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Erasmus
Plus for
Organic
Sector

# Nutrient cycling in organic horticulture - wish or reality?

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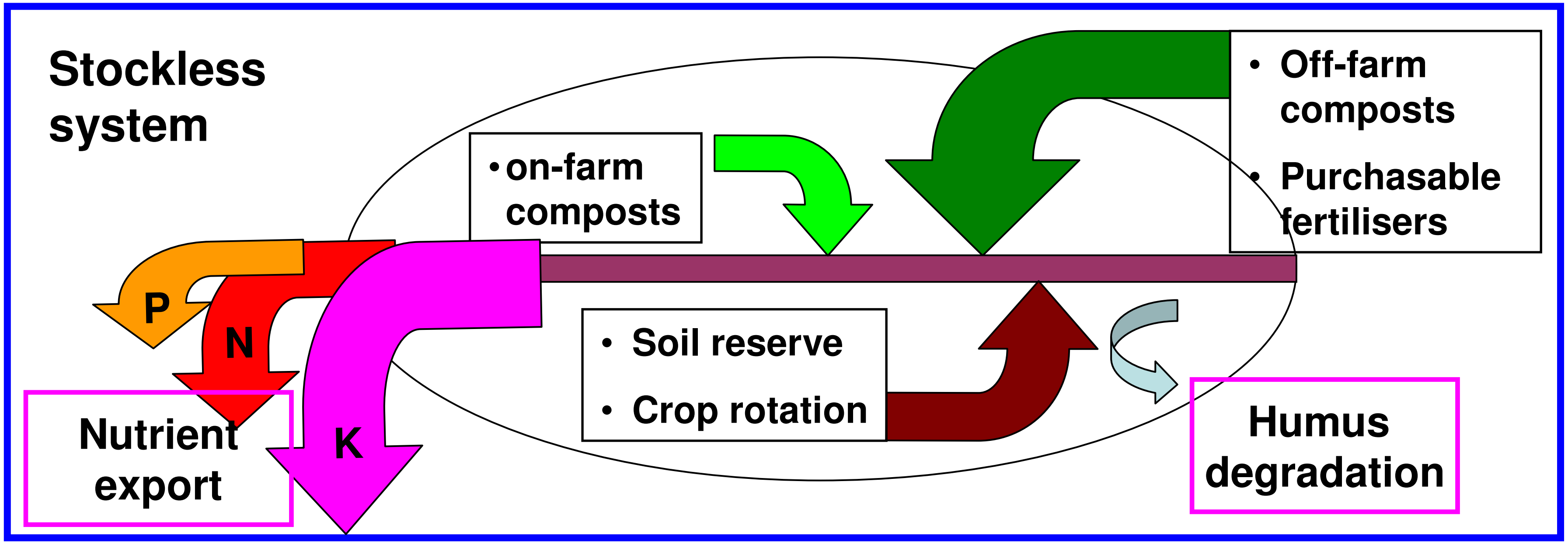
# Nutrient management in organic vegetable holdings



# Nutrient uptake of selected arable and field vegetable crops (various sources &)

| Crop | * Yield [t ha$^{-1}$] | $ Ntot [kg ha$^{-1}$] | $ Ptot [kg ha$^{-1}$] | $ Ktot [kg ha$^{-1}$] |
|---|---|---|---|---|
| Winter wheat | 4.0 | 98 | 42 | 64 |
| Winter barley | 4.0 | 98 | 39 | 59 |
| Winter rye | 4.0 | 99 | 41 | 86 |
| Spring barley | 4.0 | 89 | 38 | 63 |
| Oats | 4.0 | 105 | 40 | 121 |
| Faba bean | 3.2 | 244 | 58 | 178 |
| Field pea | 3.2 | 205 | 45 | 60 |
| Potatoes | 24.0 | 86 | 38 | 170 |
| | | | | |
| Carrot (late) | 56.0 | 149 | 55 | 238 |
| Red cabbage (late) | 32.0 | 176 | 48 | 208 |
| White cabbage | 40.0 | 192 | 52 | 224 |
| Leek | 40.0 | 180 | 48 | 220 |
| Celeriac | 40.0 | 192 | 92 | 348 |
| Beetroot | 24.0 | 113 | 41 | 192 |

& Sources from conventional farming (yield and uptake correspond to 80 % of conventional data

* Harvest products: grain, tubers, roots, shoot

$ crop residues excluded

# Yield and P- & K-uptake and –exports of selected arable and field vegetable crops

## (several sources &)

| Crop | * Yield | * P(-) | | * K(-) | |
|---|---|---|---|---|---|
| | [t $ha^{-1}$] | [kg $ha^{-1}$] | *[ % ]* | [kg $ha^{-1}$] | *[ % ]* |
| Winter wheat | 4.0 | 34 | *81* | 22 | *35* |
| Winter barley | 4.0 | 32 | *82* | 16 | *27* |
| Winter rye | 4.0 | 26 | *63* | 25 | *29* |
| Spring barley | 4.0 | 32 | *83* | 20 | *32* |
| Oats | 4.0 | 28 | *70* | 32 | *26* |
| Faba bean | 3.2 | 38 | *66* | 42 | *23* |
| Field pea | 3.2 | 30 | *68* | 36 | *60* |
| Potatoes | 24.0 | 31 | *83* | 142 | *83* |
| | | | | | |
| Carrot (late) | 56.0 | 11 | *20* | 48 | *20* |
| Red cabbage (late) | 32.0 | 20 | *42* | 96 | *46* |
| White cabbage | 40.0 | 20 | *38* | 96 | *43* |
| Leek | 40.0 | 10 | *20* | 60 | *27* |
| Celeriac | 40.0 | 19 | *21* | 108 | *31* |
| Beetroot | 24.0 | 6 | *16* | 68 | *35* |

& Sources from conventional farming (yield and uptake correspond to 80 % of conventional data)

* Harvest products: grain, tubers, roots, shoot

# Purchasable fertilisers

## (Annex II EC Dec. 2092/91)

| Products and side products of animal origin | Products and side products of plant origin | Mineral fertilisers |
|---|---|---|
| • Blood meal | • Algae- and algal products | • Soft Rock phosphate |
| • Hoof- and horn meal | • Saw dust and wooden chips | • Thomas phosphate |
| • Bone meal and –coal | • Bark compost | • Potassium salt |
| • Fish meal | • Wooden ash | • Magnesium potassium sulfate |
| • Meat meal | • Seed cakes from oil crops cacao shells, etc. | • Chalk, maerl, lime, algal lime, phosphate lime |
| • Feather- and hair meal | • Compost | • Calcium sulfate |
| • Wool | • Composted household wastes (limited till 31.03.2006) | • Magnesium sulfate |
| • Hairs and brisles | | • Bentonite |
| • Skin | • Lime from sugar production | • Rock dust |
| • Milk products | • All other products and side products of plant origin | • Trace element fertilisers |

P- & K-sources

# Nutrient inputs [kg ($ha^{-1}*a^{-1}$)] in 30 farms in NRW with substantial share of vegetables

(Lütke Besselmann 1997)

| Farm type | N | $P_2O_5$ | $K_2O$ | CaO |
|---|---|---|---|---|
| Market gardens | 71 | 32 | 82 | 341 |
| Farms | 29 | 12 | 41 | 350 |
| Average | 57 | 26 | 68 | 344 |

# Nutrient inputs [kg ($ha^{-1}*a^{-1}$)] through various fertilisers in 30 farms in NRW with vegetable shares

## (Lütke Besselmann 1997)

| | $P_2O_5$ | | | $K_2O$ | | |
|---|---|---|---|---|---|---|
| | On-farm | Organic fertilisers | Mineral fertilisers | On-farm | Organic fertilisers | Mineral fertilisers |
| Minimum | 1 | 1 | 126 | 1 | 2 | 14 |
| Average | 9 | 25 | 126 | 13 | 29 | 152 |
| Maximum | 31 | 218 | 126 | 46 | 162 | 525 |
| *No* | *18* | *18* | *1* | *18* | *18* | *16* |

29 of 30 farms without mineral P-sources

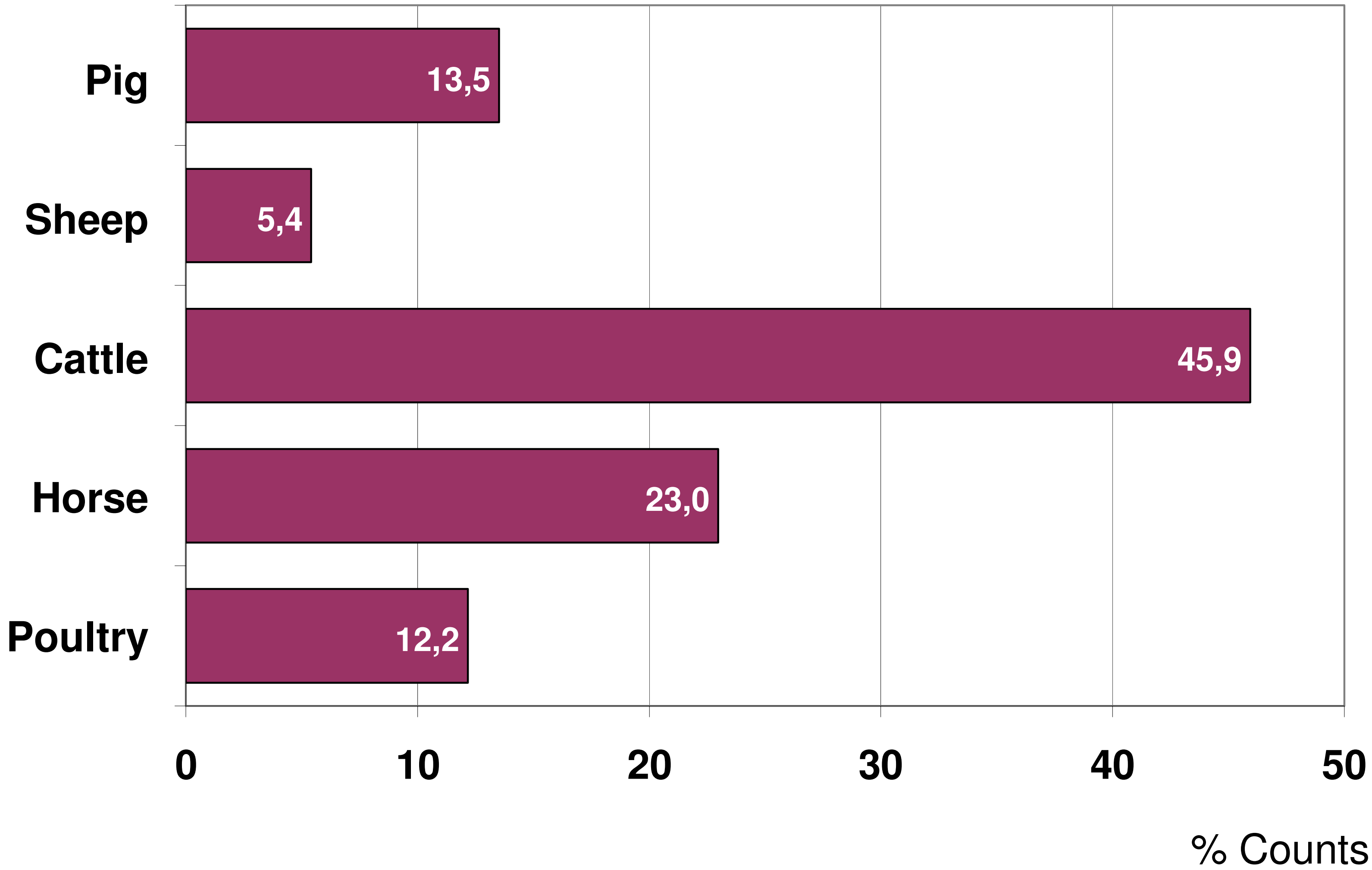
12 of 30 without on-farm fertilisers (animal, plant)

14 of 30 farms without mineral K-sources

12 of 30 without on-farm fertilisers (animal, plant)

# Use of on-farm manure

## (von Fragstein et al. 2004)



# Share of used on-farm manure in vegetable holdings referred to region (R) and organisation (O)

**[% Counts], [% Farms], [% Group]**

(von Fragstein et al. 2004)

| ( R ) | S | N/W | E | Total |
|---|---|---|---|---|
| Counts | 20 | 38 | 42 | *74* |
| Farms | 22 | 44 | 33 | *45* |
| Group | *40* | *50* | *43* | |

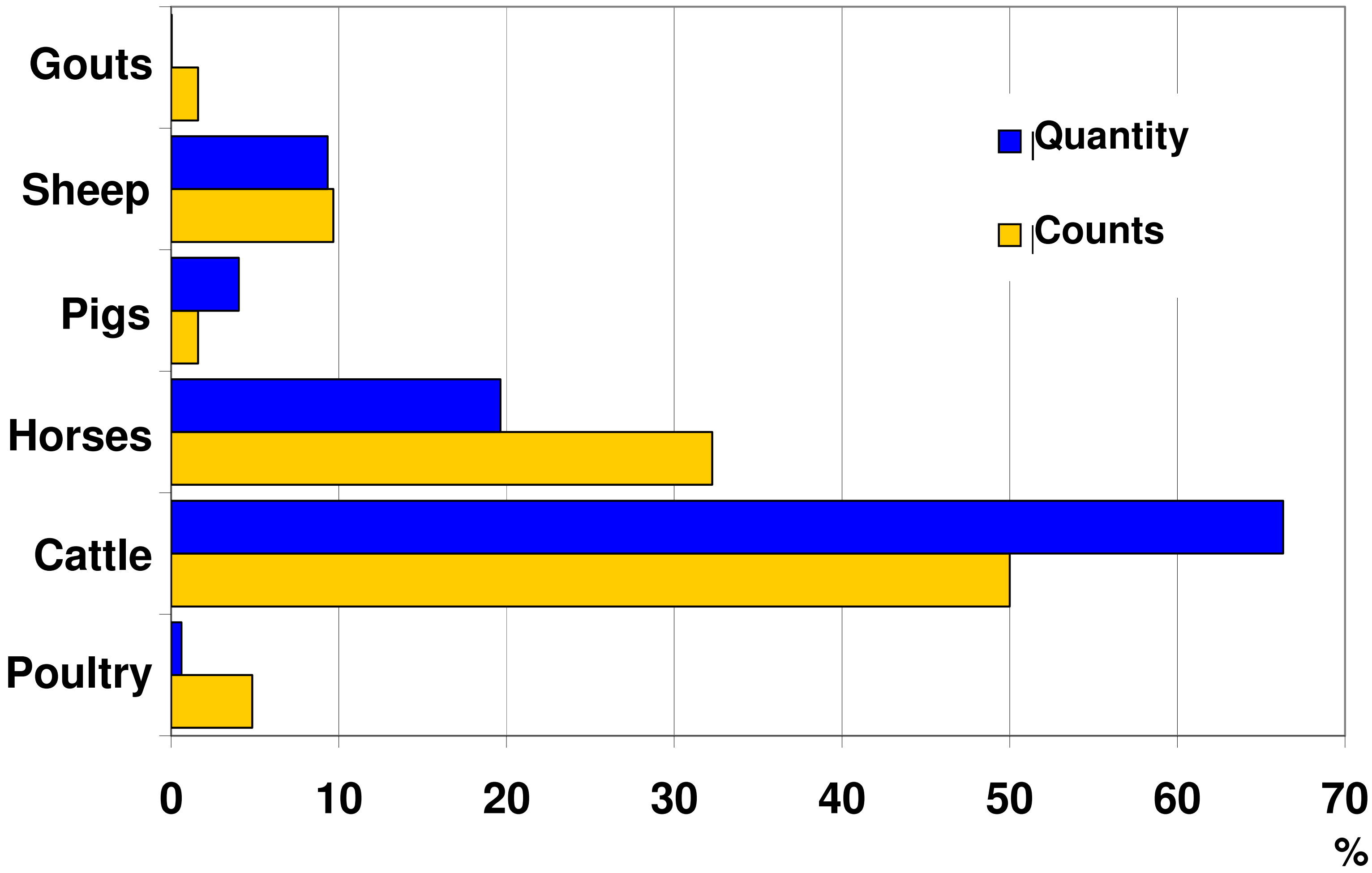
| ( O ) | B | D | E | G | N | Ö |
|---|---|---|---|---|---|---|
| Counts | 27 | 47 | 7 | *14* | 4 | 1 |
| Farms | 40 | 40 | 2 | *9* | 7 | 2 |
| Group | *38* | *62* | *50* | 31 | *50* | *100* |

| | |
|---|---|
| S | South |
| N/W | North/West |
| E | East |

| | | | |
|---|---|---|---|
| B | Bioland | G | Gäa |
| D | Demeter | N | Naturland |
| E | EU-farms | Ö | Ökosiegel |

# Frequency of counts (N = 62) and quantity ( N = 6455 t) of purchased farm yard manure

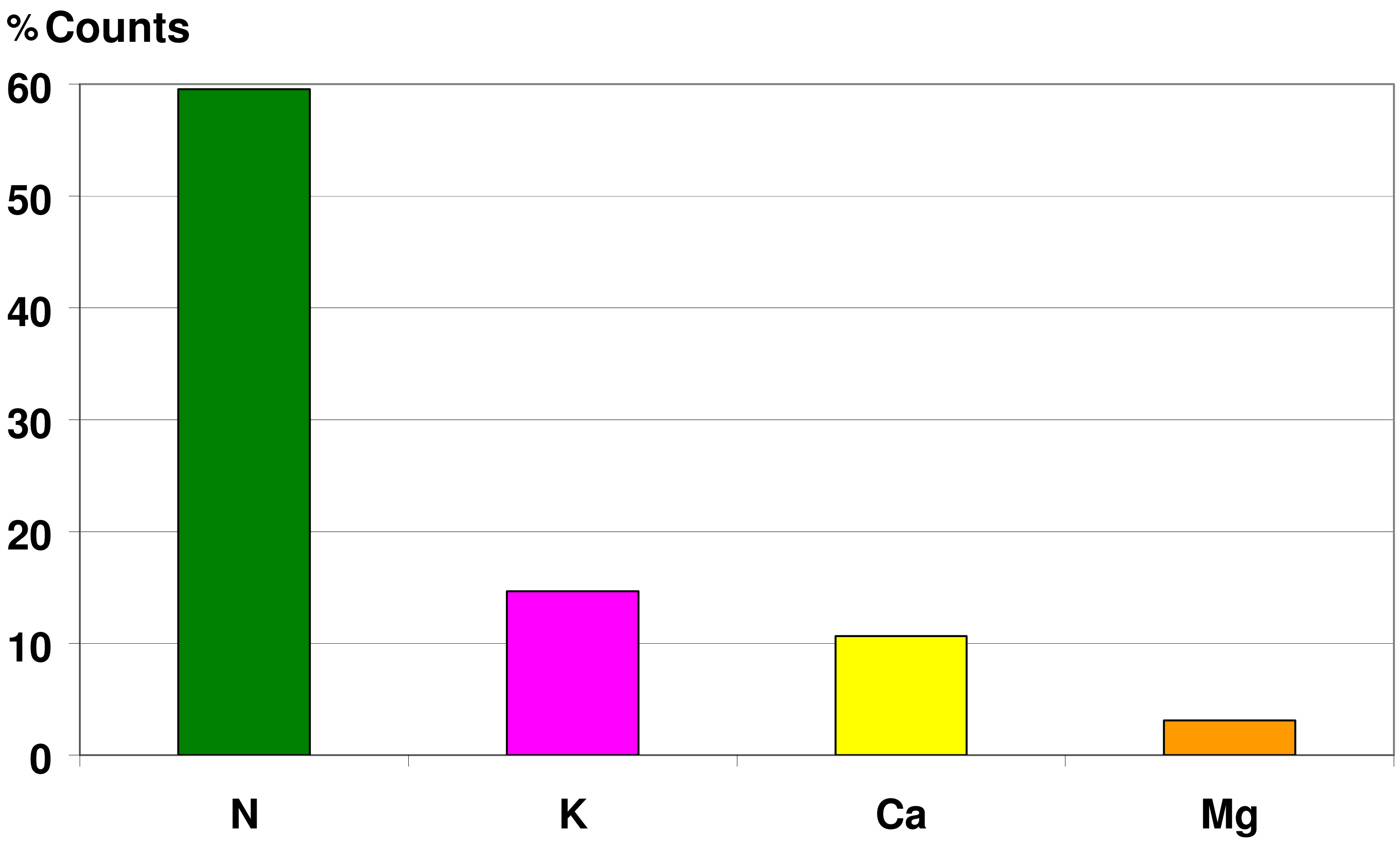
(von Fragstein et al. 2004)



# Relation of added nutrients through purchased fertilisers

**(N = 224)**

(von Fragstein et al. 2004)

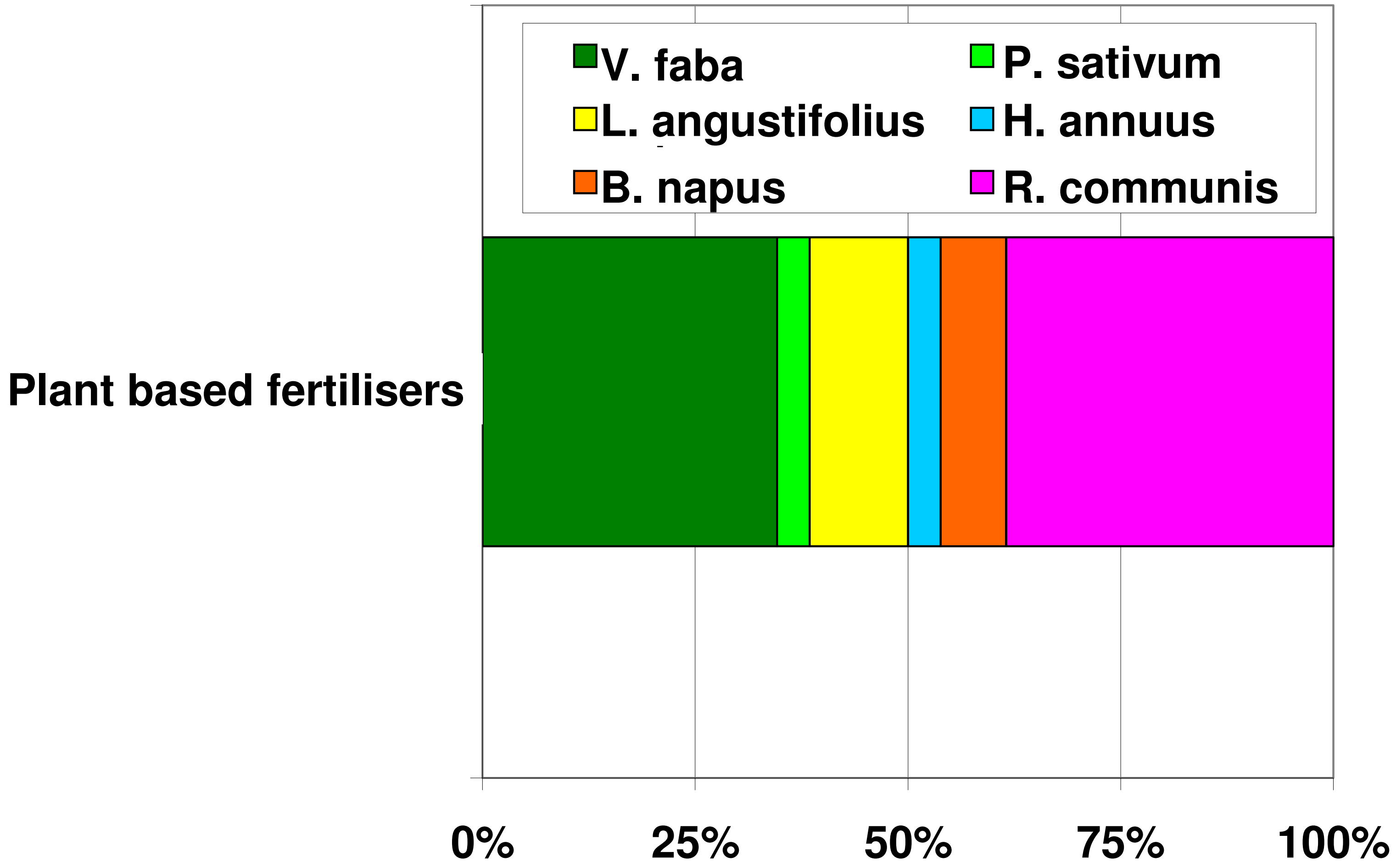


# Counts to used nitrogenous purchased fertilisers

(von Fragstein et al. 2004)

| Origin | Counts | Relation | |
|---|---|---|---|
| **Plant** | **76** | ***57*** | |
| ***seed cake pellets*** | | | ***19*** |
| ***sugar beet vinasse*** | | | ***16*** |
| **Animal** | **58** | ***43*** | |
| **Total** | **134** | | |

# Share of seed cake pellets as nitrogenous plant based fertilisers



# Application of purchased N fertilizers related to farmsize and organisation [% Farms per region]

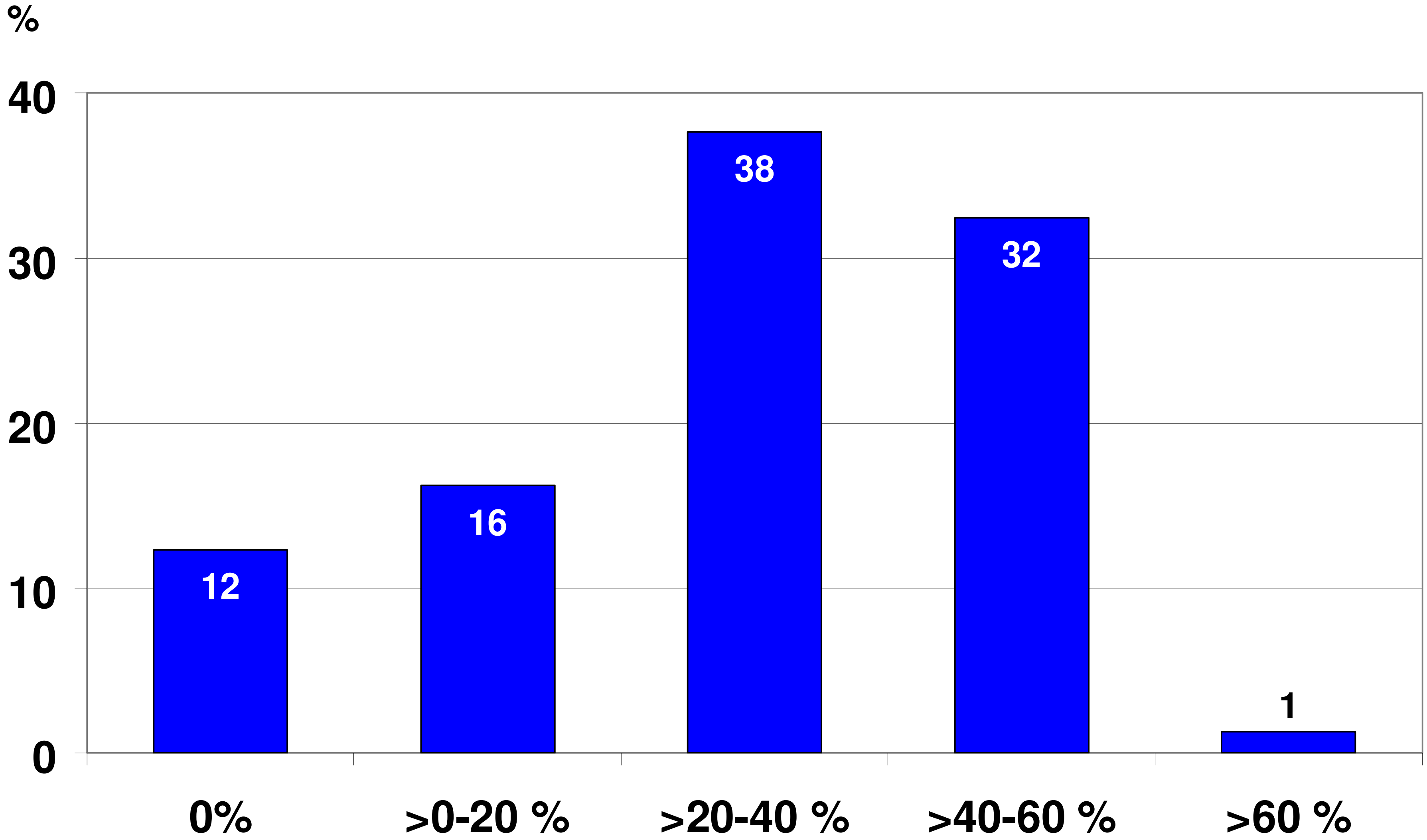
(von Fragstein et al. 2004)

| Area [ ha ] | S | N/W | E |
|---|---|---|---|
| >0 – 1 | 10 | 9 | 33 |
| >1 – 2,5 | 15 | 23 | 19 |
| >2,5 – 5 | 26 | 19 | 5 |
| >5 – 10 | 5 | 26 | 24 |
| >10 – 20 | 33 | 3 | 5 |
| >20 – 50 | 0 | 9 | 5 |
| >50 – 100 | 10 | 7 | 10 |
| >100 | 0 | 4 | 0 |
| Total | 39 | 74 | 21 |

| Organisation | S | N/W | E |
|---|---|---|---|
| Bioland | 56 | 85 | 29 |
| Biopark | 0 | 0 | 5 |
| Demeter | 36 | 11 | 24 |
| EU-Farm | 0 | 0 | 0 |
| Gäa | 0 | 1 | 43 |
| Naturland | 8 | 3 | 0 |
| Ökosiegel | 0 | 0 | 0 |
| Total | 39 | 74 | 21 |

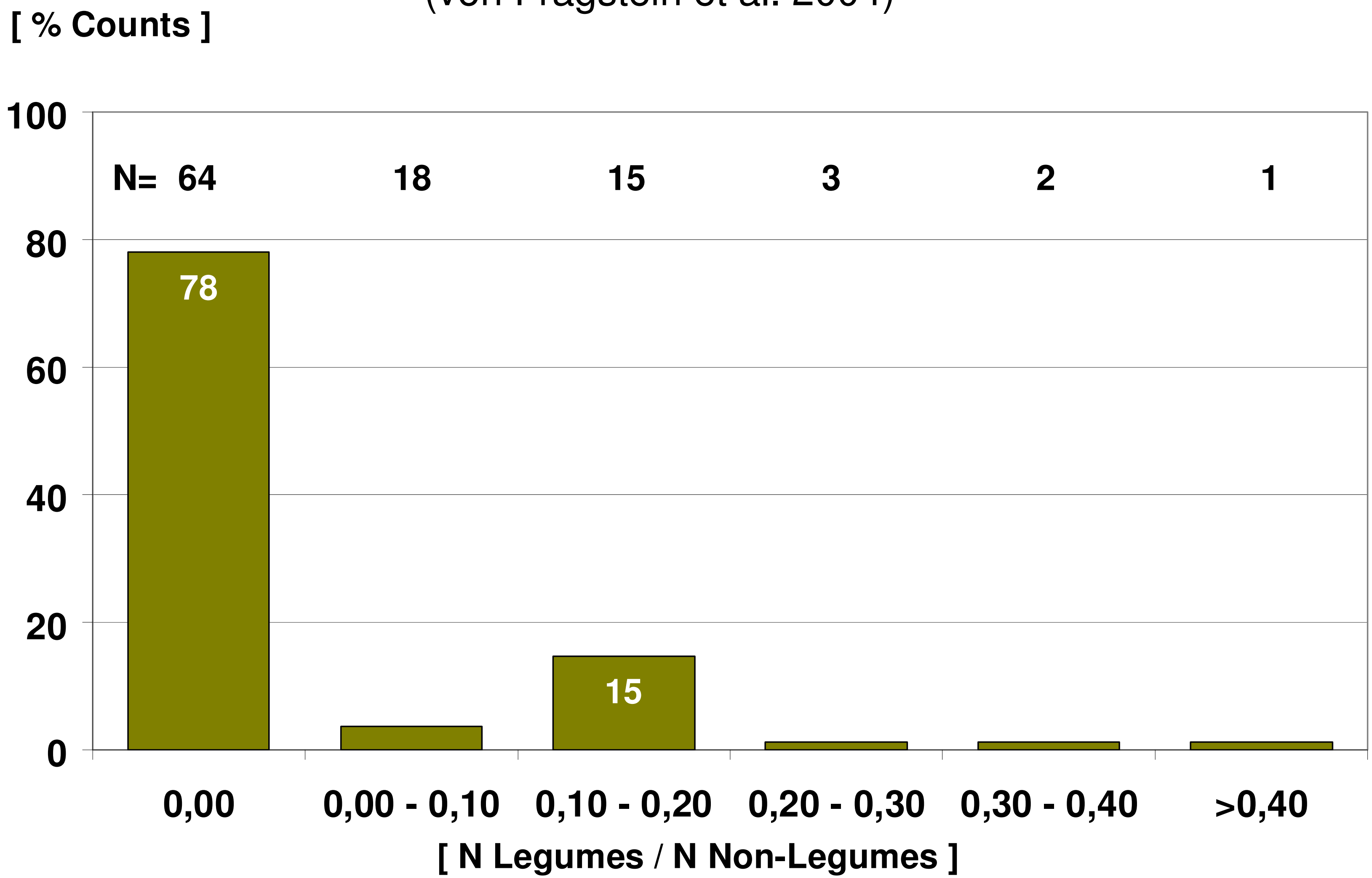
# Share of legumes in outdoor crop rotations

(von Fragstein et al. 2004)



# Ratio of legumes to non-legumes in crop rotations in sheltered production

(von Fragstein et al. 2004)



# Effects of different fertilisers (NPK vs. Composts & OF) on yield and nutrient uptake of field vegetables
## >> Crops & treatments
(von Fragstein et al. 1995)

| Year | Crop |
|---|---|
| 1987 | White cabbage |
| 1988 | Carrots |
| 1989 | Potatoes |
| 1990 | Beetroots |
| 1991 | Celeriac |

| Treatments | |
|---|---|
| CON | Control |
| N1PK | Mineral fertiliser N1PK |
| N2PK | Mineral fertiliser N2PK |
| SSC1 | Source separated compost |
| SSC2 | SSC1 (50 %) + OF |
| CMC1 | Cattle manure compost |
| CMC2 | CMC1 (100%) + OF |
| OF | Organic fertiliser (hornmeal) |

# Nutrient input through mineral and organic fertilisers
## (von Fragstein et al. 1995)

| Treatment | Unit [### / ha] | Year 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|
| **Control** | | 0 | 0 | 0 | 0 | 0 |
| **NPK 1** | kg N | 120 | 80 | 100 | 80 | 80 |
| | kg $P_2O_5$ | 100 | 80 | 80 | 80 | 80 |
| | kg $K_2O$ | 300 | 240 | 240 | 240 | 240 |
| **NPK 2** | kg N | 240 | 120 | 200 | 160 | 160 |
| | kg $P_2O_5$ | 100 | 80 | 80 | 80 | 80 |
| | kg $K_2O$ | 300 | 240 | 240 | 240 | 240 |
| **SSC 1** | t compost | **80** | **20** | **50** | **80** | **80** |
| **SSC 2** | t compost | **30** | **15** | **20** | **40** | **40** |
| | kg N | ***150*** | ***75*** | ***80*** | ***80*** | ***80*** |
| | kg $P_2O_5$ | 80 | 50 | 100 | 80 | 80 |
| | kg $K_2O$ | 200 | 100 | 100 | 120 | 120 |
| **CMC 1** | t compost | **50** | **20** | **40** | **50** | **50** |
| **CMC 2** | t compost | **50** | **20** | **40** | **50** | **50** |
| | kg N | ***120*** | ***75*** | ***80*** | ***80*** | ***80*** |
| **OF** | kg N | **150** | **75** | **80** | **80** | **80** |
| | kg $P_2O_5$ | 80 | 50 | 100 | 80 | 80 |
| | kg $K_2O$ | 200 | 100 | 100 | 120 | 120 |

SSC Source separated compost
CMC Cattle manure compost
OF Organic fertiliser (horn meal)

# Effect of off-farm and on-farm composts on yield and quality of field vegetables (Fragstein et al. 1995)

## >> *Chemical composition of cattle manure compost*

| Parameter | Unit | Minimum | Average | Maximum |
|---|---|---|---|---|
| **Dry matter** | [% FM] | 26.30 | **37.40** | 44.90 |
| **Volume** | [g $l^{-1}$ FM] | 606.00 | **833.60** | 962.00 |
| **pH value** | | 8.10 | **8.62** | 9.10 |
| **Conductivity** | [mS $cm^{-1}$] | 2.06 | **2.30** | 2.54 |
| **Salt** | [g KCl $l^{-1}$] | 9.27 | **10.35** | 11.43 |
| **Organic matter** | [% DM] | 28.60 | **41.80** | 55.10 |
| **$N_t$** | [% DM] | 1.31 | **1.85** | 2.30 |
| **$N_{min}$** | [% DM] | 0.04 | **0.05** | 0.05 |
| **C/N ratio** | | 13.30 | **14.70** | 17.10 |
| **$P_2O_5$** | [% DM] | 0.85 | **1.32** | 1.71 |
| **CAL-sol. $P_2O_5$** | [% $P_2O_5$] | 34.30 | **54.14** | 63.70 |
| **$K_2O$** | [% DM | 2.75 | **4.29** | 5.80 |
| **CAL-sol. $K_2O$** | [% $K_2O$] | 94.00 | **97.80** | 100.00 |
| **MgO** | [% DM] | 0.68 | **1.01** | 1.44 |
| **CaO** | [% DM] | 2.86 | **3.43** | 4.10 |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# Effect of off-farm and on-farm composts on yield and quality of field vegetables (Fragstein et al. 1995)

## >> *Chemical composition of source separated compost*

| Parameter | Unit | Minimum | Average | Maximum |
|---|---|---|---|---|
| **Dry matter** | [% FM] | 57.00 | **65.08** | 69.70 |
| **Volume** | [g $l^{-1}$ FM] | 731.00 | **797.40** | 1.008.00 |
| **pH value** | | 7.60 | **7.76** | 7.90 |
| **Conductivity** | [mS $cm^{-1}$] | 1.06 | **1.17** | 1.28 |
| **Salt** | [g KCl $l^{-1}$] | 4.67 | **5.15** | 5.62 |
| **Organic matter** | [% DM] | 23.60 | **26.72** | 29.10 |
| **$N_t$** | [% DM] | 0.94 | **1.23** | 1.39 |
| **$N_{min}$** | [% DM] | 0.04 | **0.06** | 0.08 |
| **C/N ratio** | | 10.90 | **12.76** | 14.60 |
| **$P_2O_5$** | [% DM] | 0.68 | **0.87** | 1.04 |
| **CAL-sol. $P_2O_5$** | [% $P_2O_5$] | 32.40 | **44.18** | 53.90 |
| **$K_2O$** | [% DM | 0.61 | **1.16** | 1.44 |
| **CAL-sol. $K_2O$** | [% $K_2O$] | 83.70 | **93.40** | 100.00 |
| **MgO** | [% DM] | 0.43 | **0.76** | 1.07 |
| **CaO** | [% DM] | 3.30 | **4.76** | 7.13 |

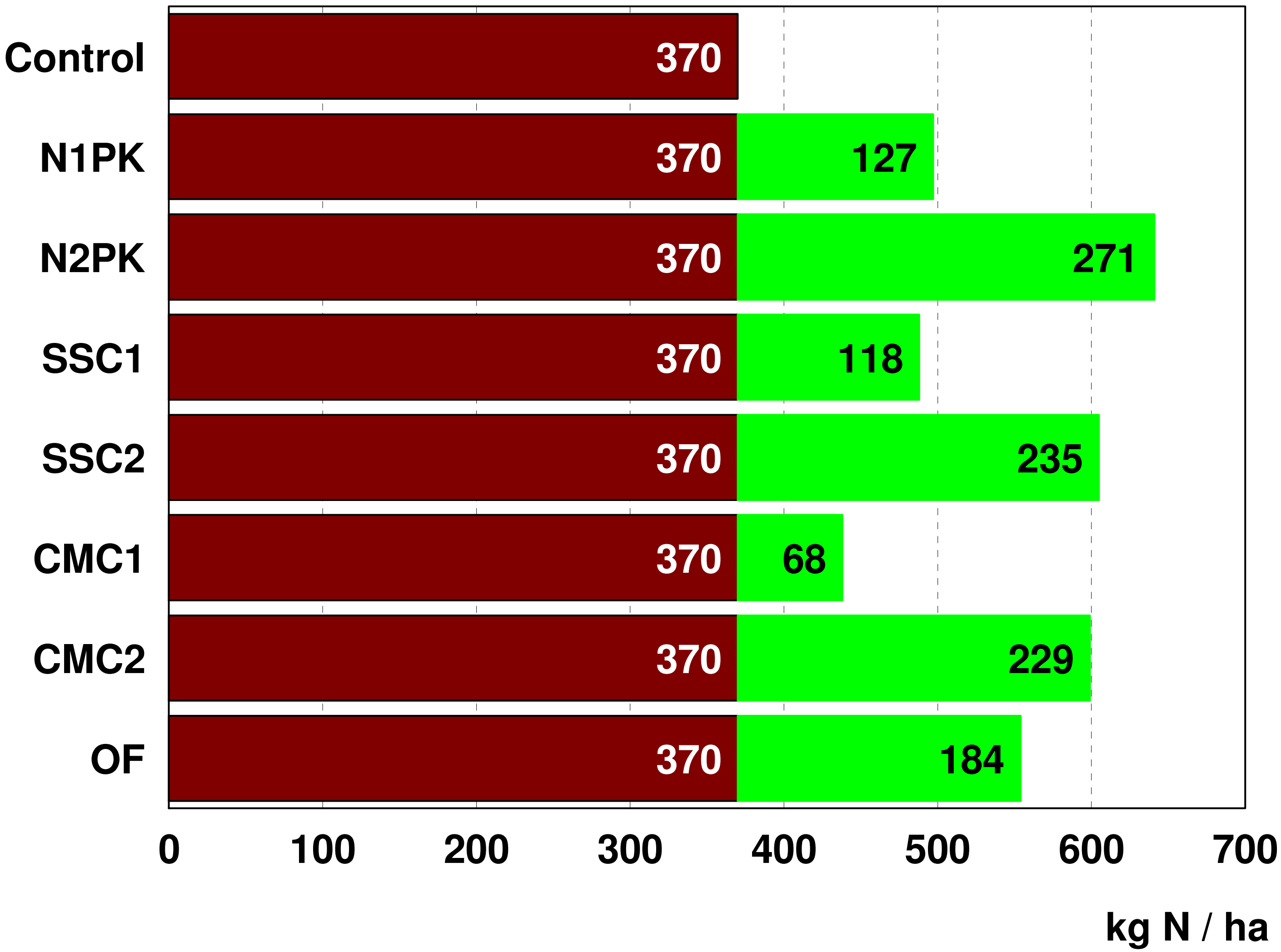
# DM-yield of field vegetables in response to fertilisers

(NPK vs. composts (& OF))

(von Fragstein et al. 1995)

| [t $ha^{-1}$] | 1987 | 1988 | 1989 | 1990 | 1991 | 1987-1991 | |
|---|---|---|---|---|---|---|---|
| | White cabbage | Carrots | Potatoes | Beetroots | Celeriac | Total | [ % control ] |
| Control | 8.1 | 6.9 | 6.9 | 5.4 | 2.2 | 29.5 | 100 |
| N1PK | 9.8 | 7.1 | 6.9 | 7.6 | 2.4 | 33.8 | 115 |
| N2PK | 9.8 | 7.2 | 7.2 | 9.0 | 3.3 | 36.4 | 123 |
| SSC1 | 8.9 | 7.0 | 7.3 | 8.3 | 3.9 | 35.3 | 120 |
| SSC2 | 10.2 | 7.3 | 7.3 | 8.8 | 2.9 | 36.5 | 124 |
| CMC1 | 8.2 | 6.6 | 7.4 | 7.3 | 2.9 | 32.3 | 110 |
| CMC2 | 9.5 | 7.5 | 7.1 | 9.9 | 3.4 | 37.4 | 127 |
| OF | 9.8 | 7.7 | 7.2 | 8.7 | 3.1 | 36.4 | 123 |

# N-uptake in response to fertilisers
## (sum of 5 crops cultivated from 1987 to 1991)
## (von Fragstein et al. 1995)



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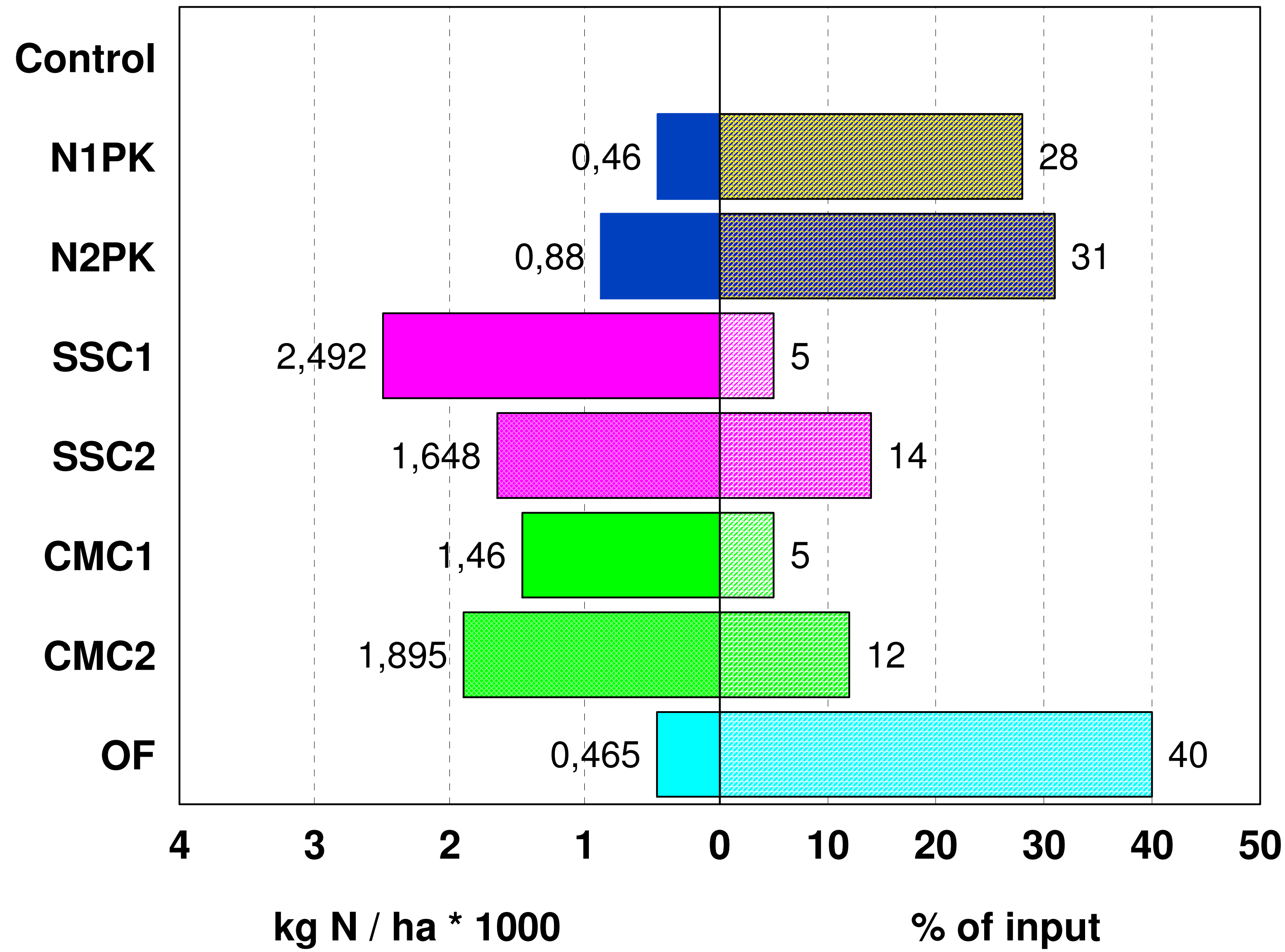
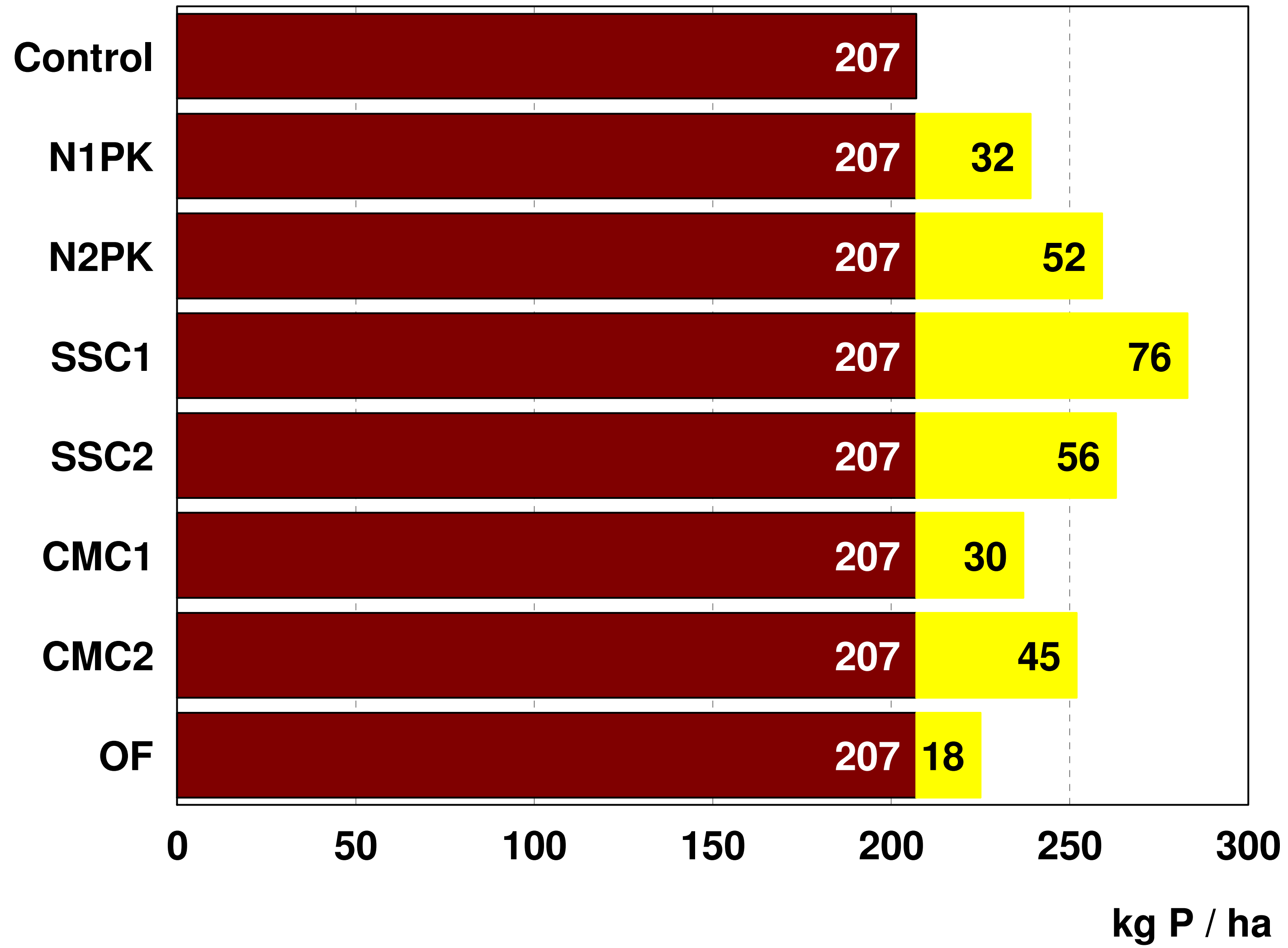
# N-input and N-efficiency in response to fertilisers
## (sum of 5 crops cultivated from 1987 to 1991)

## (von Fragstein et al. 1995)

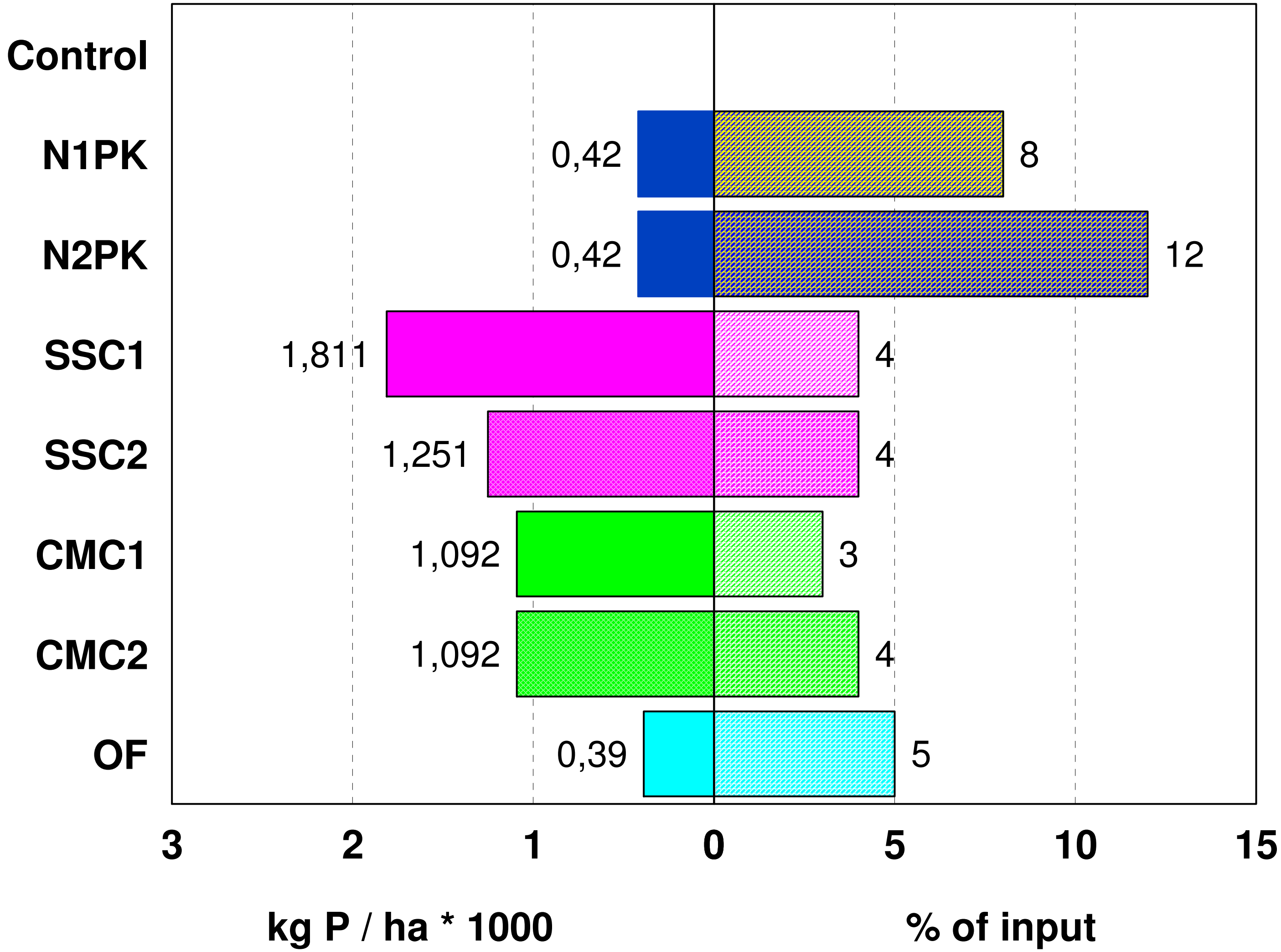


# P-uptake in response to fertilisers
## (sum of 5 crops cultivated from 1987 to 1991)
## (von Fragstein et al. 1995)



# P-input and P-efficiency in response to fertilisers
## (sum of 5 crops cultivated from 1987 to 1991)

## (von Fragstein et al. 1995)



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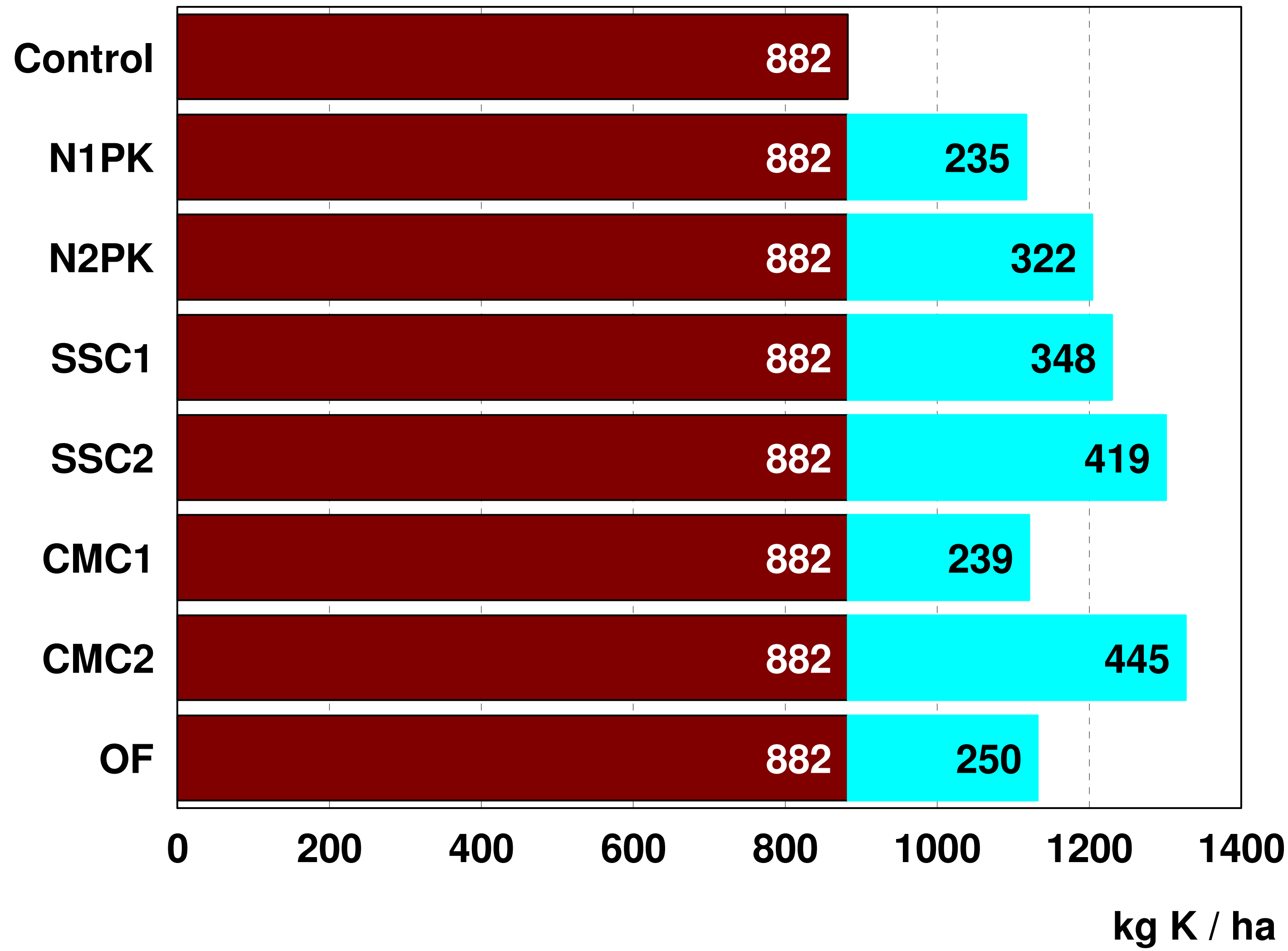
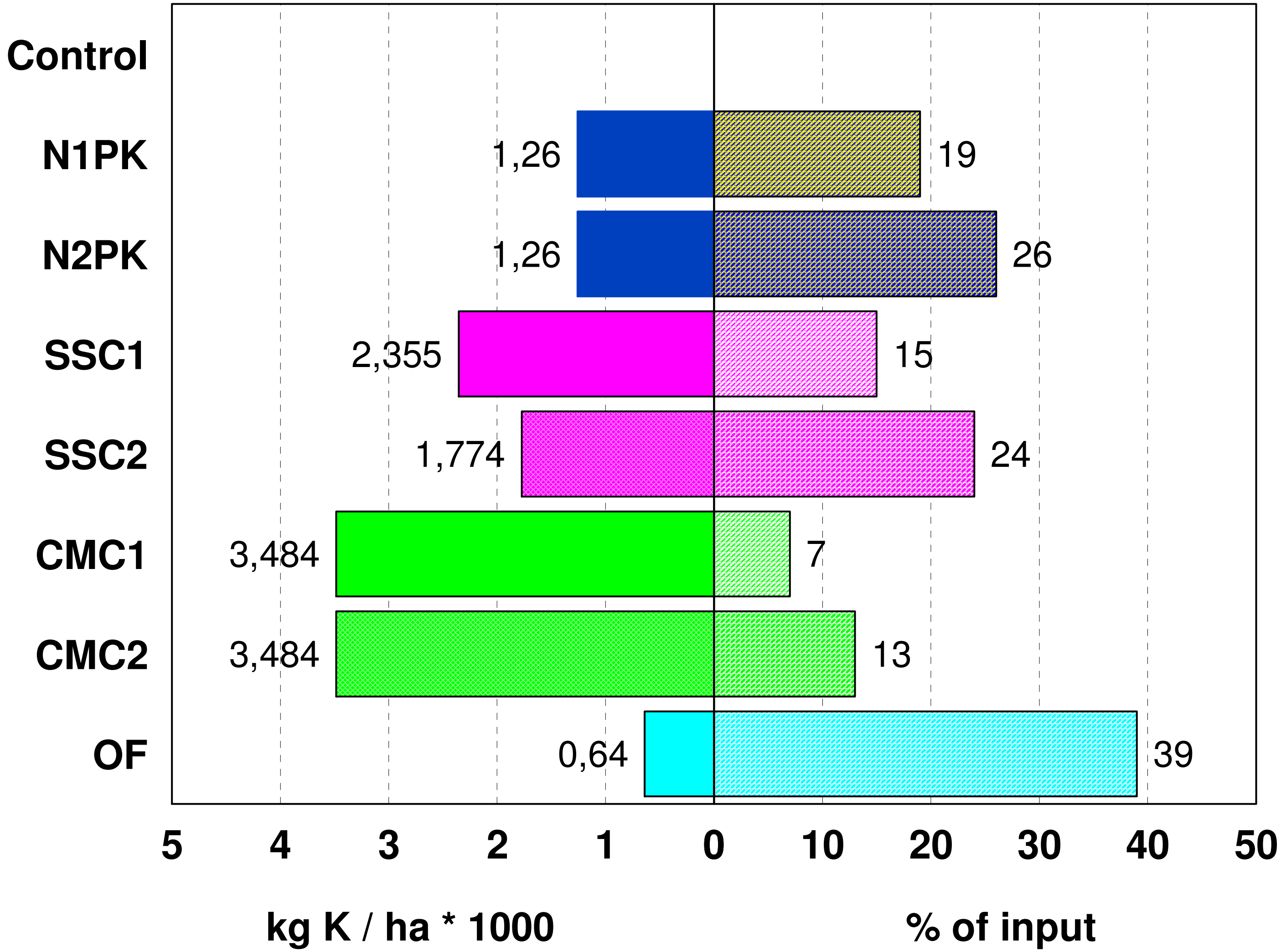
# K-uptake in response to fertilisers
## (sum of 5 crops cultivated from 1987 to 1991)
## (von Fragstein et al. 1995)



# K-input and K-efficiency in response to fertilisers
## (sum of 5 crops cultivated from 1987 to 1991)

## (von Fragstein et al. 1995)

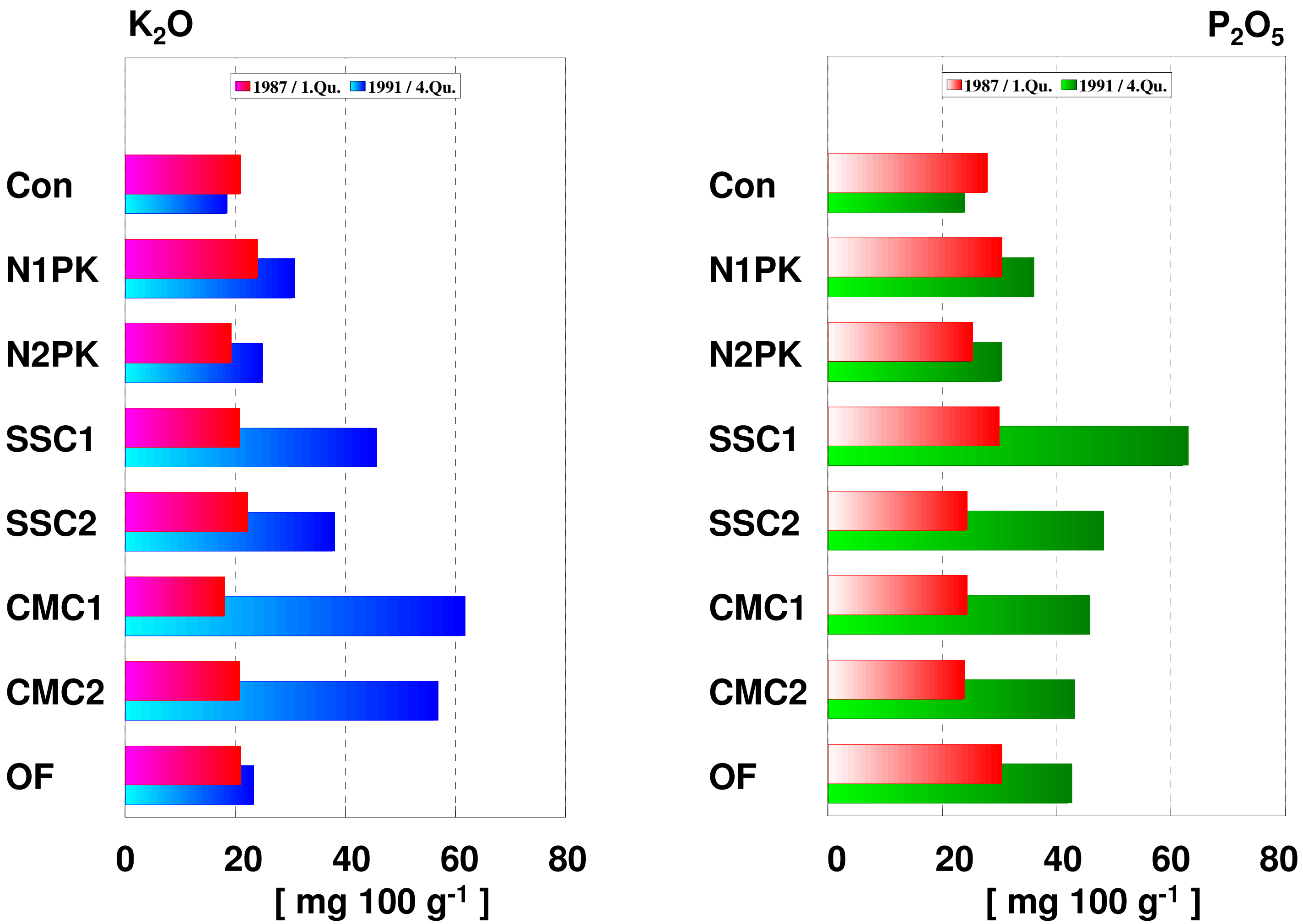


# Comparison of N shares – export, input and mobile sources

| Compost | $N_{export\ fert}$ | $N_{input\ fert}$ | | Compost-$N_{min}$ | | $N_{Horn\ meal}$ |
|---|---|---|---|---|---|---|
| SSC 1 | 118 | 115 | = | 115 | | |
| SSC 2 | 235 | 239 | = | 55 | + | 184 |
| CMC 1 | 68 | 39 | = | 39 | | |
| CMC 2 | 229 | 223 | = | 39 | + | 184 |

# DL-soluble K- and P-content 5 years after annual applications of different nutrient sources

**(Fragstein et al. 1995)**



# Effect of different nutrient sources on the Transfer of Cd and Zn after 5 years annual application

| Cd<br>Fertiliser | Input<br>[ g $ha^{-1}$ ] | $Uptake_{total}$<br>[ g $ha^{-1}$ ] | $Uptake_{fert}$<br>[ g $ha^{-1}$ ] | Efficiency<br>[ % ] |
|---|---|---|---|---|
| Con | 0.00 | 4.21 | 0.00 | 0.00 |
| N2PK | 10.00 | 7.39 | 3.18 | 30.40 |
| SSC1 | 93.53 | 4.46 | 0.25 | 0.27 |
| CMC1 | 35.65 | 4.29 | 0.08 | 0.22 |

| Zn<br>Fertiliser | Input<br>[ g $ha^{-1}$ ] | $Uptake_{total}$<br>[ g $ha^{-1}$ ] | $Uptake_{fert}$<br>[ g $ha^{-1}$ ] | Efficiency<br>[ % ] |
|---|---|---|---|---|
| Con | 0.00 | 526.47 | 0.00 | 0.00 |
| N2PK | 2682.48 | 807.89 | 281.42 | 10.49 |
| SSC1 | 41909.43 | 679.29 | 152.82 | 0.36 |
| CMC1 | 8036.15 | 570.38 | 43.91 | 0.55 |

## Pro | Contra

# Source separated compost

**Pro**

- Off-farm humus- and nutrient cycling
- Soil improvement
- Optimisation of nutrient balances
- Less use of limited resources (i.e. rock phosphate)

**Contra**

- Unwanted pollutants
- Not foreseeable development of contamination
- Accumulation of heavy metals and xenobiotics
- Environmental impact through overdosaging
- Potential contamination by GMO‘s

# Demands

- Continuous control of process regulation (Compost plant)
- Continuous control of end product (Source separated composts)

- Reduction of pollutants in compost components and compost processes
- Support of compost use by financial programs and accompanying research

# Necessity for legume-based N-sources in Organic horticulture?

1. **Concept of on-farm nutrient cycling**

| | |
|---|---|
| ***Synthetic N fertilisers:*** | ***not allowed*** |
| ***Use of purchased N:*** | ***limited to 110 kg N $ha^{-1}$ $a^{-1}$*** |
| | ***for field vegetables (= 1,4 MU $ha^{-1}$)*** |
| ***N-supply for crops:*** | ***mainly through N-fixation*** |

2. **Short-fall of N-provision in early spring**

    ***N-mineralisation of organic matter not sufficient***

3. **High proportion of small scale and stockless organic market gardens**

    ***no access to on-farm manure sources***

    ***limitations for soil fertility improving crops***

    ***need for purchase of N fertilisers***

# Permitted N-fertilisers

| Annex II<br>EU dec. 2092/91 | German standards<br>In response to BSE<br>& further considerations |
|---|---|
| Animal based fertilisers | ~~blood meal, meat meal~~, horn meal |
| Plant based fertilisers | ~~seed cake (castor, rape)~~ |
| Microbe based fertilisers | dried fermentation residues **(?)** |

# Consequences for organic N-management

- **Rely more on plant based N sources that suit better for principles of Organic Agriculture**
  - On-farm production
  - Production on other organic farms (including farms in conversion)
  - Regional production to avoid global transports

- **Use seeds as fertilisers**
  - (precrop effect of incorparated seedlings)
  - Nutrient shifting through the application of crushed seeds on other fields

# Aims

- **Effect of plant based organic fertilisers on organically grown vegetables**
- **Differences between legume species**
- ***Microbial processes***
- **Soil-N after harvest**

# Plot trial 2003

Hessian State Estate
Frankenhausen

Central Germany: 51°25'N, 9°25'E

Soil
Cumuli Anthrosol Ut3

| | |
|---|---|
| $pH_{CaCl2}$ | 7.2 |
| $C_t$ | 1.4 % |
| $N_t$ | 0.15 % |
| $P_2O_5$ | 27 mg 100 $g^{-1}$ |
| $K_2O$ | 19 mg 100 $g^{-1}$ |
| Mg | 9 mg 100 $g^{-1}$ |


# Plot trial 2003

Hessian State Estate
Frankenhausen

Central Germany: 51°25'N, 9°25'E


Crop sequence

2002 winter rye (*Secale cereale* L.) //
blue lupin (*Lupinus angustifolius* L.)
& tansy phacelia (*Phacelia tanacetifolia* Benth.)

2001 winter wheat (Triticum aestivum L.)

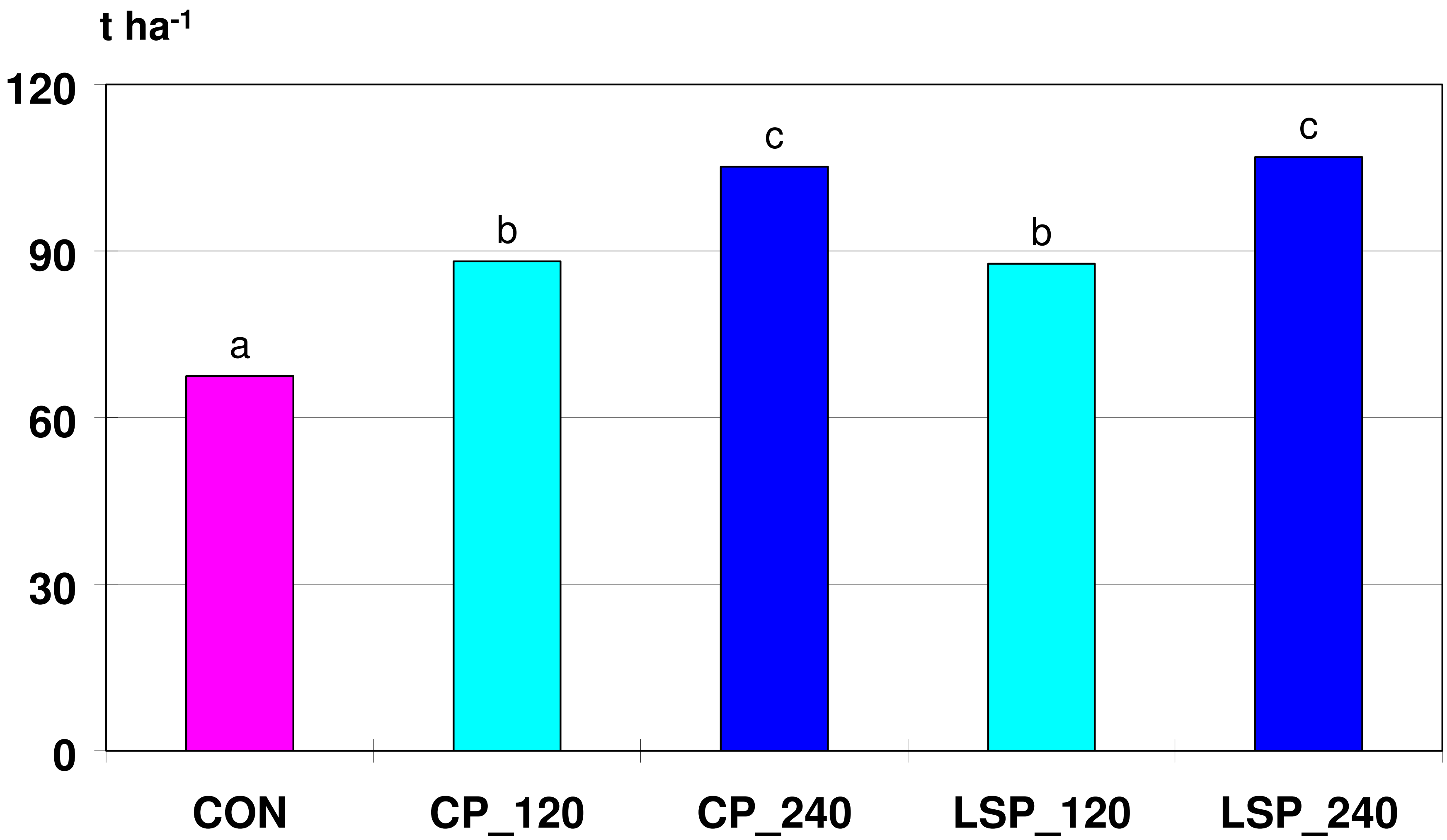
# Chemical composition of used fertilisers

| Fertiliser | $C_t$ [%DM] | $N_t$ [%DM] | $C_t/N_t$ | Van Soest analysis | | |
|---|---|---|---|---|---|---|
| | | | | Lignin [%DM] | Hemi-cellulose [%DM] | Cellulose [%DM] |
| Castor pomace | 48.2 | 5.7 | 8.5 | 31.3 | 9.7 | 9.1 |
| Lupin seed pellet | 45.3 | 6.6 | 6.9 | 1.6 | 3.9 | 16.2 |
| Faba bean seed pellet | 43.8 | 4.6 | 9.6 | 1.7 | 18.2 | 11.3 |
| Phytoperls® | 41.3 | 8.0 | 5.2 | 31.1 | 20.7 | 1.2 |

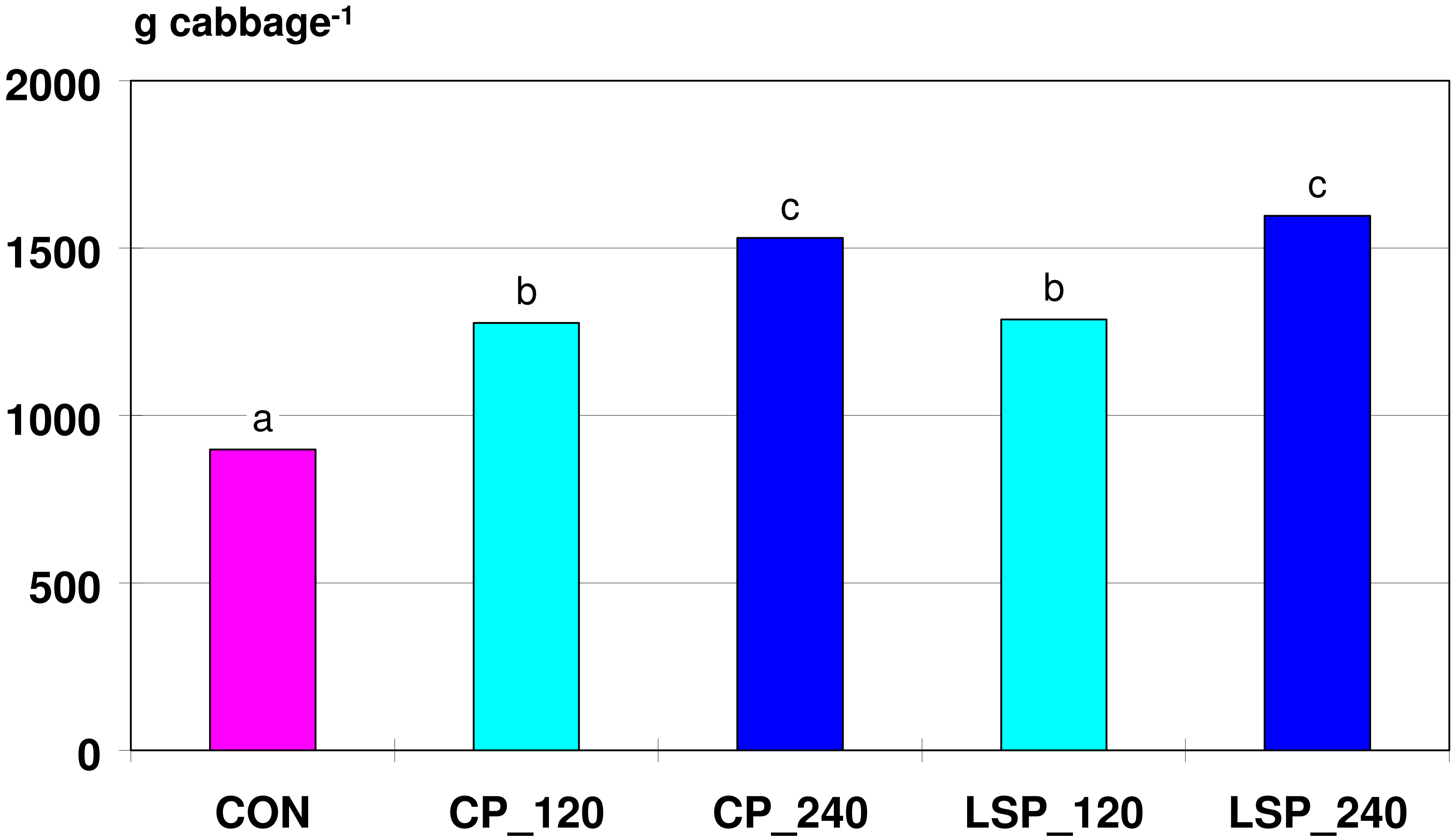
# Records of the field trials

| | White cabbage | Radishes |
|---|---|---|
| **Cultivar** | ***Sunta F1*** | ***Raxe*** |
| **Fertilization** | **04.04.2003** | **25.03.2003** |
| **Sowing/Planting** | **11.04.2003** | **08.04.2003** |
| **Harvest** | **17.06.2003** | **12.05.2003** |
| **Plot size** | **3 x 6 m²** | **3 x 5 m²** |
| **Replicates** | **5** | **4** |
| **Treatments** | **5** | **9** |
| **N-level** | **0, 120, 240 kg N $ha^{-1}$** | **0, 80, 140 kg N $ha^{-1}$** |
| **Fertiliser** | **Castor pomace (CP)** | **Castor pomace (CP)** |
| | **Lupin seed pellet (LSP)** | **Lupin seed pellet (LSP)** |
| | | **Faba bean seed pellet (FSP)** |
| | | **Phyto perls® (PP)** |
| **Parameters for assessment** | **Yield, N-content, nitrate content and N yield** | |
| **Statistical calculations** | **Analyses of variance, HSD (Tukey test, p☼0.05)** | |

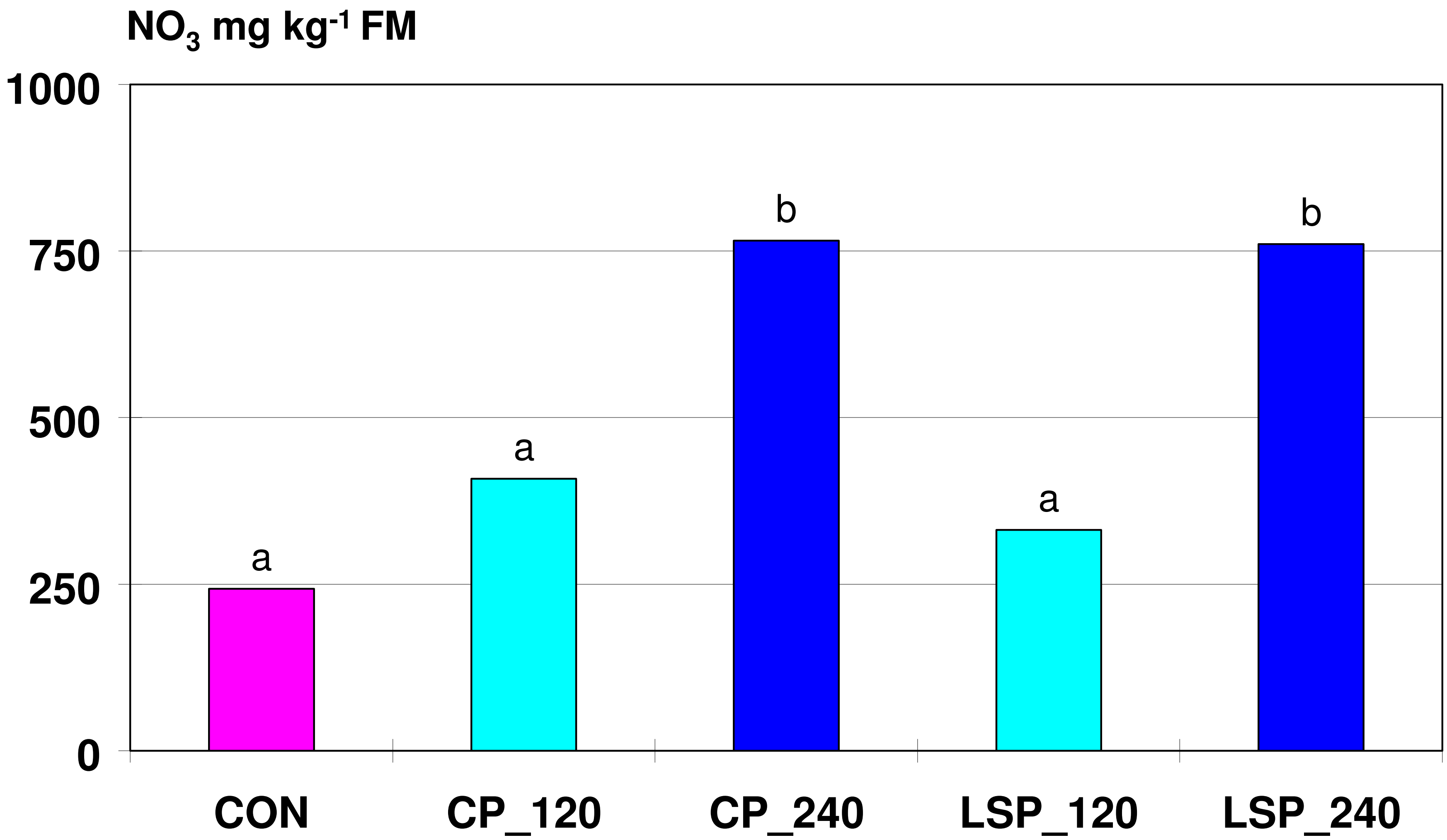
# Cabbage trial – raw FM yield



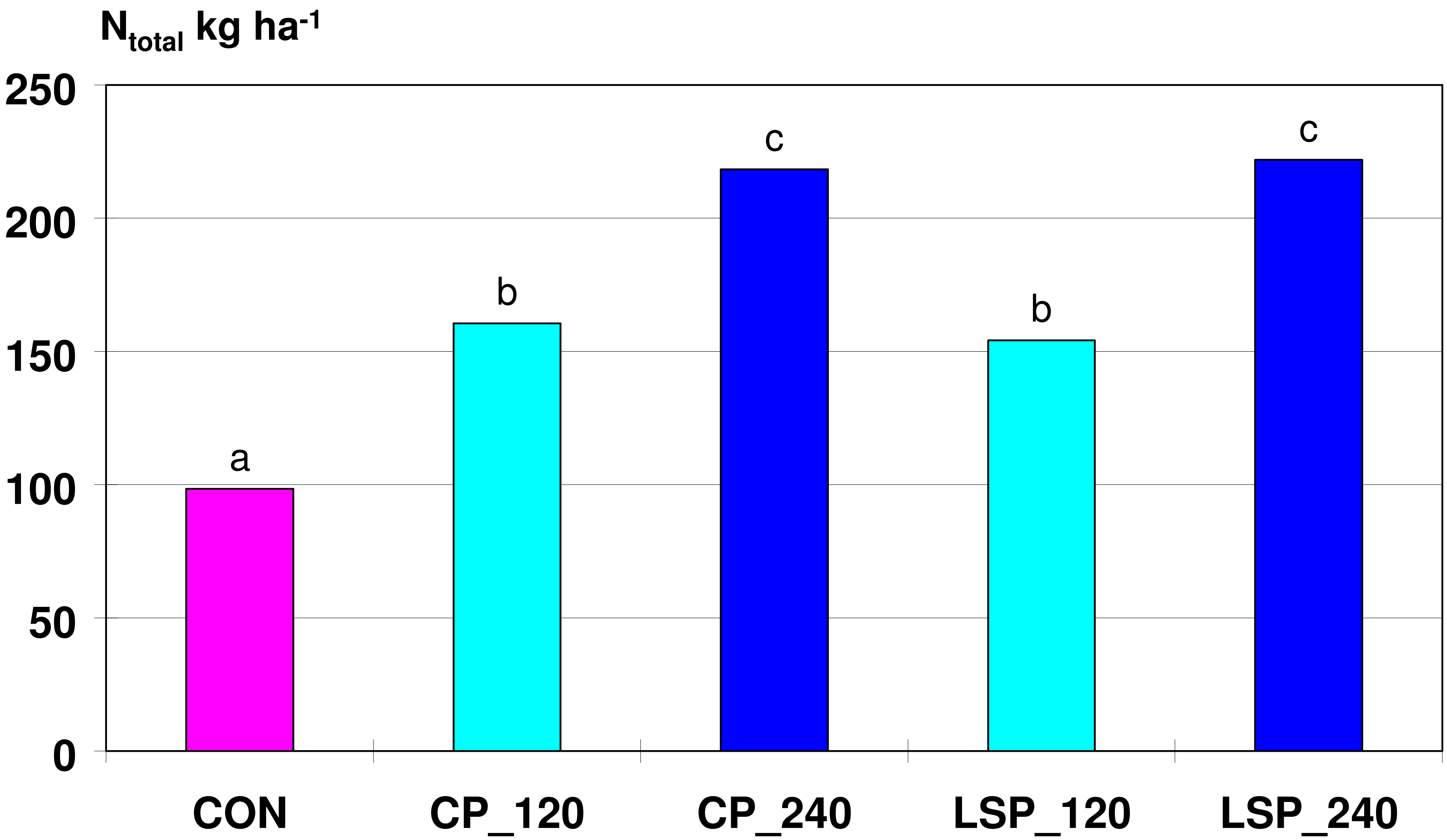
# Cabbage trial – Weight per cabbage



# Cabbage trial – Nitrate content



# Cabbage trial – N uptake







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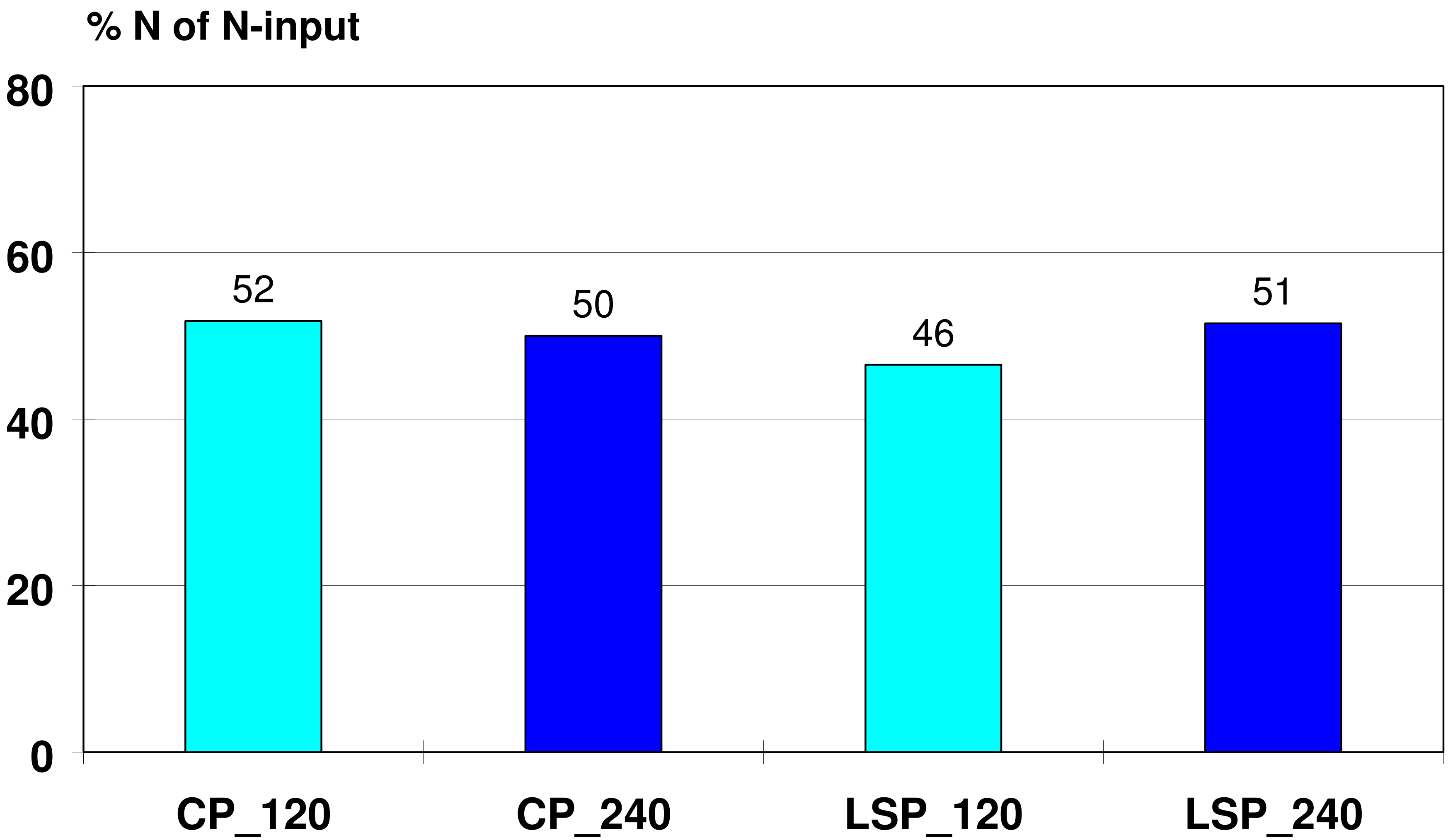
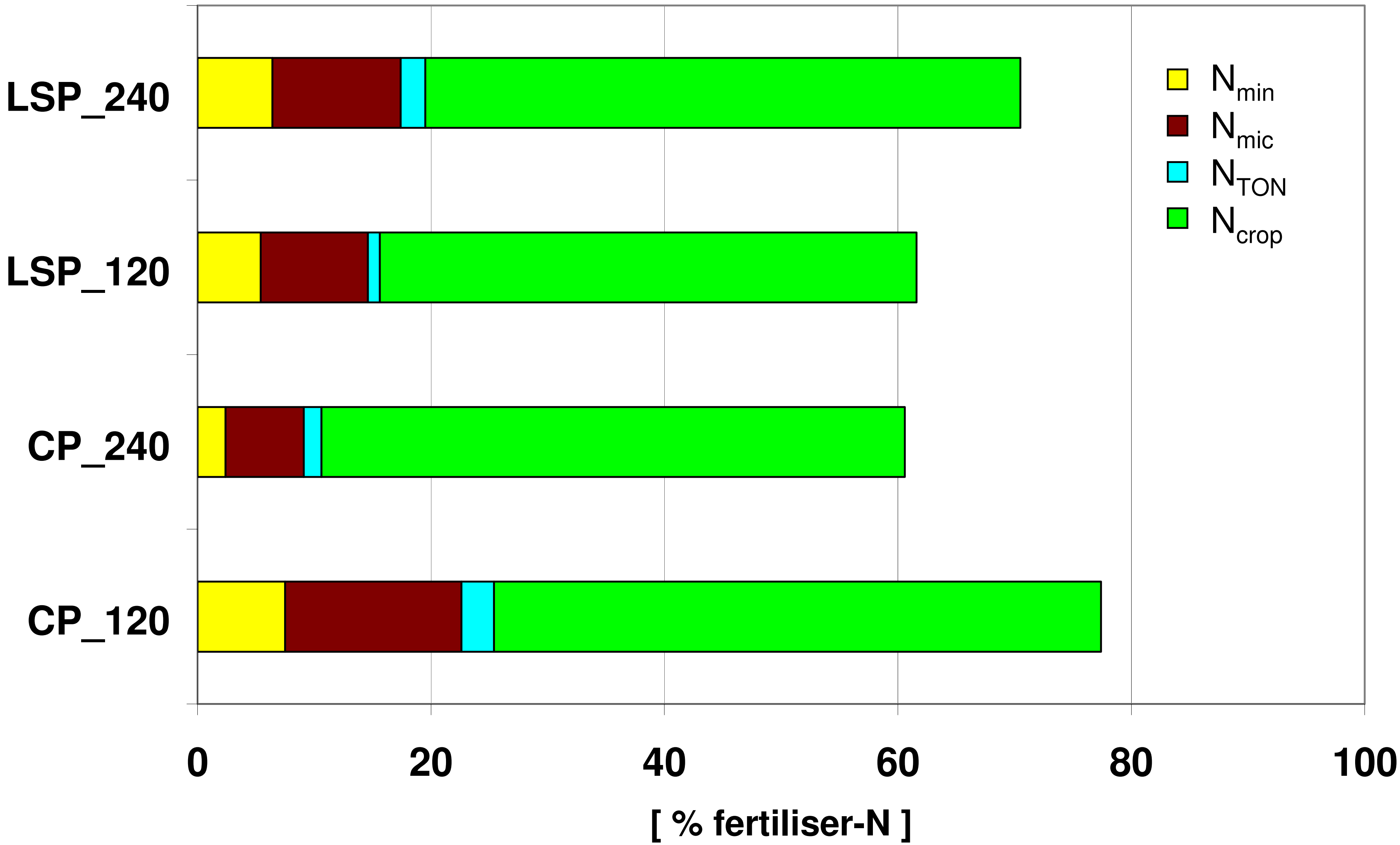
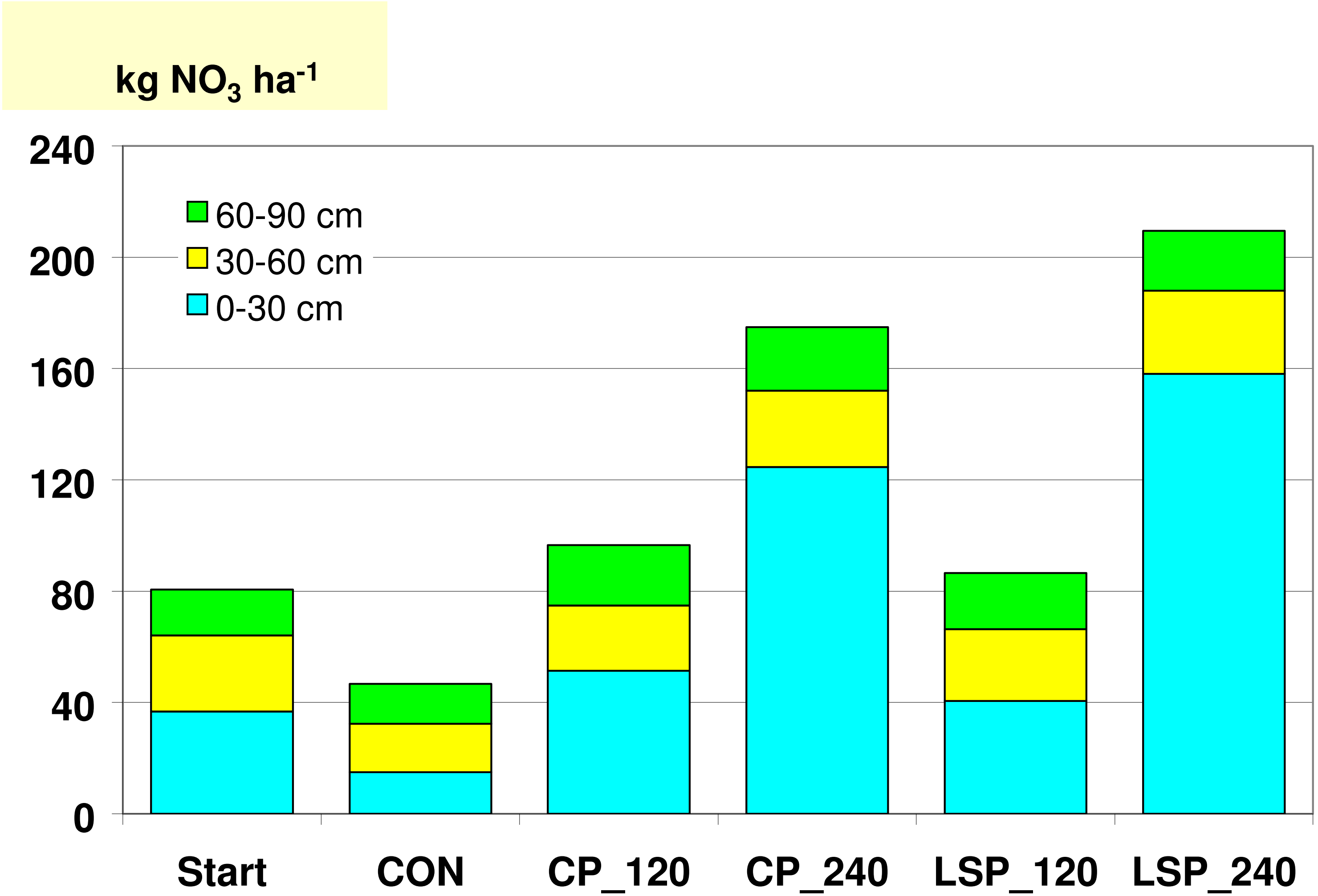
# Cabbage trial – N-efficiency



# Cabbage trial – Fertiliser-N



# Cabbage trial – $N_{min}$ after harvest



# Conclusions

- Leguminous seed pellets as plant based organic fertilisers — Valid alternative for organic (questionable) fertilisers

  Better correspondance to original concepts of organic farming

- Valid N source for early spring cultivation — higher mineralisation rates compared to castor pomace or horn meal

- Legume species — Lupin >> faba bean

- Soil-N after harvest — Increased amounts of $N_{min}$

***Adequate rotational management***

- ***to conserve mobil N for succeeding crops***
- ***to avoid economic losses***
- ***to minimise negative environmental impacts***

# Thank you

# for

# your interest