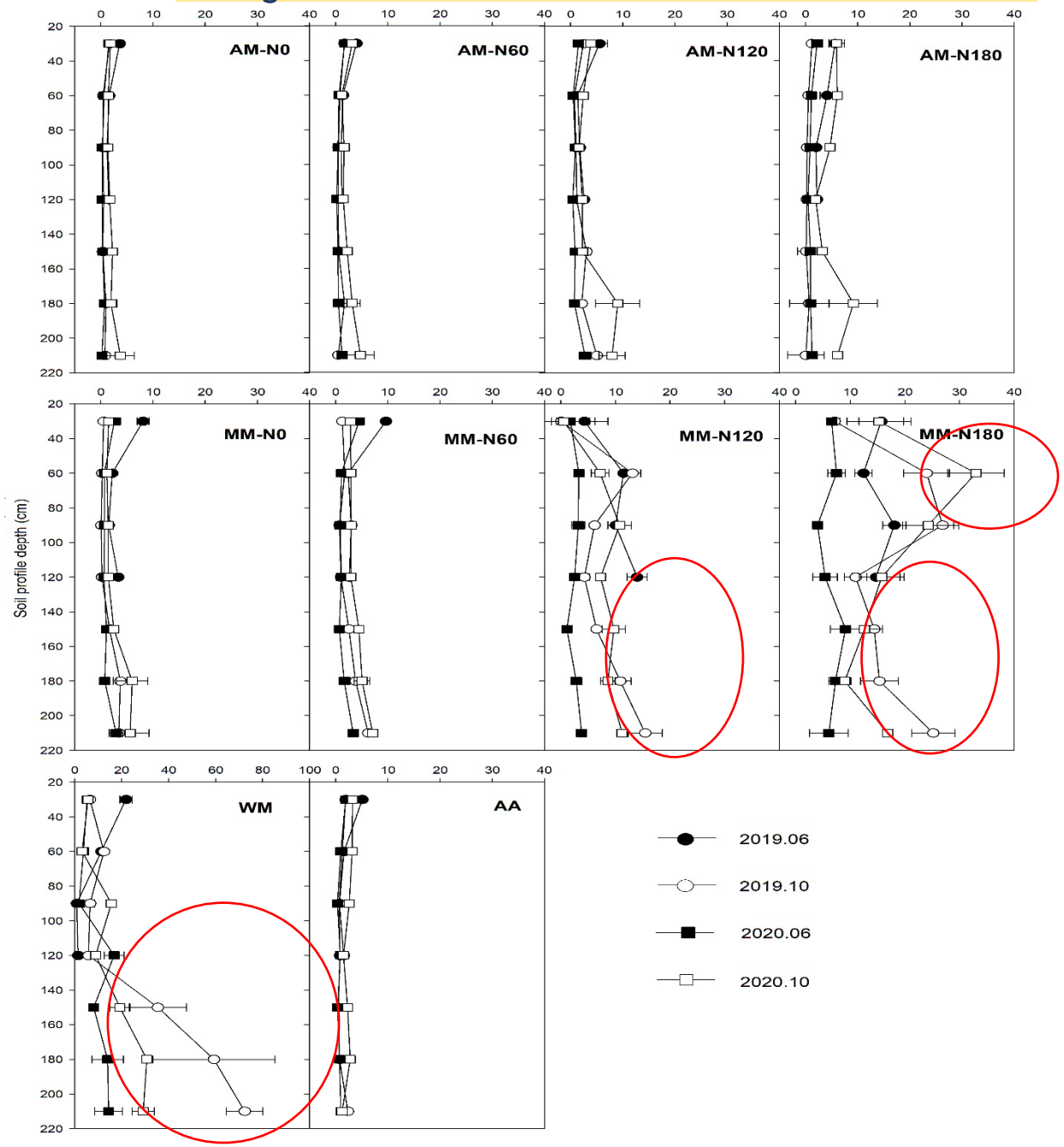


➢ Ammonia volatilization was mainly affected by N rates

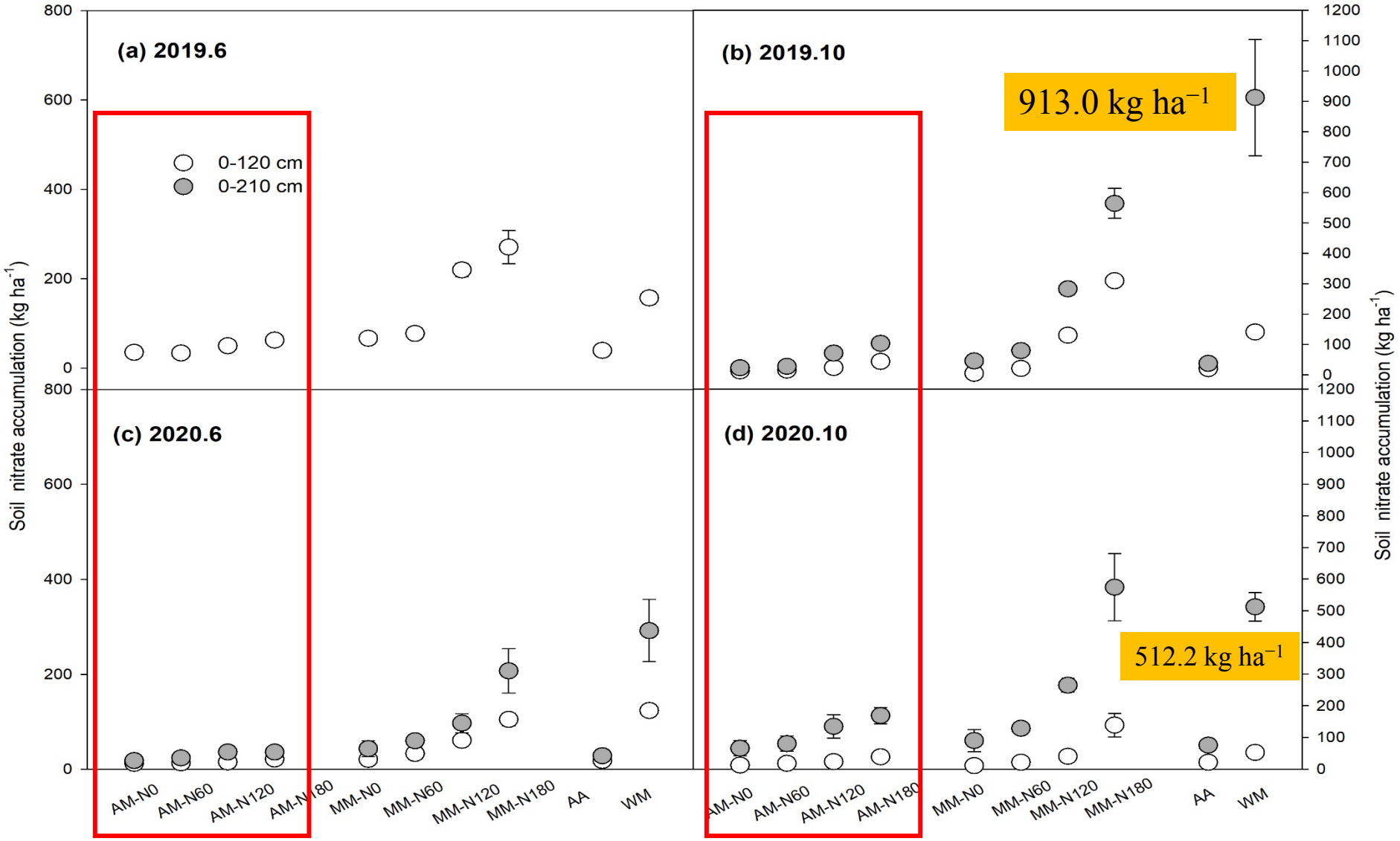
Nitrate distribution in 0-210 cm soil

- Alfalfa efficiently lowered Nitrate content within cereal root zone (1m) and out of cereal root zone
- Alfalfa absorbed soil N and stored N in the root

NO_3-N distribution （0-210cm）



Nitrate accumulation in 0-210 cm soil profile



Resource consumption

Yield-scaled N fertilizer use and yield-scaled irrigation water use in different treatments during 2017–2020

Treatment		2017	2018	2019	2020	4-yr average
Yield-scaled N fertilizer use，(kg N t^{-1})						
Intercropping	A+M	6.8 b	5.3 c	4.6 c	6.7 c	5.9 c
Solo corn	MM	6.8 b	7.1 b	6.9 b	9.2 b	7.5 b
Wheat-Corn	W−M	13.2 a	14.2 a	14.2 a	14.4 a	13.7 a
Yield-scaled irrigation water use, (mm t^{-1})						
Intercropping	A+M	6.8b	2.7c	2.3c	3.3 c	3.9d
Solo corn	MM	6.8b	3.5b	3.5b	4.6 b	4.6c
Solo alfalfa	AA	11.7a	3.3b	3.2b	3.2 c	6.1b
Wheat-Corn	W−M	6.0b	7.8a	8.6a	8.7 a	7.5a

Soil characteristics

Soil characteristics (0-30 cm) as affected by different treatments in October 2019 after 3-yr treatment

	treatment	Total N (g kg^{-1})	Total C (g kg^{-1})	TOC (g kg^{-1})	MBN (mg kg^{-1})	MBC (g kg^{-1})	Avail. P (mg kg^{-1})	Avail. K (mg kg^{-1})
Intercropping	A+M	0.94	18.6 a	7.8	22.0 a	1.1	4.0	86.0
Solo corn	MM	0.87	17.3 ab	6.7	18.9 a	1.0	3.9	94.0
Solo alfalfa	AA	0.93	18.9 a	7.4	21.2 a	1.0	3.6	113.0
Wheat-Corn	W–M	0.84	16.2 b	6.3	6.3 b	0.7	3.3	104.0
Source of variation	*P* value							
		ns	0.006	ns	<0.001	ns	ns	ns

Conclusion and outlook

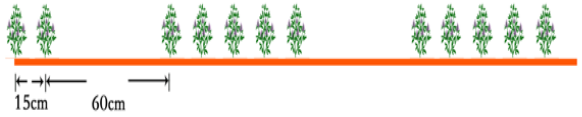
Conclusions

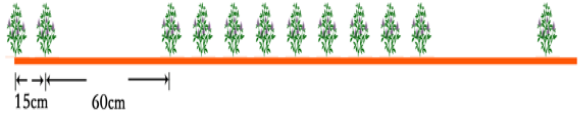
- Alfalfa is both “N source ” and “N sink ”, and playing significant role in nitrogen management at farm scale.
- Alfalfa-silage corn intercropping provides an efficient solution for the areas which have hot-rainy summer for alfalfa production.

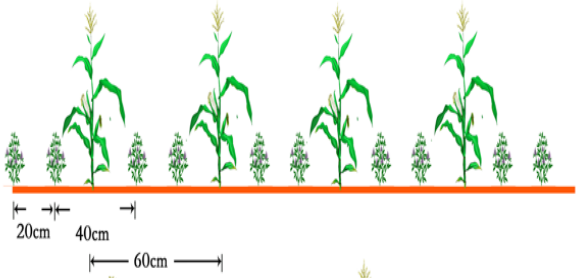
Hebei-NCP

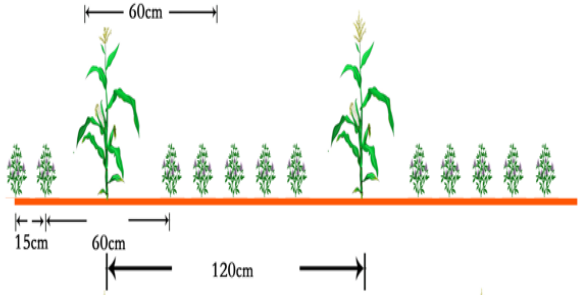
Ningxia-Northwestern China

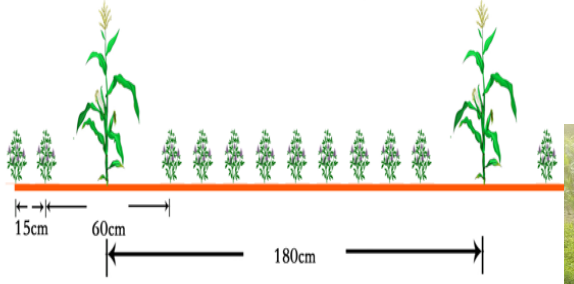
Shanxi-Northern China











Line-spacing expansion and row-spacing shrinkage

Thanks for your attention