



Knowledge grows

## solide vs liquide

Effet de la forme physique sur  
l'efficacité des engrais azotés  
simples sur BTH

Synthèse de 6 essais 2019-2021



# Contexte

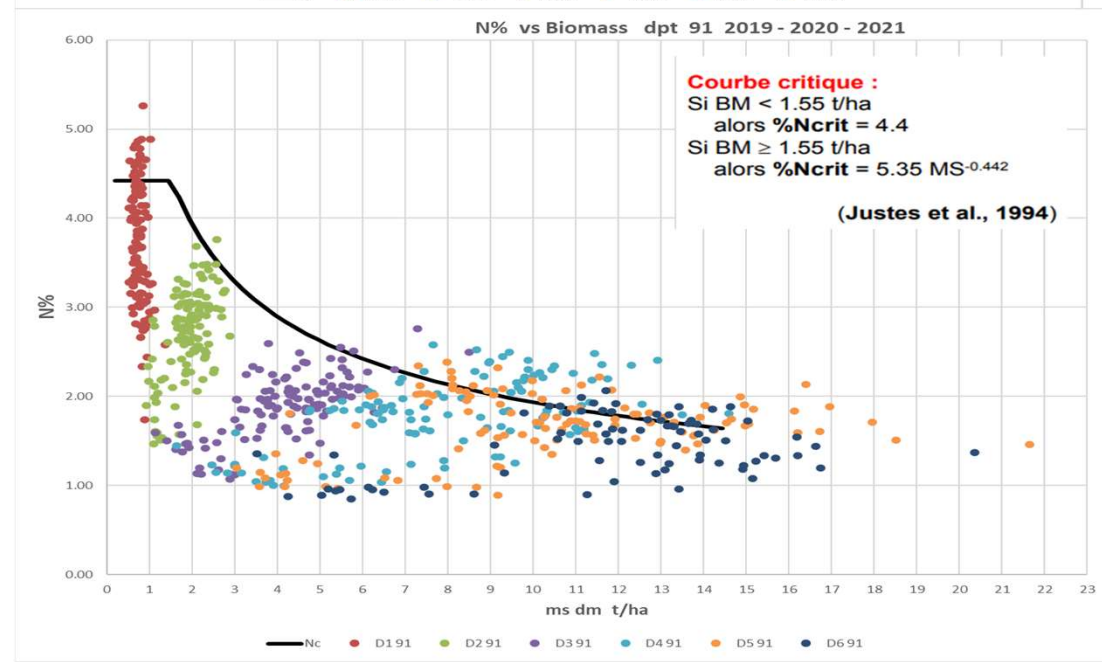
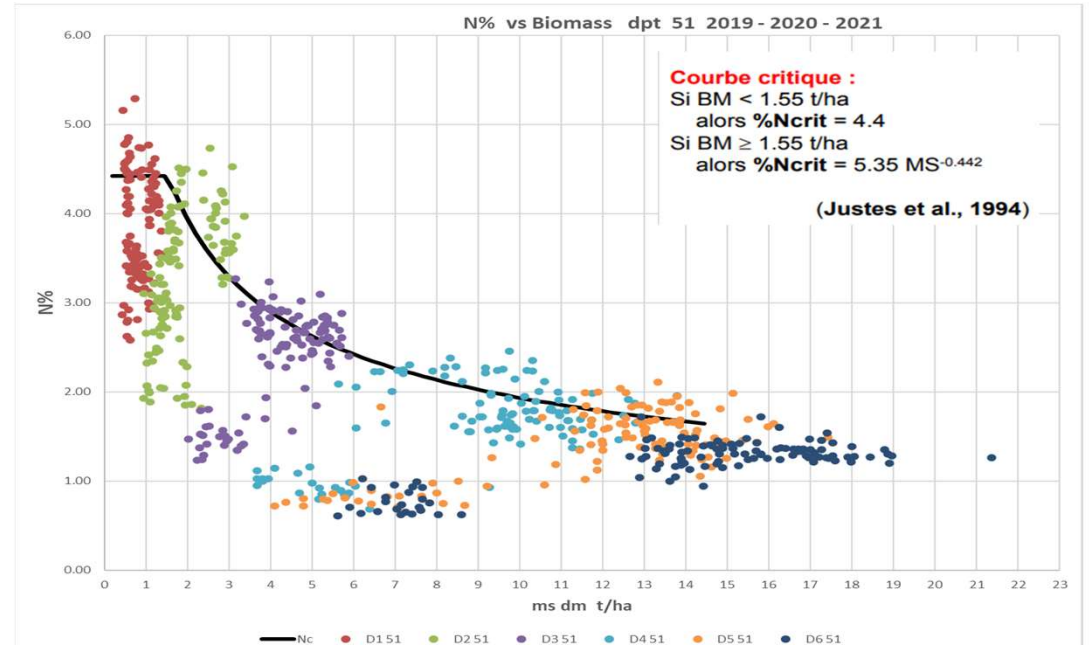
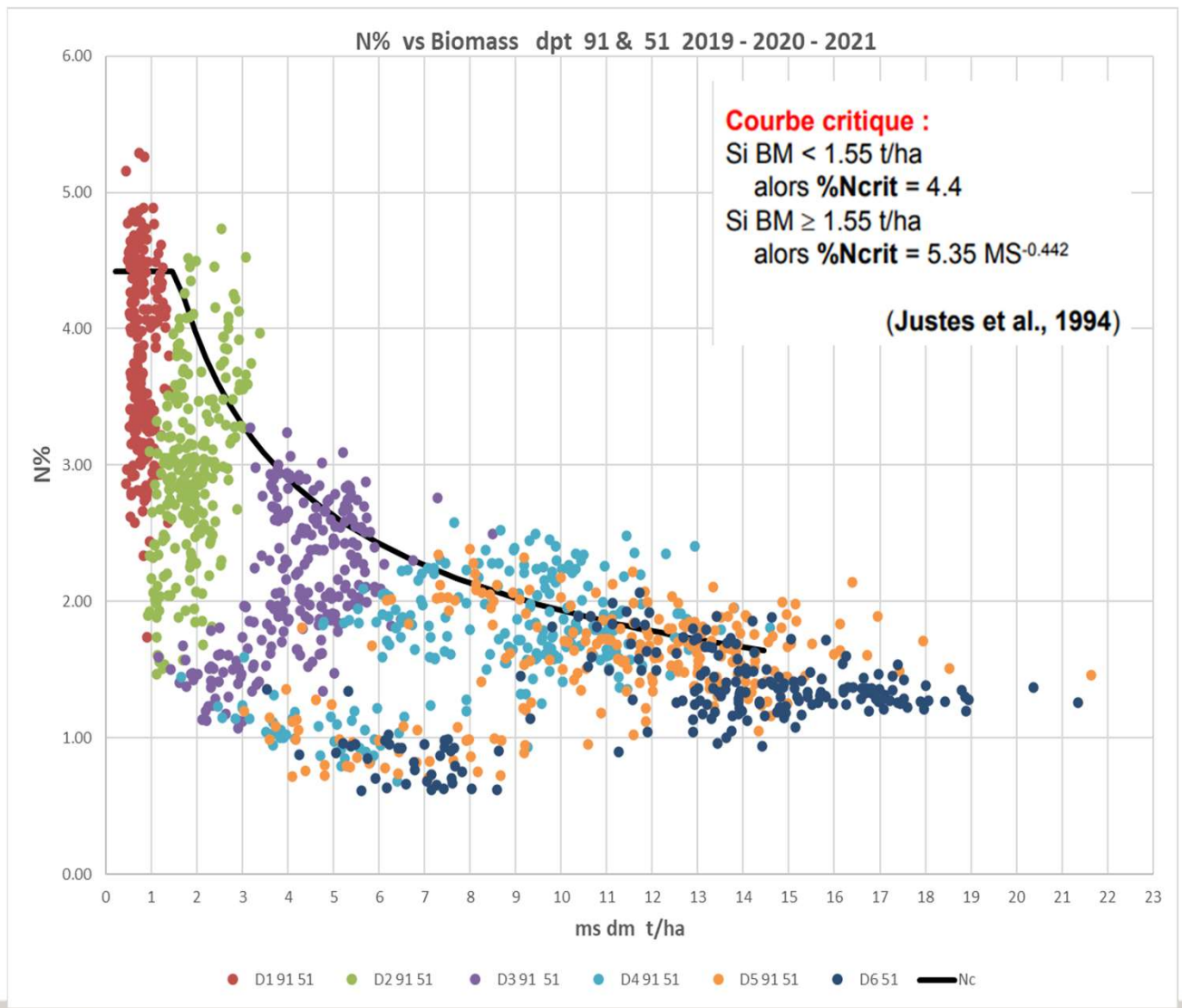
- Les agronomes débattent sur les formes d'azote depuis plus de # 40 ans ...
- La moindre efficacité de la solution azotée vs Ammonitrate ou urée a été établie à travers de multiples réseaux d'essais
- Spécificité de la solution azotée : ... le seul engrais azoté liquide largement utilisé
- L'idée :

Essayer de faire la part des choses au niveau agronomique entre

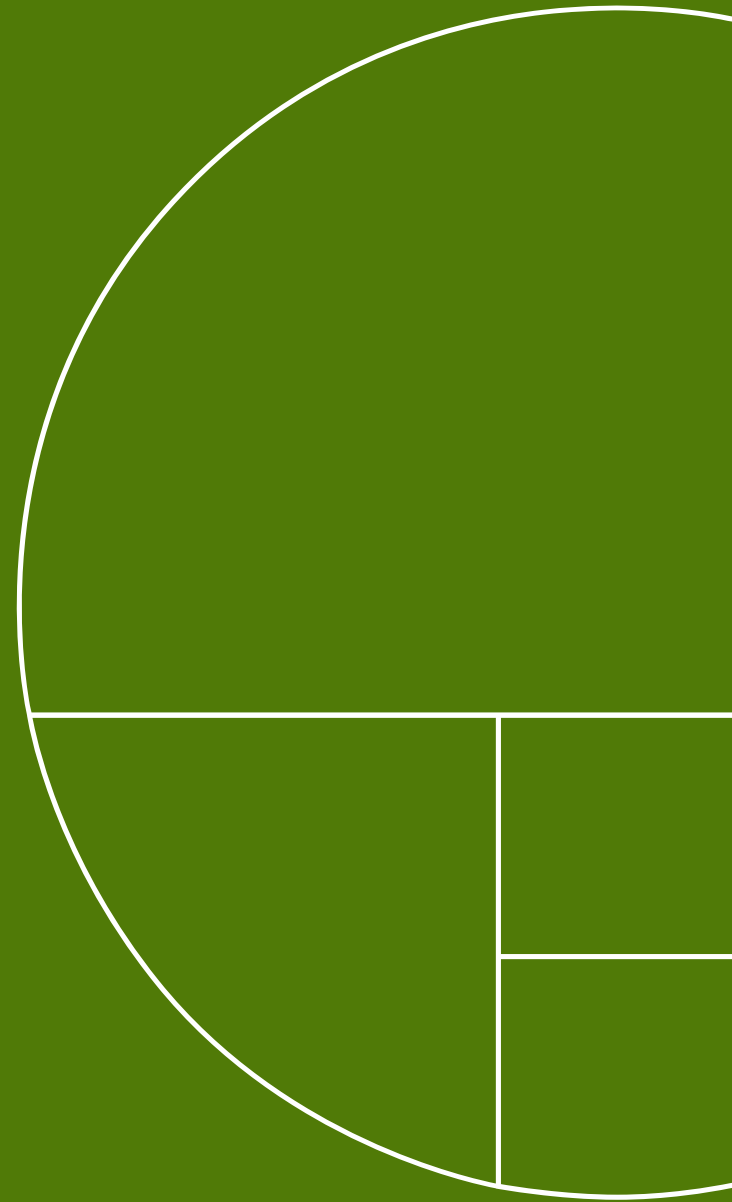
- **l'effet de la composition chimique** de l'engrais : du nitrate pur à l'urée
- et **l'effet de sa présentation physique** : solide ou liquide

- Le réseau expérimental
  - 6 essais sur 3 ans - 2 essais /an
  - 2 types de sol : craie de champagne & limons argileux de Beauce
  - Culture : BTH

# Résultats consolidés 6 essais Dynamique INN



# Essais et protocole experimental



# Protocole expérimental

- **Modalités** : 8 engrais azotés simples combinant 4 formes chimiques x 2 formes physiques
  - CN : Nitrate de calcium solide CN (Tropicote) & liquide CN (Calsal)
  - AN : Nitrate d’ammonium solide (Extran 33.5) & liquide AN (Amnitra L)
  - UAN : Solution azotée (UAN 30 – S39) & “UAN solide” = apport successif d’AN & d’urée solide
  - Urée : Urée granulée (Ugran 46) & Urée liquide (→ Adblue)
  - + témoin ON (x2)

- **Sites expérimentaux** : 2 essais par an en 2019 – 2020 – 2021
  - 1 essai en sol de craie (Marne 51 ) - Prestataire Antedis
  - 1 essai sur limons argileux de Beauce ( sud Essonne 91) - Prestataire Eurofins Phyliae

- **Conduite N** : X # 200 N sur chaque site
  - 40 N tallage Z22-25 - 100 N epi 1 cm Z30 - 60 N Dernière feuille [Z37-39]

- **Dispositif** :
  - essais factoriels 2 facteurs 10 traitements x 4 blocs → taille parcelle élémentaire 3m x 11-14 m
  - les parcelles expérimentales sont doublées : → parcelles récoltées et → parcelles dédiées aux prélèvements de plantes

| Engrais/ Fertil.                      | Solid Form  | Liquid Form  |
|---------------------------------------|---|--|
| Nitrate de calcium<br>Calcium Nitrate | YaraLiva Tropicote<br>15.5% N<br>granulé<br>densité = 1<br>origine Yara Porsgrunn                                       | YaraTera Calsal<br>8.5% N p/p w/w<br>12.6% N p/v w/v<br>densité = 1.48<br>origine Yara Porsgrunn |
| Ammonitrate<br>Ammonium Nitrate       | YaraBela Extran 33.5<br>33.5 %N<br>granulé<br>densité = 1<br>origine Yara Montoir                                       | YaraTera Amnitra<br>18% N p/p w/w<br>22.3 % p/v w/v<br>densité = 1.23<br>origine Yara Vlardingen |
| Solution Azotée<br>UAN                | <u>splitted application of</u><br>gran. Ammonium Nitrate<br>gran. Urea<br>origine Yara Sluiskil<br>origine Yara Montoir | <u>conventional UAN</u><br>30% N p/p w/w<br>39% N p/v w/v<br>densité = 1.3<br>origine farm       |
| Urée<br>Urea                          | YaraVera Ugran<br>46% N<br>densité = 0.75<br>origine Yara Sluiskil  | Adblue<br>14.95% N p/v w/v<br>densité = 1.09<br>origine Total                                    |



# Suivi et analyse des essais

- **Suivi expérimental :**

- analyse sol - Rsh + bilan
- itinéraire technique
- couverture soufre ( Kieserite 40 kg SO<sub>3</sub>)
- plantes sortie hiver
- données climato pluie Tmin Tmax Tmoy journalière

- **Récolte :** parcelles dédiées

- rendement, PS , Pmg , épis , grains/m<sup>2</sup>
- Proteines (Nirs/ Infratec)

- **Suivi plantes**

- prélèvements de plantes à différents stades :  
2 x 2 rangs contigus par parcelle élémentaire

- 1. Plein tallage Z22-27
- 2. E1cm-1nd Z30-31
- 3. 2nds-Sdf Z32-37
  
- 4. Sdf-Gonflement Z37-45
- 5. Pleine Epiaison Z55-59
- 6. Floraison Z65-69
- 7. Maturité Z92

- **Variables analysées :**

- rendements et composantes,
- Proteines
- HI
- biomasse
- teneur N (P-K-Mg-S),
- absorption N (P-K-Mg-S),
- CAU%
- INN

- **Méthodes statistiques**

- Anova par essai  
+ test tukey sur les moyennes
  
- Analyse du réseau global par modèle linéaire mixte  
+ test tukey sur les moyennes

# Dispositif expérimental et plan

## Dispositif : Essai Factoriel 2 facteurs

8 modalités  
 2 TON en extrémité de chaque bloc  
 4 blocs  
 parcelles doublées pour le prélèvement de plantes  
 taille parcelle : 11-13m x 3m

2 facteurs :  
 Forme Chimique : CN - AN - UAN - URE  
 Forme Physique : Sol - Liq

|          |       |       |
|----------|-------|-------|
| 1 T 0 N  | 0_TO  | 0_TO  |
| 2 CN-L   | 1_CN  | 2_LIQ |
| 3 CN-S   | 1_CN  | 1_SOL |
| 4 AN-S   | 2_AN  | 1_SOL |
| 5 AN-L   | 2_AN  | 2_LIQ |
| 6 UAN-S  | 3_UAN | 1_SOL |
| 7 UAN-L  | 3_UAN | 2_LIQ |
| 8 U-L    | 4_UR  | 2_LIQ |
| 9 U-S    | 4_UR  | 1_SOL |
| 10 T 0 N | 0_TO  | 0_TO  |

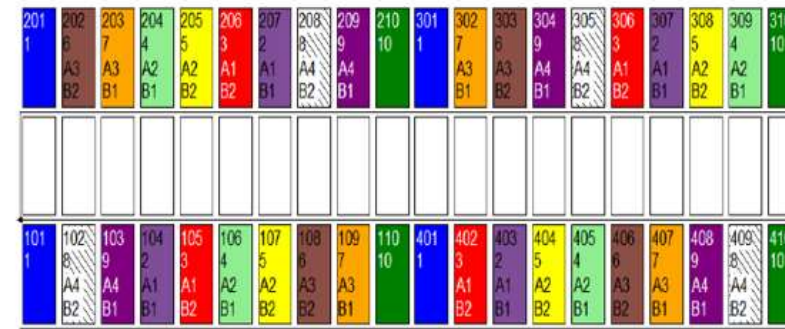
### Eurofins Standard Trial Plan

Form n°: F022-05(e)  
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|                            |                                     |
|----------------------------|-------------------------------------|
| EAS Study - Trial code     | S21-01016-01                        |
| Sponsor Study - Trial code | 2019-FR-DV-19031 - 2019-FR-DV-19031 |

| Trial Map              |          |         |   |
|------------------------|----------|---------|---|
| Width x Length of plot | 3m x 11m | % Slope | 0 |



| Randomisation |       |       |       |       |  |
|---------------|-------|-------|-------|-------|--|
| Trt No        | Rep 1 | Rep 2 | Rep 3 | Rep 4 |  |
| 1             | 101   | 201   | 301   | 401   |  |
| 2             | 104   | 207   | 307   | 403   |  |
| 3             | 105   | 206   | 306   | 402   |  |
| 4             | 106   | 204   | 309   | 405   |  |
| 5             | 107   | 205   | 308   | 404   |  |
| 6             | 108   | 202   | 303   | 406   |  |
| 7             | 109   | 203   | 302   | 407   |  |
| 8             | 102   | 208   | 305   | 409   |  |
| 9             | 103   | 209   | 304   | 408   |  |
| 10            | 110   | 210   | 310   | 410   |  |

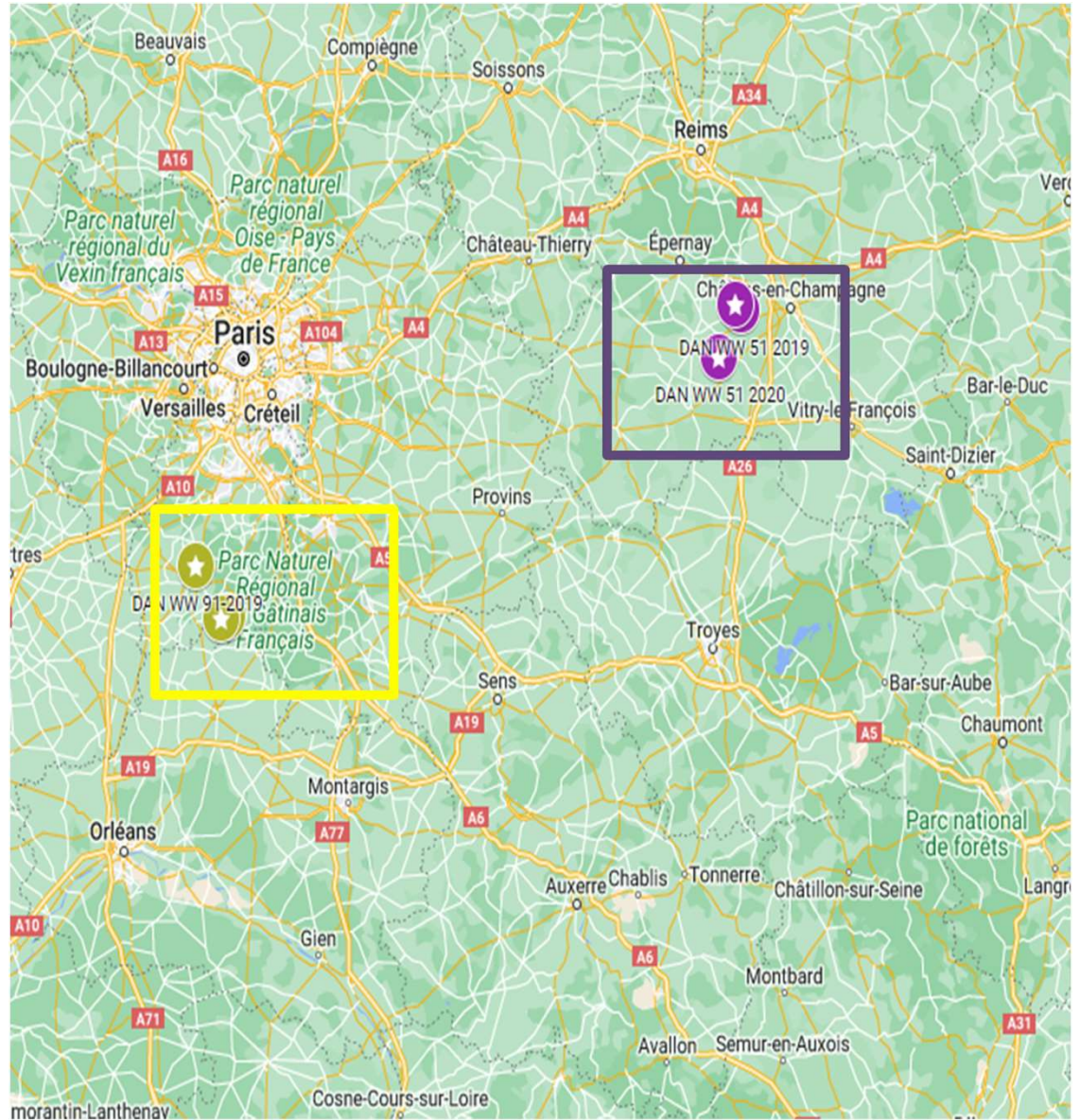
### Antedis Standard Trial Plan

|                  | bloc 4        | bloc 3        | bloc 2        | bloc 1        |
|------------------|---------------|---------------|---------------|---------------|
| Vers Champigneul | <b>Border</b> | <b>Border</b> | <b>Border</b> | <b>Border</b> |
|                  | 410 - 10 bis  | 310 - 10 bis  | 210 - 10 bis  | 110 - 10 bis  |
|                  | 410 - 10      | 310 - 10      | 210 - 10      | 110 - 10      |
|                  | 409 - 7 bis   | 309 - 8 bis   | 209 - 3 bis   | 109 - 4 bis   |
|                  | 409 - 7       | 309 - 8       | 209 - 3       | 109 - 4       |
|                  | 408 - 6 bis   | 308 - 9 bis   | 208 - 2 bis   | 108 - 5 bis   |
|                  | 408 - 6       | 308 - 9       | 208 - 2       | 108 - 5       |
|                  | 407 - 2 bis   | 307 - 4 bis   | 207 - 6 bis   | 107 - 8 bis   |
|                  | 407 - 2       | 307 - 4       | 207 - 6       | 107 - 8       |
|                  | 406 - 3 bis   | 306 - 5 bis   | 206 - 7 bis   | 106 - 9 bis   |
|                  | 406 - 3       | 306 - 5       | 206 - 7       | 106 - 9       |
| D37              | 405 - 5 bis   | 305 - 3 bis   | 205 - 8 bis   | 105 - 7 bis   |
|                  | 405 - 5       | 305 - 3       | 205 - 8       | 105 - 7       |
|                  | 404 - 4 bis   | 304 - 2 bis   | 204 - 9 bis   | 104 - 6 bis   |
|                  | 404 - 4       | 304 - 2       | 204 - 9       | 104 - 6       |
|                  | 403 - 9 bis   | 303 - 6 bis   | 203 - 4 bis   | 103 - 2 bis   |
|                  | 403 - 9       | 303 - 6       | 203 - 4       | 103 - 2       |
|                  | 402 - 8 bis   | 302 - 7 bis   | 202 - 5 bis   | 102 - 3 bis   |
|                  | 402 - 8       | 302 - 7       | 202 - 5       | 102 - 3       |
|                  | 401 - 1 bis   | 301 - 1 bis   | 201 - 1 bis   | 101 - 1 bis   |
|                  | 401 - 1       | 301 - 1       | 201 - 1       | 101 - 1       |
| Vers Poceancy    | <b>Border</b> | <b>Border</b> | <b>Border</b> | <b>Border</b> |

parcelle pour prélèvements

# Sites d'essais & principales caractéristiques sol

| Trial location Year              | DAN 91 2019         | DAN 91 2020             | DAN 91 2021       | DAN 51 2019         | DAN 51 2020         | DAN 51 2021           |
|----------------------------------|---------------------|-------------------------|-------------------|---------------------|---------------------|-----------------------|
| contractor                       | Eurofins            | Eurofins                | Eurofins          | Antedis             | Antedis             | Antedis               |
| GPS coordinates                  | 48.459754, 2.174377 | 48.3602902, 2.289337956 | 48.355407, 2.2668 | 48.950197, 4.181238 | 48.862146, 4.095304 | 48.962680, 4.156804   |
| CP-Zip                           | 91433               | 91150                   | 91150             | 51130               | 51578               | 51150                 |
| location                         | Morigny-Champigny   | Mespuits                | Mespuits          | Pocancy             | Trecon              | Champigneul-Champagne |
| cult. / crop                     | WW                  | WW                      | WW                | WW                  | WW                  | WW                    |
| Variété                          | Pakito              | Absalon                 | Absalon           | Chevignon           | Filon               | Syllon                |
| semis / sowing :                 | 27/10/2018          | 25/10/2019              | 04/11/2020        | 17/10/2018          | 24/10/2019          | 26/10/2020            |
| prec / prev. Crop                | OSR                 | Sunflower               | OSR               | Hemp                | Sbeet               | Hemp                  |
| <b>soil type</b>                 | Sable Limoneux      | Limons Argileux         | Limons Argileux   | Craie               | Craie               | Craie                 |
| <b>soil type depth :</b>         | Sandy Loam          | Clay loam               | Clay loam         | Chalk               | Chalk               | Chalk                 |
| <b>Soil Analysis</b>             |                     |                         |                   |                     |                     |                       |
| pH                               | 8.02                | 8.3                     | 8.3               | 8.2                 | 8.4                 | 8.4                   |
| CaCO3 tot g/kg                   | < 30                | 441                     | 187               | 773                 | 753                 | 798                   |
| argile - clay %                  | 159                 | 260                     | 238               | 228                 | 225                 | 309                   |
| limons fins - fine silt %        | 168                 | 222                     | 299               | 290                 | 297                 | 374                   |
| limons grossiers - coarse silt % | 256                 | 219                     | 406               | 90                  | 113                 | 106                   |
| sables - sand %                  | 417                 | 299                     | 29                | 392                 | 364                 | 215                   |
| SOM %                            | 18.1                | 26.7                    | 2.2               | 43.0                | 32.7                | 32.7                  |
| C Org %                          | 10.5                | 15.5                    | 1.3               | 24.8                | 19.0                | 18.9                  |
| C/N                              | 9.3                 | 10.3                    |                   | 13.9                | 13.9                | 13.9                  |
| CEC metson mg/kg                 | 170                 | 179                     | 156               | 61.5                | 63.6                | 87                    |
| % saturation                     |                     | 100                     |                   | 100                 | 100                 | 388                   |
| P2O5 olsen %                     | 66                  | 41                      | 30                | 65                  | 141                 | 70                    |
| K2O %                            | 204                 | 218                     | 237               | 90                  | 386                 | 249                   |
| MgO %                            | 75                  | 101                     |                   | 48                  | 108                 | 98                    |
| CaO %                            | 3992                | 8132                    |                   | 8339                | 8620                | 9161                  |
| <b>N min - RSH kg N/ha</b>       | 32                  | 52                      | 51                | 41                  | 24                  | 45                    |
|                                  | [0-60cm]            | [0-60cm]                | [0-60cm]          | [0-60cm]            | [0-60cm]            | [0-60cm]              |
|                                  | 05/02/2019          | 24/01/2020              | 19/02/2021        | 07/02/2019          | 04/02/2020          | 26/01/2021            |



[https://www.google.com/maps/d/u/0/viewer?mid=1OC0LMOL\\_ZOA4wnL29Y\\_S0C850A9KFhQ&ll=48.96268000000002%2C4.156803999999985&z=11](https://www.google.com/maps/d/u/0/viewer?mid=1OC0LMOL_ZOA4wnL29Y_S0C850A9KFhQ&ll=48.96268000000002%2C4.156803999999985&z=11)

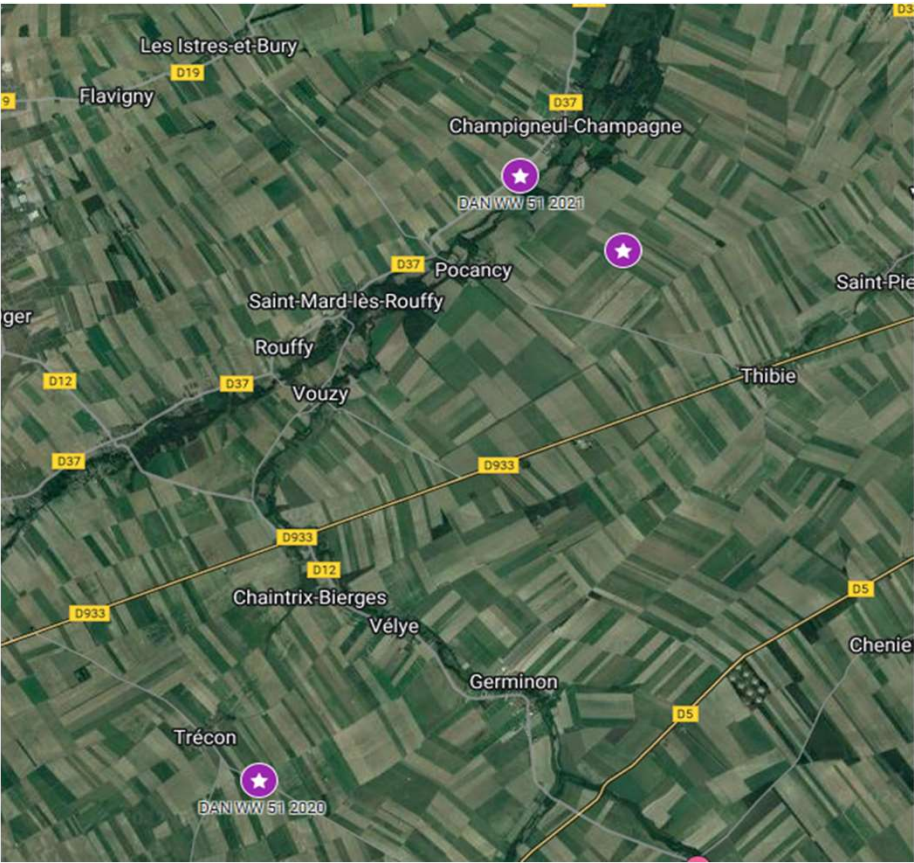
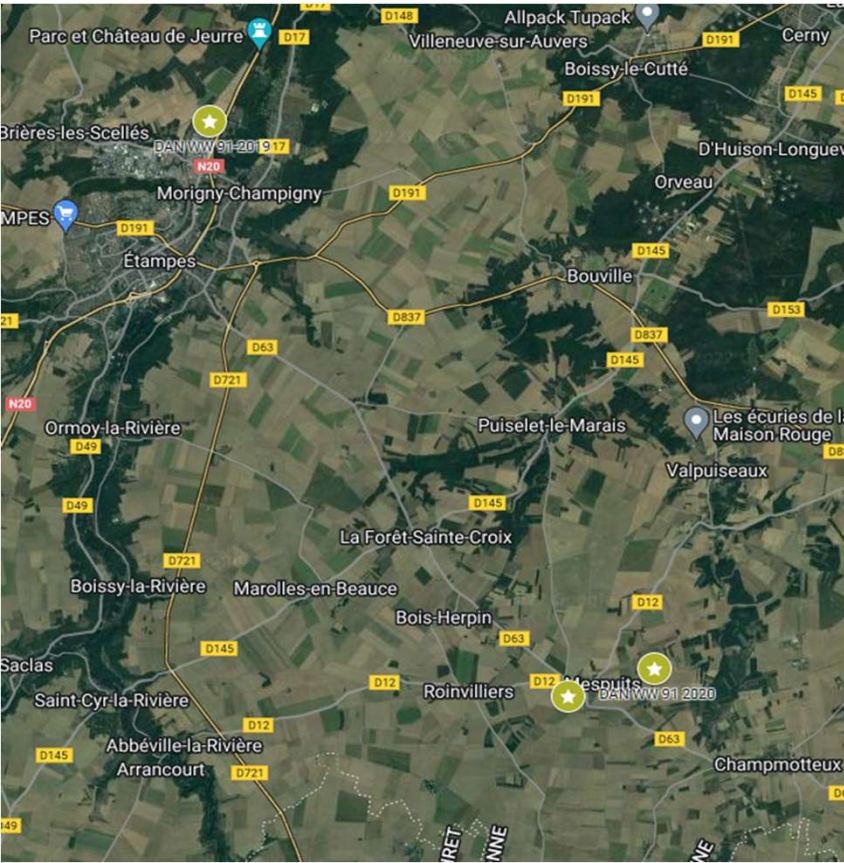




# Sites et dates apports N

Doses N et fractionnement X # 200 N

| site<br>année             | DAN 91<br>2019 | DAN 91<br>2020 | DAN 91<br>2021 | DAN 51<br>2019 | DAN 51<br>2020 | DAN 51<br>2021 |
|---------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>N1 = 40 N - Z22-25</b> | 21/2           | 21/2           | 23/2           | 8/3            | 20/2           | 22/2           |
| <b>N2 = 100 N - Z30</b>   | 20/3           | 20/3           | 26/3           | 1/4            | 17/3           | 9/4            |
| <b>N3 = 60 N - Z37-45</b> | 10/5           | 21/4           | 12/5           | 7/5            | 16/4           | 21/5           |



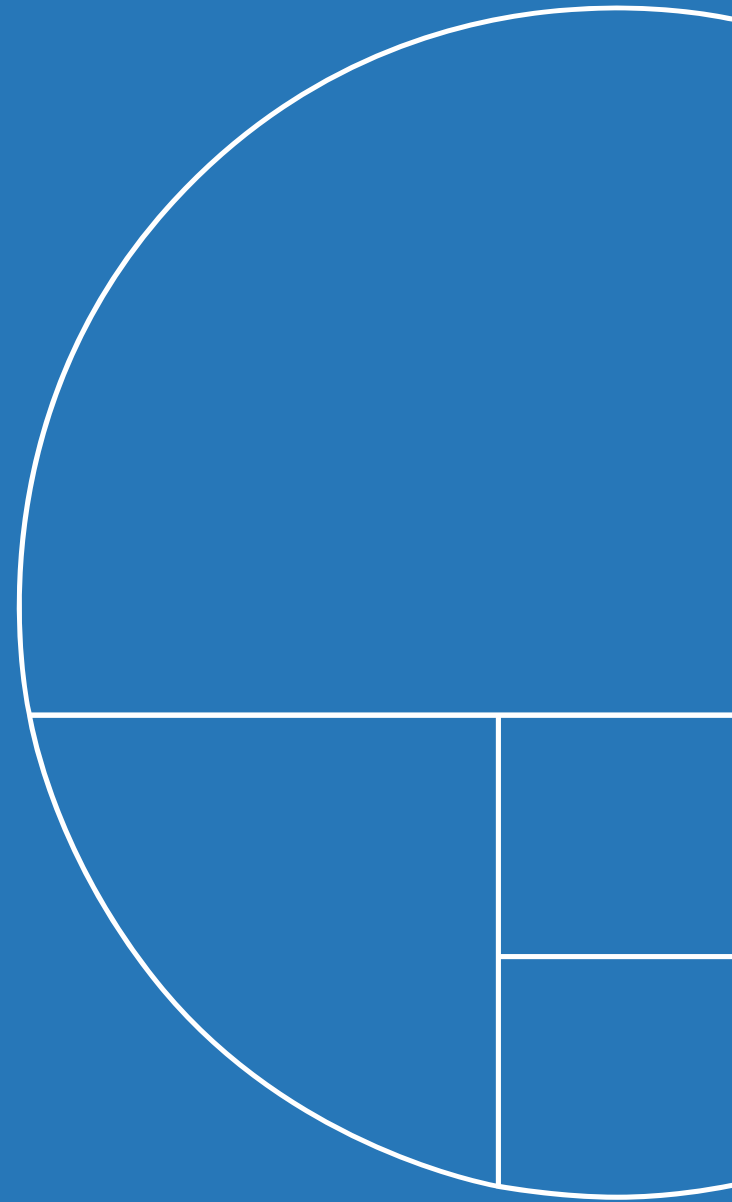
# Champigneul Champagne 51 2021



# Mespuits 91 2021



**Résultats consolidés  
sur 6 essais et 3 années**



# Résultats consolidés 6 essais – Récolte

N = 200 kg/ha

Nmin [0-60]= kg N/ha

Date / Stage  
N 200

| N1  | N2  | N3     |
|-----|-----|--------|
| Z25 | Z30 | Z37-45 |
| 40  | 100 | 60     |

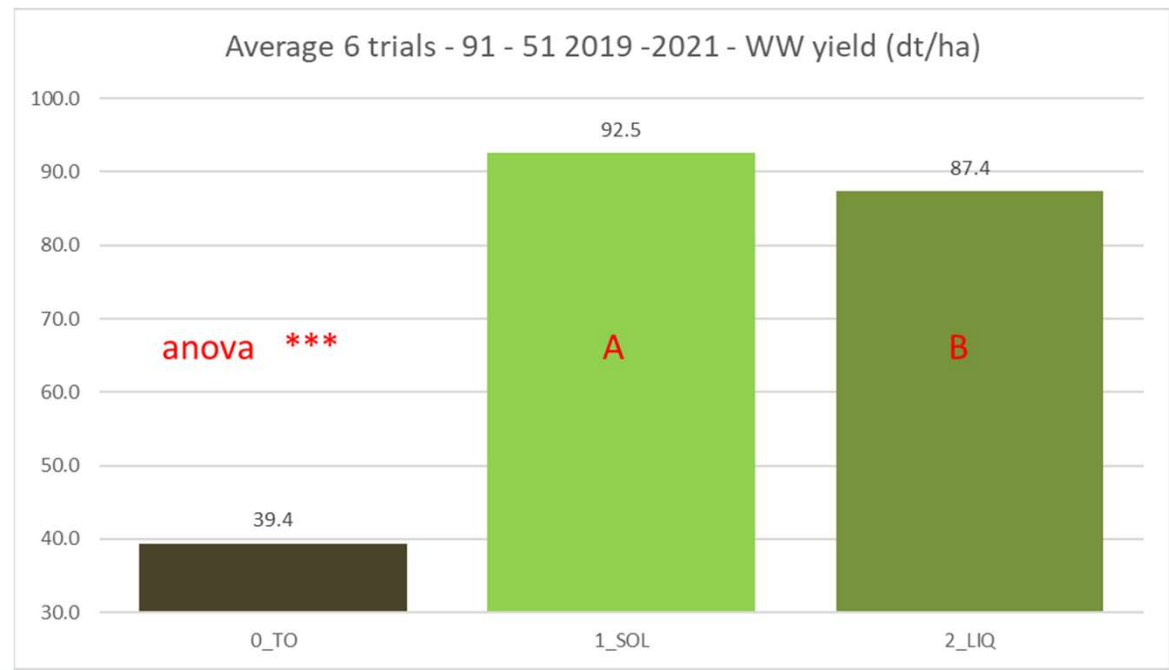
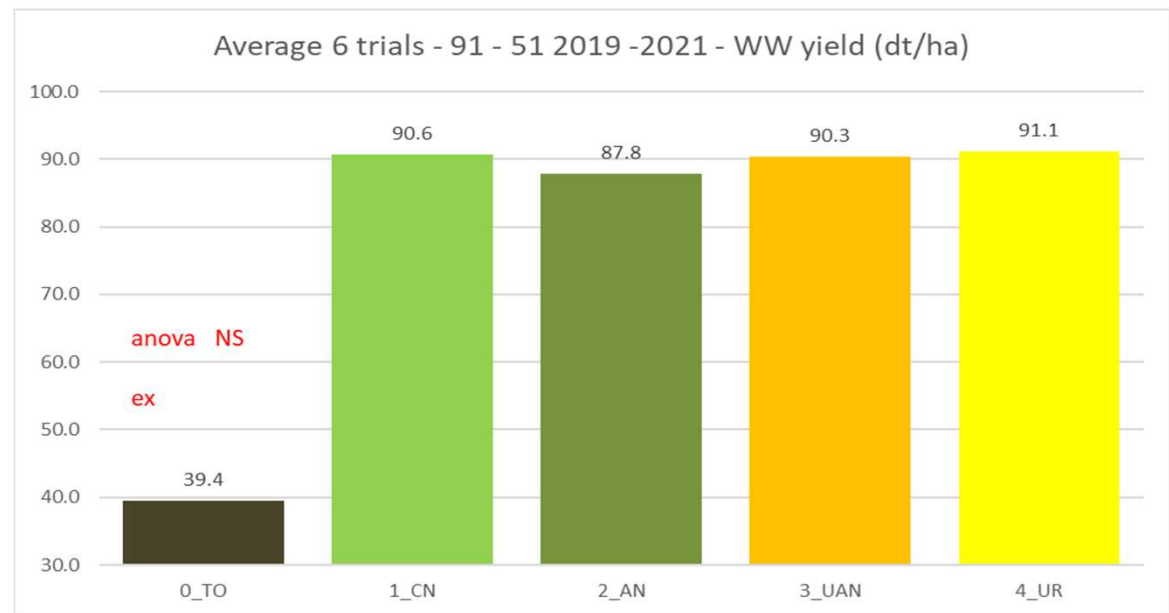
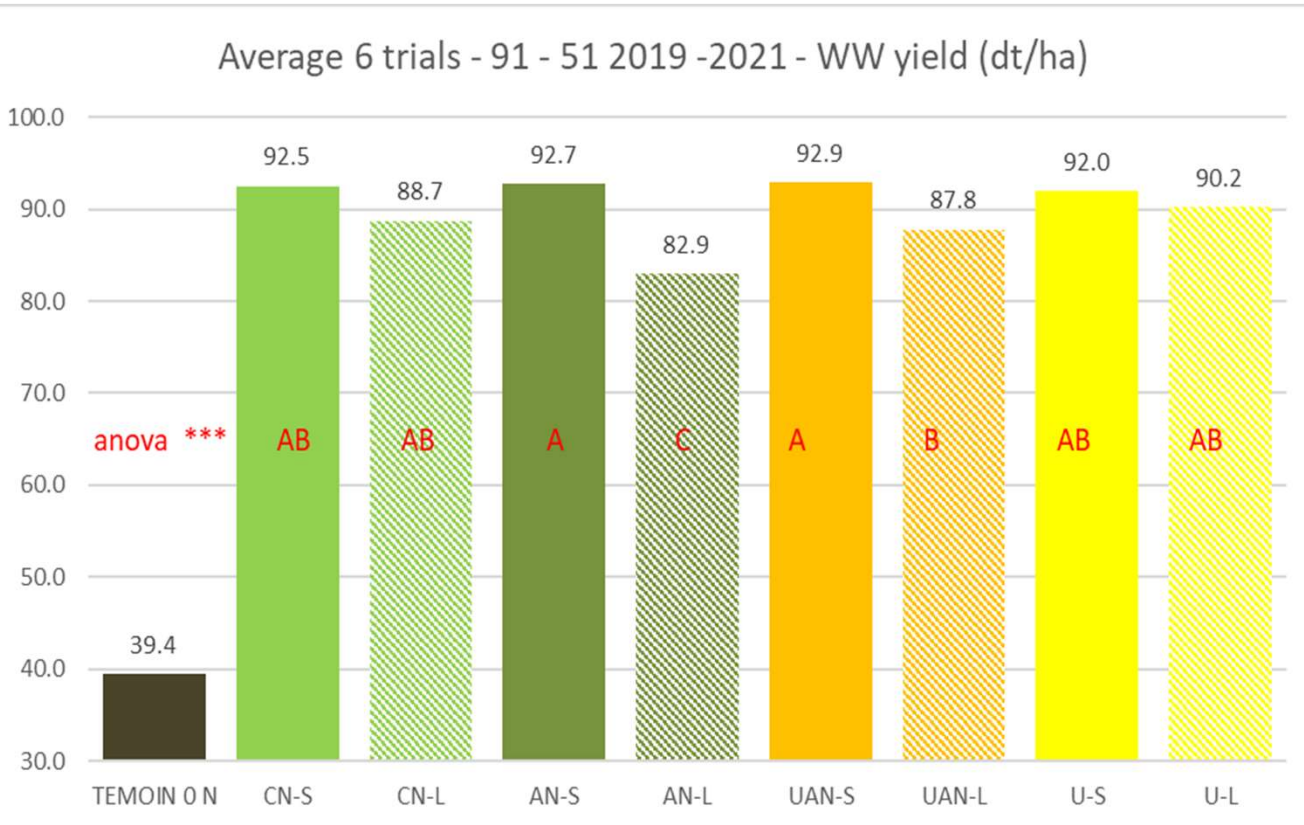
**HARVEST**

| date stage                  | Yield (dt/ha) |            | proteins % dm |            | N uptake grain kg N/ha (NIR / prot%) |            | Ears/m <sup>2</sup> |           | grains/m <sup>2</sup> |            | tgw (g) |           | Specific Weight |           |
|-----------------------------|---------------|------------|---------------|------------|--------------------------------------|------------|---------------------|-----------|-----------------------|------------|---------|-----------|-----------------|-----------|
| control ON                  | 39.4          | (+/- 9.2)  | 8.8           | (+/- .96)  | 52                                   | (+/- 17)   | 363                 | (+/- 99)  | 9146                  | (+/- 2190) | 43.4    | (+/- 4.1) | 75.6            | (+/- 4.4) |
| <b>Chemical x Phys Form</b> |               | <b>***</b> |               | <b>***</b> |                                      | <b>***</b> |                     |           |                       | <b>***</b> |         | <b>NS</b> |                 | <b>*</b>  |
| CN solid                    | 92.5          | (+/- 12.3) | 12.1          | (+/- .98)  | 167                                  | (+/- 18)   | 536                 | (+/- 106) | 21820                 | (+/- 5228) | 43.6    | (+/- 5.4) | 77.4            | (+/- 3.2) |
| CN liq.                     | 88.7          | (+/- 12.2) | 12.1          | (+/- 1.09) | 158                                  | (+/- 16)   | 515                 | (+/- 98)  | 21024                 | (+/- 4998) | 43.3    | (+/- 5.5) | 77.4            | (+/- 2.8) |
| AN solid                    | 92.7          | (+/- 11.7) | 12.0          | (+/- 1.07) | 165                                  | (+/- 14)   | 520                 | (+/- 109) | 21634                 | (+/- 4743) | 43.9    | (+/- 5.4) | 77.6            | (+/- 3.3) |
| AN liq.                     | 82.9          | (+/- 10.5) | 10.5          | (+/- 1.57) | 131                                  | (+/- 26)   | 470                 | (+/- 68)  | 19689                 | (+/- 3921) | 42.9    | (+/- 5.4) | 76.5            | (+/- 2.7) |
| UAN solid                   | 92.9          | (+/- 10.6) | 11.8          | (+/- 1.07) | 163                                  | (+/- 15)   | 523                 | (+/- 109) | 21582                 | (+/- 4669) | 44.1    | (+/- 5.2) | 77.2            | (+/- 3.1) |
| UAN liq.                    | 87.8          | (+/- 11.4) | 10.8          | (+/- .83)  | 141                                  | (+/- 16)   | 540                 | (+/- 106) | 20857                 | (+/- 4614) | 43.1    | (+/- 5.0) | 77.0            | (+/- 2.9) |
| UREA solid                  | 92.0          | (+/- 12.1) | 12.0          | (+/- 1.12) | 163                                  | (+/- 16)   | 540                 | (+/- 128) | 21509                 | (+/- 4933) | 43.8    | (+/- 5.2) | 77.8            | (+/- 3.4) |
| UREA liq.                   | 90.2          | (+/- 11.1) | 11.2          | (+/- 1.12) | 150                                  | (+/- 15)   | 517                 | (+/- 120) | 21287                 | (+/- 4496) | 43.3    | (+/- 5.6) | 77.1            | (+/- 3.5) |
| <b>Chemical N form</b>      |               | <b>NS</b>  |               | <b>***</b> |                                      | <b>**</b>  |                     |           |                       | <b>NS</b>  |         | <b>NS</b> |                 | <b>NS</b> |
| CN                          | 90.6          | (+/- 12.3) | 12.1          | (+/- 1.03) | 162                                  | (+/- 18)   | 526                 | (+/- 100) | 21422                 | (+/- 5076) | 43.4    | (+/- 5.3) | 77.4            | (+/- 3.0) |
| AN                          | 87.8          | (+/- 12.0) | 11.3          | (+/- 1.53) | 148                                  | (+/- 27)   | 495                 | (+/- 93)  | 20662                 | (+/- 4416) | 43.4    | (+/- 5.1) | 77.0            | (+/- 3.1) |
| UAN                         | 90.3          | (+/- 11.2) | 11.3          | (+/- 1.09) | 152                                  | (+/- 19)   | 531                 | (+/- 106) | 21220                 | (+/- 4606) | 43.6    | (+/- 5.4) | 77.1            | (+/- 3.0) |
| UREA                        | 91.1          | (+/- 11.5) | 11.6          | (+/- 1.18) | 156                                  | (+/- 17)   | 528                 | (+/- 122) | 21398                 | (+/- 4670) | 43.6    | (+/- 5.4) | 77.5            | (+/- 3.4) |
| <b>Physical N form</b>      |               | <b>**</b>  |               | <b>***</b> |                                      | <b>***</b> |                     |           |                       | <b>*</b>   |         | <b>*</b>  |                 | <b>**</b> |
| Solid                       | 92.5          | (+/- 11.5) | 12.0          | (+/- 1.0)  | 164                                  | (+/- 16)   | 530                 | (+/- 110) | 21636                 | (+/- 4821) | 43.8    | (+/- 5.4) | 77.5            | (+/- 3.2) |
| Liquid                      | 87.4          | (+/- 11.5) | 11.1          | (+/- 1.3)  | 145                                  | (+/- 21)   | 510                 | (+/- 100) | 20714                 | (+/- 4494) | 43.1    | (+/- 5.2) | 77.0            | (+/- 3.0) |
| etr                         |               | 3.6        |               | 0.5        |                                      | 9.5        |                     |           |                       | 1033       |         | 1.3       |                 | 1.1       |
| cv%                         |               | 4%         |               | 4%         |                                      | 6%         |                     |           |                       | 5%         |         | 3%        |                 | 1%        |



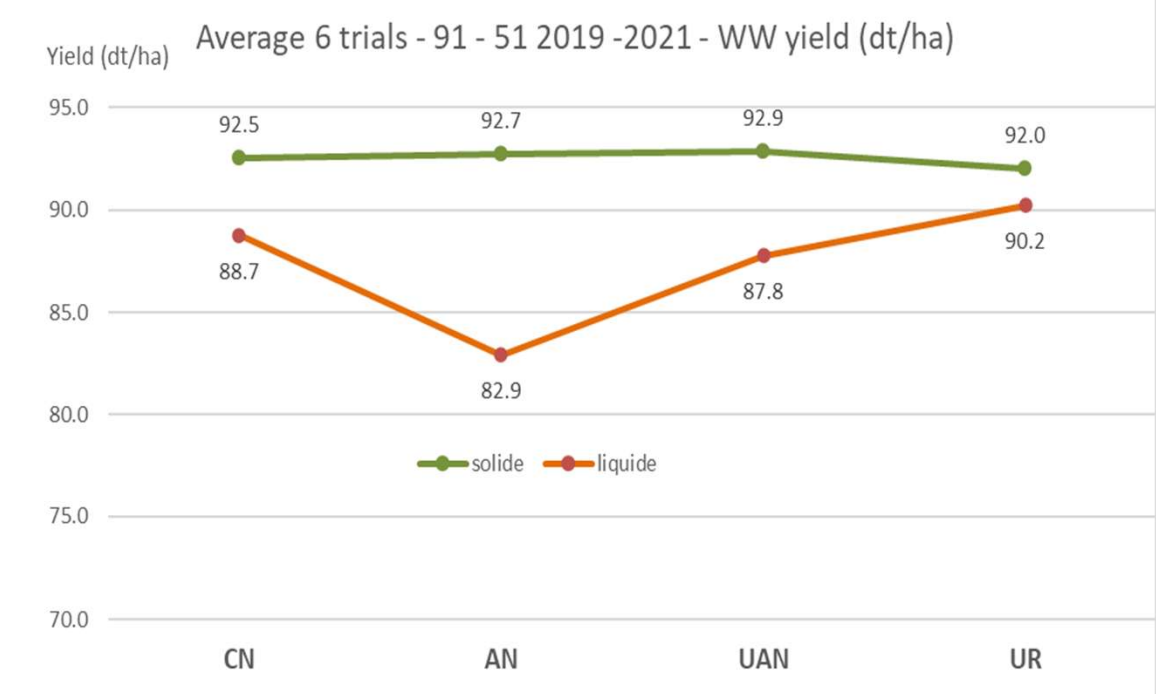
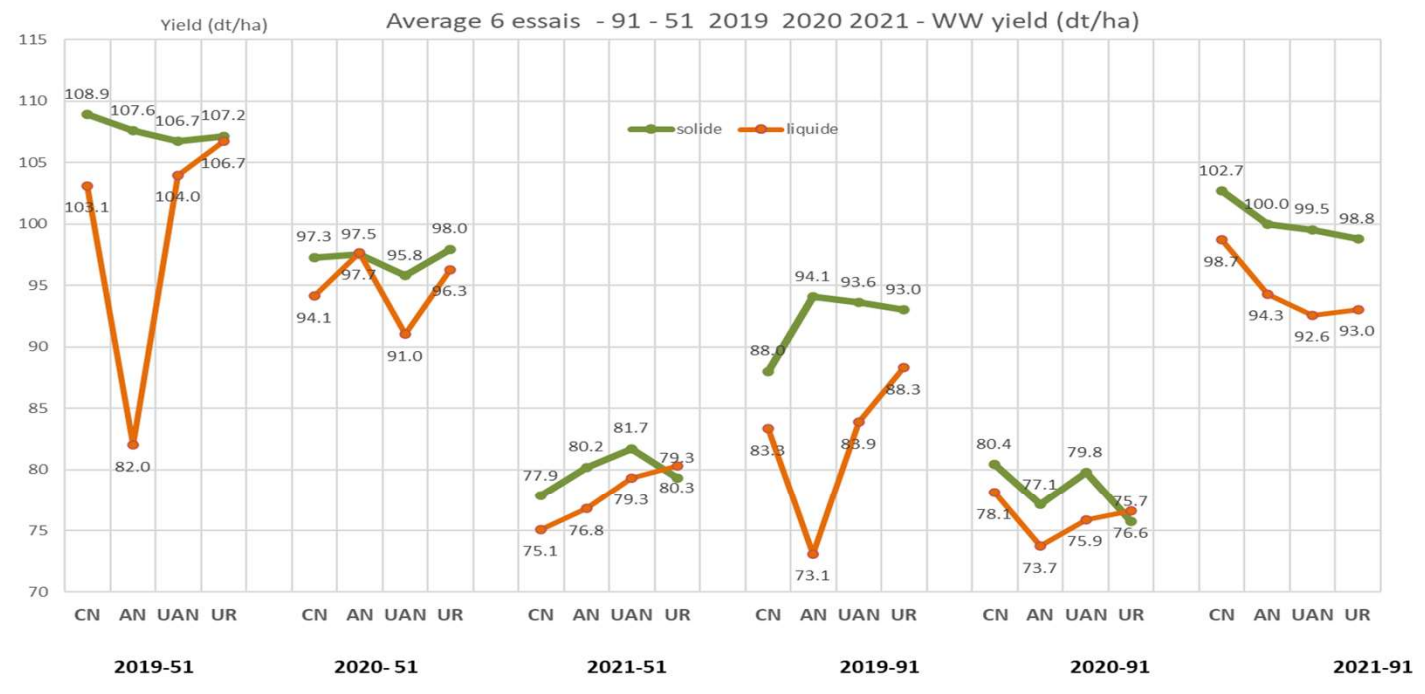
# Résultats consolidés 6 essais

## Rendement



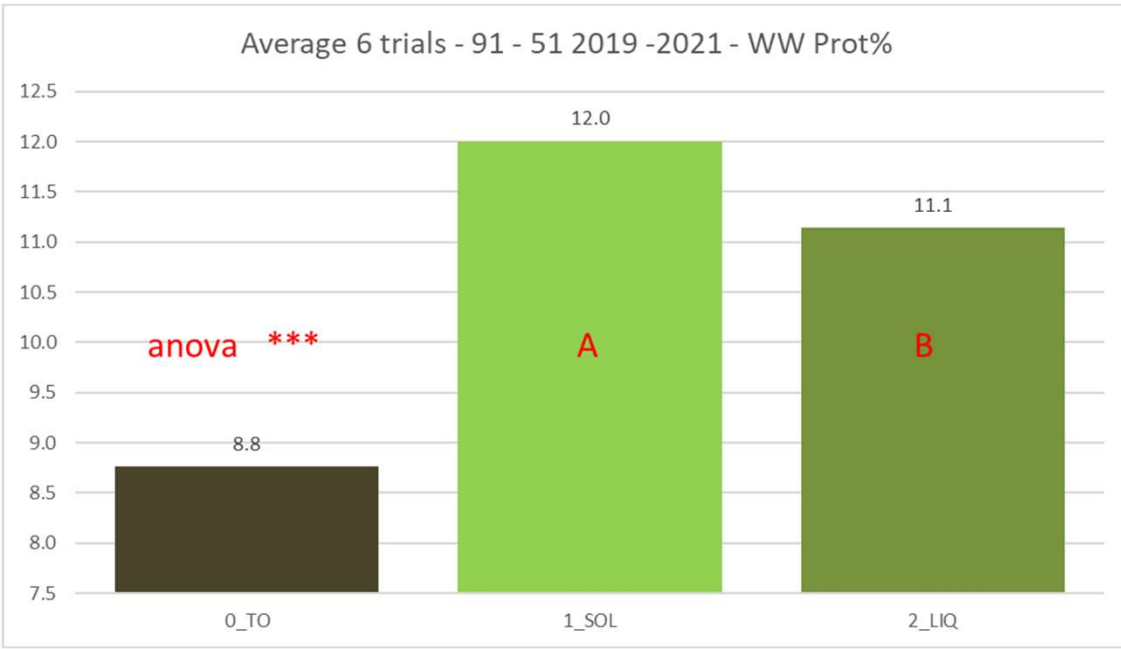
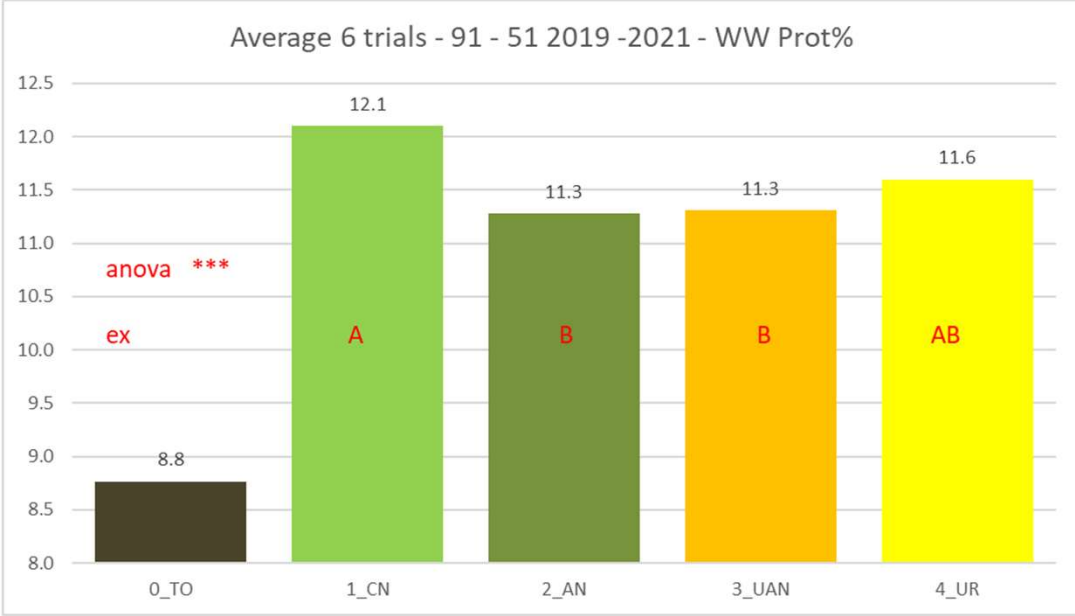
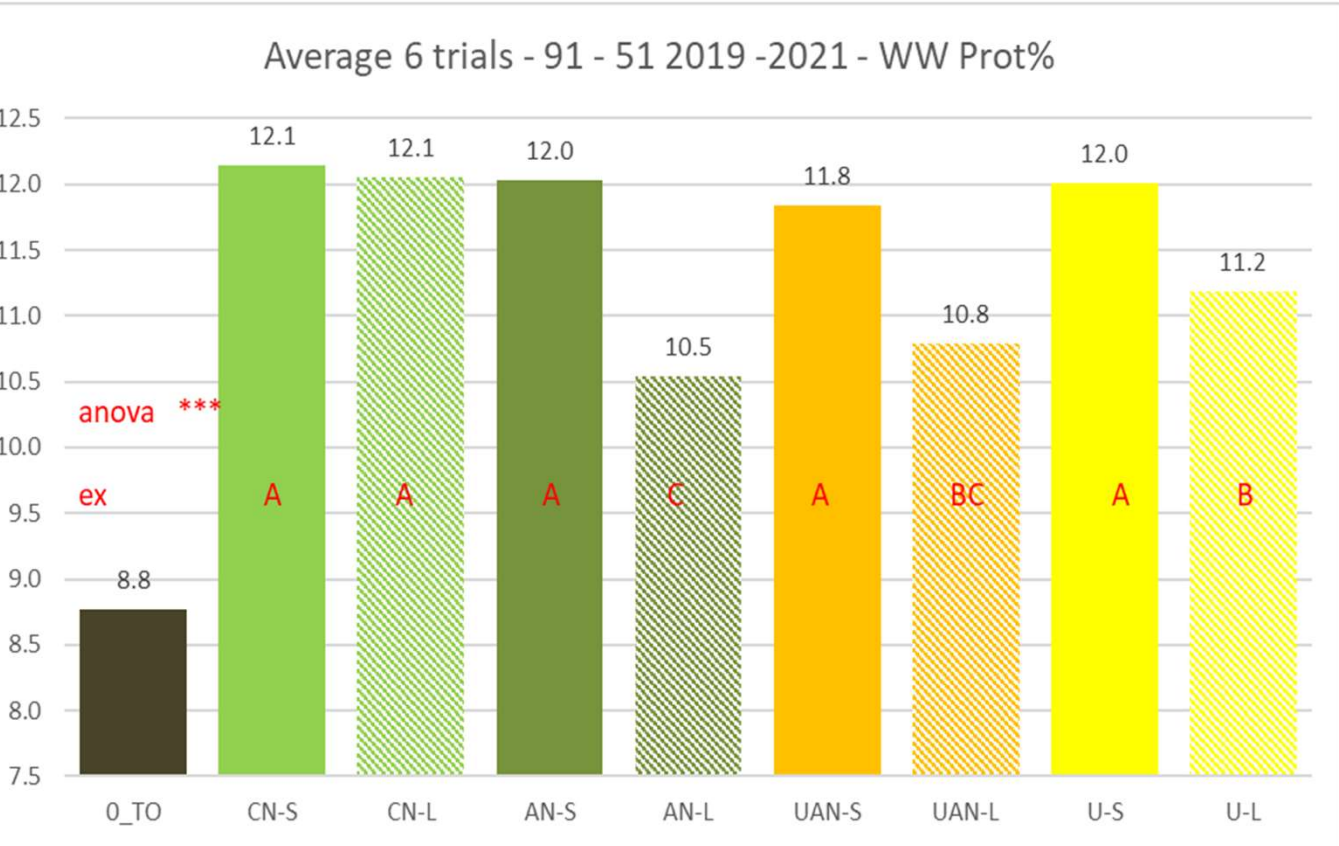
# Résultats consolidés 6 essais

## Rendement



# Résultats consolidés 6 essais

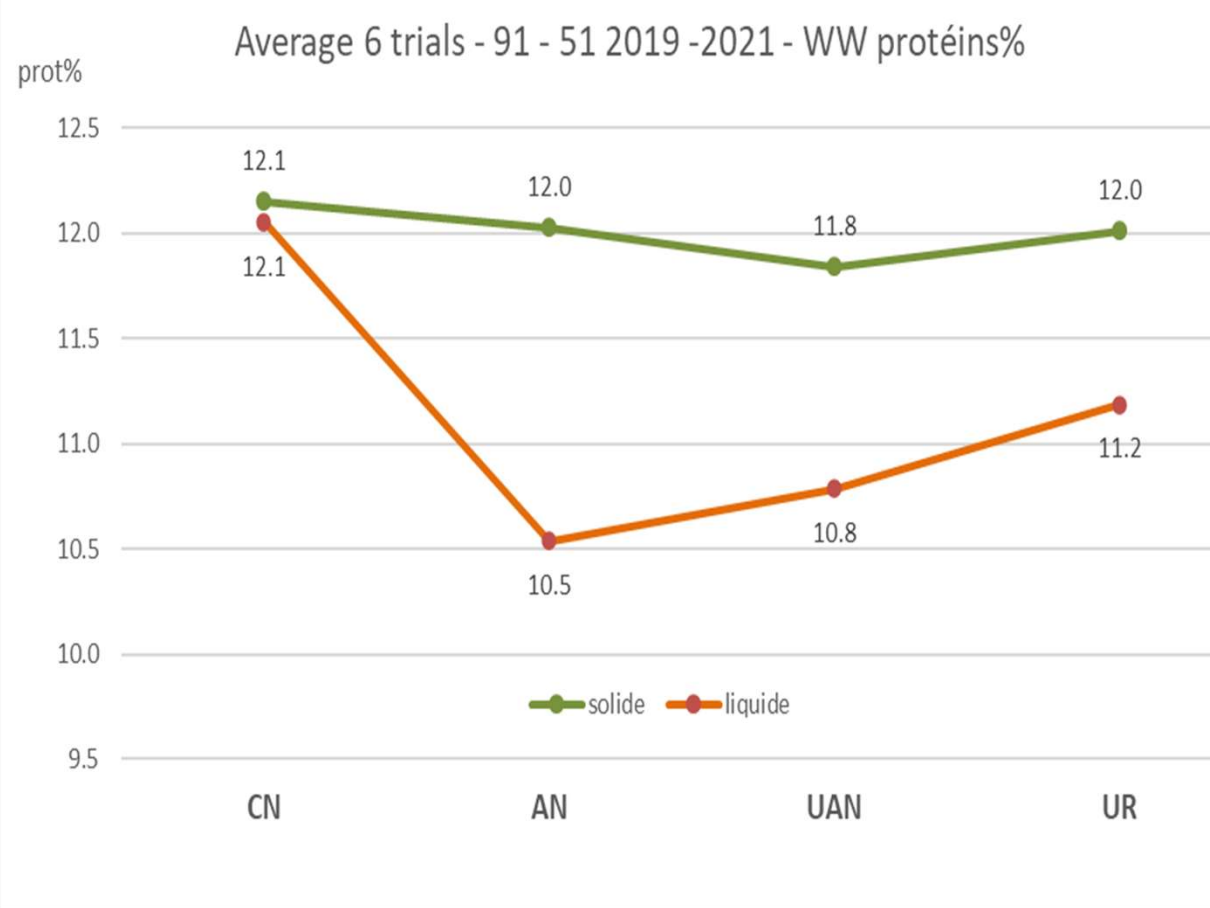
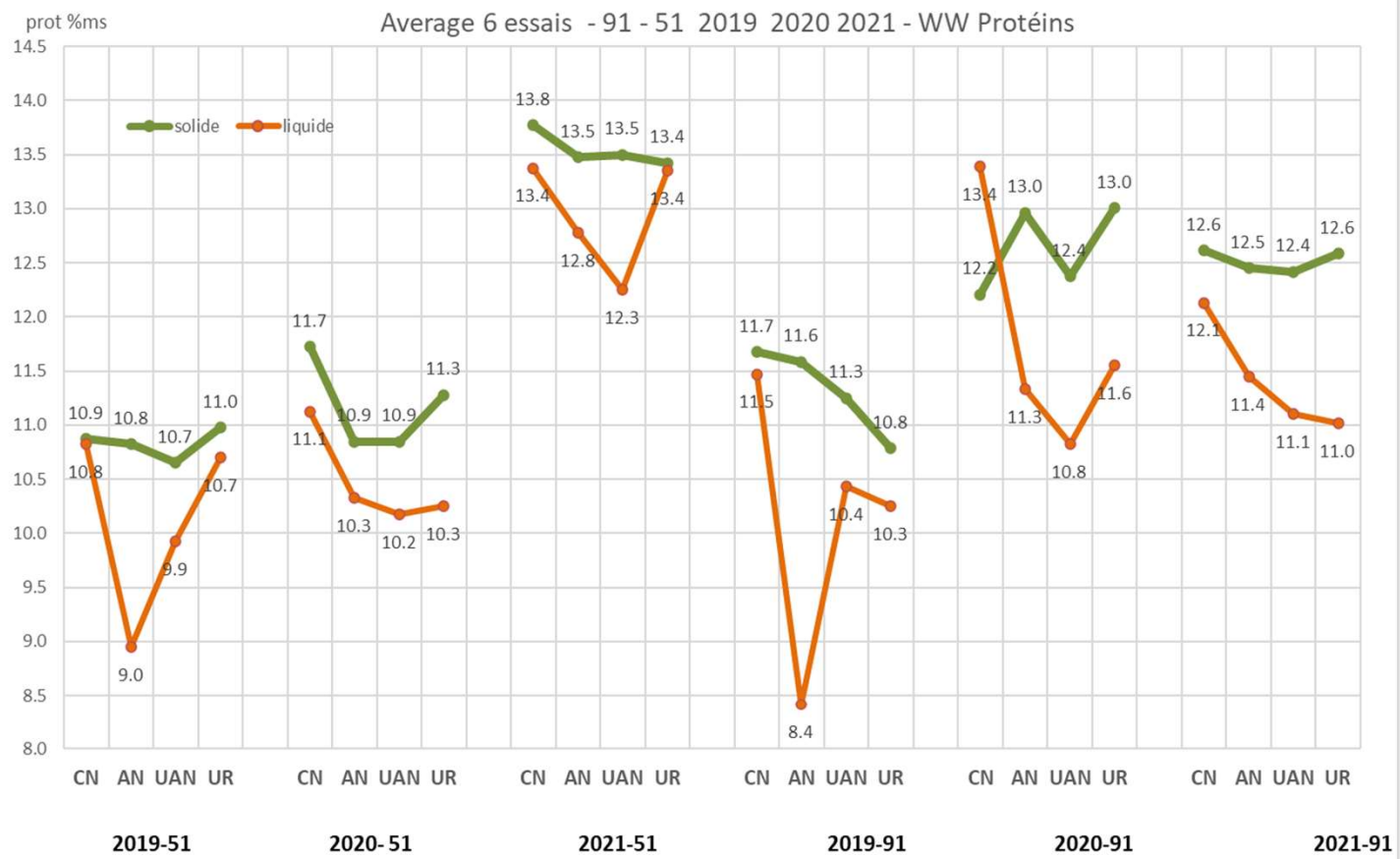
## Protéines





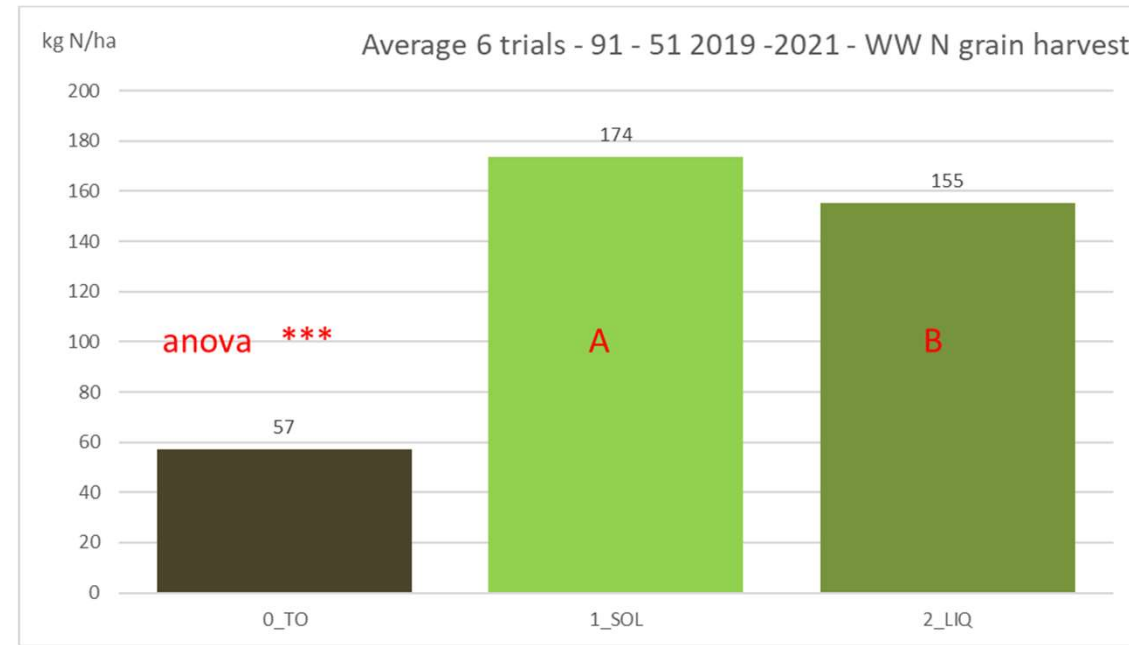
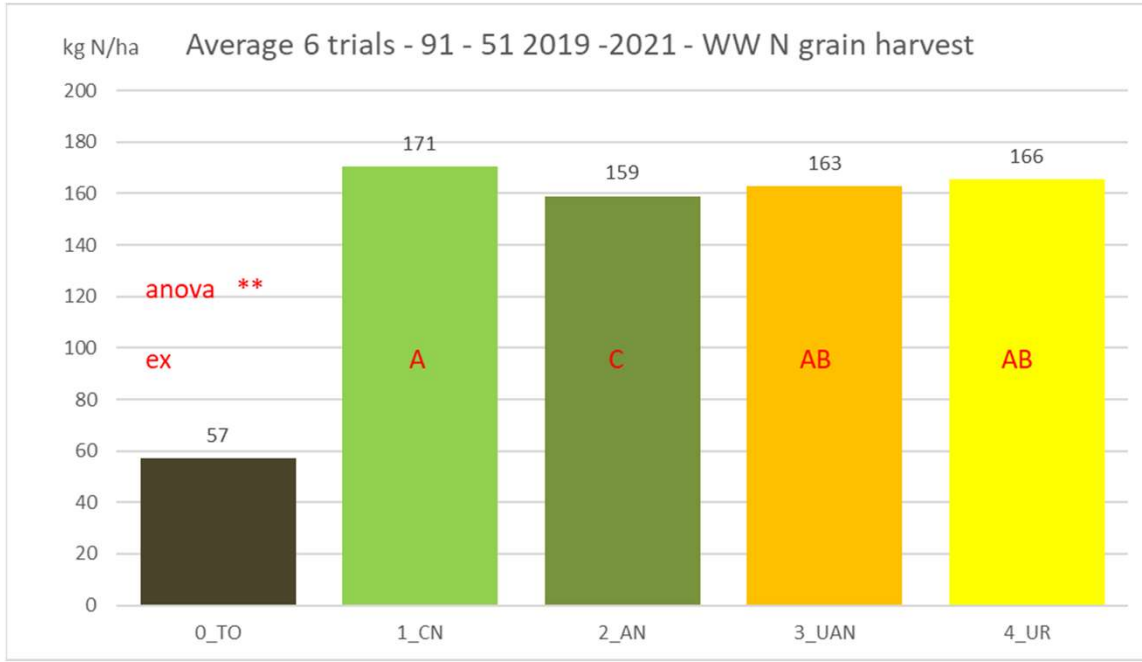
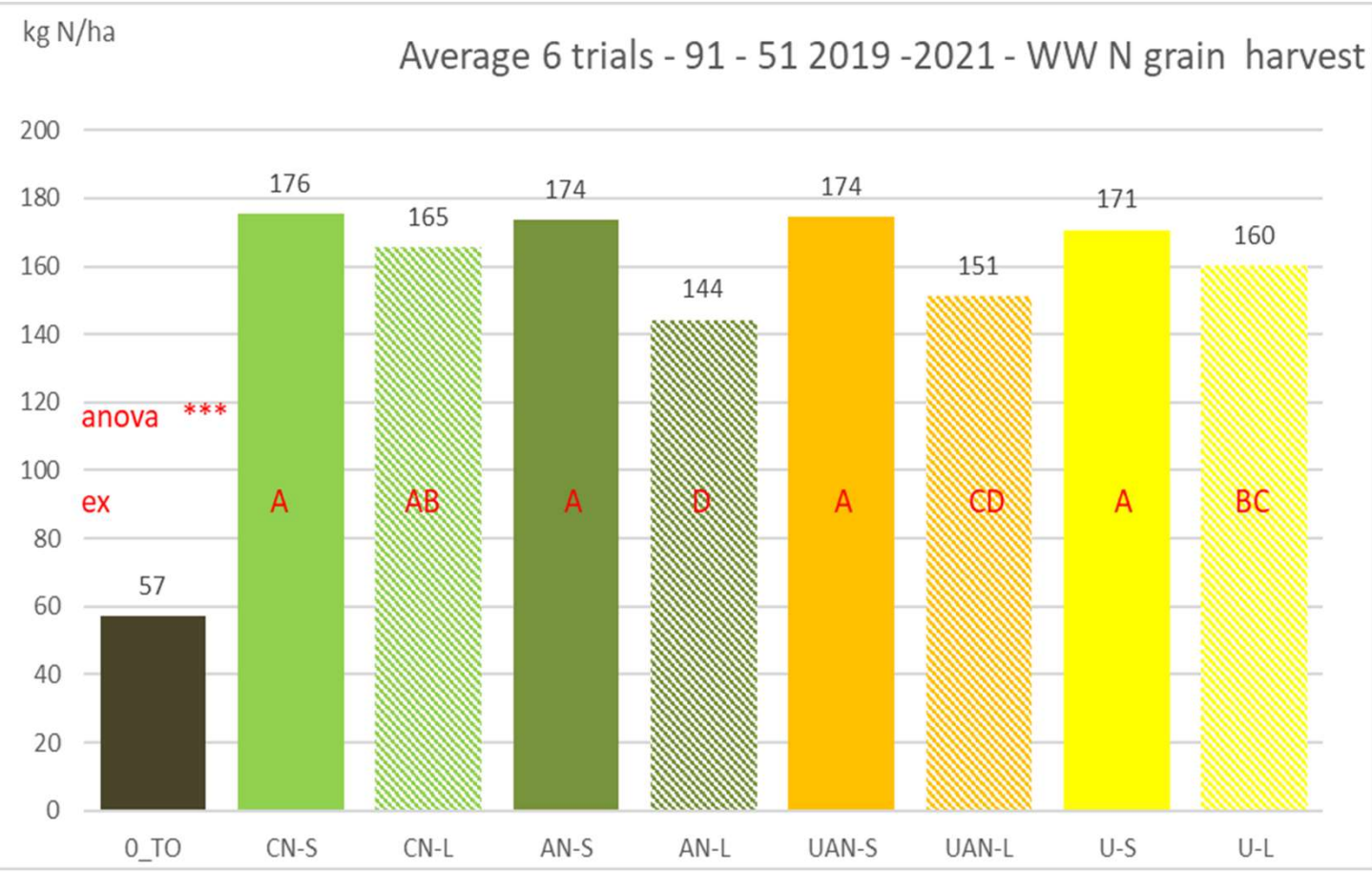
# Résultats consolidés 6 essais

## Protéines



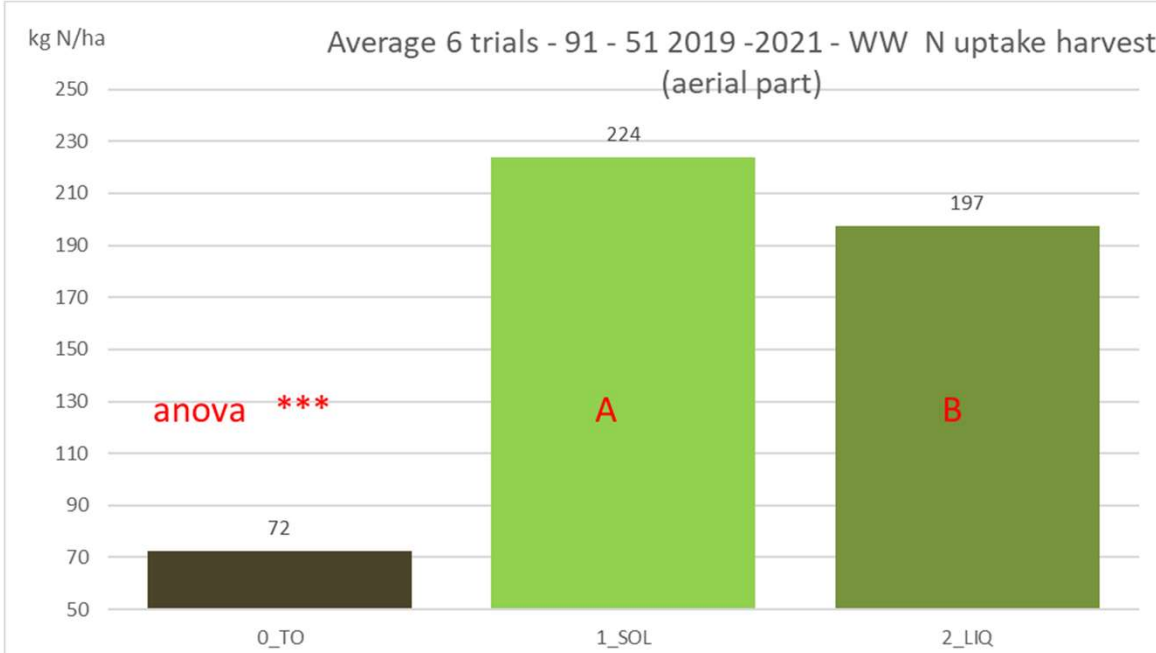
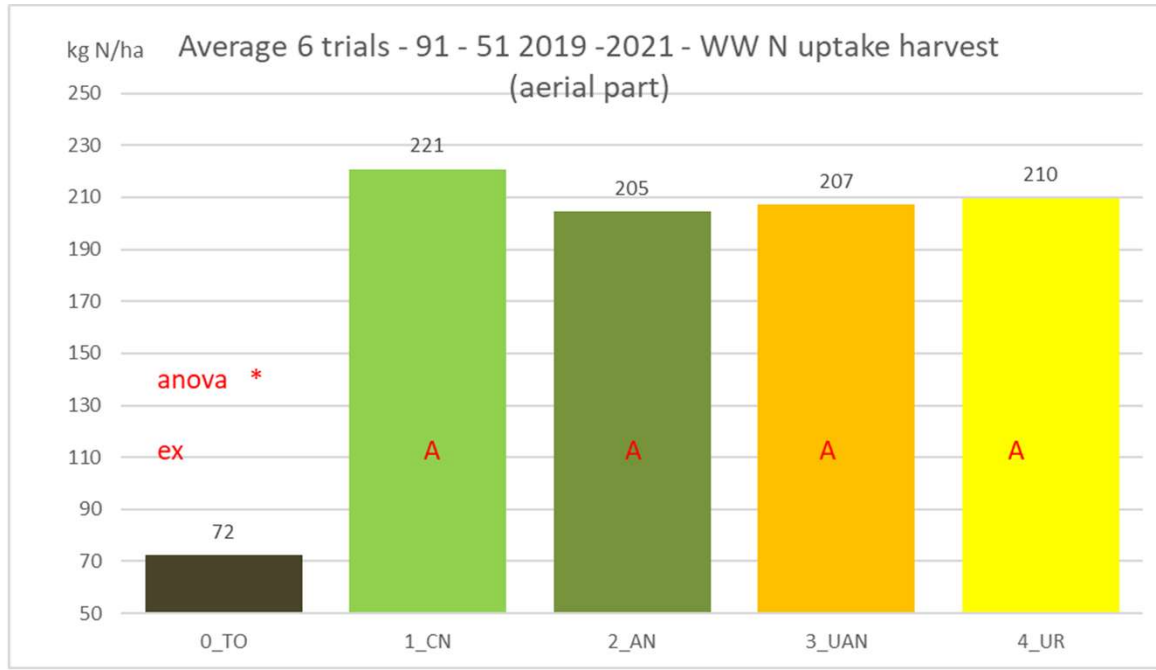
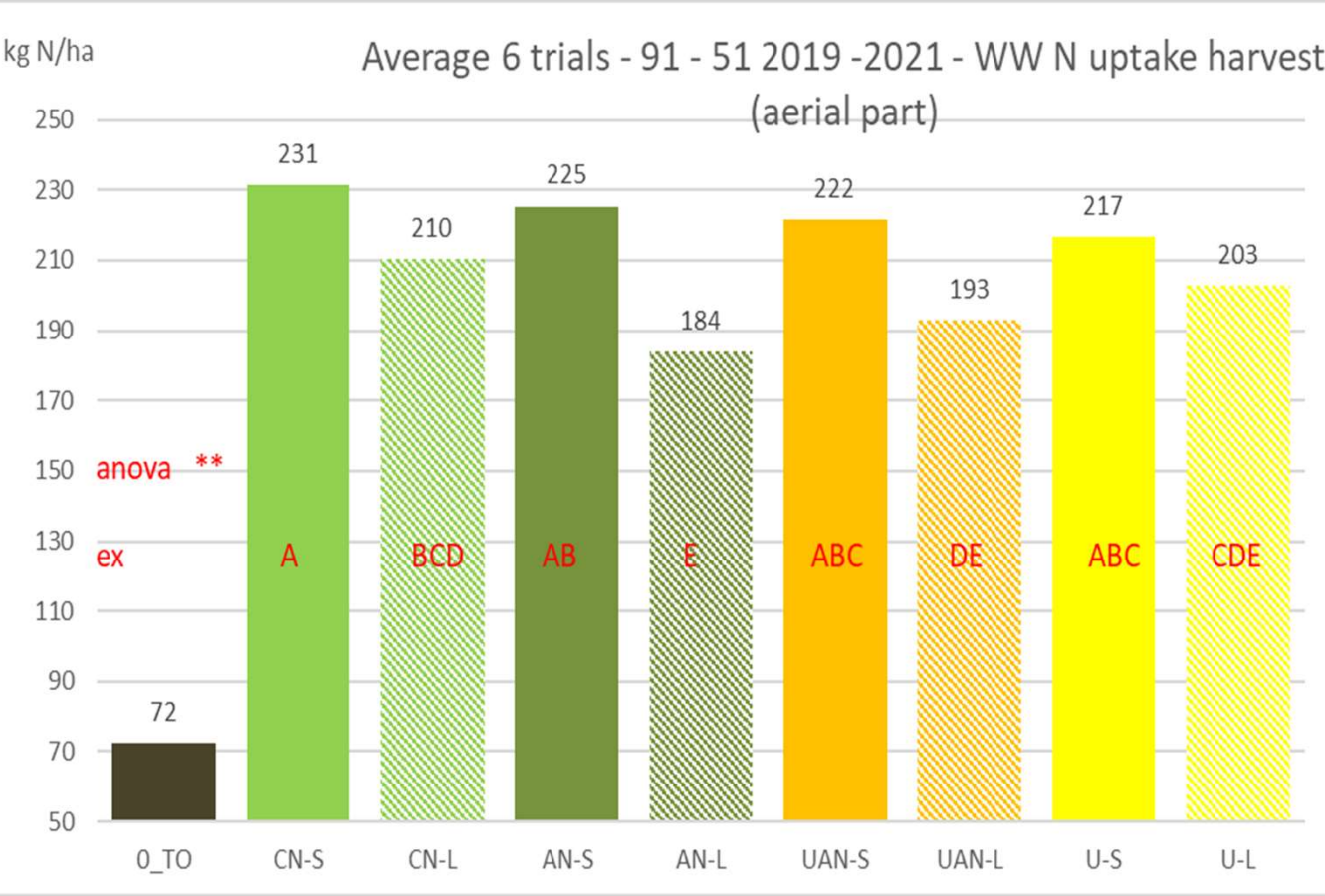
# Résultats consolidés 6 essais

## N abs grains



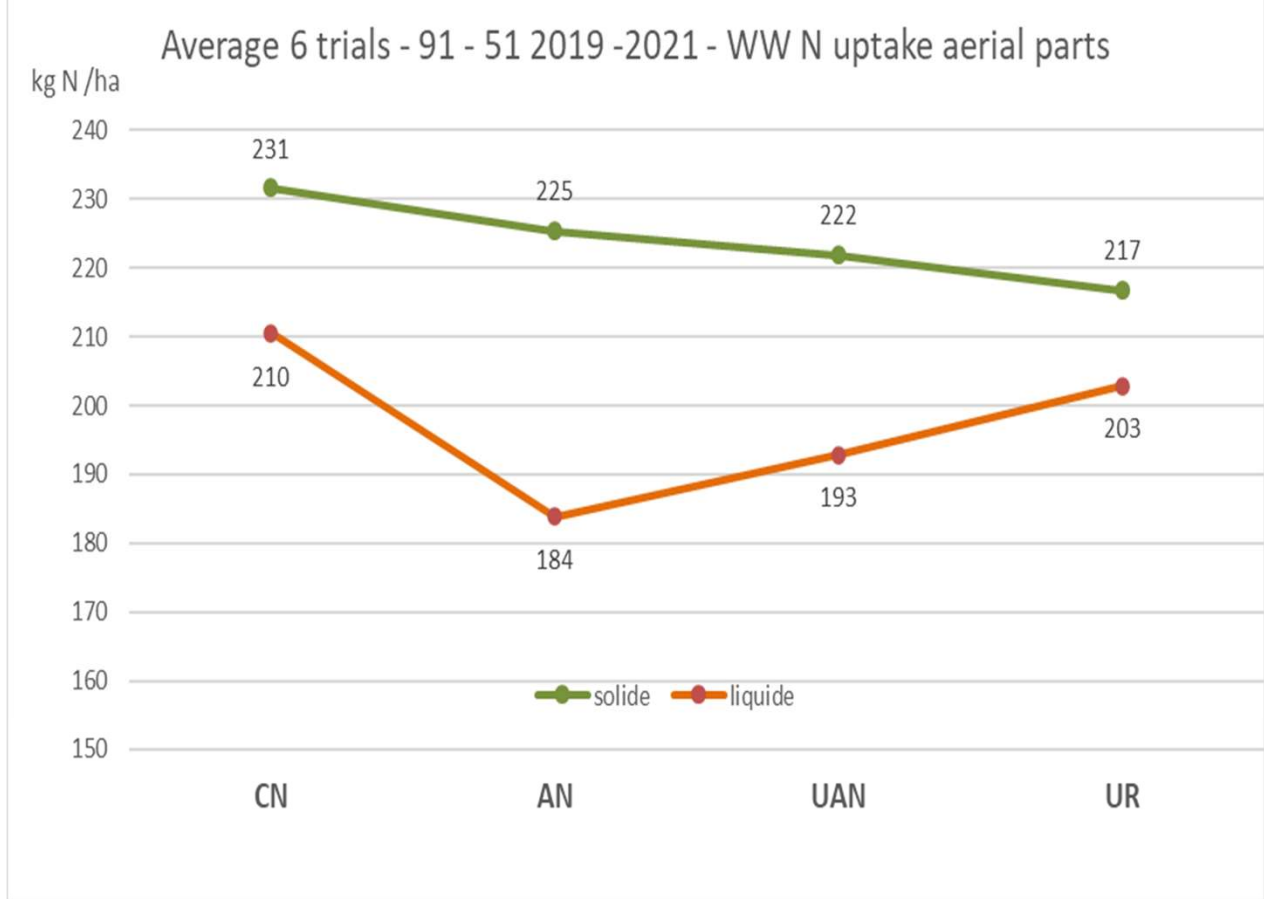
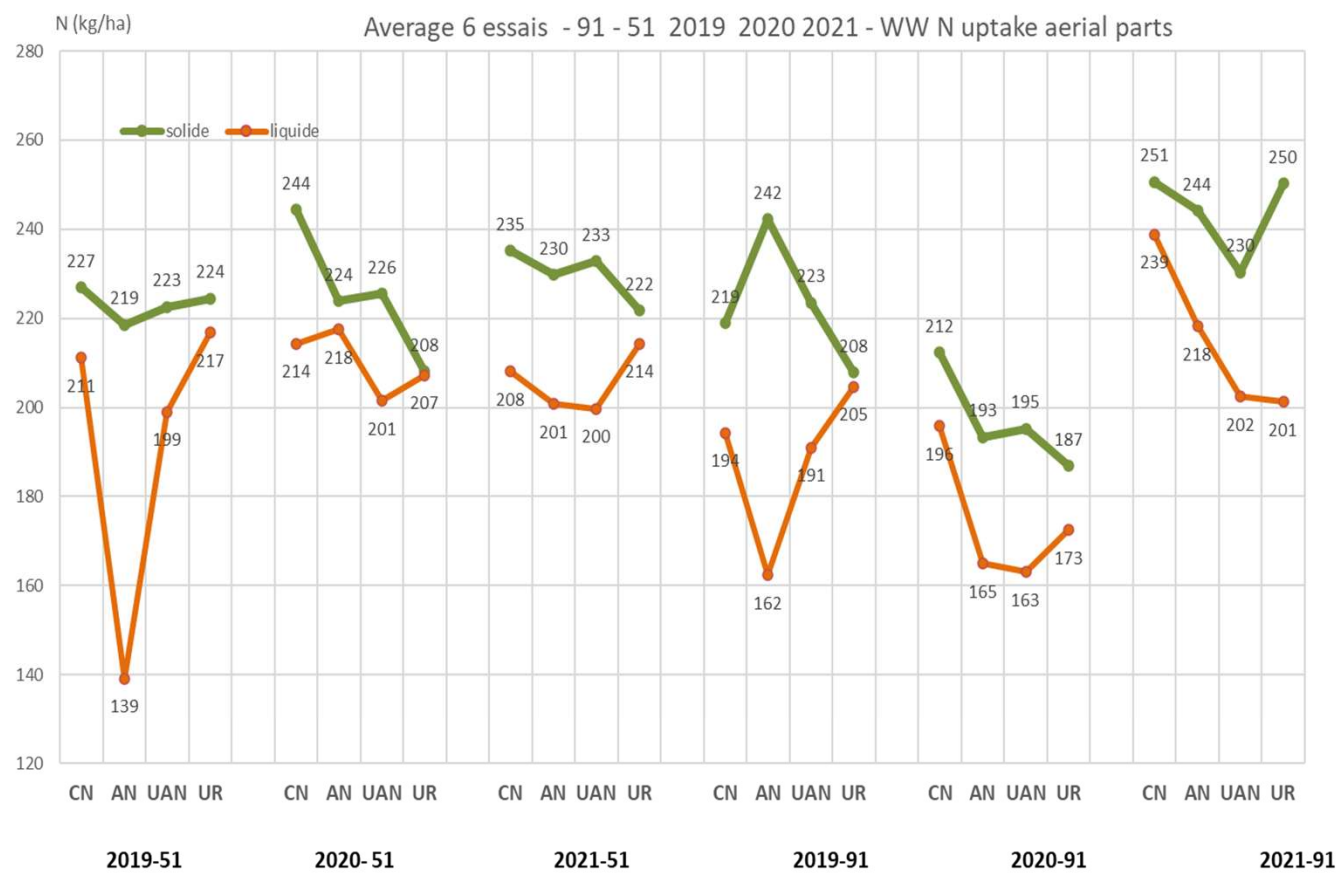
# Résultats consolidés 6 essais

## N abs parties aériennes



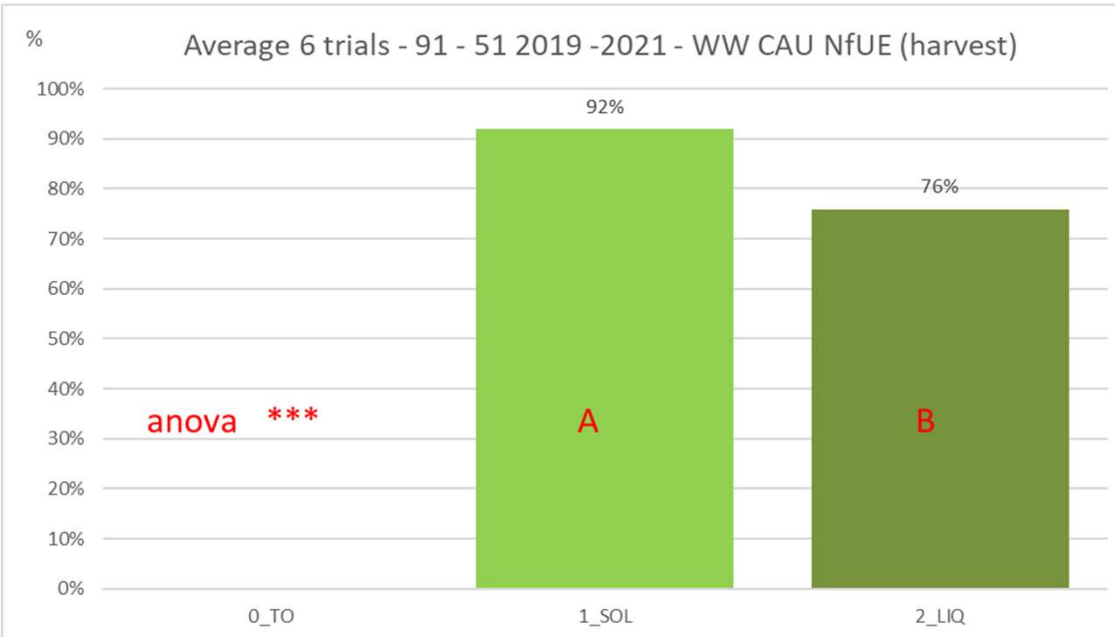
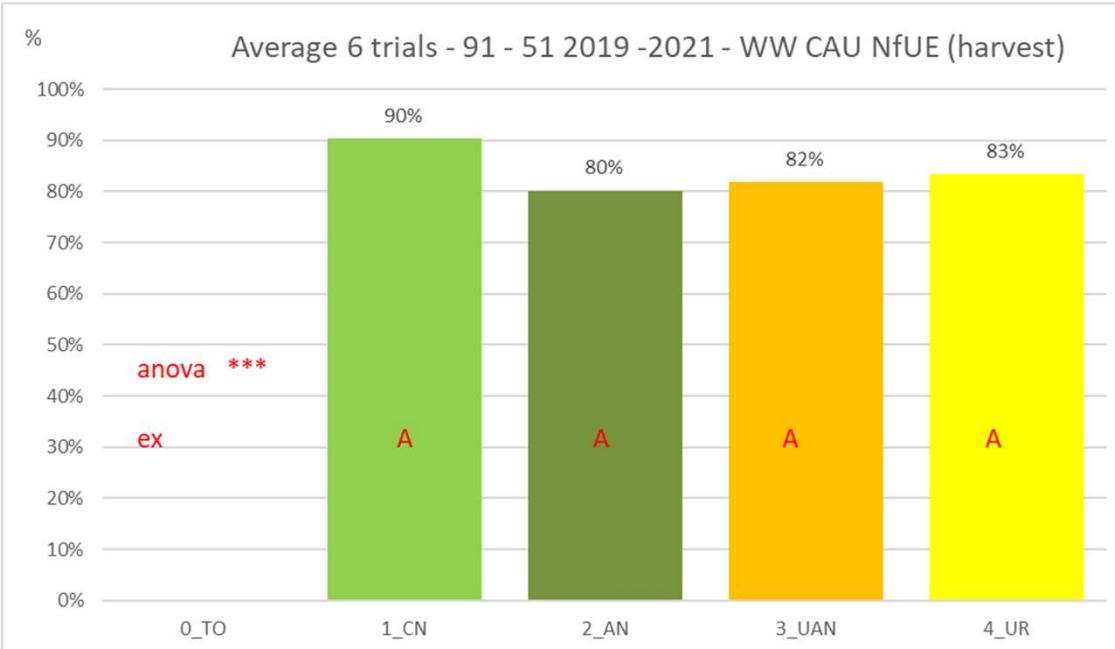
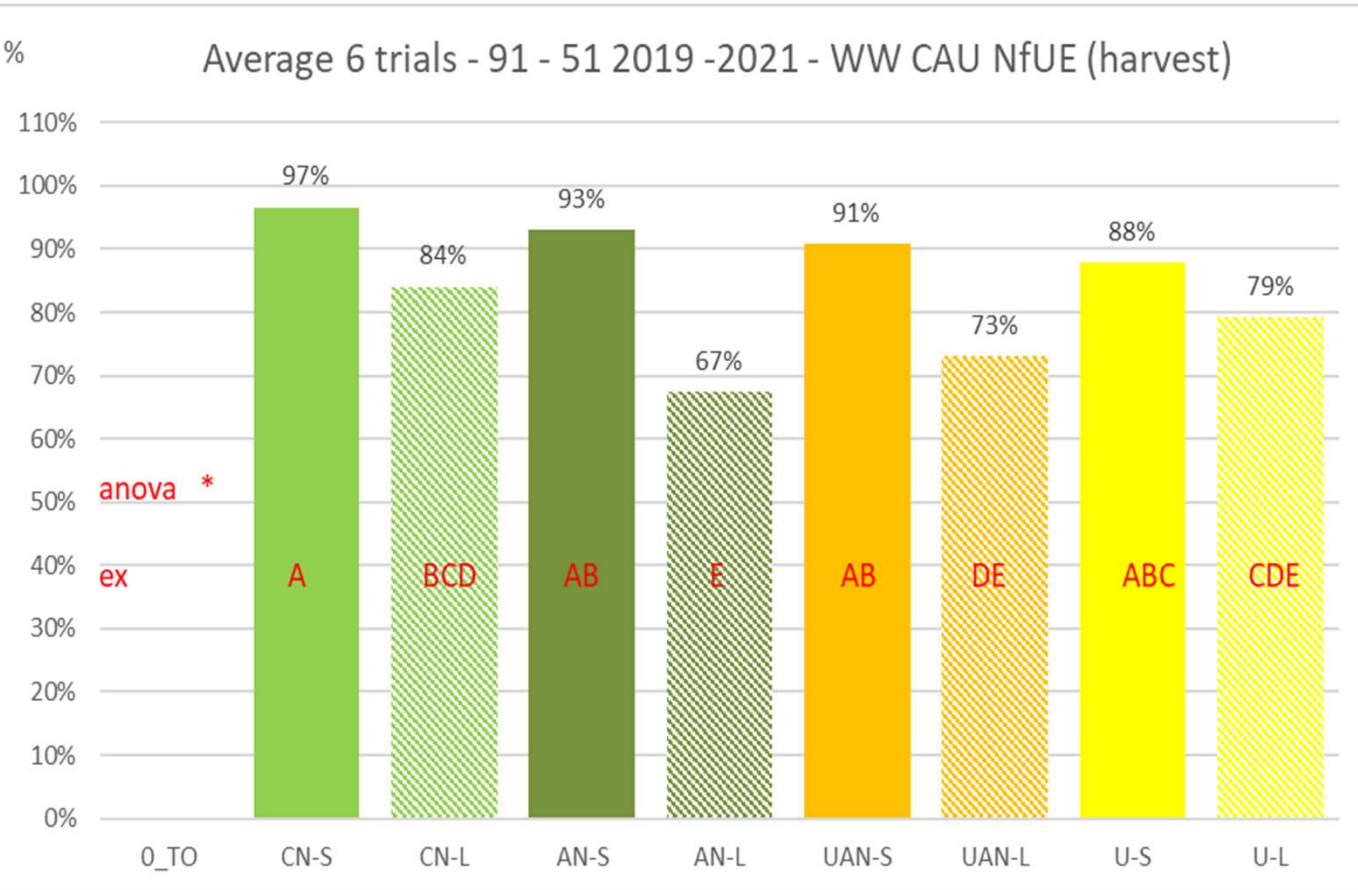
# Résultats consolidés 6 essais

## N abs parties aériennes



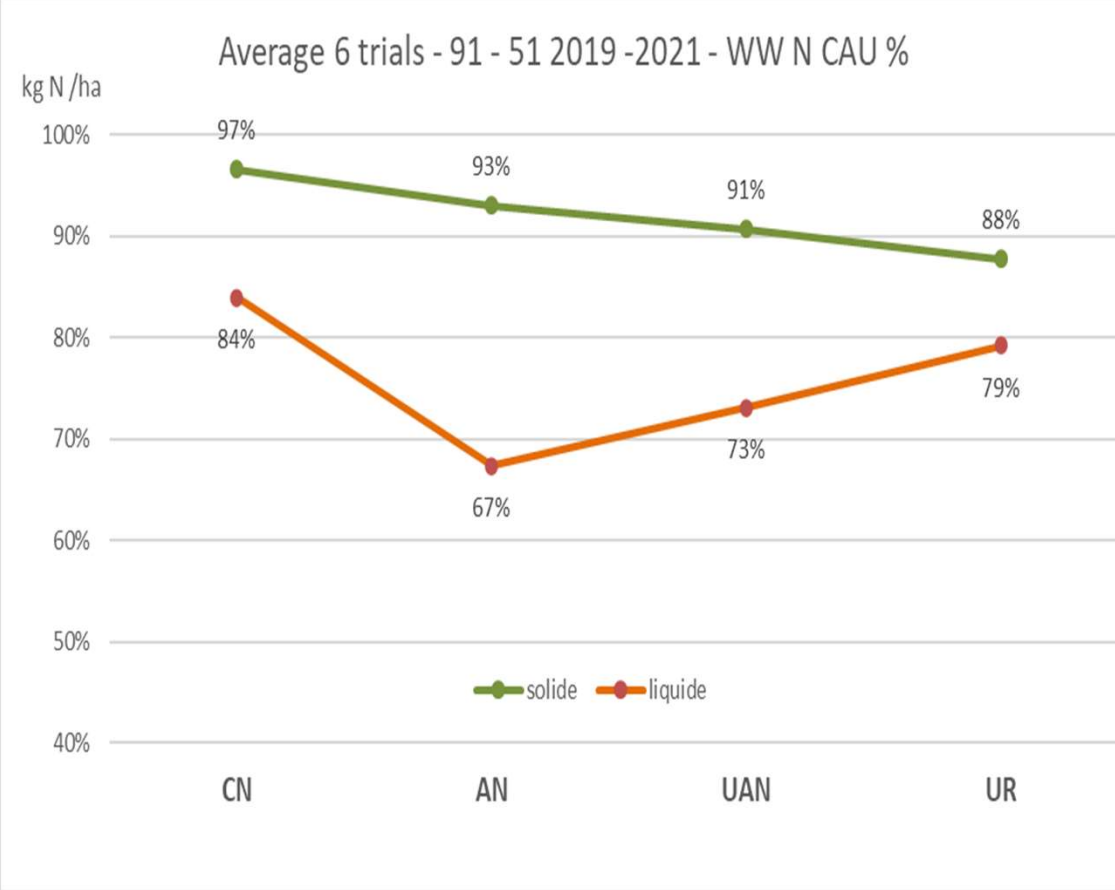
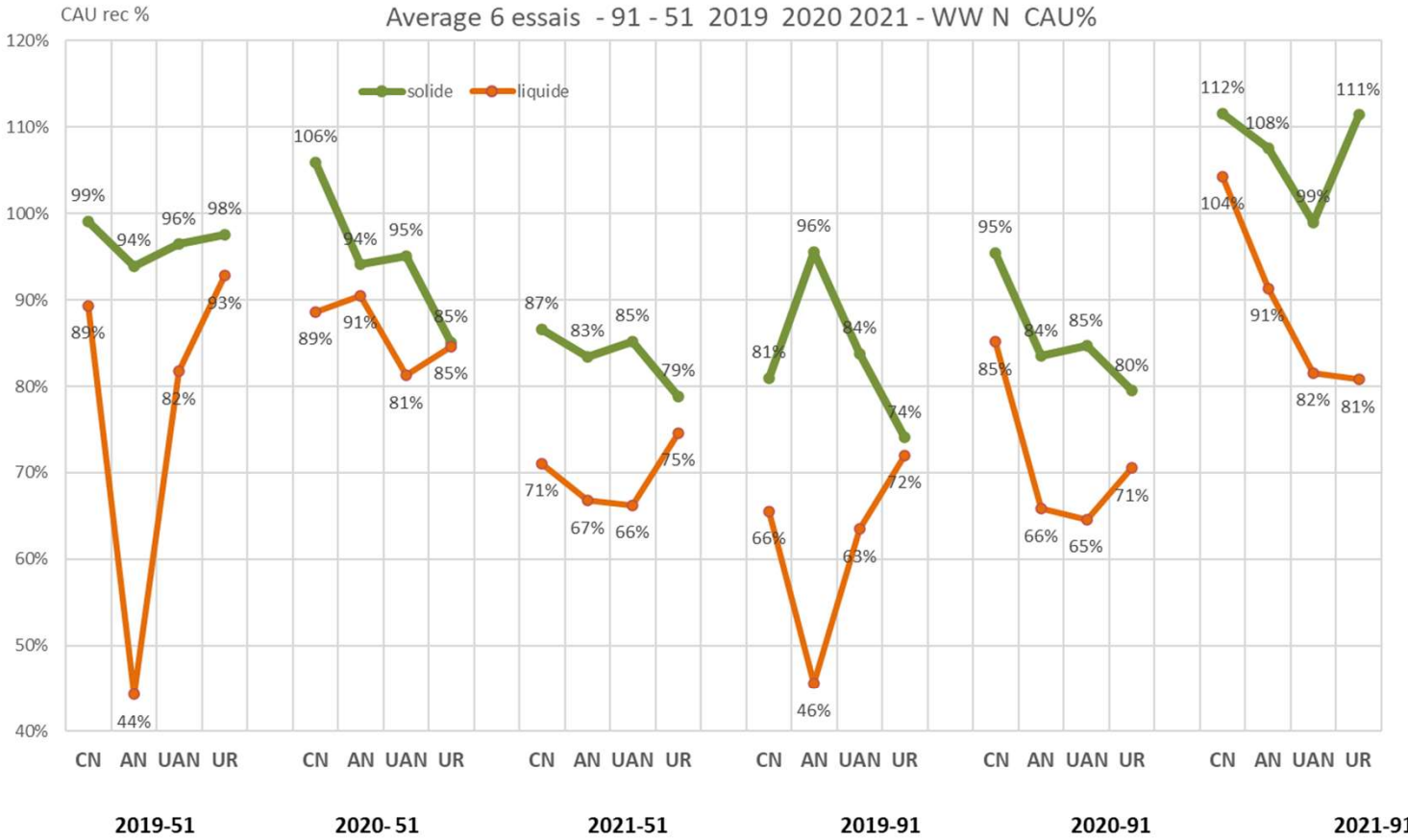
# Résultats consolidés 6 essais

## CAU recolte %



# Résultats consolidés 6 essais

## CAU recolte %



# Résultats consolidés 6 essais

## Dynamique Nabs

N uptake dynamic (kg N/ha)

| date<br>stage<br>average date | D1        |          | D2         |          | D3         |          | D4        |          | D5         |          | D6        |          | D7 Harvest   |          | harvest    |          |            |          |            |  |
|-------------------------------|-----------|----------|------------|----------|------------|----------|-----------|----------|------------|----------|-----------|----------|--------------|----------|------------|----------|------------|----------|------------|--|
|                               | Z24-27    |          | Z30-31     |          | Z32        |          | Z45-47    |          | Z59        |          | Z69       |          | Z89          |          | 20/7       |          |            |          |            |  |
|                               | 8/3       |          | 4/4        |          | 24/4       |          | 13/5      |          | 27/5       |          | 9/6       |          | aerial parts |          | grain      |          | straw      |          |            |  |
| control ON                    | 25        | (+/- 7)  | 28         | (+/- 8)  | 36         | (+/- 11) | 47        | (+/- 17) | 56         | (+/- 21) | 56        | (+/- 15) | 72           | (+/- 20) | 57         | (+/- 18) | 15         | (+/- 5)  |            |  |
| <b>Chemical x Phys Form</b>   | <b>NS</b> |          | <b>***</b> |          | <b>**</b>  |          | <b>NS</b> |          | <b>***</b> |          | <b>**</b> |          | <b>***</b>   |          | <b>***</b> |          | <b>***</b> |          | <b>*</b>   |  |
| CN solid                      | 31        | (+/- 12) | 70         | (+/- 24) | 116        | (+/- 30) | 177       | (+/- 51) | 200        | (+/- 47) | 211       | (+/- 30) | 231          | (+/- 18) | 176        | (+/- 19) | 56         | (+/- 15) | A          |  |
| CN liq.                       | 28        | (+/- 7)  | 63         | (+/- 21) | 110        | (+/- 31) | 180       | (+/- 43) | 194        | (+/- 29) | 200       | (+/- 23) | 210          | (+/- 20) | 165        | (+/- 20) | 45         | (+/- 9)  | BC         |  |
| AN solid                      | 31        | (+/- 10) | 68         | (+/- 22) | 111        | (+/- 19) | 180       | (+/- 44) | 211        | (+/- 34) | 220       | (+/- 32) | 225          | (+/- 23) | 174        | (+/- 17) | 52         | (+/- 13) | AB         |  |
| AN liq.                       | 31        | (+/- 8)  | 58         | (+/- 23) | 89         | (+/- 22) | 150       | (+/- 46) | 161        | (+/- 46) | 169       | (+/- 31) | 184          | (+/- 35) | 144        | (+/- 23) | 40         | (+/- 17) | C          |  |
| UAN solid                     | 30        | (+/- 9)  | 66         | (+/- 21) | 108        | (+/- 18) | 175       | (+/- 44) | 208        | (+/- 37) | 204       | (+/- 25) | 222          | (+/- 17) | 174        | (+/- 15) | 47         | (+/- 11) | ABC        |  |
| UAN liq.                      | 29        | (+/- 8)  | 60         | (+/- 20) | 97         | (+/- 24) | 154       | (+/- 35) | 183        | (+/- 42) | 182       | (+/- 26) | 193          | (+/- 21) | 151        | (+/- 17) | 42         | (+/- 13) | C          |  |
| UREA solid                    | 30        | (+/- 9)  | 57         | (+/- 21) | 97         | (+/- 32) | 168       | (+/- 53) | 179        | (+/- 49) | 195       | (+/- 51) | 217          | (+/- 22) | 171        | (+/- 18) | 46         | (+/- 9)  | BC         |  |
| UREA liq.                     | 32        | (+/- 9)  | 62         | (+/- 25) | 99         | (+/- 19) | 163       | (+/- 35) | 180        | (+/- 36) | 187       | (+/- 24) | 203          | (+/- 19) | 160        | (+/- 15) | 42         | (+/- 10) | B          |  |
| <b>Chemical N form</b>        | <b>NS</b> |          | <b>NS</b>  |          | <b>S6%</b> |          | <b>NS</b> |          | <b>NS</b>  |          | <b>NS</b> |          | <b>NS</b>    |          | <b>*</b>   |          | <b>NS</b>  |          | <b>*</b>   |  |
| CN                            | 30        | (+/- 10) | 66         | (+/- 23) | 113        | (+/- 30) | 178       | (+/- 47) | 197        | (+/- 39) | 205       | (+/- 27) | 221          | (+/- 22) | 171        | (+/- 20) | 50         | (+/- 13) | A          |  |
| AN                            | 31        | (+/- 9)  | 63         | (+/- 23) | 100        | (+/- 23) | 165       | (+/- 47) | 186        | (+/- 47) | 195       | (+/- 41) | 205          | (+/- 36) | 159        | (+/- 25) | 46         | (+/- 16) | A          |  |
| UAN                           | 30        | (+/- 8)  | 63         | (+/- 21) | 102        | (+/- 22) | 165       | (+/- 41) | 195        | (+/- 41) | 193       | (+/- 27) | 207          | (+/- 24) | 163        | (+/- 20) | 44         | (+/- 13) | A          |  |
| UREA                          | 31        | (+/- 9)  | 59         | (+/- 23) | 98         | (+/- 26) | 165       | (+/- 44) | 179        | (+/- 43) | 191       | (+/- 40) | 210          | (+/- 21) | 166        | (+/- 17) | 44         | (+/- 10) | A          |  |
| <b>Physical N form</b>        | <b>NS</b> |          | <b>NS</b>  |          | <b>***</b> |          | <b>*</b>  |          | <b>**</b>  |          | <b>*</b>  |          | <b>***</b>   |          | <b>***</b> |          | <b>***</b> |          | <b>***</b> |  |
| Solid                         | 30        | (+/- 22) | 65         | (+/- 22) | 108        | (+/- 26) | 175       | (+/- 47) | 200        | (+/- 44) | 207       | (+/- 37) | 224          | (+/- 21) | 174        | (+/- 17) | 50         | (+/- 17) | A          |  |
| Liquid                        | 30        | (+/- 22) | 61         | (+/- 22) | 99         | (+/- 25) | 162       | (+/- 41) | 179        | (+/- 40) | 184       | (+/- 28) | 197          | (+/- 26) | 155        | (+/- 20) | 42         | (+/- 20) | B          |  |
| Etr (kg Nha)                  | 4         |          | 11         |          | 16         |          | 29        |          | 33         |          | 25        |          | 15           |          | 11         |          | 8          |          | 18%        |  |
|                               | 14%       |          | 17%        |          | 16%        |          | 18%       |          | 17%        |          | 13%       |          | 7%           |          | 6%         |          |            |          |            |  |

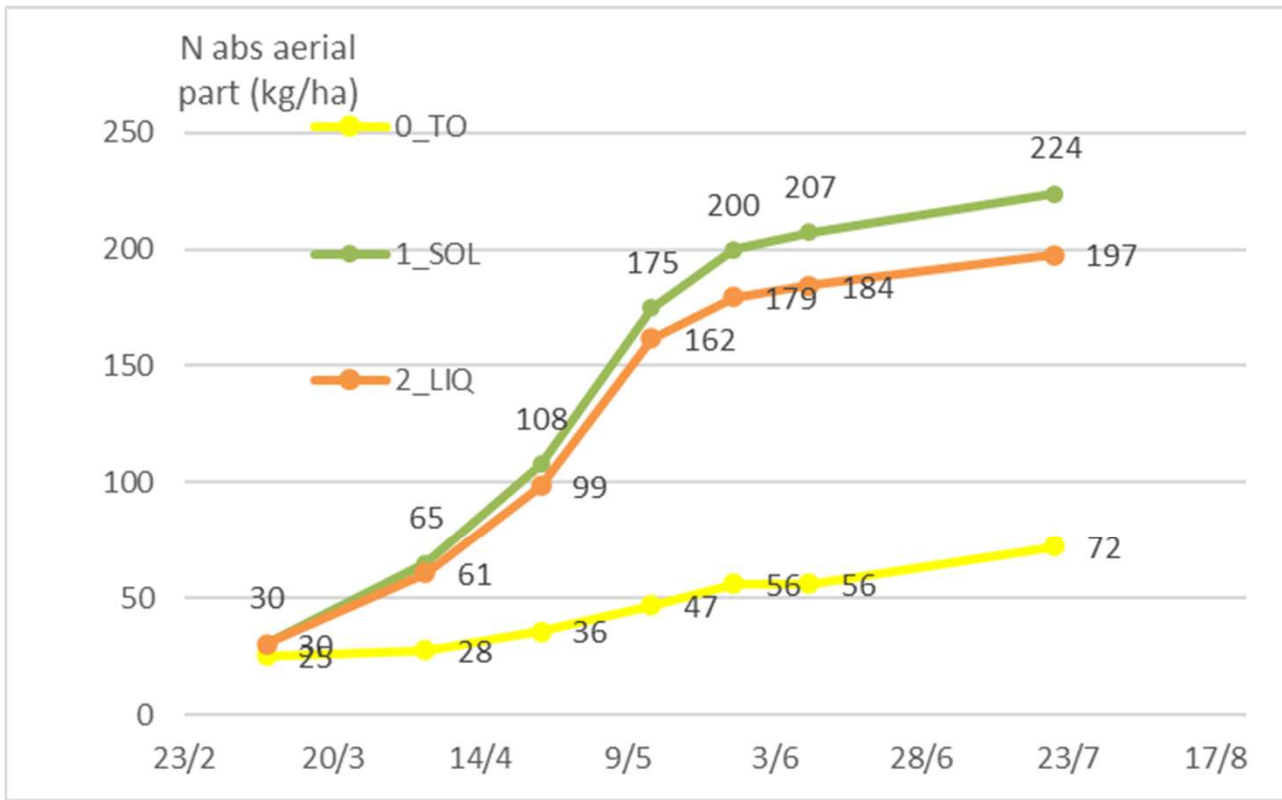
NS non significant proba >0.05 \* S proba < 0.05 \*\* S proba < 0.01 \*\*\* S proba < 0.001



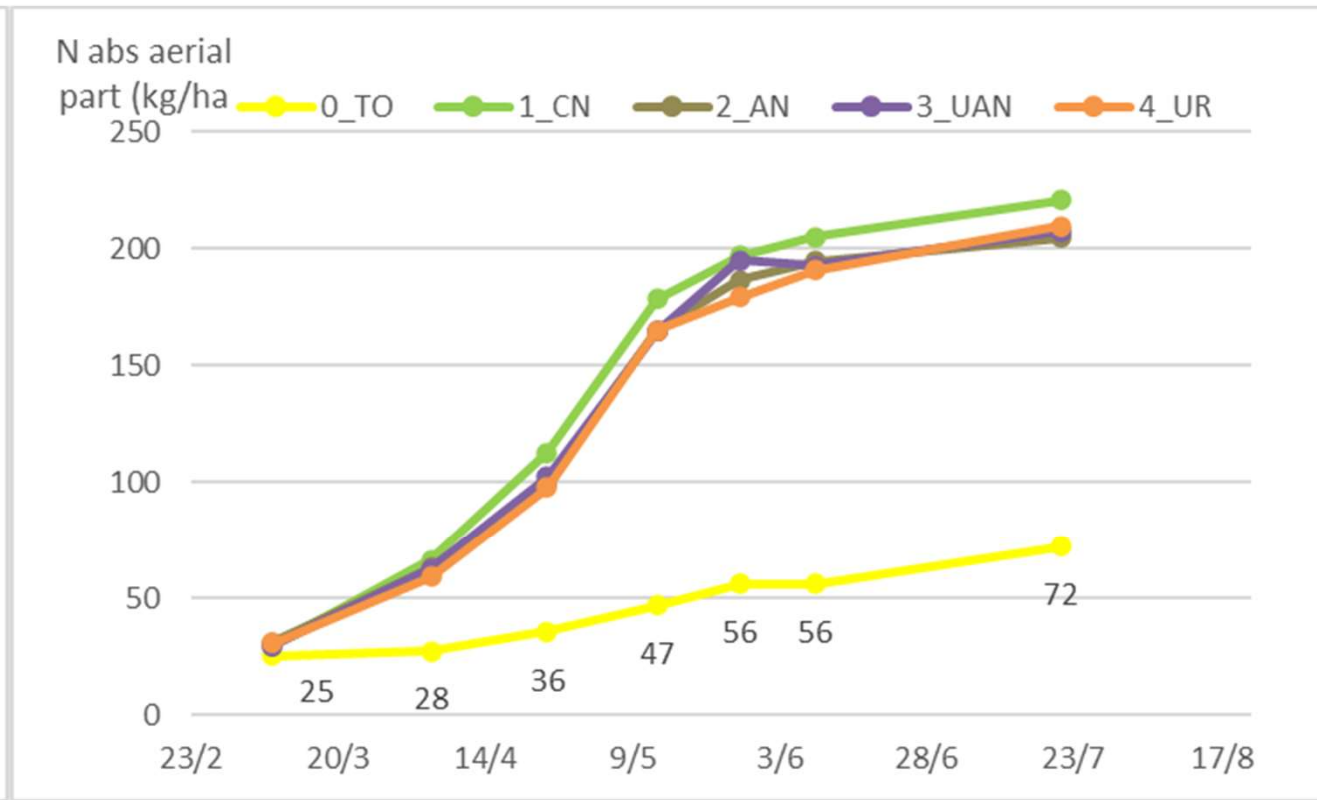
# Résultats consolidés 6 essais

## Dynamique Nabs

- Physical N form : Solid vs liquid



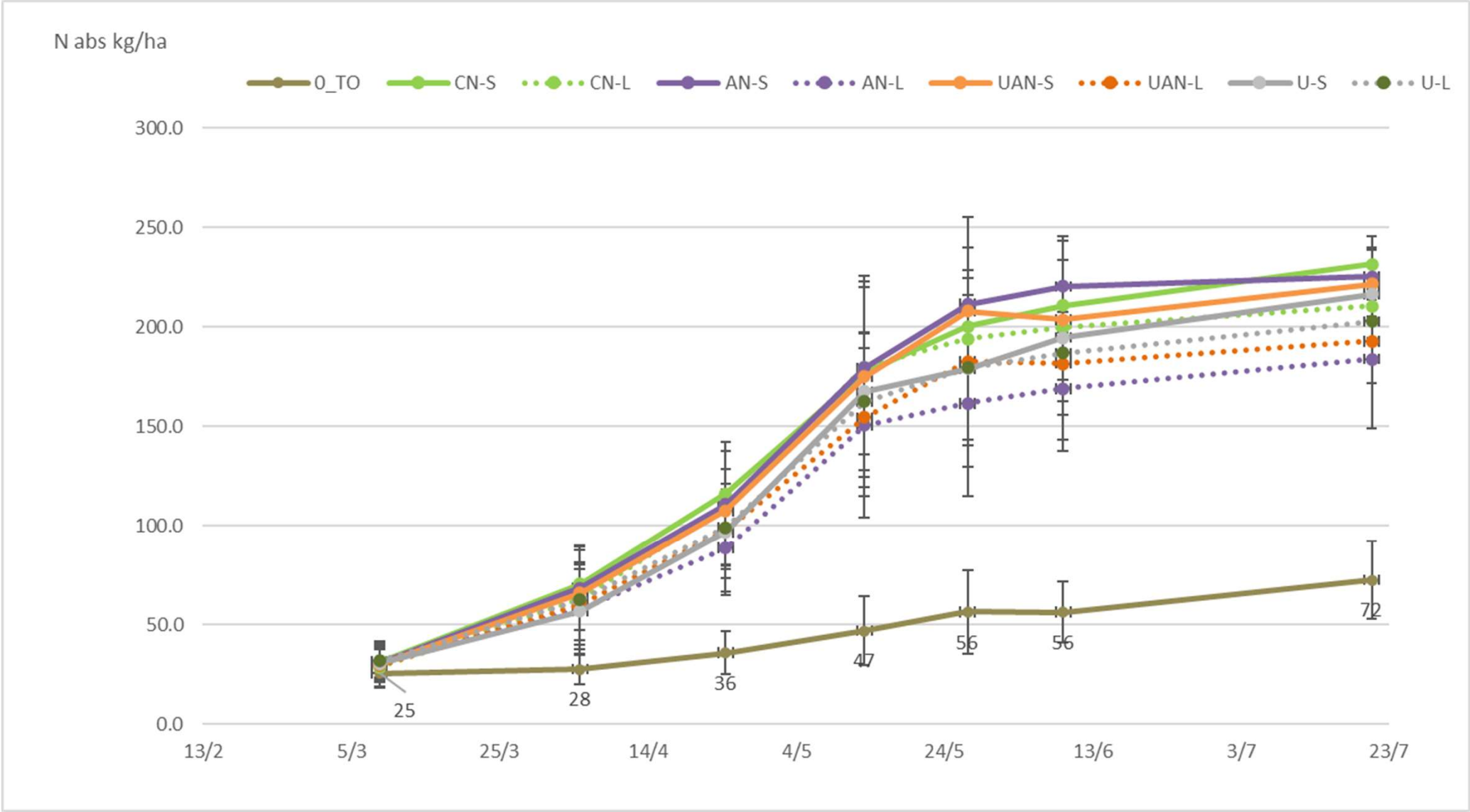
- Chemical N form : CN – AN – UAN - UR





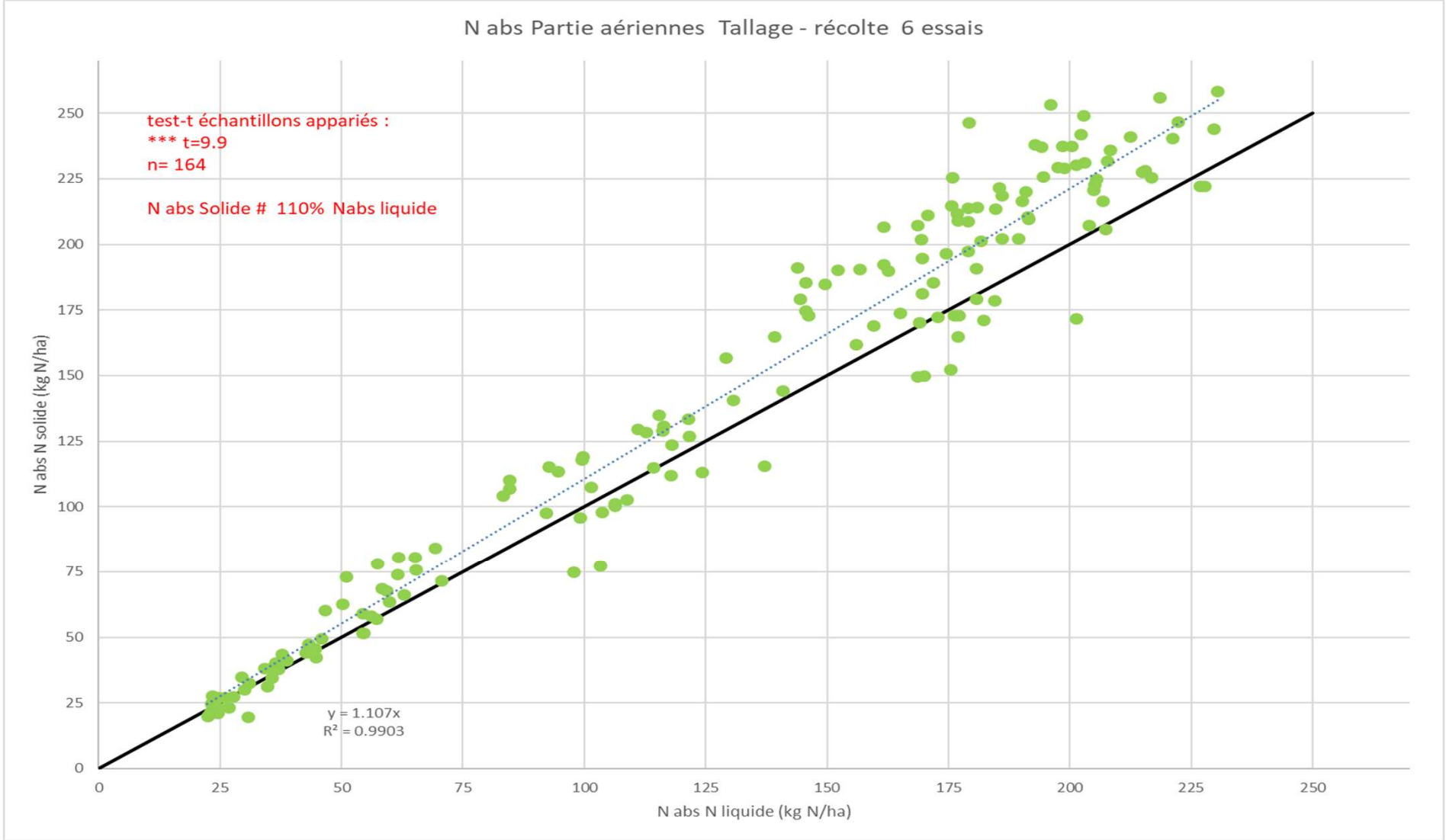
# Résultats consolidés 6 essais

## Dynamique Nabs



# Résultats consolidés 6 essais

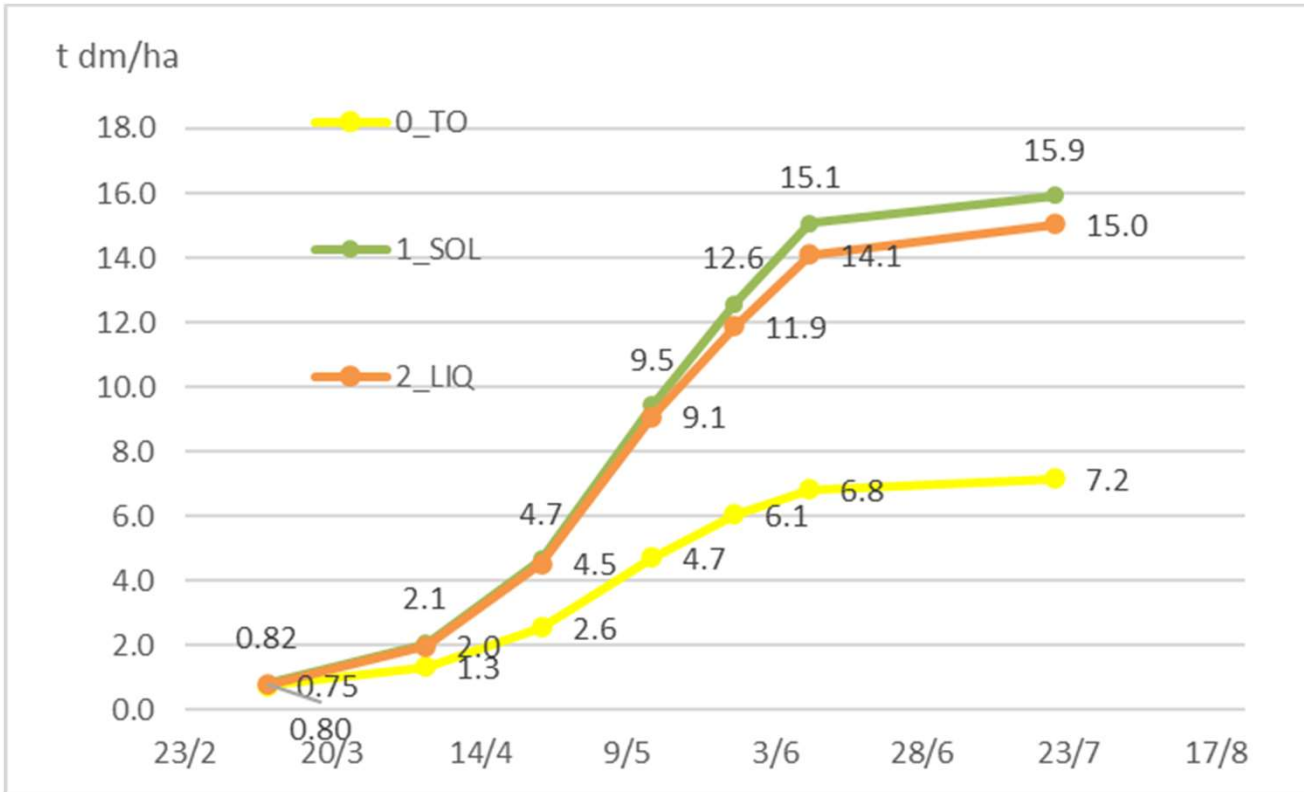
## Dynamique Nabs



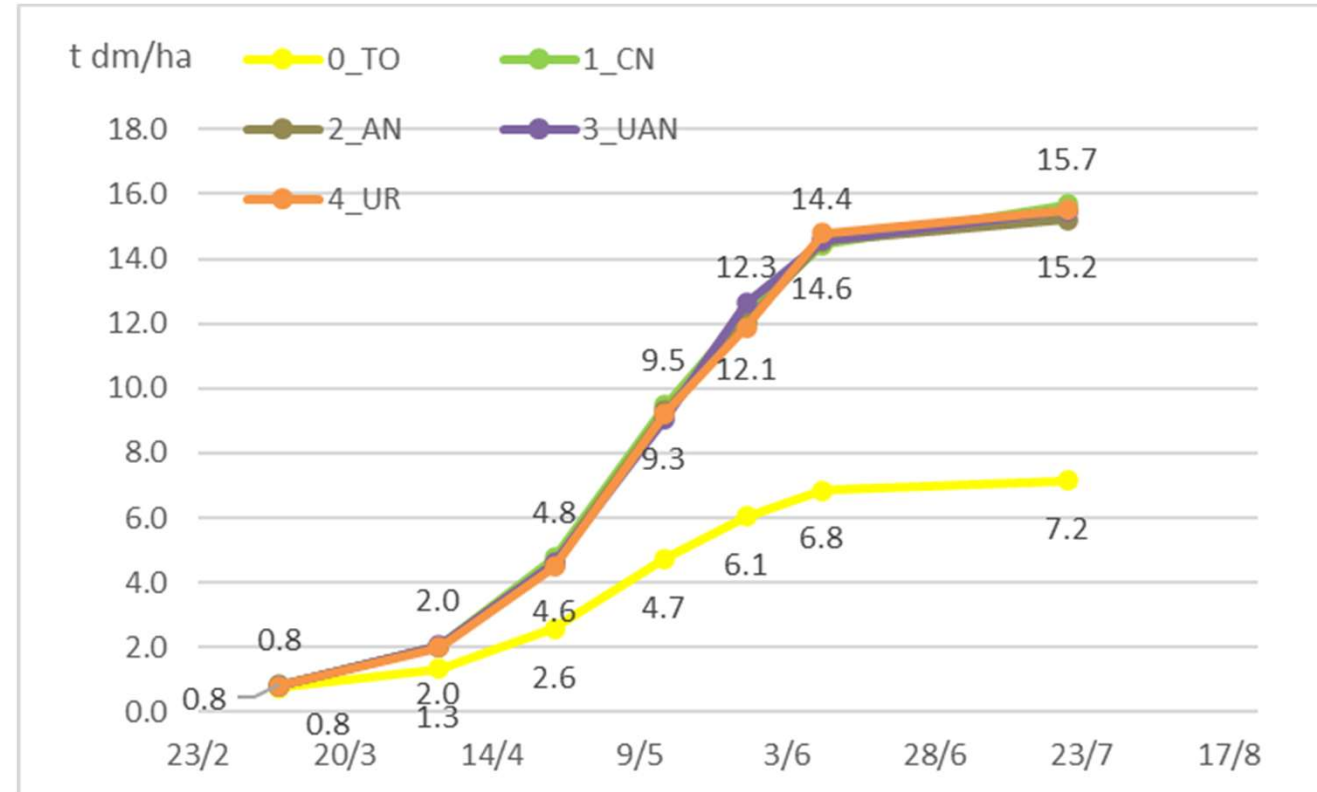
# Résultats consolidés 6 essais

## Biomasse (tms/ha)

- Physical N form : Solid vs liquid



- Chemical N form : CN – AN – UAN - UR



# Résultats consolidés 6 essais

## Dynamique CAU%

**NUE % as CAU% = [N uptake - Nupt Control] x 1.15 / N applied**

| date stage                  | D1<br>Z24-27<br>8/3 |       | D2<br>Z30-31<br>4/4 |       | D3<br>Z32<br>24/4 |     | D4<br>Z45-47<br>13/5 |     | D5<br>Z59<br>27/5 |       | D6<br>Z69<br>9/6 |     | D7 Harvest<br>Z89 |    |            |       |     |
|-----------------------------|---------------------|-------|---------------------|-------|-------------------|-----|----------------------|-----|-------------------|-------|------------------|-----|-------------------|----|------------|-------|-----|
| control ON                  |                     |       |                     |       |                   |     |                      |     |                   |       |                  |     |                   |    |            |       |     |
| <b>Chemical x Phys Form</b> | <b>NS</b>           |       | <b>***</b>          |       | <b>**</b>         |     | <b>*</b>             |     | <b>***</b>        |       | <b>***</b>       |     | <b>***</b>        |    |            |       |     |
| CN solid                    | 17%                 | (28%) | 38%                 | (18%) | A                 | 72% | (24%)                | A   | 81%               | (26%) | A                | 90% | (29%)             | AB | 97%        | (13%) | A   |
| CN liq.                     | 10%                 | (19%) | 31%                 | (16%) | AB                | 66% | (23%)                | BC  | 82%               | (22%) | A                | 86% | (19%)             | AB | 90%        | (16%) | ABC |
| AN solid                    | 17%                 | (23%) | 37%                 | (19%) | AB                | 67% | (14%)                | AB  | 82%               | (25%) | A                | 97% | (18%)             | A  | 103%       | (21%) | A   |
| AN liq.                     | 19%                 | (20%) | 27%                 | (17%) | B                 | 47% | (15%)                | C   | 64%               | (24%) | A                | 66% | (25%)             | B  | 70%        | (26%) | C   |
| UAN solid                   | 15%                 | (21%) | 34%                 | (18%) | AB                | 64% | (15%)                | ABC | 79%               | (24%) | A                | 95% | (21%)             | A  | 92%        | (18%) | ABC |
| UAN liq.                    | 13%                 | (20%) | 29%                 | (16%) | AB                | 55% | (18%)                | BC  | 67%               | (16%) | A                | 79% | (21%)             | AB | 78%        | (18%) | BC  |
| UREA solid                  | 16%                 | (21%) | 27%                 | (15%) | B                 | 56% | (22%)                | ABC | 76%               | (26%) | A                | 78% | (25%)             | AB | 88%        | (26%) | ABC |
| UREA liq.                   | 20%                 | (23%) | 31%                 | (19%) | AB                | 57% | (13%)                | ABC | 72%               | (19%) | A                | 77% | (25%)             | AB | 82%        | (17%) | ABC |
| <b>Chemical N form</b>      | <b>NS</b>           |       | <b>NS</b>           |       | <b>NS</b>         |     | <b>NS</b>            |     | <b>NS</b>         |       | <b>NS</b>        |     | <b>NS</b>         |    | <b>*</b>   |       |     |
| CN                          | 14%                 | (24%) | 35%                 | (17%) |                   | 69% | (8%)                 |     | 82%               | (24%) |                  | 88% | (25%)             |    | 93%        | (19%) |     |
| AN                          | 18%                 | (21%) | 32%                 | (18%) |                   | 57% | (9%)                 |     | 73%               | (26%) |                  | 82% | (27%)             |    | 87%        | (28%) |     |
| UAN                         | 14%                 | (20%) | 32%                 | (17%) |                   | 60% | (10%)                |     | 73%               | (22%) |                  | 87% | (23%)             |    | 85%        | (19%) |     |
| UREA                        | 18%                 | (22%) | 29%                 | (17%) |                   | 56% | (11%)                |     | 74%               | (22%) |                  | 78% | (25%)             |    | 85%        | (22%) |     |
| <b>Physical N form</b>      | <b>NS</b>           |       | <b>NS</b>           |       | <b>*</b>          |     | <b>**</b>            |     | <b>***</b>        |       | <b>***</b>       |     | <b>**</b>         |    | <b>***</b> |       |     |
| Solid                       | 16%                 | (23%) | 34%                 | (18%) |                   | 65% | (20%)                | A   | 80%               | (25%) | A                | 90% | (25%)             | A  | 95%        | (22%) | A   |
| Liquid                      | 15%                 | (21%) | 30%                 | (17%) |                   | 56% | (19%)                | B   | 71%               | (21%) | B                | 77% | (24%)             | B  | 80%        | (21%) | B   |
| anova Etr (%)               | 13%                 |       | 8%                  |       | 13%               |     | 18%                  |     | 20%               |       | 14%              |     | 9%                |    |            |       |     |

NS non significant proba >0.05 \* S proba < 0.05 \*\* S proba < 0.01 \*\*\* S proba < 0.001

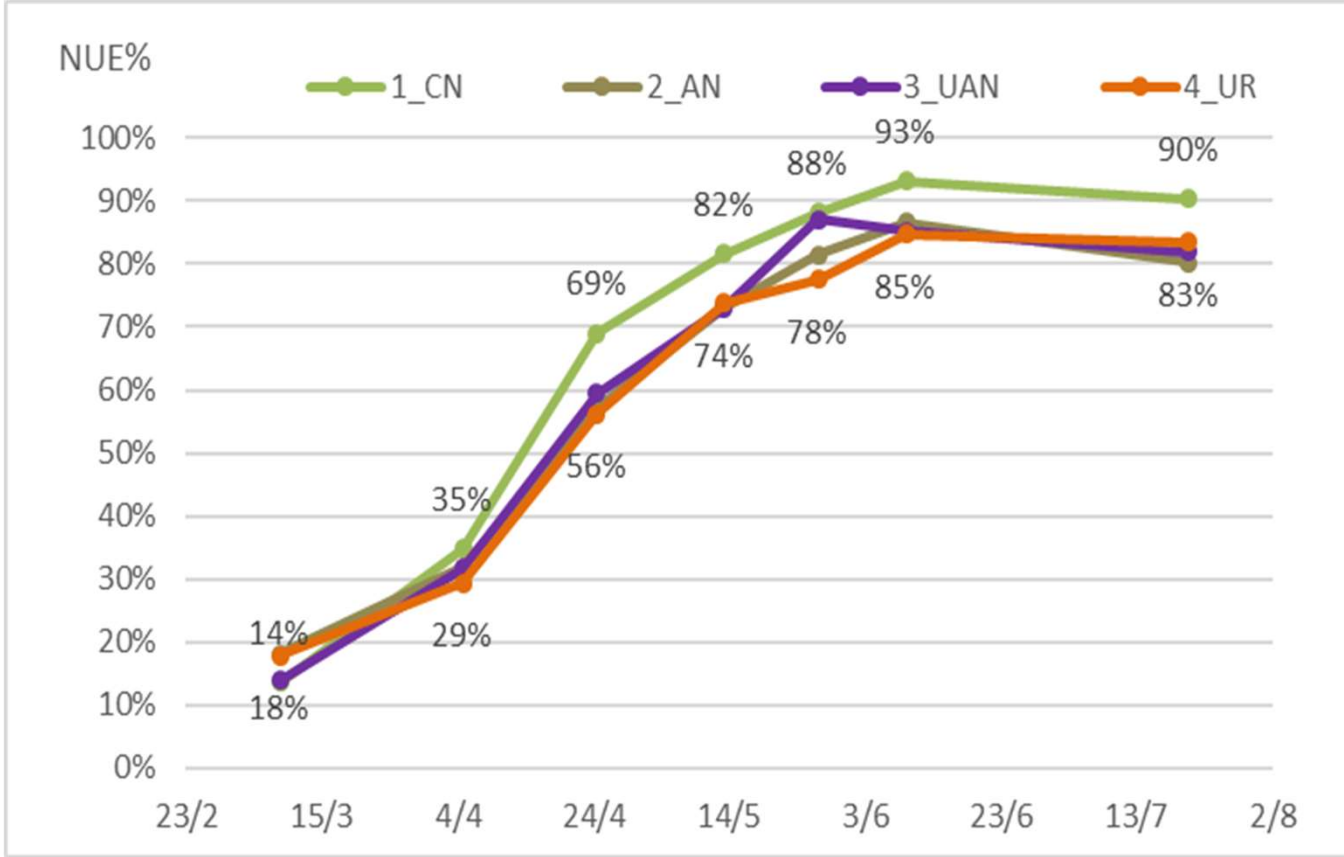
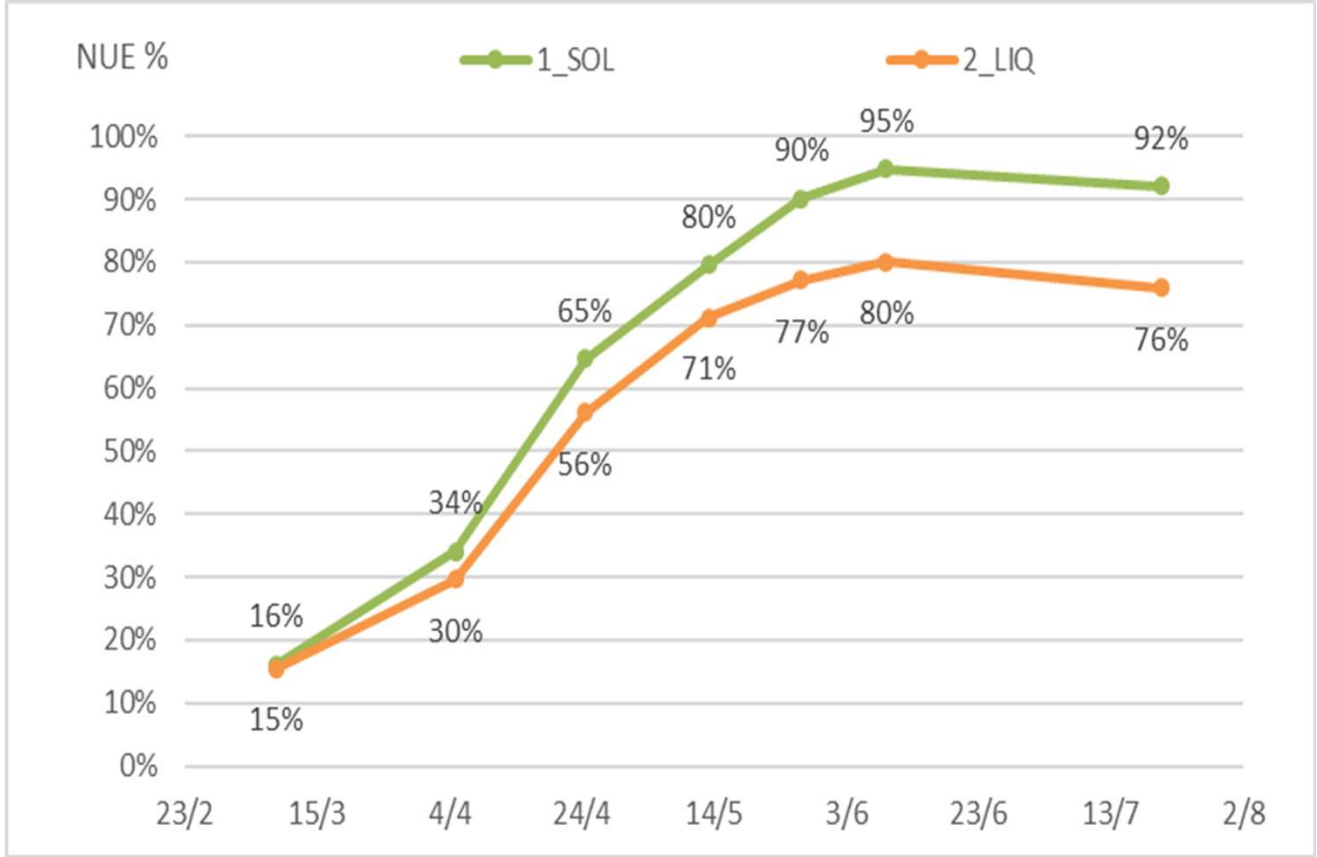


# Résultats consolidés 6 essais

## Dynamique CAU%

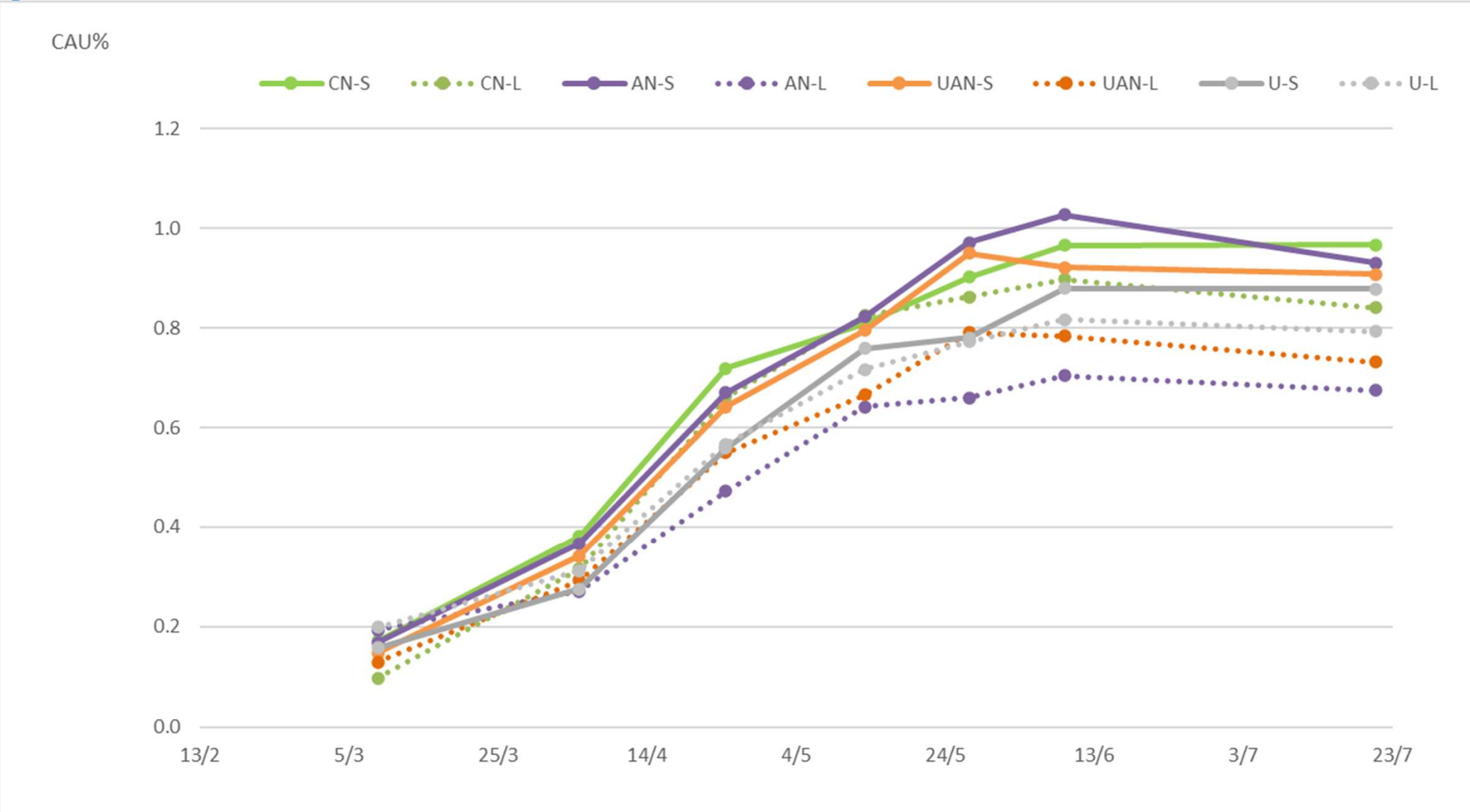
- Physical N form : Solid vs liquid

- Chemical N form : CN – AN – UAN - UR



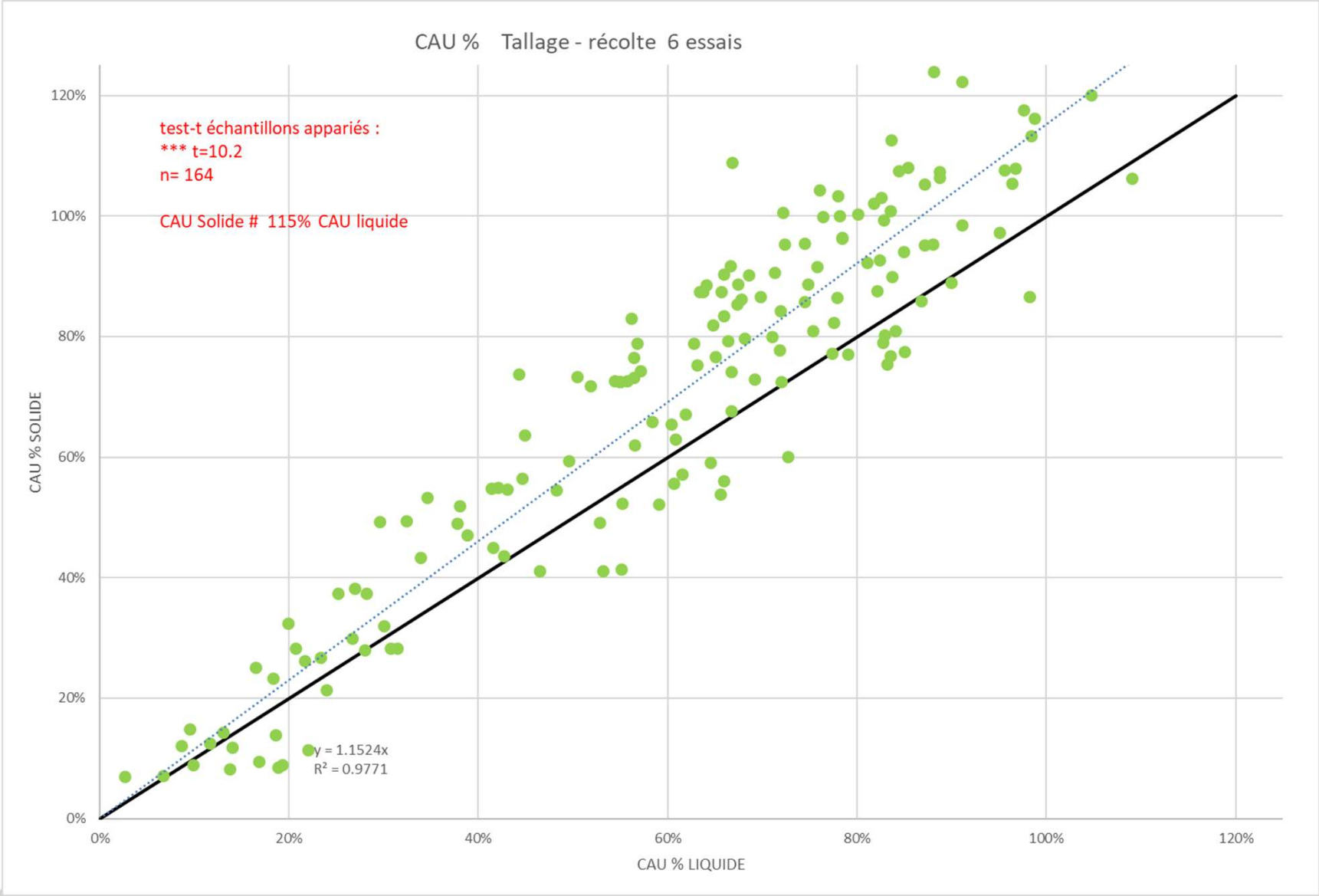
# Résultats consolidés 6 essais

## Dynamique CAU%



# Résultats consolidés 6 essais

## Dynamique CAU%



# Résultats consolidés 6 essais

## Dynamique INN

|                             |       | NNI / INN     |           |  |               |           |     |             |           |    |                |           |    |             |           |    |             |           |   |
|-----------------------------|-------|---------------|-----------|--|---------------|-----------|-----|-------------|-----------|----|----------------|-----------|----|-------------|-----------|----|-------------|-----------|---|
| date stage                  |       | D1            |           |  | D2            |           |     | D3          |           |    | D4             |           |    | D5          |           |    | D6          |           |   |
|                             |       | Z24-27<br>8/3 |           |  | Z30-31<br>4/4 |           |     | Z32<br>24/4 |           |    | Z45-47<br>13/5 |           |    | Z59<br>27/5 |           |    | Z69<br>9/6  |           |   |
| control ON                  |       | 0.80          | (+/- .19) |  | 0.49          | (+/- .09) |     | 0.41        | (+/- .07) |    | 0.38           | (+/- .09) |    | 0.40        | (+/- .12) |    | 0.53        | (+/- .07) |   |
| <b>Chemical x Phys Form</b> |       | <b>NS</b>     |           |  | <b>**</b>     |           |     | <b>***</b>  |           |    | <b>**</b>      |           |    | <b>***</b>  |           |    | <b>*</b>    |           |   |
| CN                          | solid | 0.85          | (+/- .17) |  | 0.88          | (+/- .18) | A   | 0.93        | (+/- .16) | A  | 0.98           | (+/- .17) | A  | 0.95        | (+/- .14) | A  | 0.95        | (+/- .15) | A |
| CN                          | liq.  | 0.86          | (+/- .13) |  | 0.83          | (+/- .19) | ABC | 0.89        | (+/- .16) | AB | 0.97           | (+/- .16) | A  | 0.96        | (+/- .09) | A  | 0.85        | (+/- .12) | A |
| AN                          | solid | 0.85          | (+/- .14) |  | 0.86          | (+/- .18) | AB  | 0.90        | (+/- .13) | AB | 0.98           | (+/- .16) | A  | 1.01        | (+/- .10) | A  | 0.95        | (+/- .17) | A |
| AN                          | liq.  | 0.91          | (+/- .16) |  | 0.76          | (+/- .20) | C   | 0.76        | (+/- .19) | C  | 0.84           | (+/- .18) | B  | 0.81        | (+/- .19) | B  | 0.73        | (+/- .16) | A |
| UAN                         | solid | 0.85          | (+/- .11) |  | 0.84          | (+/- .17) | AB  | 0.88        | (+/- .12) | AB | 0.96           | (+/- .17) | A  | 0.99        | (+/- .12) | A  | 0.90        | (+/- .13) | A |
| UAN                         | liq.  | 0.88          | (+/- .13) |  | 0.78          | (+/- .15) | BC  | 0.81        | (+/- .17) | BC | 0.89           | (+/- .12) | AB | 0.90        | (+/- .12) | AB | 0.82        | (+/- .09) | A |
| UREA                        | solid | 0.90          | (+/- .11) |  | 0.74          | (+/- .23) | BC  | 0.81        | (+/- .24) | BC | 0.92           | (+/- .26) | AB | 0.88        | (+/- .23) | AB | 1.02        | (+/- .12) | A |
| UREA                        | liq.  | 0.91          | (+/- .20) |  | 0.81          | (+/- .22) | ABC | 0.83        | (+/- .18) | BC | 0.92           | (+/- .14) | AB | 0.89        | (+/- .09) | AB | 0.92        | (+/- .12) | A |
| <b>Chemical N form</b>      |       | <b>NS</b>     |           |  | <b>NS</b>     |           |     | <b>*</b>    |           |    | <b>NS</b>      |           |    | <b>NS</b>   |           |    | <b>NS</b>   |           |   |
| CN                          |       | 0.85          | (+/- .15) |  | 0.86          | (+/- .19) |     | 0.91        | (+/- .16) | A  | 0.98           | (+/- .16) |    | 0.96        | (+/- .12) |    | 0.90        | (+/- .13) |   |
| AN                          |       | 0.88          | (+/- .15) |  | 0.81          | (+/- .20) |     | 0.83        | (+/- .17) | AB | 0.91           | (+/- .18) |    | 0.90        | (+/- .18) |    | 0.84        | (+/- .18) |   |
| UAN                         |       | 0.87          | (+/- .12) |  | 0.81          | (+/- .16) |     | 0.85        | (+/- .15) | AB | 0.93           | (+/- .15) |    | 0.94        | (+/- .13) |    | 0.86        | (+/- .12) |   |
| UREA                        |       | 0.91          | (+/- .16) |  | 0.78          | (+/- .23) |     | 0.82        | (+/- .21) | AB | 0.92           | (+/- .21) |    | 0.89        | (+/- .18) |    | 0.97        | (+/- .12) |   |
| <b>Physical N form</b>      |       | <b>NS</b>     |           |  | <b>NS</b>     |           |     | <b>*</b>    |           |    | <b>**</b>      |           |    | <b>S6%</b>  |           |    | <b>S10%</b> |           |   |
| Solid                       |       | 0.86          | (+/- .13) |  | 0.83          | (+/- .20) |     | 0.88        | (+/- .17) | A  | 0.96           | (+/- .19) | A  | 0.95        | (+/- .17) |    | 0.95        | (+/- .14) |   |
| Liquid                      |       | 0.89          | (+/- .16) |  | 0.79          | (+/- .19) |     | 0.82        | (+/- .18) | A  | 0.91           | (+/- .16) | A  | 0.89        | (+/- .14) |    | 0.83        | (+/- .14) |   |
| anova Etr (kg Nha)          |       | 0.09          |           |  | 0.07          |           |     | 0.07        |           |    | 0.09           |           |    | 0.08        |           |    | 0.08        |           |   |

NS non significant proba >0.05 \* S proba < 0.05 \*\* S proba < 0.01 \*\*\* S proba < 0.001

n= 144

n= 71



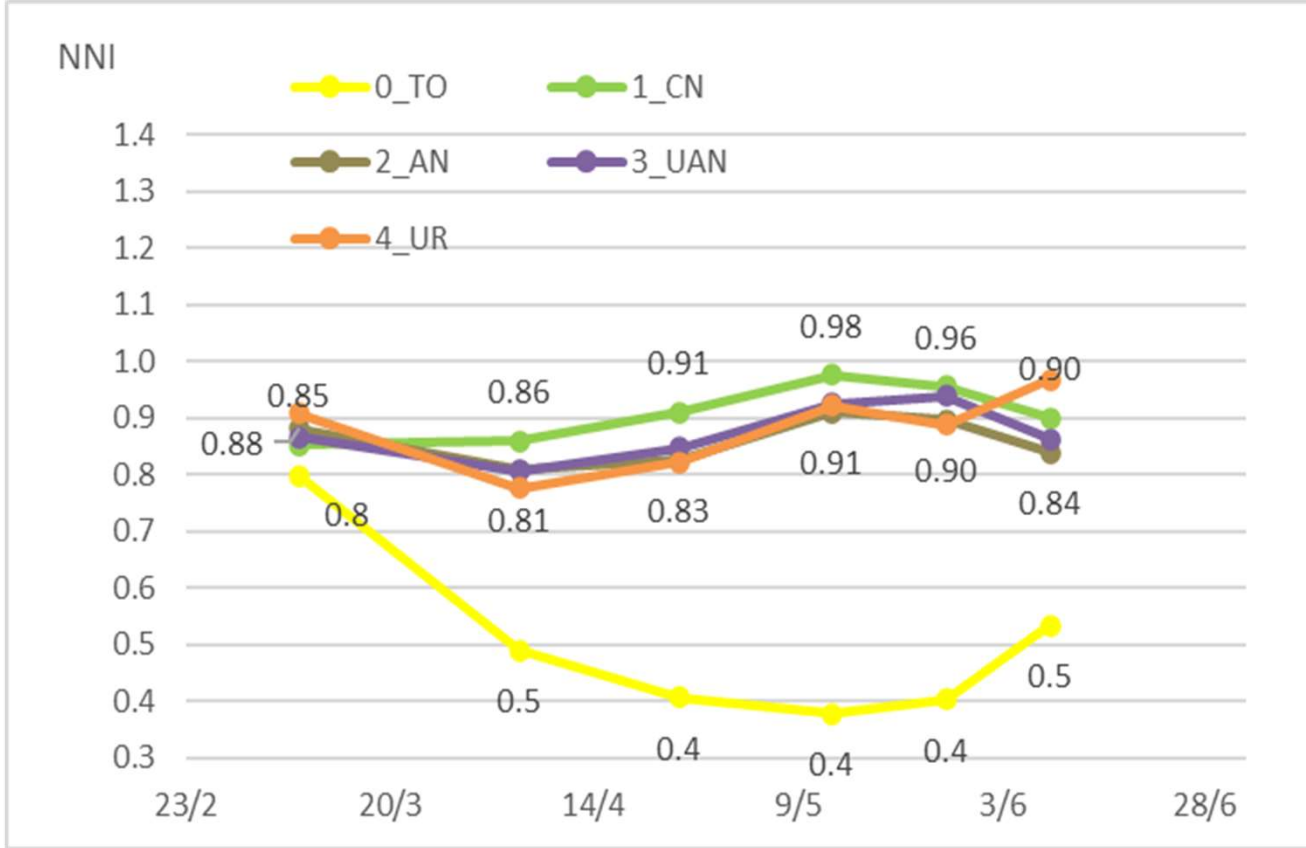


# Résultats consolidés 6 essais

## Dynamique INN

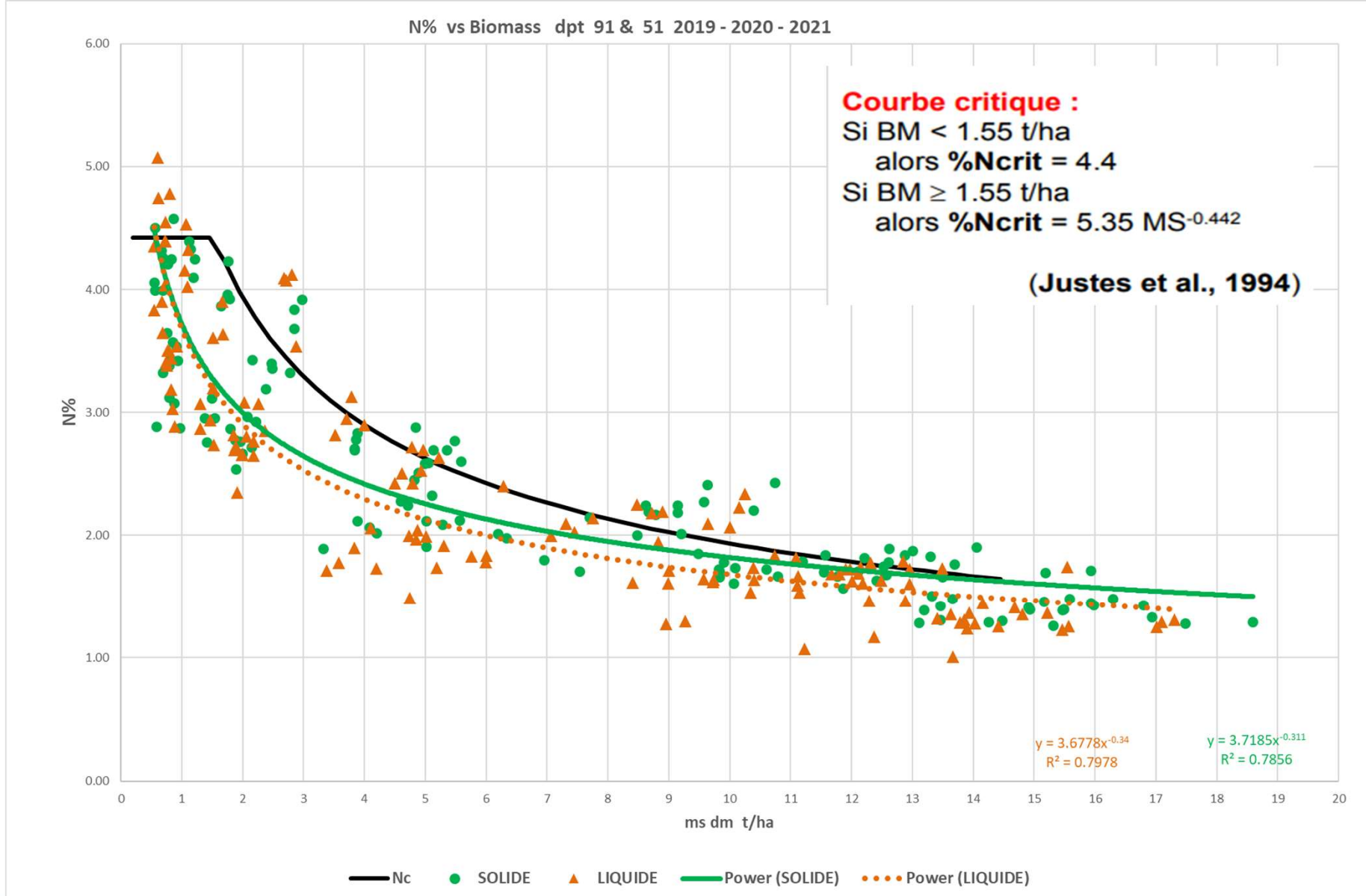
- Physical N form : Solid vs liquid

- Chemical N form : CN – AN – UAN - UR



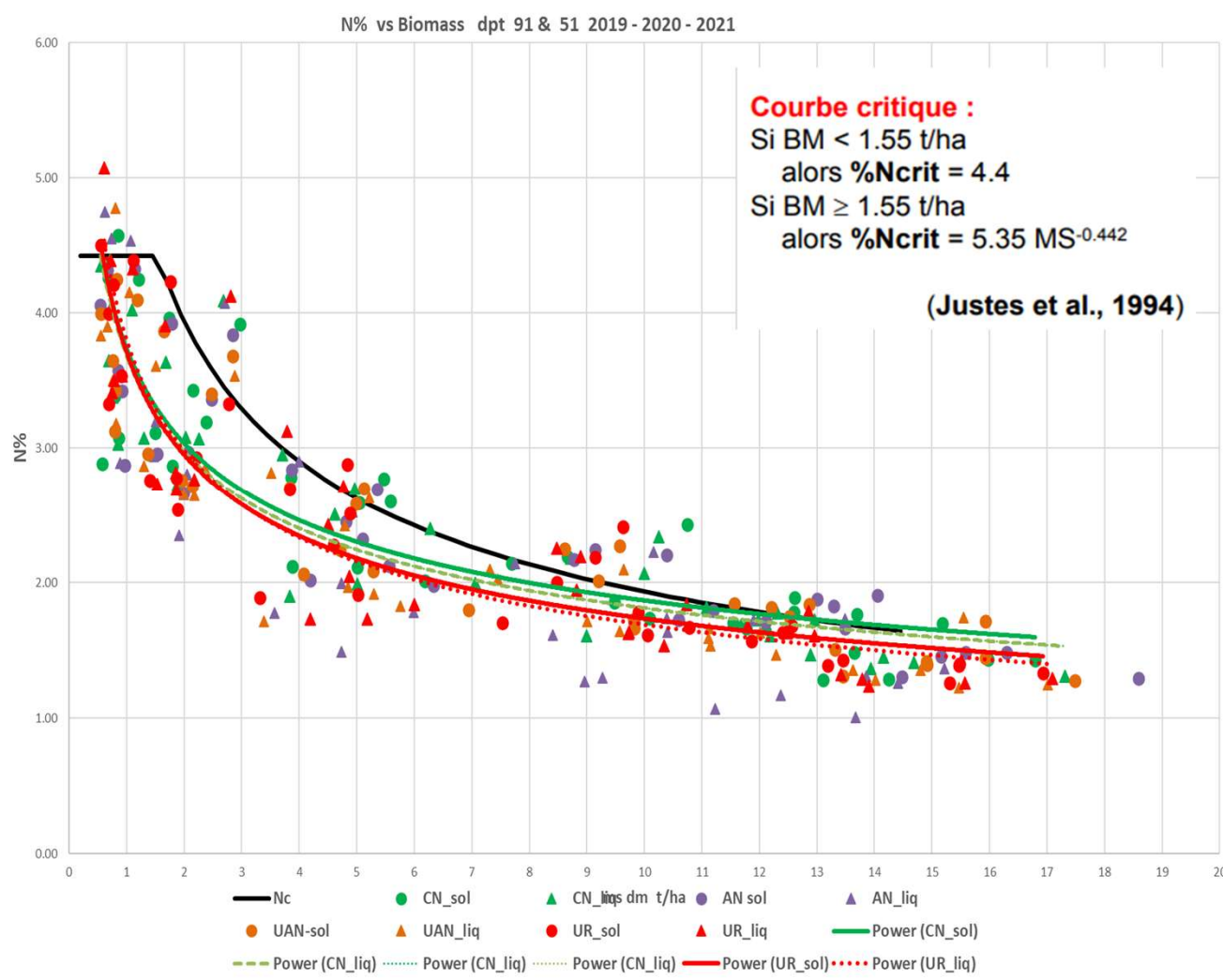
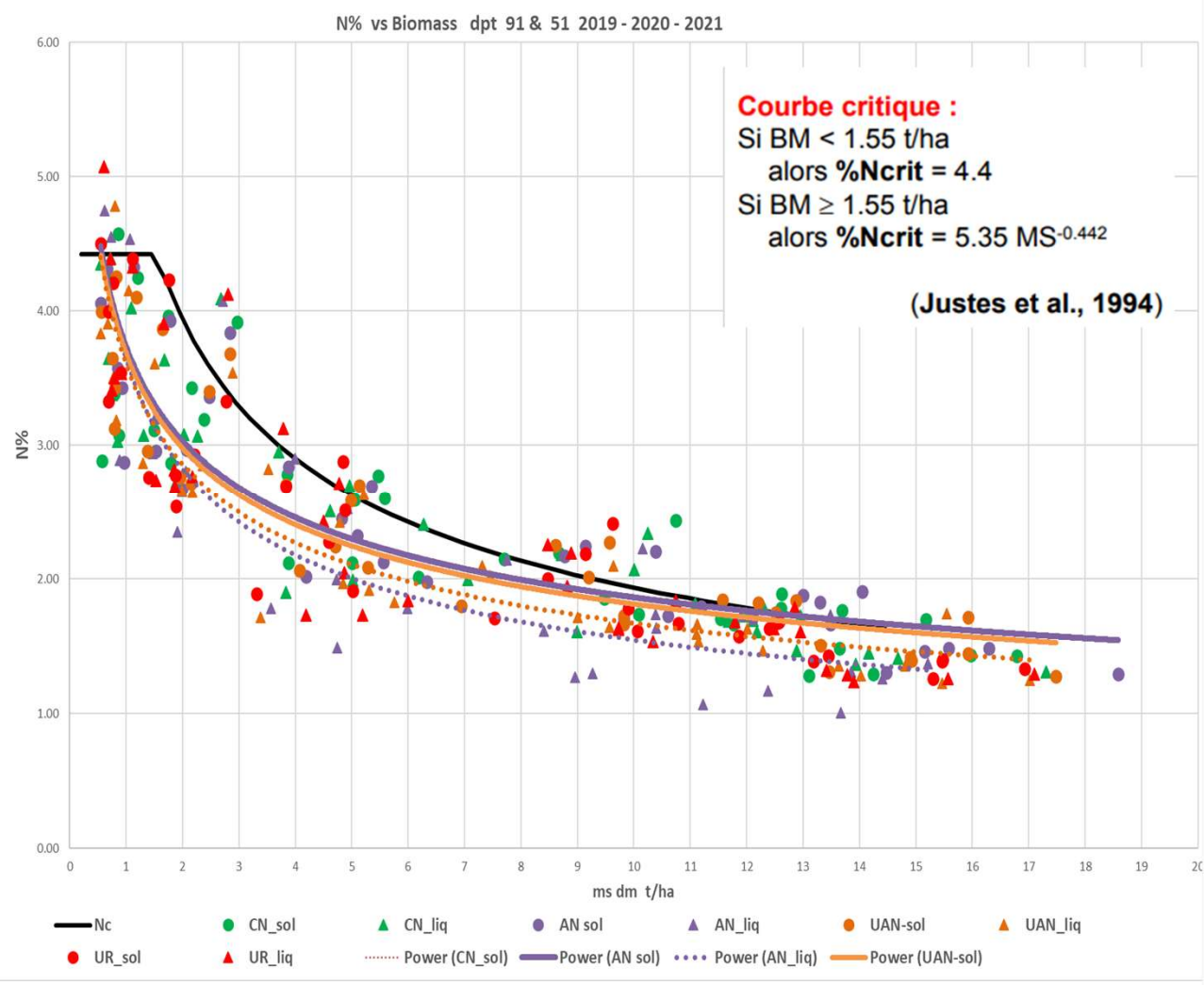
# Résultats consolidés 6 essais

## Dynamique INN



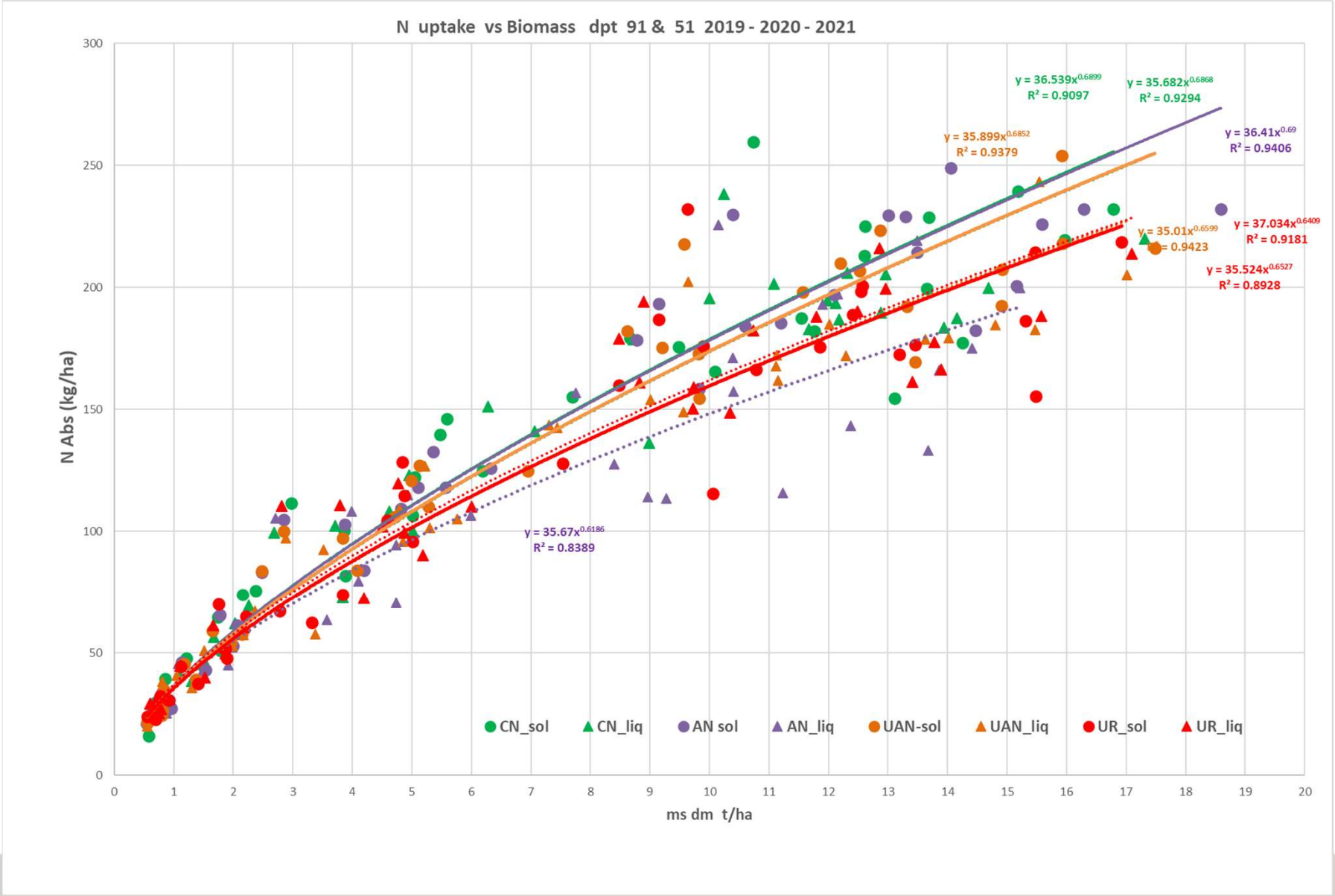
# Résultats consolidés 6 essais

## Dynamique INN



# Résultats consolidés 6 essais

## Dynamique N abs

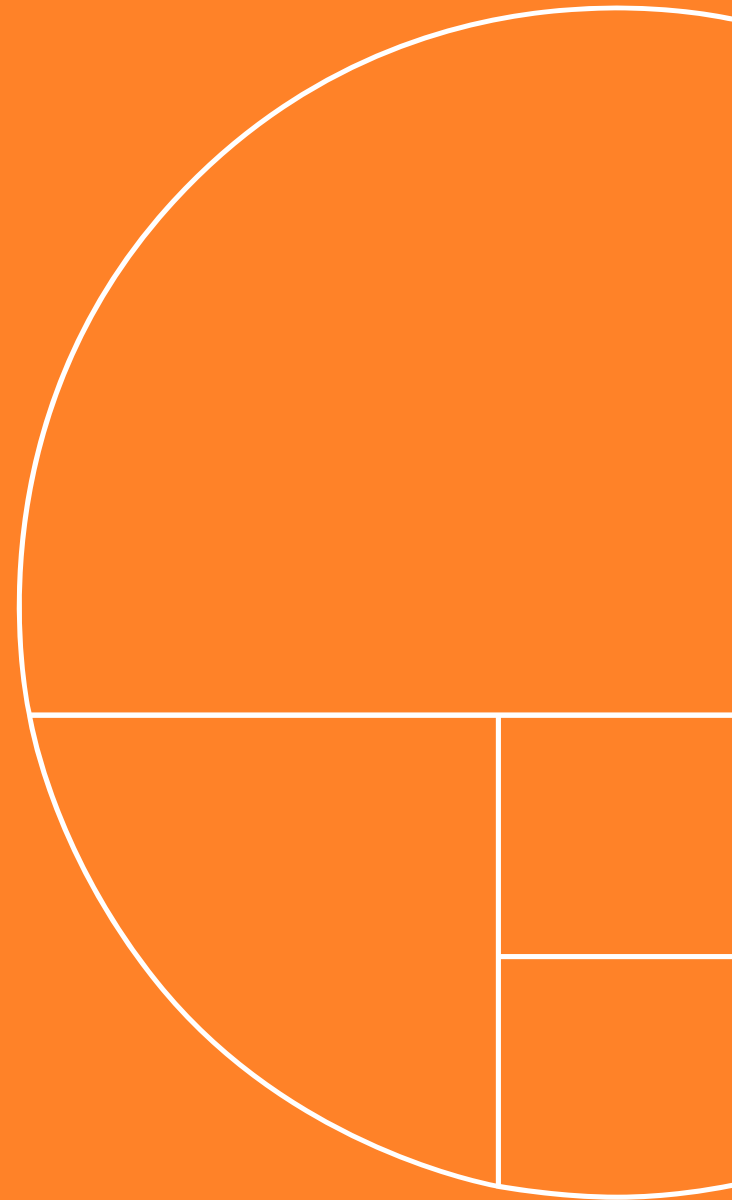


**Interaction avec les autres nutriments ?**

**teneur N / P – K – Mg - S**

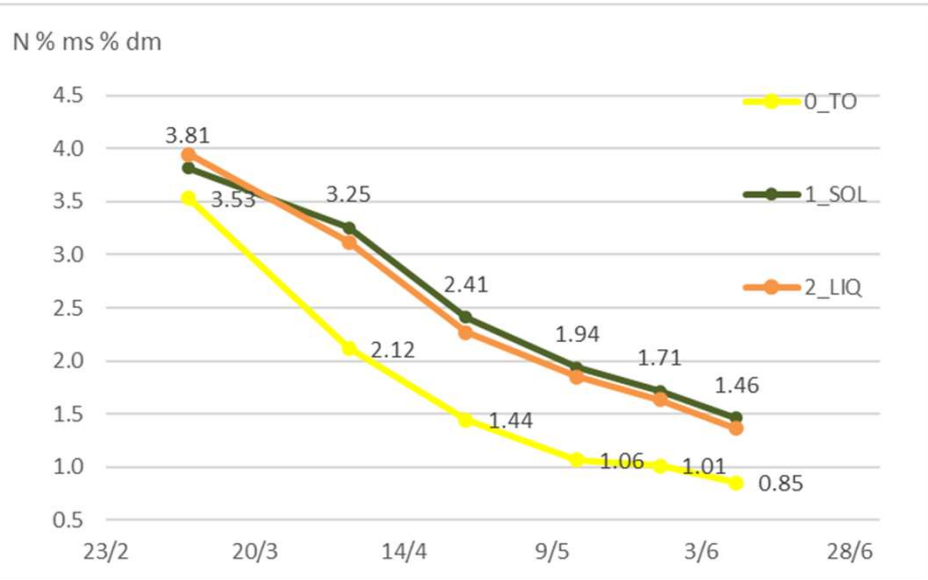
**&**

**absorption N / P<sub>2</sub>O<sub>5</sub> – K<sub>2</sub>O – MgO – SO<sub>3</sub> uptake**

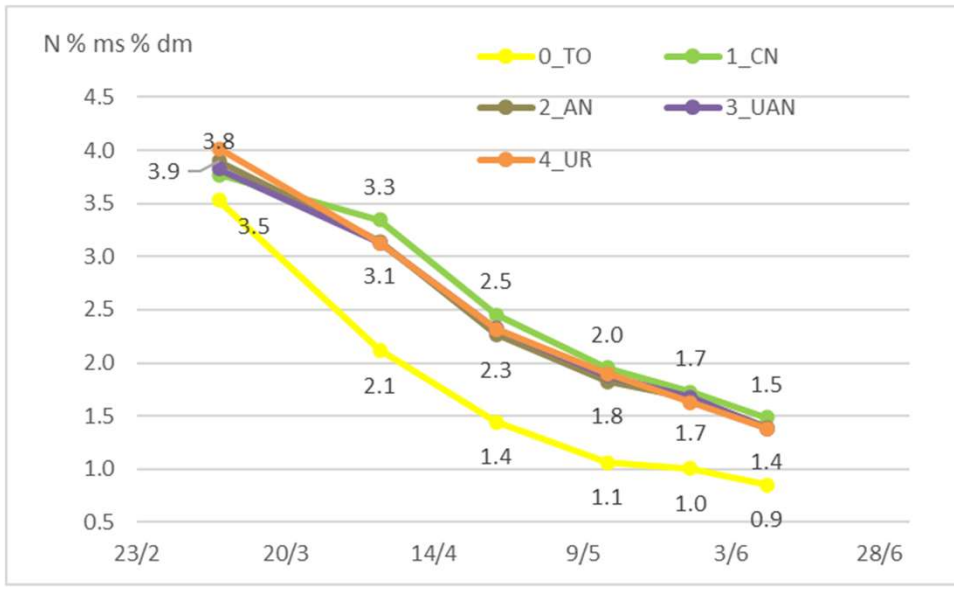


# Overall averages 2019-2021 N%

- Physical N form : Solid vs liquid



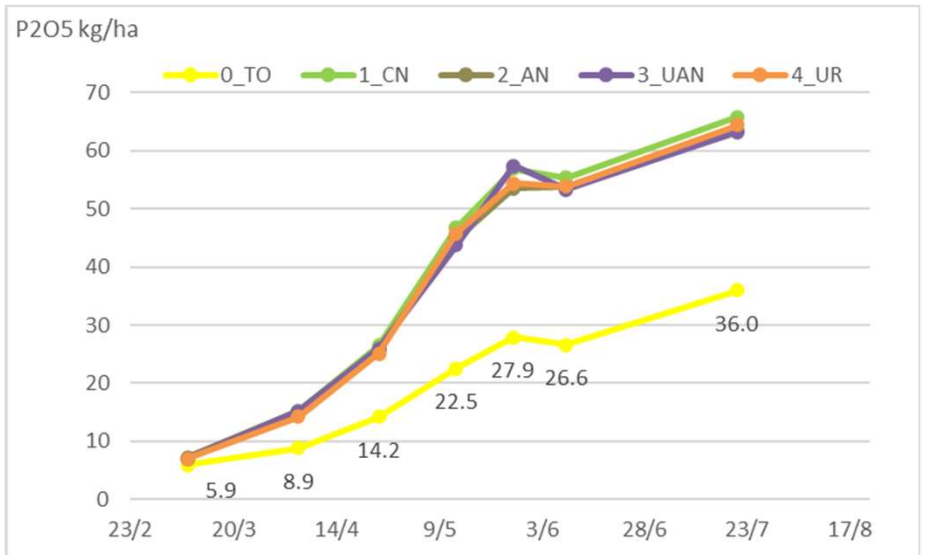
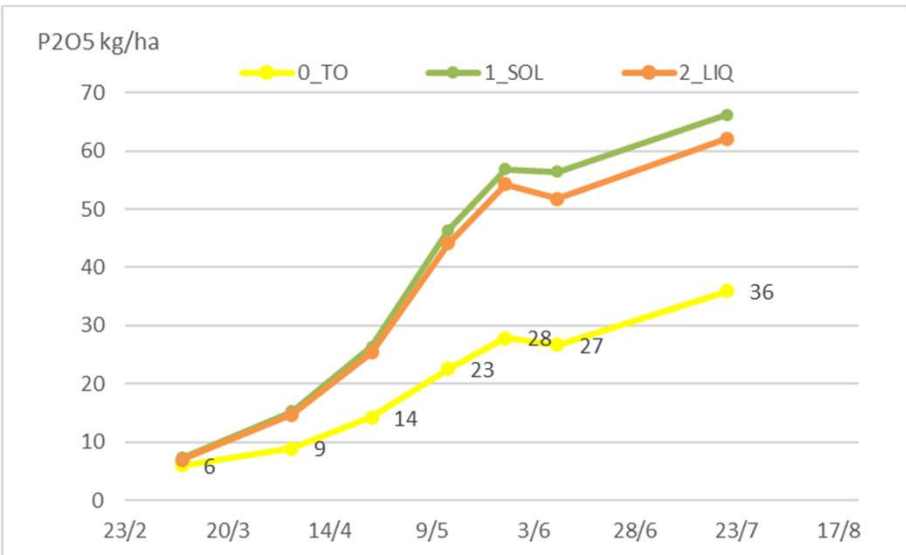
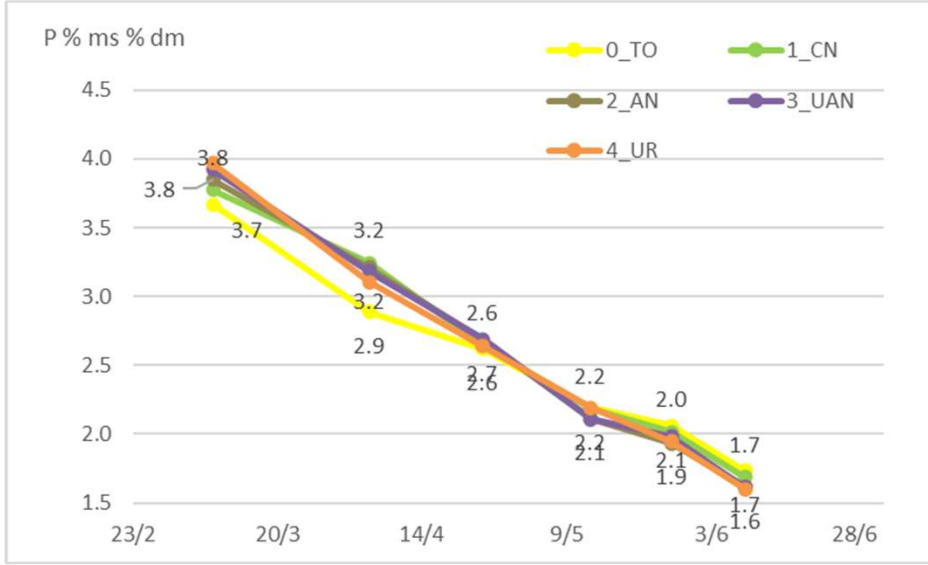
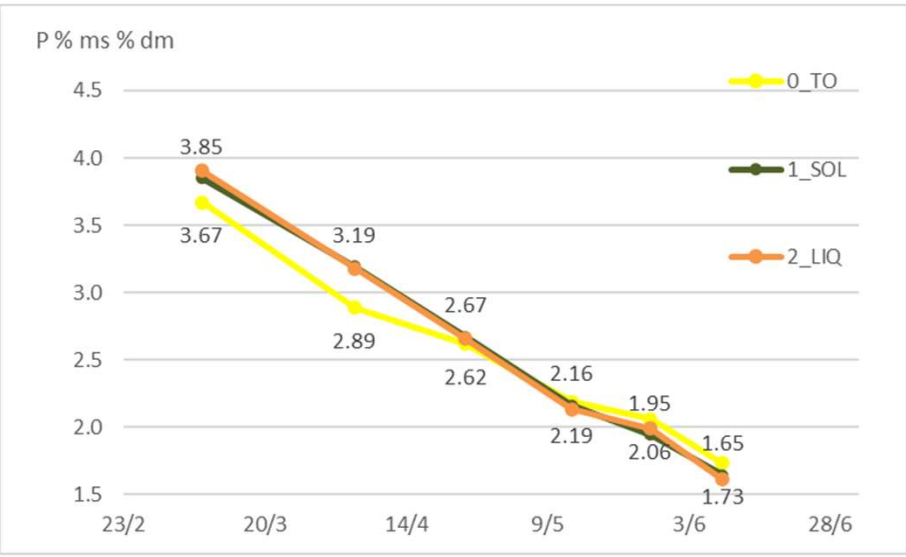
- Chemical N form : CN – AN – UAN - UR



# Overall averages 2019-2021 P% & P2O5 uptake

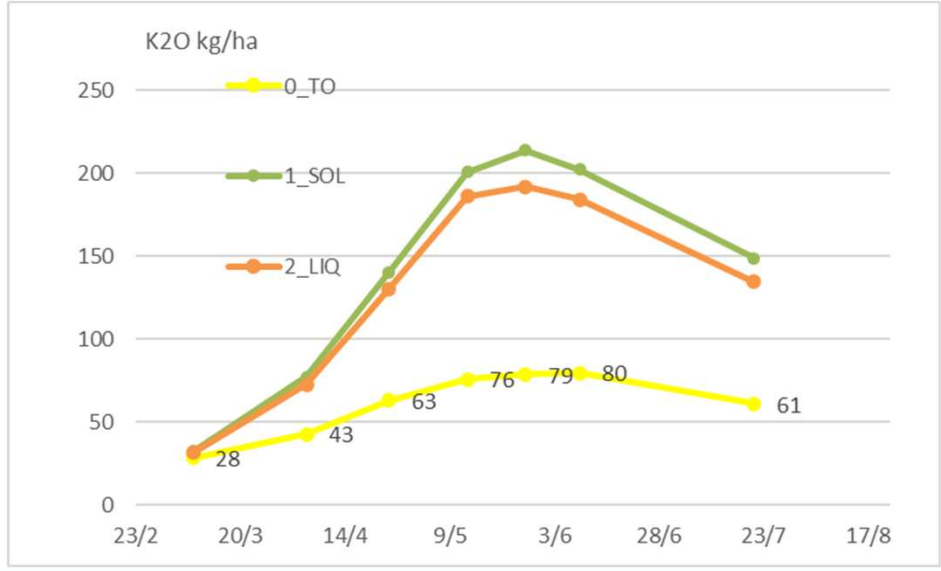
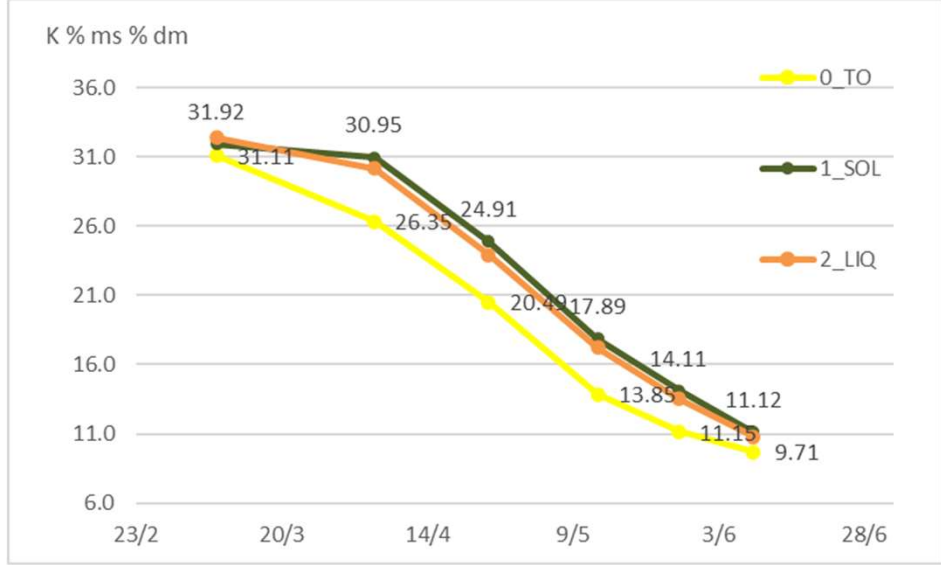
- Physical N form : Solid vs liquid

- Chemical N form : CN – AN – UAN - UR

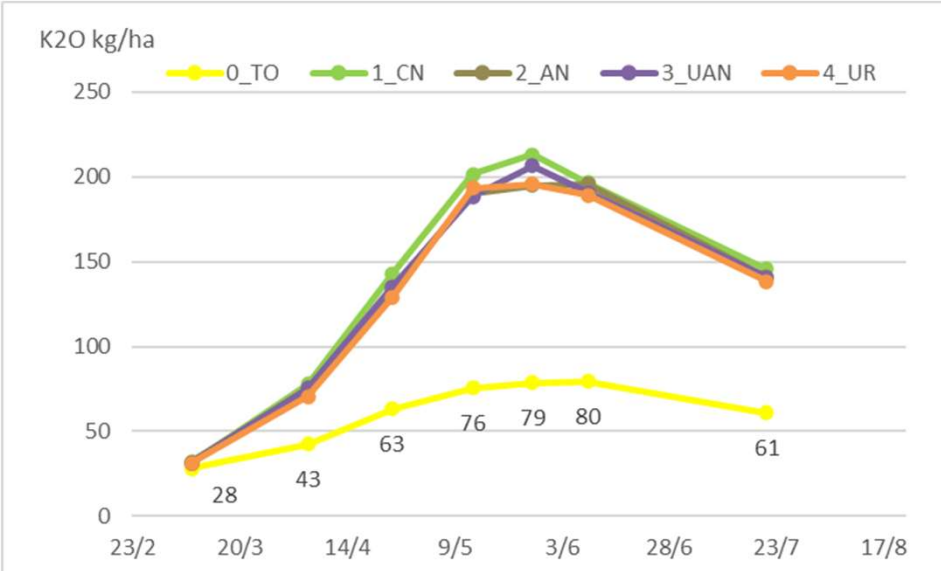
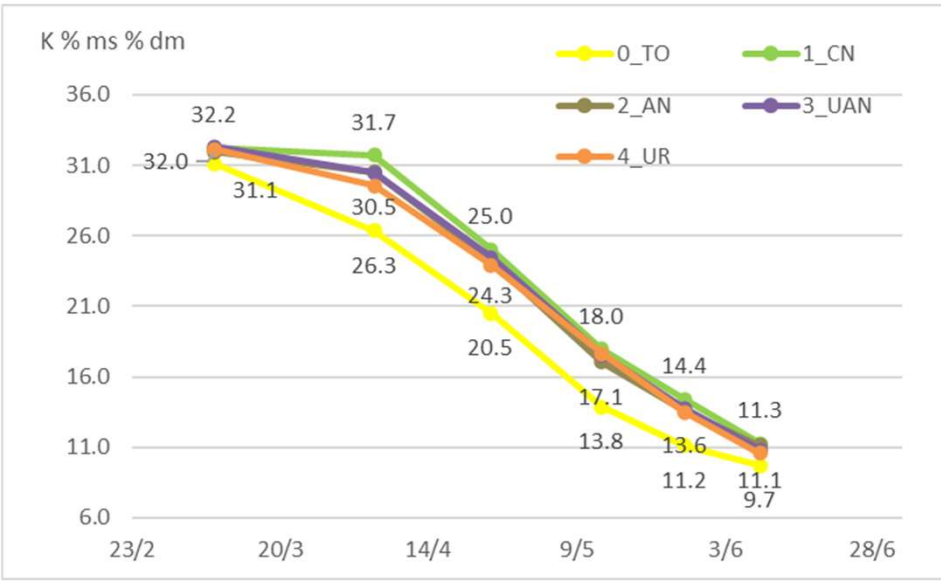


# Overall averages 2019-2021 K% & K2O uptake

- Physical N form : Solid vs liquid



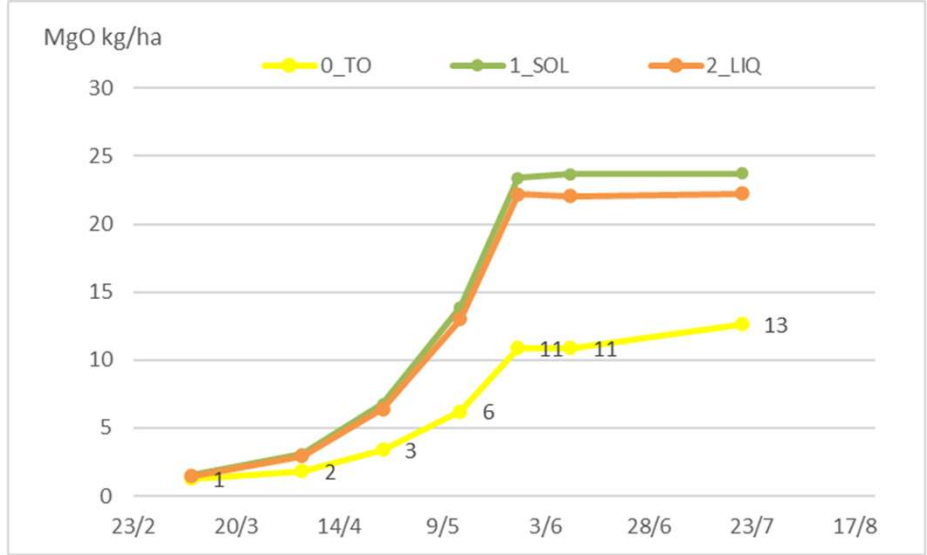
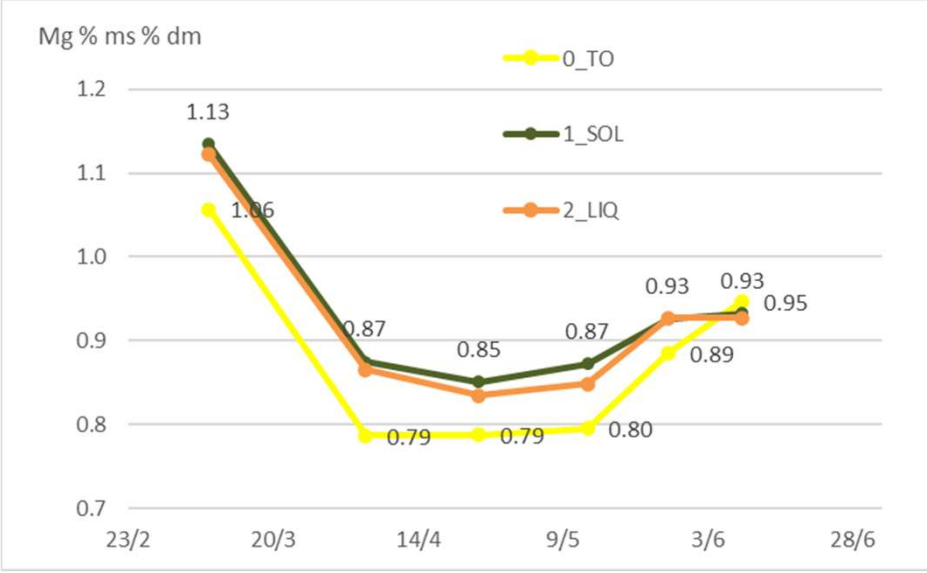
- Chemical N form : CN – AN – UAN - UR



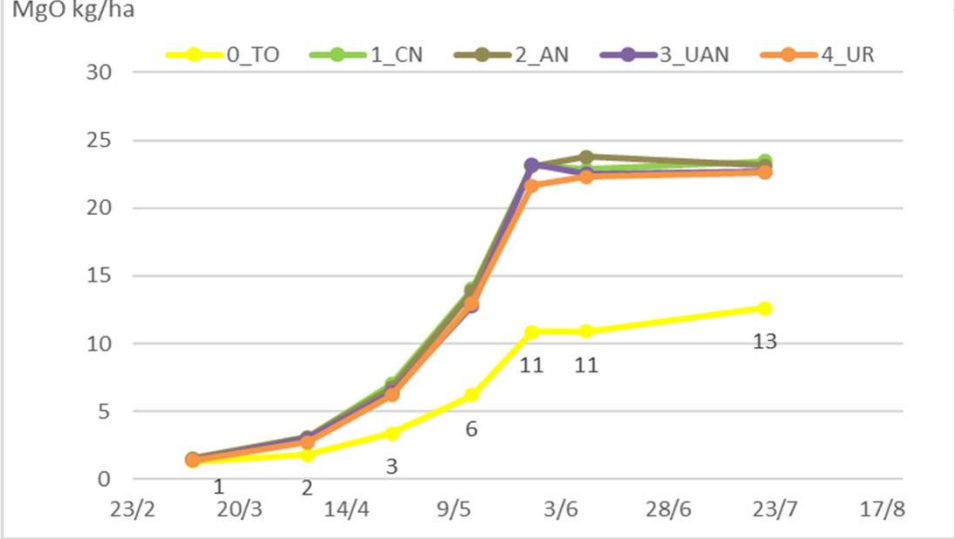
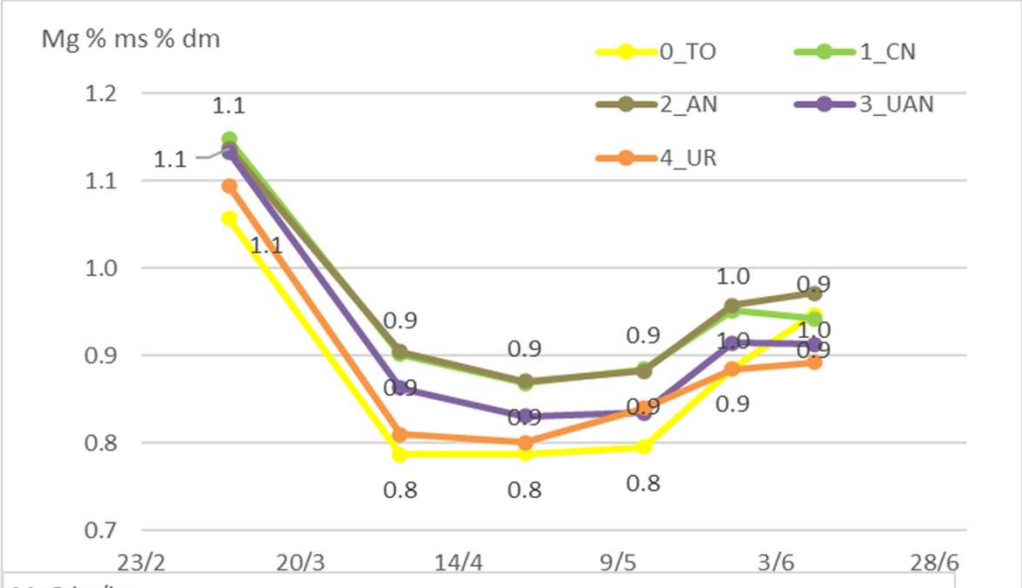


# Overall averages 2019-2021 Mg% & MgO uptake

- Physical N form : Solid vs liquid

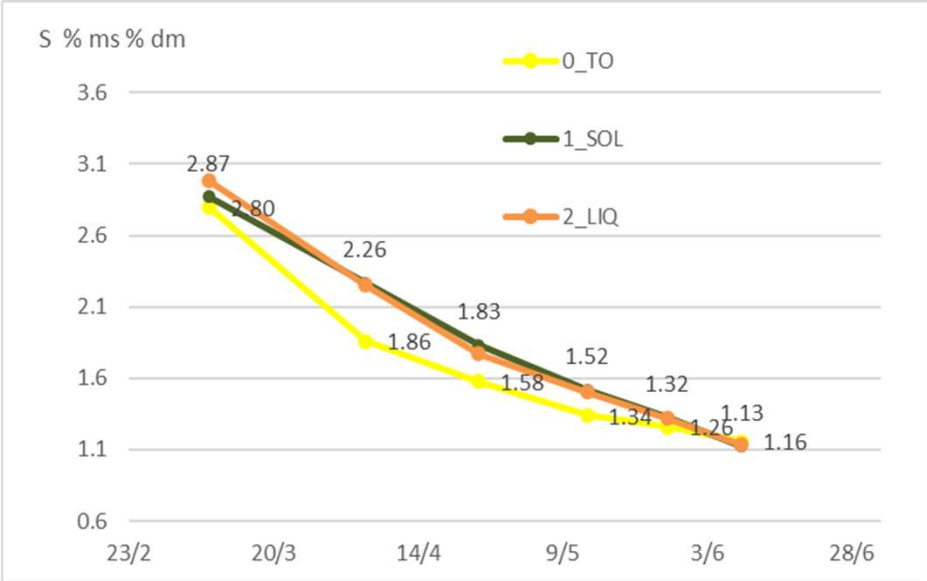


- Chemical N form : CN – AN – UAN - UR

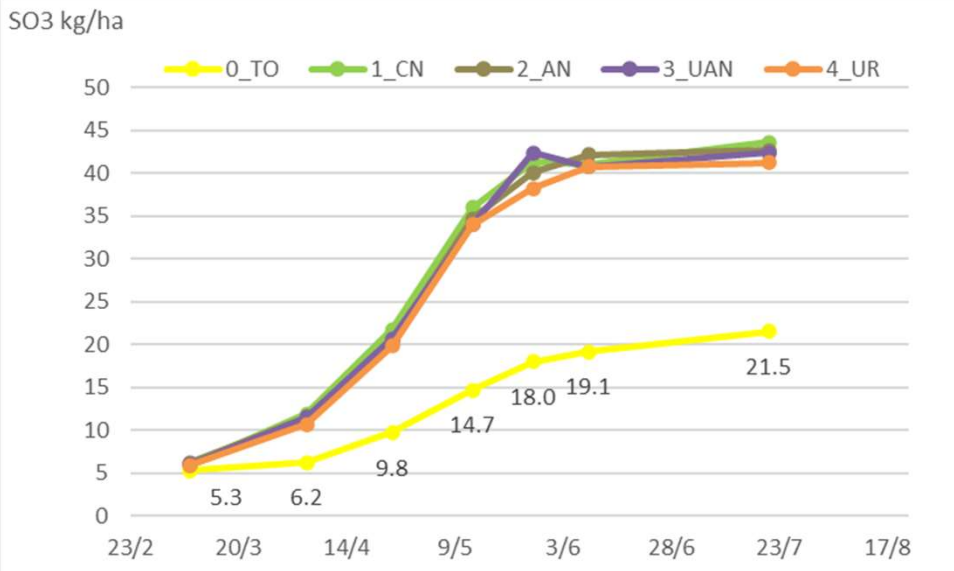
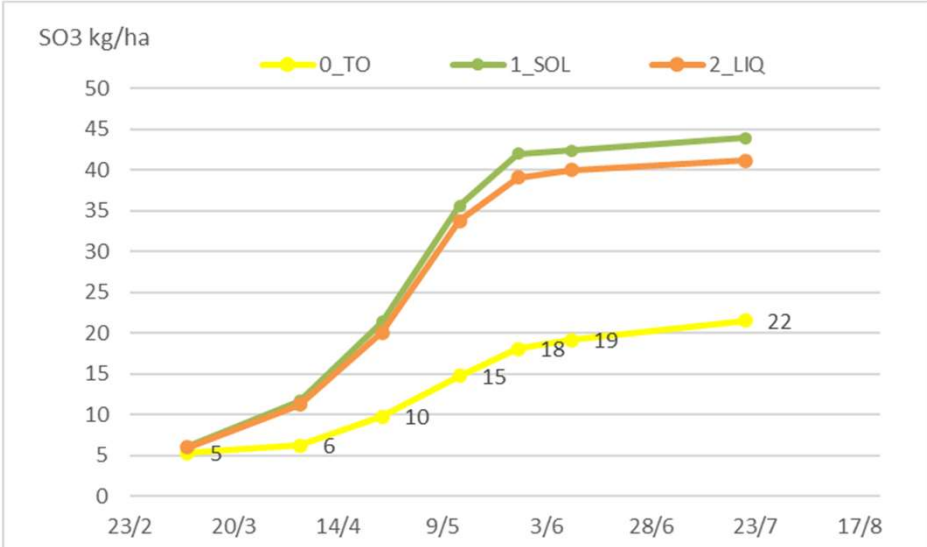
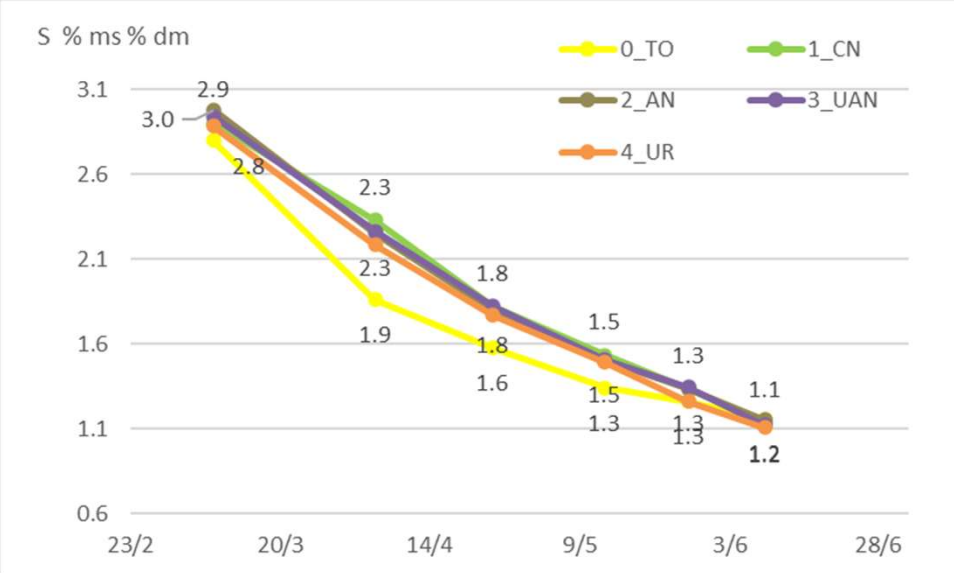


# Overall averages 2019-2021 S% & SO3 uptake

- Physical N form : Solid vs liquid



- Chemical N form : CN – AN – UAN - UR



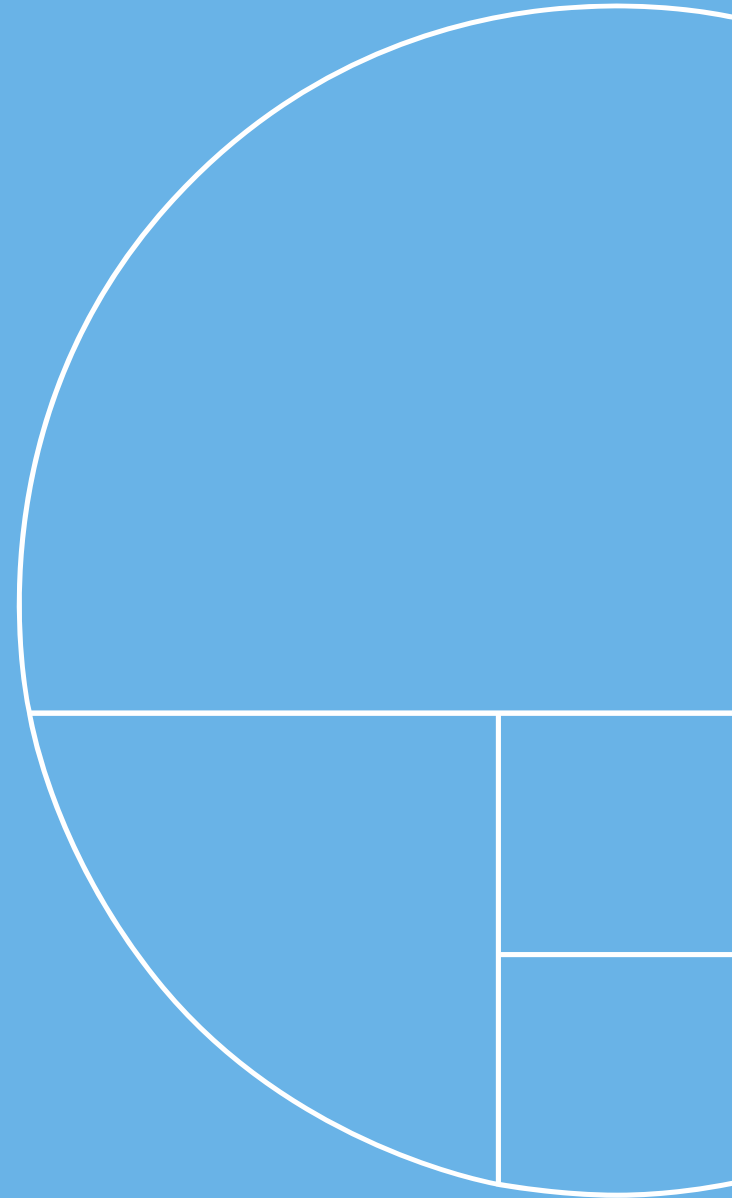
# Principales conclusions

Sur BTH , sur 3 ans et 6 essais

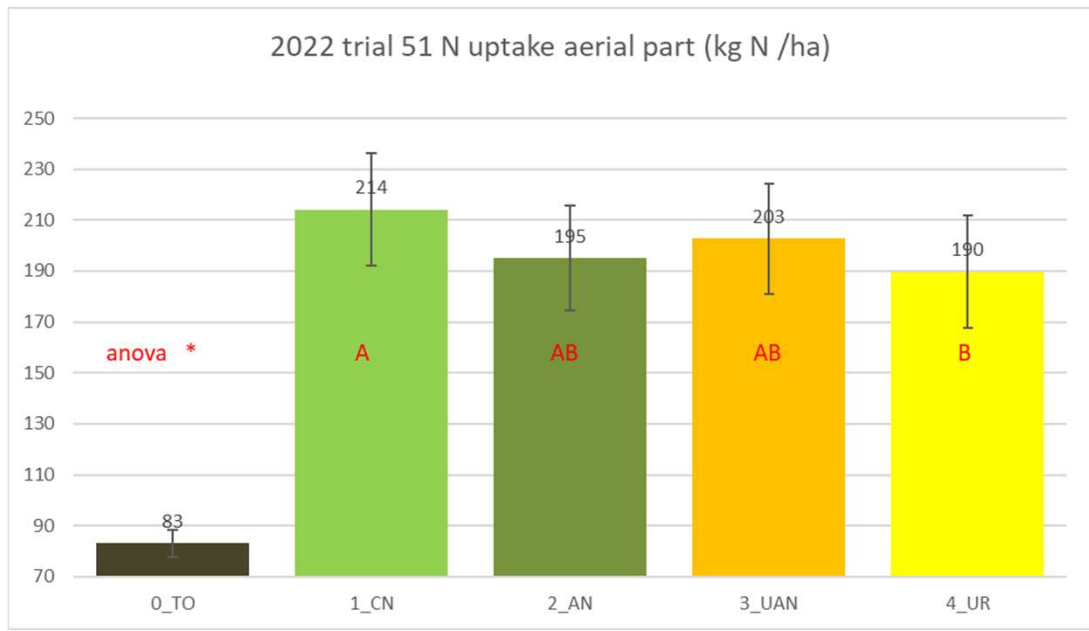
- **Mise en évidence d'un effet de la présentation physique de l'engrais N en faveur de l'apport solide**  
sur les critères suivants
  - Biomasse
  - rendement
  - Proteines
  - Absorption N
  - CAU
  - INN
- Le phénomène paraît plus marqué pour les formes AN & UAN et dans une moindre amplitude pour CN et Urée
- Les pires performances sont obtenues avec l'AN liquid
- Pas véritablement d'effet de la forme chimique de l'engrais azoté bien que le CN performe mieux en tendance sur les critères ,
  - Proteines , N absorbé , CAU et INN NNI
  - Pas d'effet rendement de la forme chimique
- Pas d'interaction entre les engrais azotés et les autres nutriments excepté peut-être pour le magnésium :  
→ teneur plus faible pour les formes urée et UAN vs AN - CN

**Perspectives :**

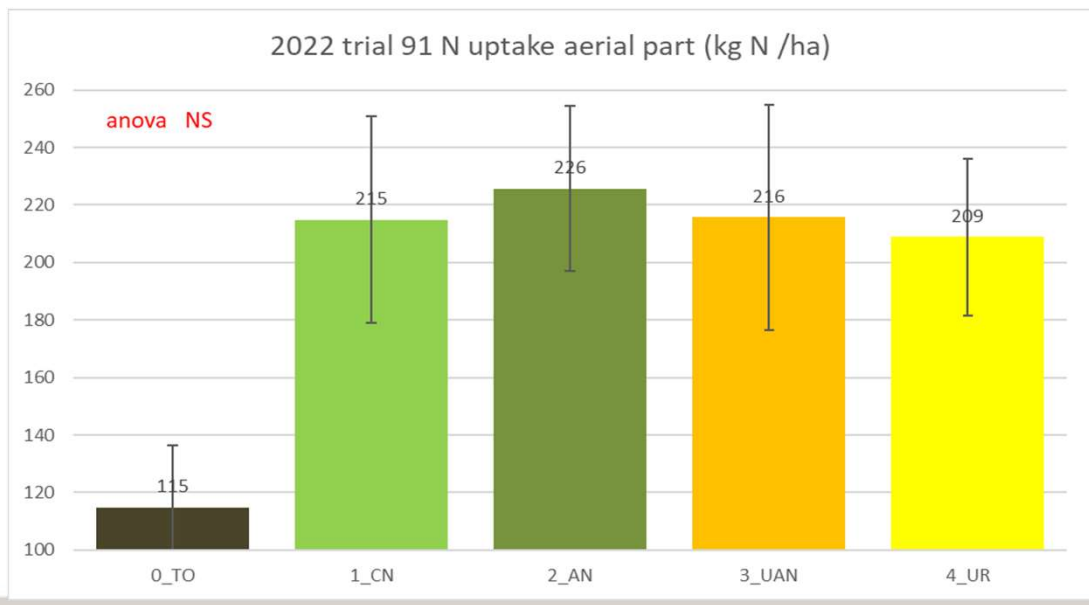
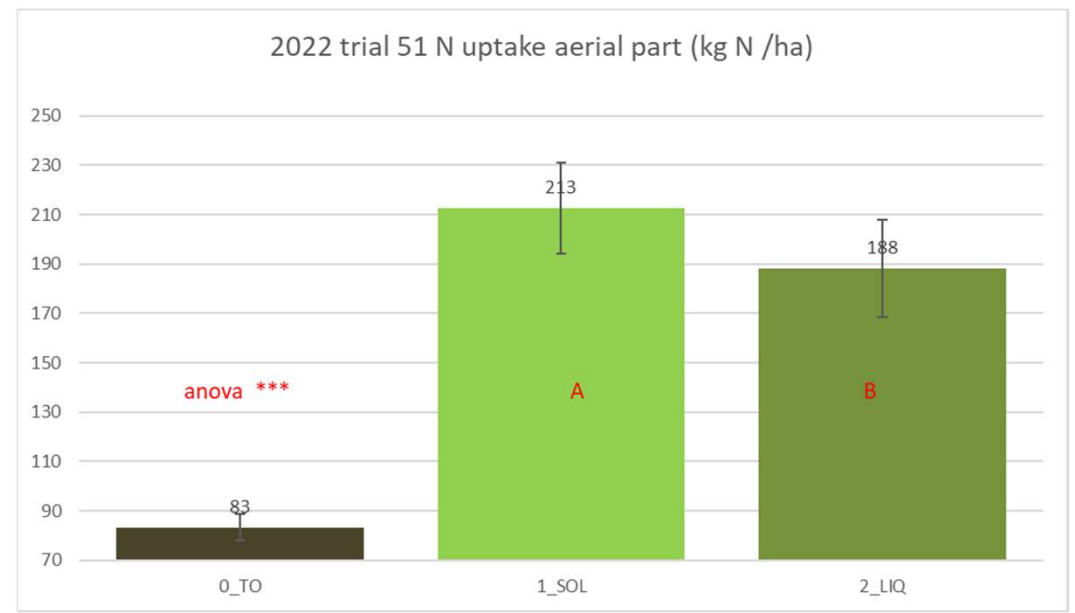
**2022 : 2 essais selon le même protocole sur Colza**



# Résultats colza 2022



**X = 200 N**



**X = 160 N**

