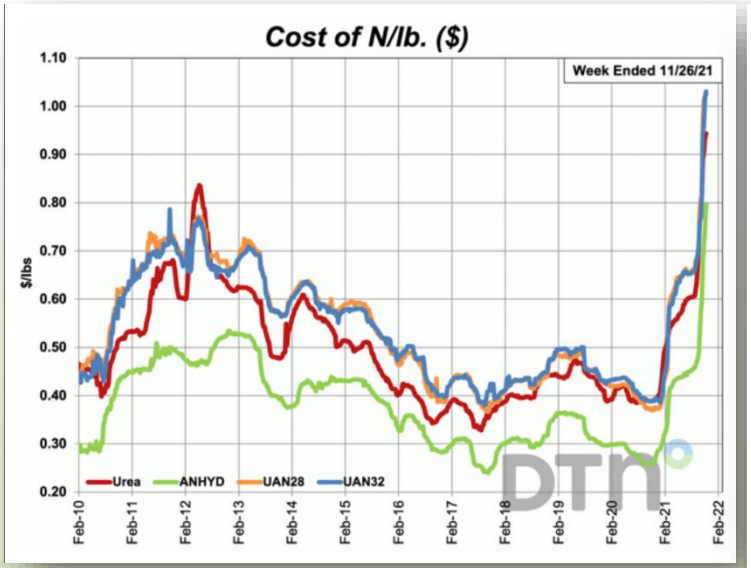
Digestate to fertilizers

Ksawery Kuligowski, Adam Cenian, Izabela Konkol, Lesław Świerczek

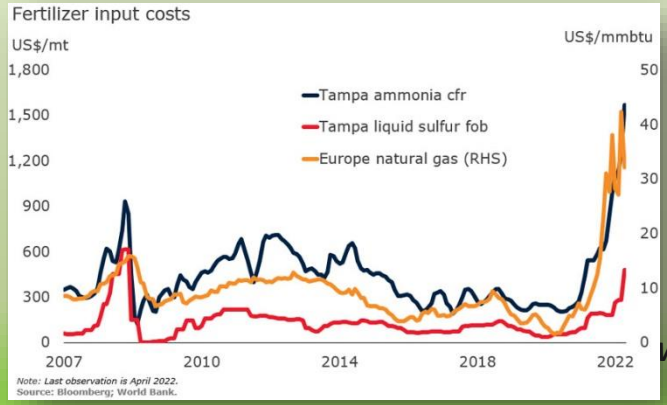
Institute of Fluid-Flow Machinery Polish Academy of Sciences

WASTEMAN ***Integrated Sustainable Waste Management Systems decreasing pollution discharges in the South Baltic area.***

Before we start

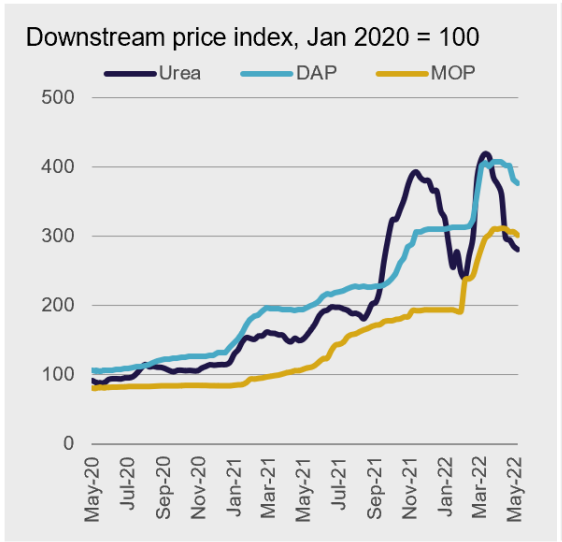


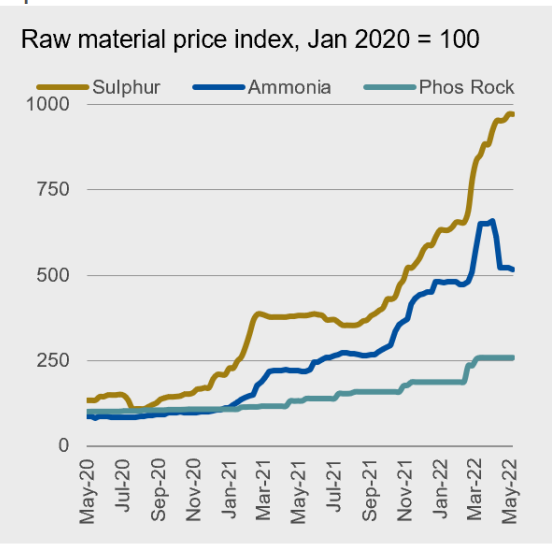
https://farmpolicynews.illinois.edu/2021/12/fertilizer-prices-continue-to-climb-2022-planted-acreage-analysis-continues/



https://blogs.worldbank.org/opendata/fertilizer-prices-expected-remain-higher-longer

CRU downstream and raw material fertilizer price index





DATA: CRU. NOTE: Key benchmark prices consolidated to trade weighted index.

NOTE: Urea and DAP index adjusted from 18 November to exclude China price and trade weight

NOTE: Ammonia index adjusted from 14 April to exclude Black Sea price and trade weight and again on 28 April to exclude Baltic Sea price and trade weight

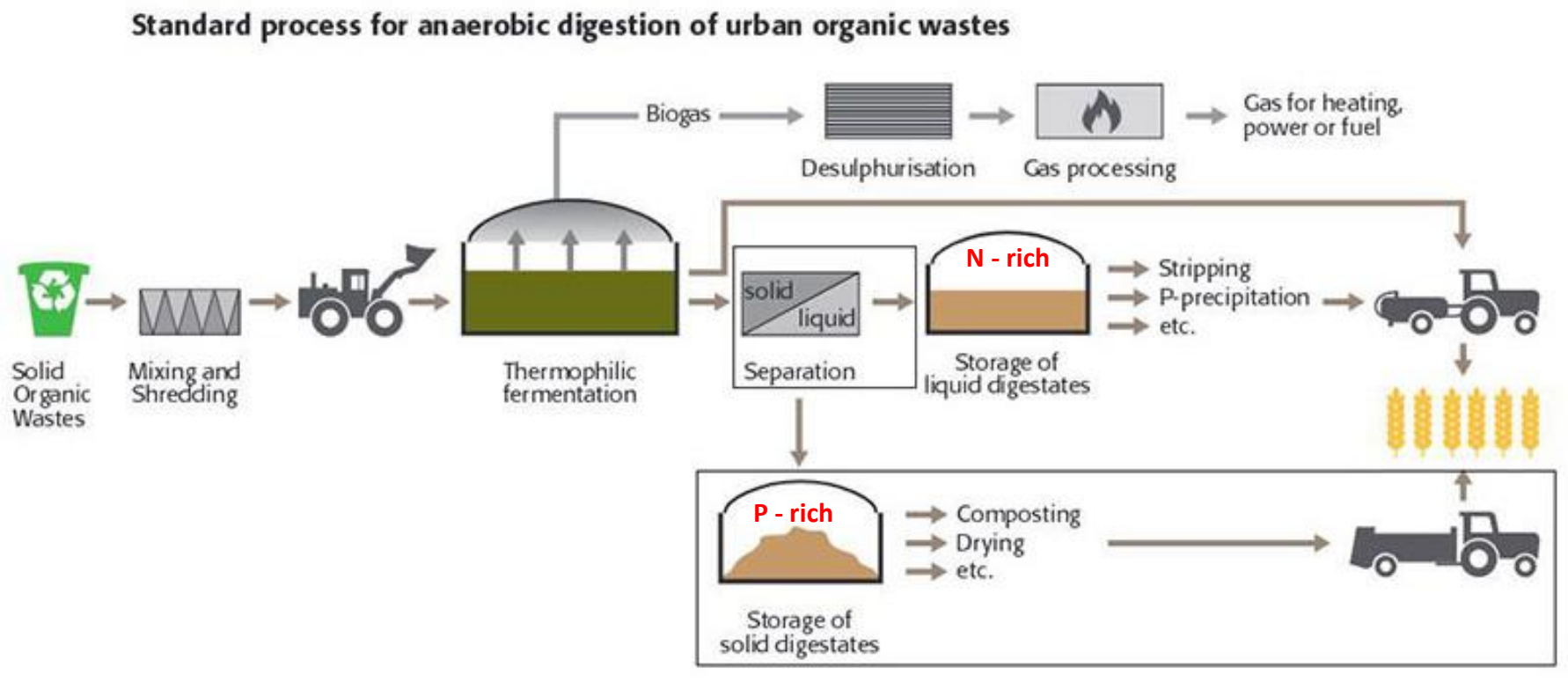
https://mobile.twitter.com/fertilizerweek1

Waste Management Systems decreasing pollution discharges in the South Baltic area.

Presentation Plan

- Why digestates?
- Biowaste from source separation: national scale
- Biowaste legislation issues,
- IMP experience in waste-to-fertilizers,
- Kitchen waste based fertilizers – our idea,
- Social readiness for usage of such fertilizers,
- Economics aspects of the potential implementation
- Summary

How to produce it?

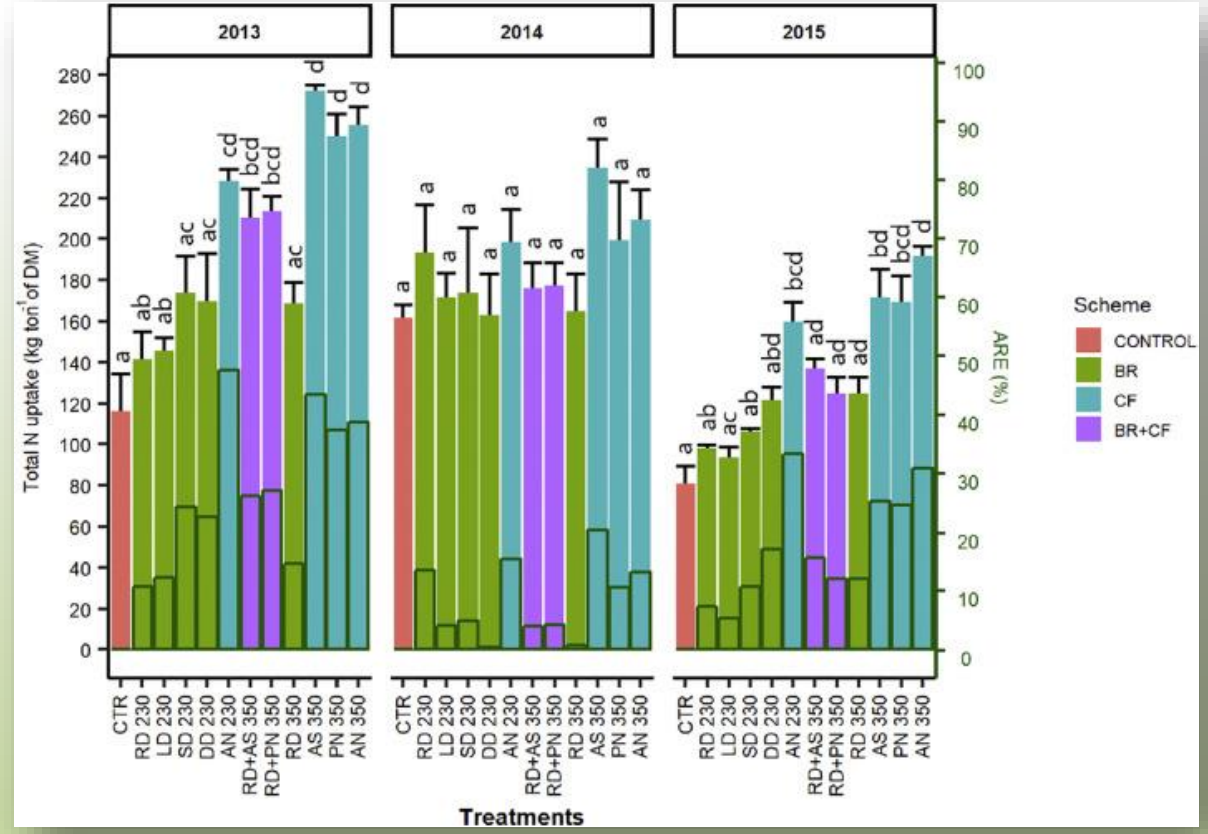


https://www.fertilizer-machines.com/solution/fertilizer-technology/biogas-digestate-compost-fertilizer-produ.html

What is it?

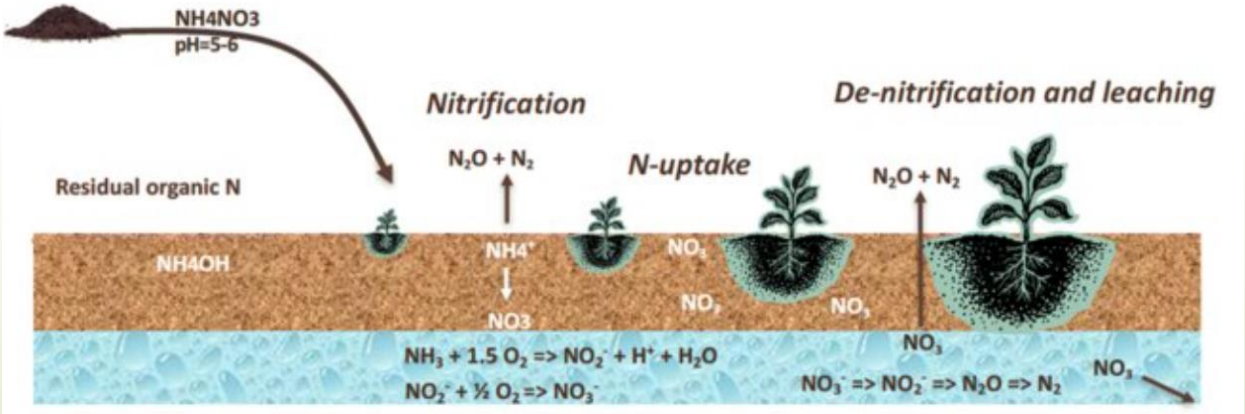
Feature	Digestate
Definition	Anaerobic fermentation residue after biogas production in 3 forms: liquid, solid, fibre.
Materials	Manures, slurries, food wastes, alcohol production by-products, manures and crops
Advantages	Stabilized organic matter and mineralized nutrients, easy to handle, less odorous
Composition	organic matter 36-49%, humic acid 10-24%, protein 5-9%, **N** 0.8-1.5% (<**30% N is N-NH^{4+}**), **P** 0.4-0.6%, **K** (0.6-1.2%)
Applied technologies	Composting, Dewatering (liquid: 1-6% d.m. and solid: 20-40% d.m.), Granulation, Microbial enhancement/ incubation! (a novel approach)
Product composition	3.6% N, 2.2% P_2O_5 6.8% K_2O (Biovakka Suomi Oy Biogas Plant, Finland)
Cautions	High NH_3 emissions (70% of N), ammonium rich - digestates has to be treated (N – removed) prior to use, i.e. its direct injection should be acidified

Why is it so good?



Bella Tsachidou, Marie Scheuren, Jérôme Gennen, Vincent Debbaut, Benoît Toussaint, Christophe Hissler, Isabelle George, Philippe Delfosse:
Biogas residues in substitution for chemical fertilizers: A comparative study on a grassland in the Walloon Region
Science of The Total Environment, Volume 666, 20 May 2019, Pages 212-225, https://doi.org/10.1016/j.scitotenv.2019.02.238

Theory behind



David B. Graves, Lars Bakken, Morten B. Jensen, Rune Ingels: **Plasma Activated Organic Fertilizer**, Springer, January 2019, Plasma Chemistry and Plasma Processing 39(5), DOI: 10.1007/s11090-018-9944-9

- Application of biogas digestate, containing mainly ammonium nitrate, typically has a pH of about 5–6.
- The delivered nitrate will be immediately available to plants, allowing 'just-in-time' application,
- The remaining solvated ammonium hydroxide (NH_4OH) will be nitrified by soil bacteria to form nitrate (NO^{3-}) and volatile nitrous oxide (N_2O),
- But with less emissions because the ammonium concentration is reduced,
- Excess nitrate will still be lost either by denitrification (right) or by leaching to groundwater,
- Denitrification adds to the undesirable (N_2O) loss, but the acidic conditions may reduce the action of the denitrification bacteria, thus reducing N_2O emissions

Can we make it look so nice?

https://biovoima.com/en/solutions/digestate-post-treatment

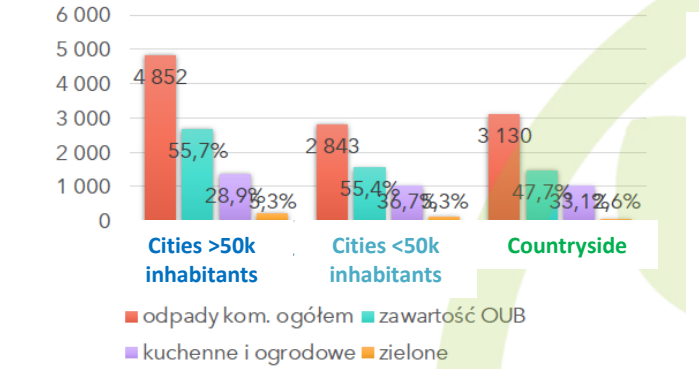
Biowaste and municipal waste

Goals: 25% (2022), 35% (2023), 45% (2024), 55% (2025)

Source: „Szkolenia praktyczne - selektywna zbiórka bioodpadów dla kadry kierowniczej samorządu terytorialnego, liderów lokalnych, NGO", 26.03.2021, Ministerstwo Klimatu i Środowiska, Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej

Biowaste: city and countryside

Waste Amounts in Poland

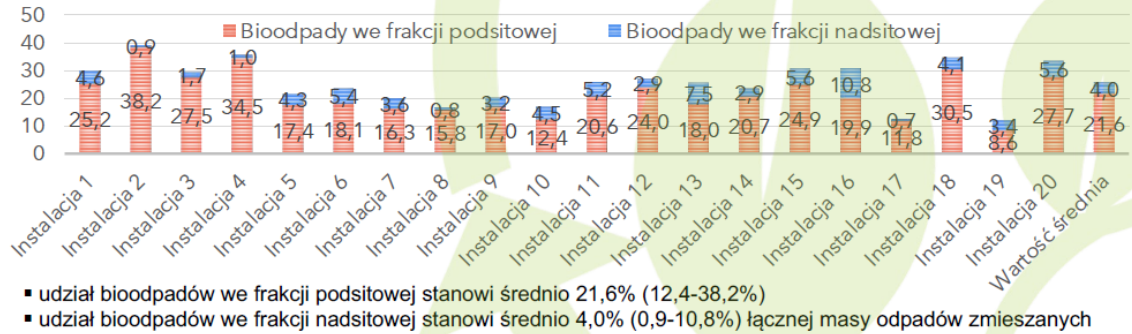


Biowaste in MSW:

4 M tonnes, including

3.5 M tonnes kitchen waste and

0.5 M tonnes green waste,
5.9 M biodegradable waste tonnes (55% MSW)



- udział bioodpadów we frakcji podsitowej stanowi średnio 21,6% (12,4-38,2%)
- udział bioodpadów we frakcji nadsitowej stanowi średnio 4,0% (0,9-10,8%) łącznej masy odpadów zmieszanych

Source: „Szkolenia praktyczne - selektywna zbiórka bioodpadów dla kadry kierowniczej samorządu terytorialnego, liderów lokalnych, NGO", 26.03.2021, Ministerstwo Klimatu i Środowiska, Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej

Legal aspects – source separation!

Directive 2008/98 / EC of the European Parliament and of the Council of 19 November 2008 on waste:

art. 3

For the purposes of this Directive, the following definitions apply:

"bio-waste" means biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, wholesalers, canteens, caterers and retailers, and comparable waste from food processing plants (point 4).

art. 22 sec. 1

Member States shall ensure that **by 31 December 2023** and subject to Art. 10 sec. 2 and 3 bio-waste was **separated and recycled at source or collected separately and not mixed** with other types of waste.

art. 11 sec. 4

From 1 January 2027, Member States may **only count** municipal bio-waste undergoing aerobic or anaerobic treatment **as recycled** waste if it has been **separately collected or separated at source** in accordance with Art. 22.

Legal aspects - fertilizers

Generally there are no strictly biological treatment requirements, but:

- BAT requirements for composting and fermentation
- veterinary regulations - requirements for the processing of the so-called Category III (kitchen waste containing animal fractions)
- requirements resulting from the applicable (Act on fertilizers and fertilization) and proposed regulations regarding the product (compost, digestate used for natural purposes)

The most advantageous option is to obtain the status of an organic fertilizer or a soil conditioner.

Solid organic fertilizers

- min. 30% of organic matter in dry matter,
- 0.3% by mass of total nitrogen,
- 0.2% by mass of phosphorus expressed as P_2O_5,
- 0.2% by mass of potassium expressed as K_2O.
- limit values for heavy metals,
- live eggs of intestinal parasites (Ascaris sp., Trichuris sp., Toxocara sp.) and bacteria of the genus Salmonella must not be present.

IMP research on biofertilizers

- Production of test batches of (1) pellets from bio-waste EM incubated and (2) digestate from biogas production from bio-waste, (3-6) other treatments,
- Effect of fertilizer dose on the grass yield (winter, summer),
- Effect of fertilizer dose on nitrogen uptake (winter, summer),
- Effect of fertilizer dose on soil quality (winter, summer)
- Influence of temperature sterilization and double dose of EM (summer)
- Determining the social readiness to apply the above-mentioned bio-waste based fertilizers and its economics

Waste-to-Fertilizer suggestion

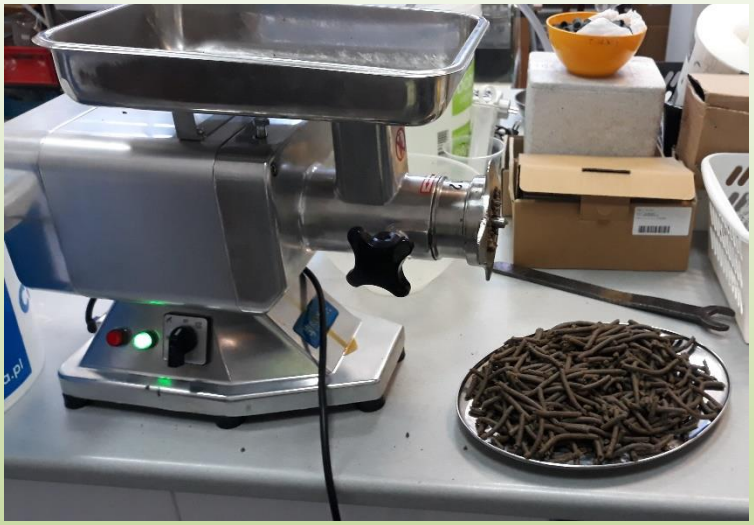
Product	Amount [g]
Apple	25
Lemon	25
Bun	25
Butter	25
Cream	25

Product	Ilość [g]
Milk	25
Cottage cheese	25
Yoghurt	25
Eggs	25
Meat and Bones	25

Product	Amount [g]
Sausage	25
Fish meat	25
Potatoes	25
Bananas	25
Tomatoes	25

Product	Amount [g]
Lettuce	25
Fruit juice	25
Bun	25
Flowers & Paper	50

Model kitchen waste mix



Drying and pelleting

Dry pellet

Research glasshouse – 2020

Research glasshouse – 2021

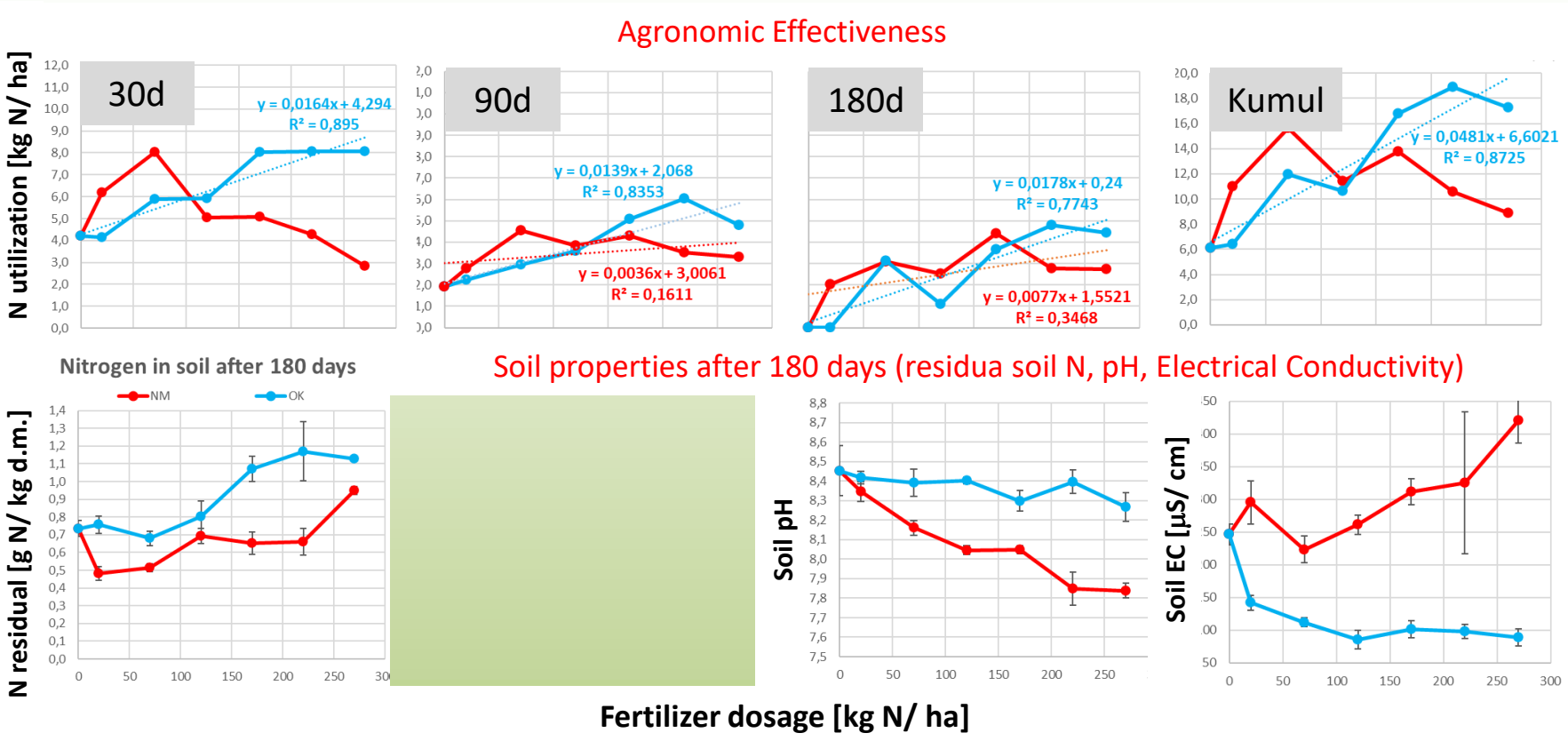
Research glasshouse - 2022

Glasshouse Experiment 1

- **Autumn 2020 – Spring 2021,**
- Kitchen Waste + 1 x EM **(KW)**,
- Mineral Fertilizer for comparison **(MF)**
- Dosages from 20 to 270 kg N/ ha
- Harvests after 30, 90, 180 days

Kitchen waste as biofertilizers

- Autumn – Winter (X 2020 – IV 2021)



Glasshouse Experiment 2

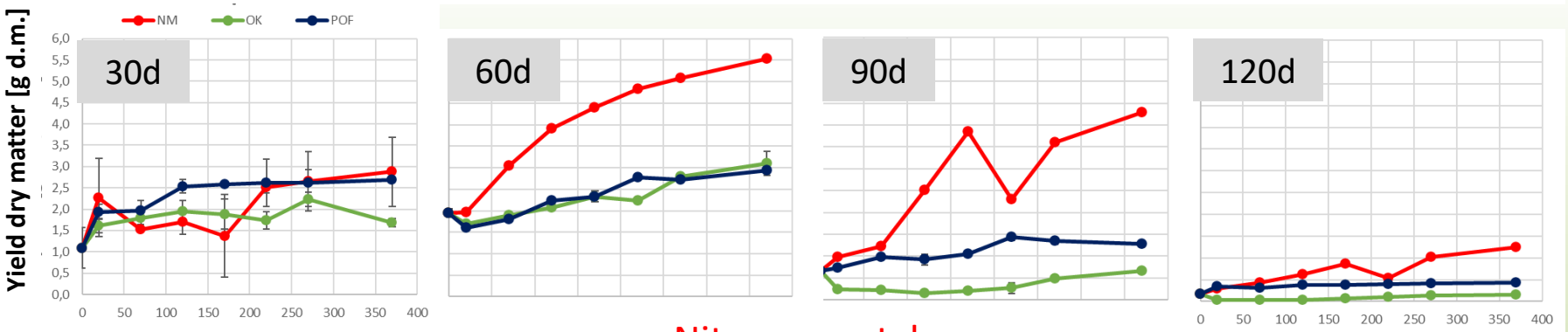
Summer – Autumn 2021

- Kitchen Waste + 1 x EM **(KW)**,
- Digestate from Kitchen Waste **(KW-dig)**,
- Mineral Fertilizer for comparison **(MF)**
- Dosages from 20 to 370 kg N/ ha
- Harvests after 30, 60, 90, 120 days

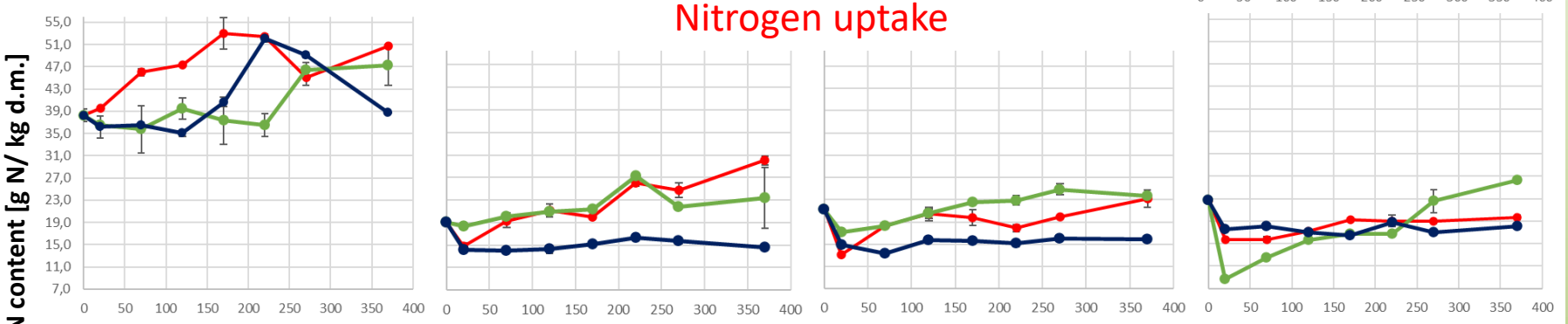
Kitchen waste as biofertilizers

- Summer – Autumn (VII-X 2021)

Plant yield biomass increment

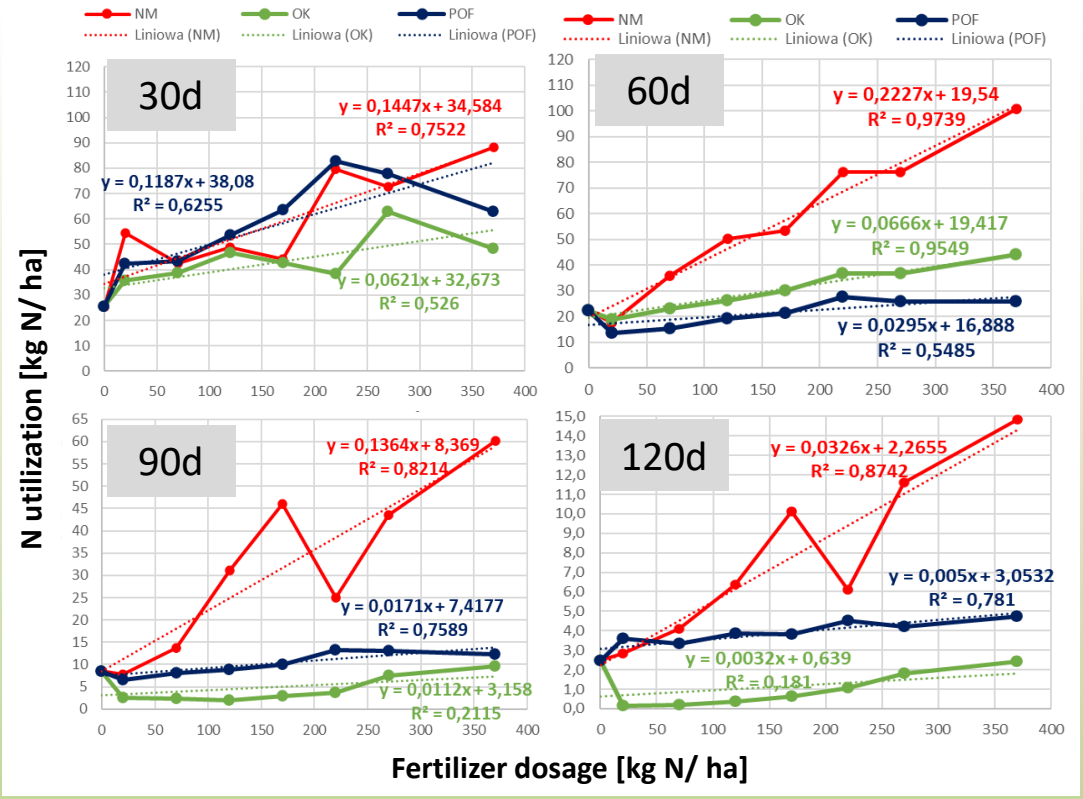


Nitrogen uptake

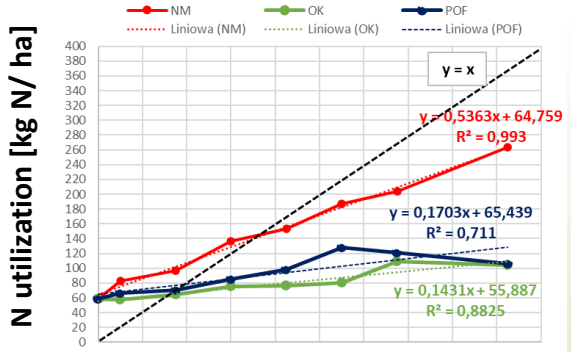


Kitchen waste as biofertilizers

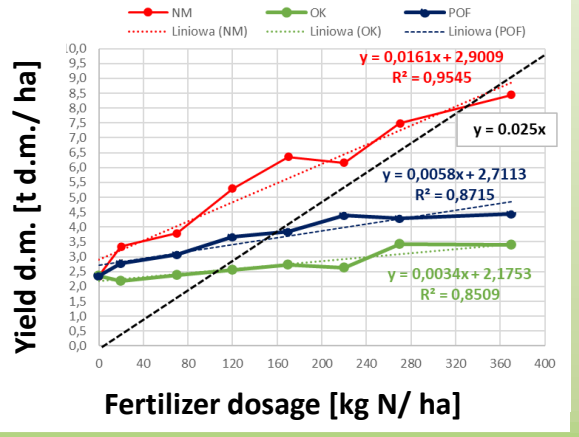
Agronomic effectiveness: VII - X 2021



Cumulative N utilization after 120d [kg N/ ha]



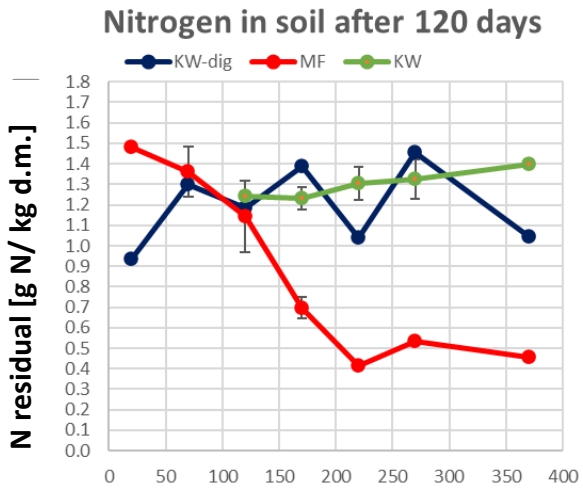
Cumulative yield d.m. after 120d [t d.m./ ha]

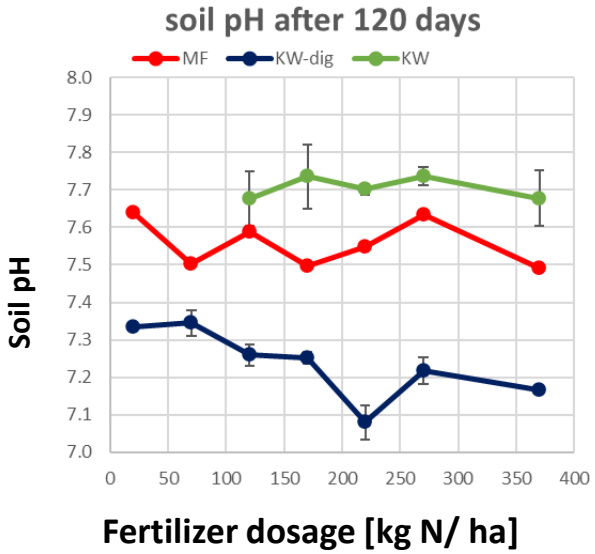


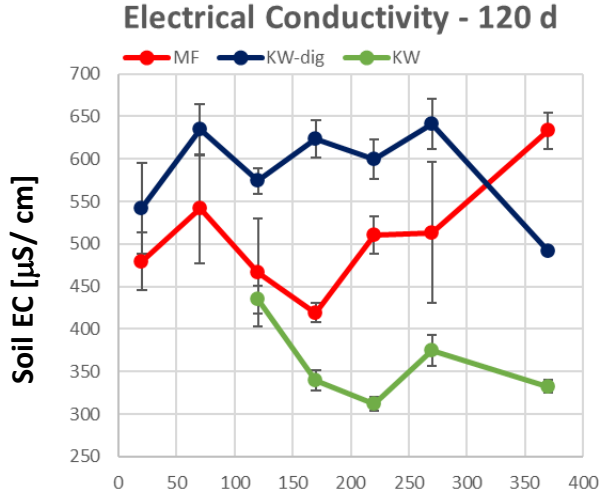
Kitchen waste as biofertilizers

- Summer – Autumn (VII – X 2021)

Soil properties after 120 days (residua soil N, pH, Electrical Conductivity)



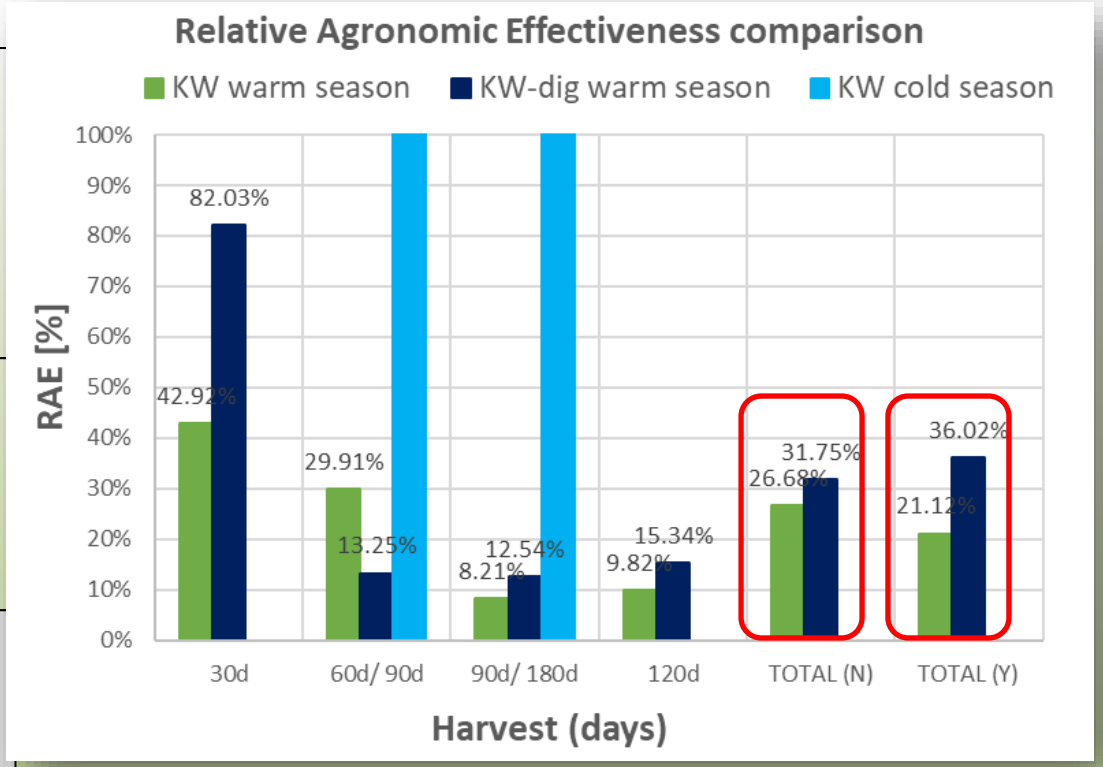




Kitchen waste as biofertilizers

Effectiveness comparison: cold vs. warm season

X-IV	VII-X
Yield d.m.	**Yield d.m.**
30d (%)	**30d (%)**
MF: 10-14	MF: 10-20
KW: 10-12	KW: 12-14
	KW-dig: 12-18
90d (%)	**90d (%)**
MF: 17-25	MF: 17-24
KW: 21-32	KW: **4-19**
	KW-dig: 17-20
180d (%)	**120d (%)**
MF: 22-30	MF: 12-35
KW: 21-25	KW: **2-12**
	KW-dig: 12-24



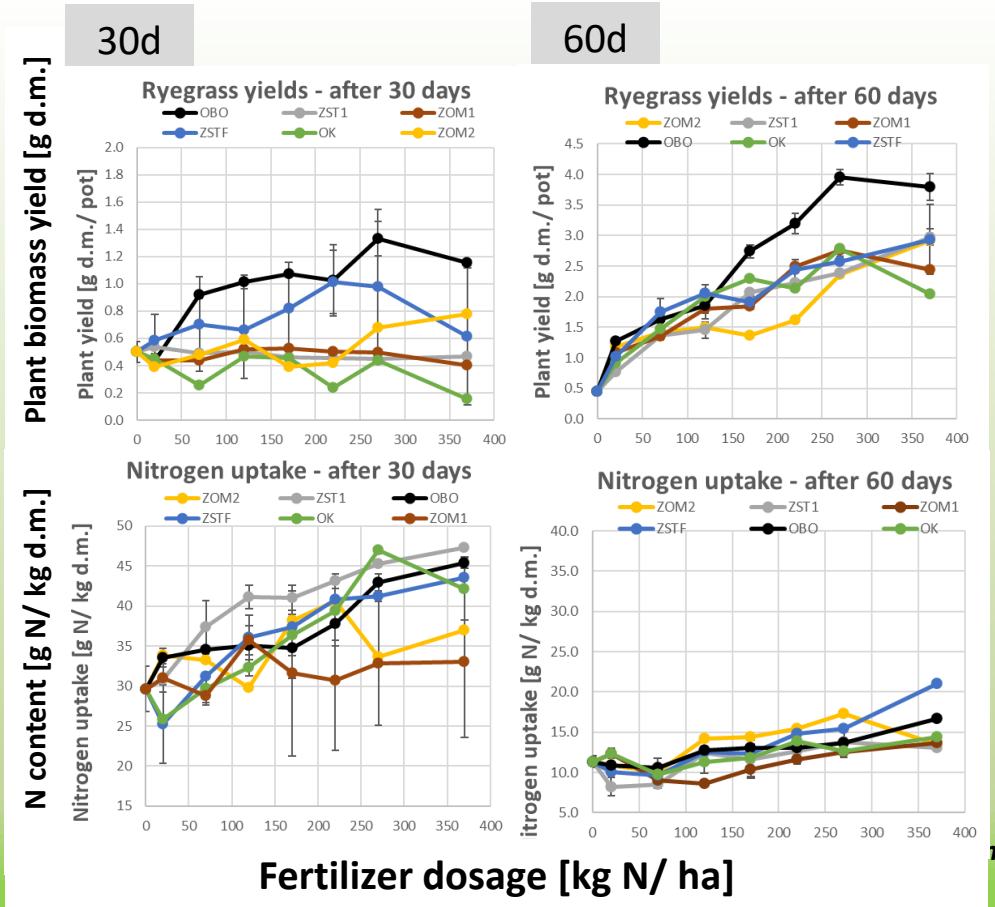
Glasshouse Experiment 3

Spring – Summer 2022 (running)

- Kitchen Waste **(OK)**
- Kitchen Waste + 1x EM **(ZOM1)**
- Kitchen Waste + 2 x EM **(ZOM2)**
- Kitchen Waste Sterilised (70 deg. C, 1 hr) **(ZST1)**
- Digestate from Kitchen Waste Sterilised **(ZSTF)**
- Chicken Manure and Mineral Fertilizer for comparison **(OBO)**
- Dosages from 20 to 370 kg N/ ha
- Harvests after **30, 60**, 90, 120 days

Kitchen waste as biofertilizers

- Spring – Summer 2022 (IV – VIII)

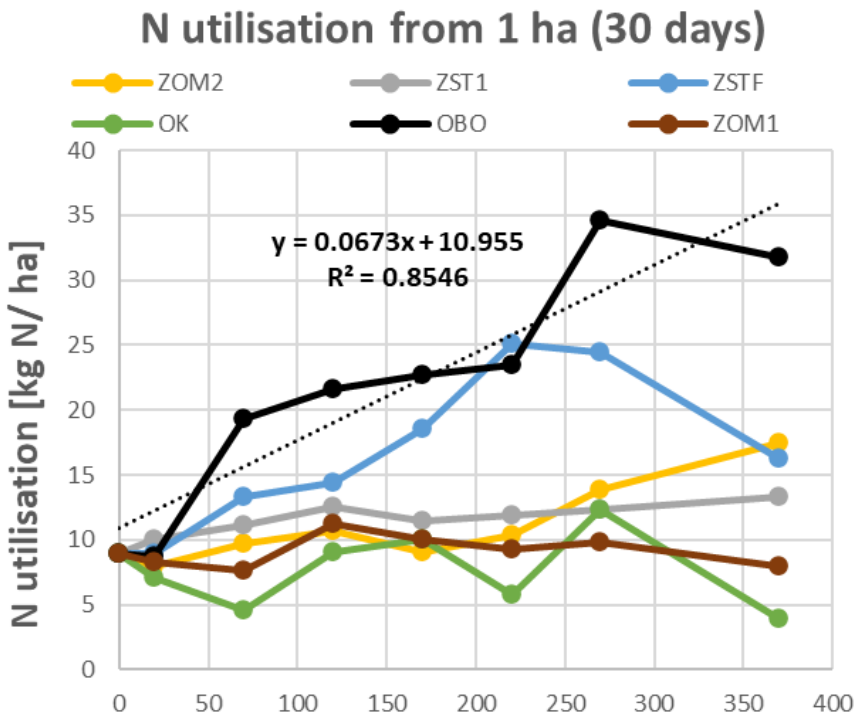


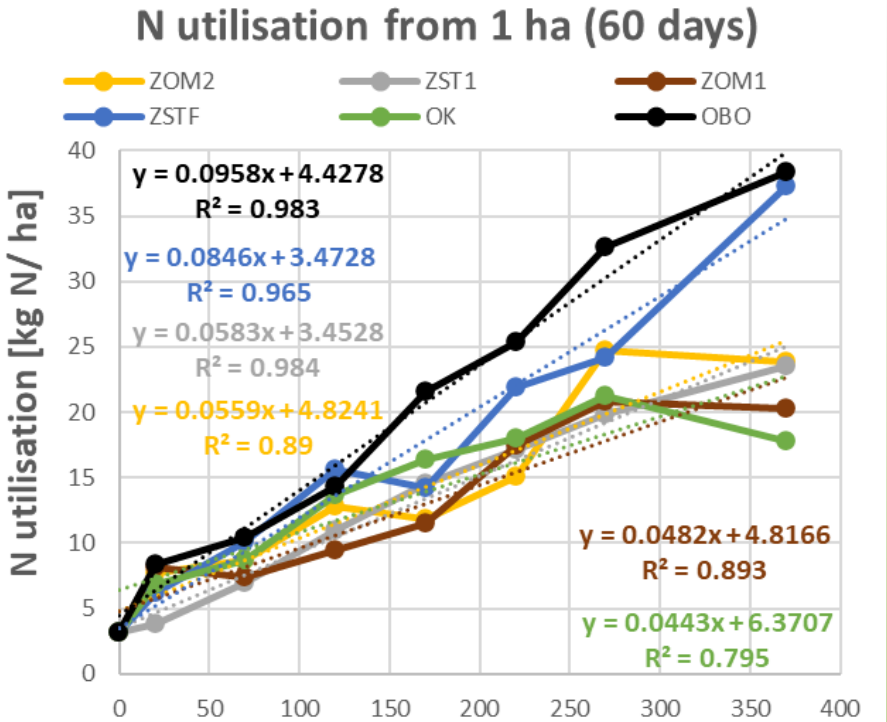
Key findings:

- Up to 3 x more plant yields after 60 d,
- But up to 3 x lower N contents after 60 d (early storage effect)
- ZSTF up to 2 x more yields after 30 d, then similar to others, but lower than chicken manure,
- The effect of KW treatment mostly seen at the beginning of growth (both yield and N content-wise)

Kitchen waste as biofertilizers

Agronomic effectiveness: IV - VI 2022

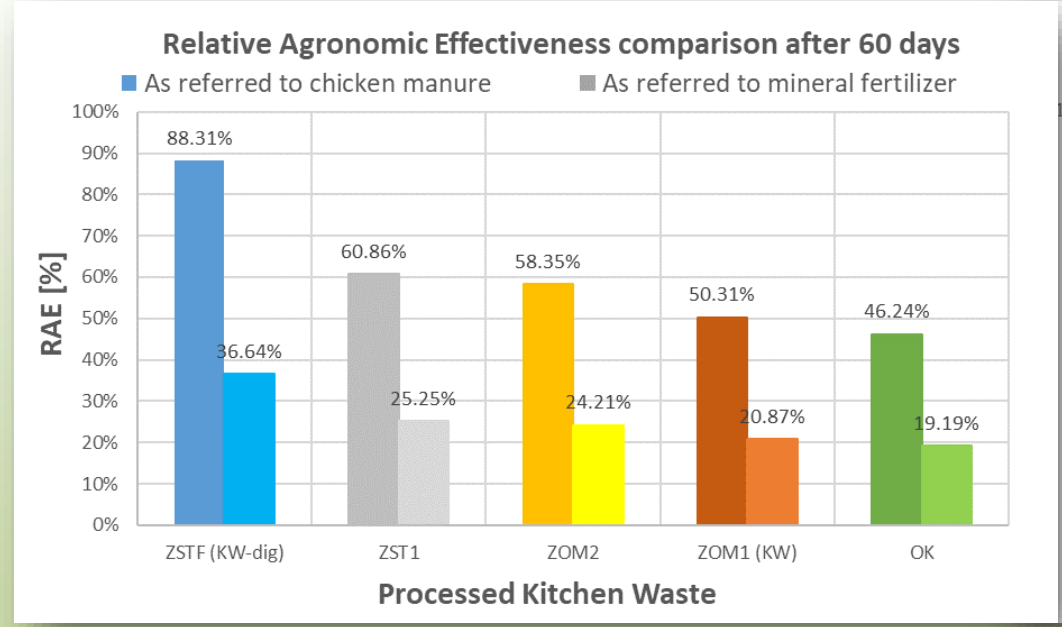


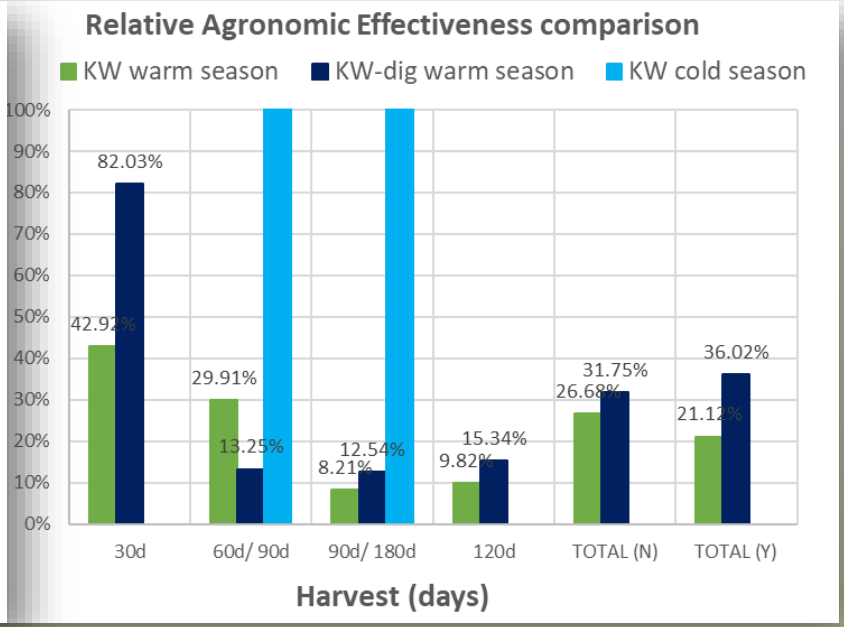


Fertilizer dosage [kg N/ ha]

Kitchen waste as biofertilizers

SUMMARY





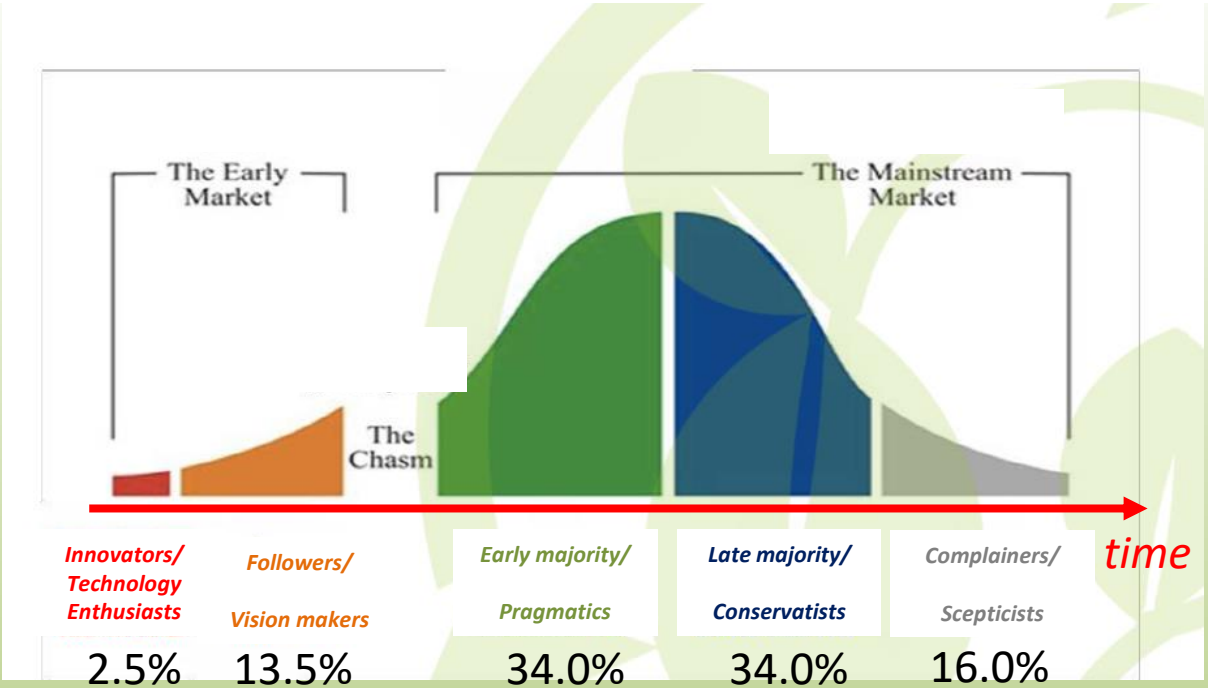
Visualisation

Fertilizer dosage [kg N/ ha]

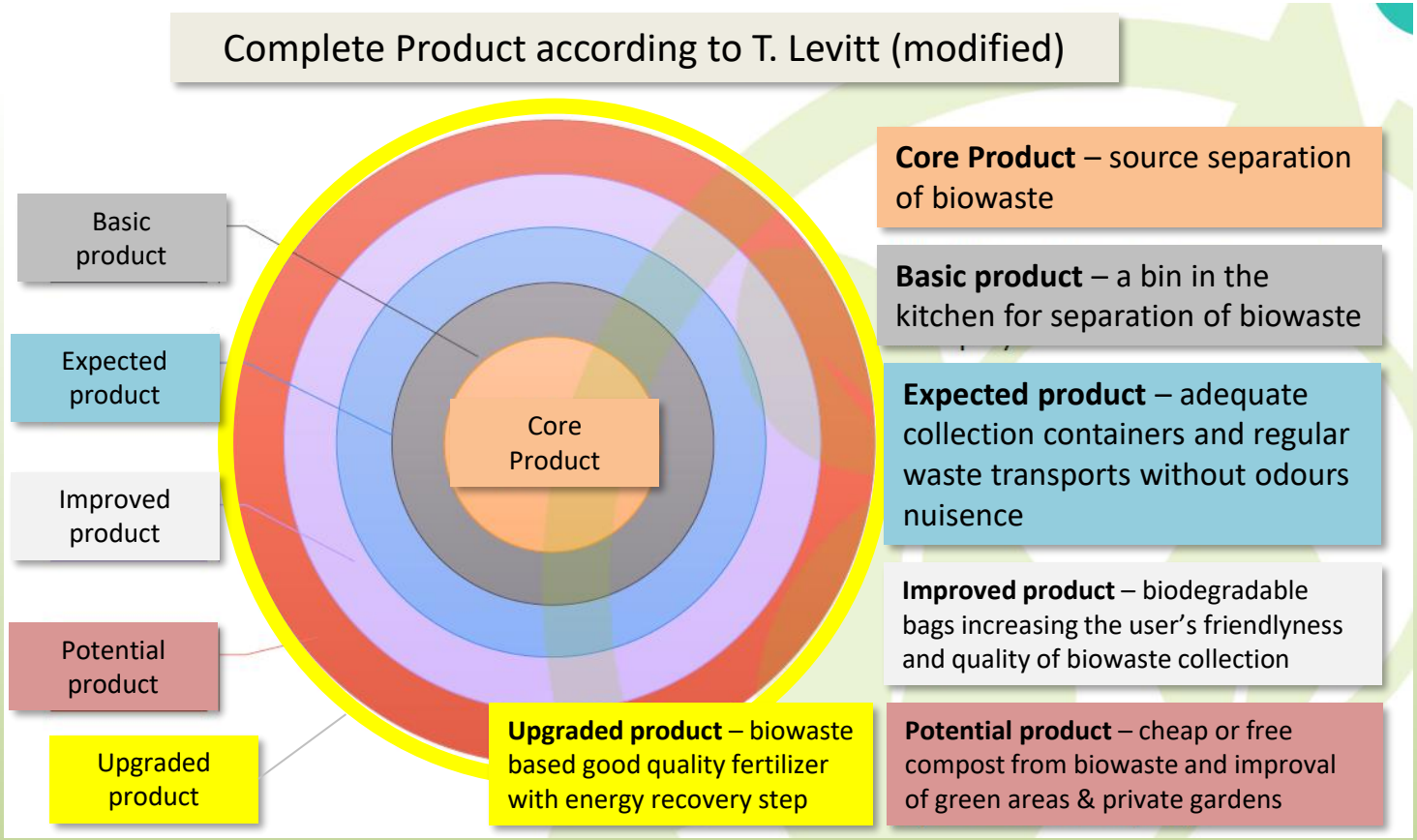
Fertilizer dosage [kg N/ ha]

Social readiness for biofertilizers usage

The cycle of new technologies adaptation by the socjety according to G.A. MOORE



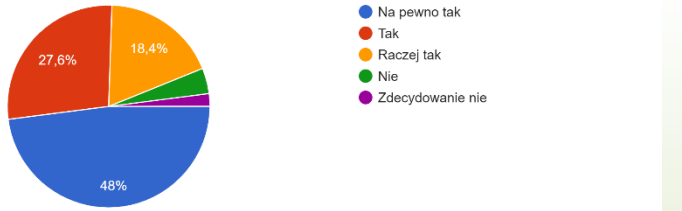
Social readiness for biofertilizers usage



Social readiness for biofertilizers usage

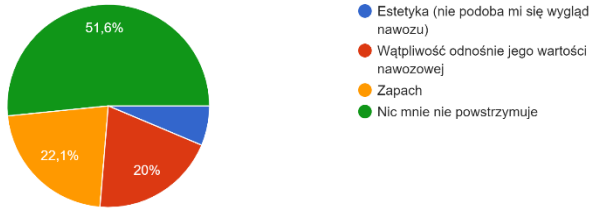
5. Czy korzystałbyś z nawozu z odpadów miejskich (odpady organiczne z selektywnej zbiórki, odpady zielone) do nawożenia trawnika/kwiatów (celów niekonsumpcyjnych)?
96 odpowiedzi

7. Czy uważasz, że stosowanie nawozu rozwiązuje częściowo problem ekologiczny nagromadzenia się odpadów z żywności?
98 odpowiedzi



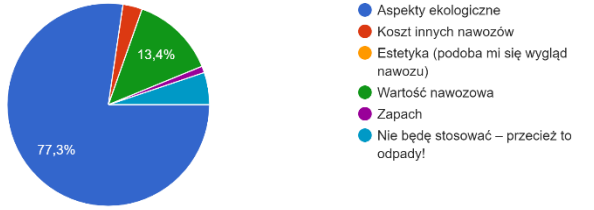
8. Czy łatwo Cię będzie zachęcić do stosowania ww. nawozu u siebie w ogródku do celów niekonsumpcyjnych?
98 odpowiedzi

9. Co powstrzymuje cię przed stosowaniem nawozu z odpadów organicznych?
95 odpowiedzi



10. Co by Cię przekonało do stosowania takiego nawozu?
95 odpowiedzi

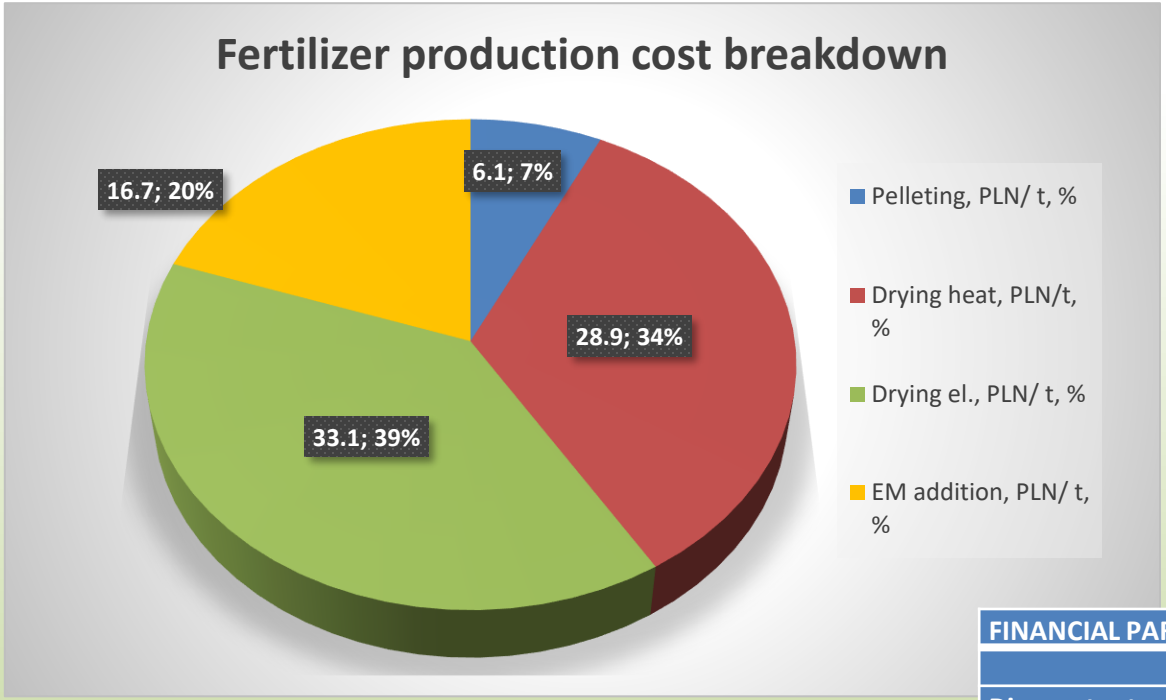
11. Co zachęca Cię by stosować nawóz/kompost z odpadów organicznych?
97 odpowiedzi



Economics of the implementation

Parameter	Symbol	Unit	Value	SD/ Comment
INPUT DATA				
Model food waste at source segregation				SD
Total Solids	TS	%	25.44	0.147
Total Organic Solids	TOS	%	93.15	0.399
Total Nitrogen	TN	g N/ kg TS	34.18 (3.4%)	1.1
Total Phosphorus	TP	mg P/ kg TS	1511.19 (0.34%)	174.8
Phosphorus-Olsen (available)	Olsen-P	mg P/ kg TS	48.6	15.4
Phosphorus-Olsen (available)	Olsen-P	% TP	3.21	
Total Potassium	TK	mg K/ kg TS	8482 (1.02%)	113.3
Potassium-Olsen (available)	Olsen-K	mg K/ kg TS	5715.3	73.8
Potassium-Olsen (available)	Olsen-K	% TK	67.4	

Economics of the implementation



Scale:

140 – 600 t/ year Kitchen waste

35 – 152 t/ year Fertilizer product

Fertilizer price (>0.5t supplies)	PLN/t	800.0
Fertilizer price (100-500 kg)	PLN/t	3600.0
Fertilizer price (20-100 kg)	PLN/t	4 800.0
Fertilizer price (<20 kg packaging)	PLN/t	6 000.0

Fertilizer price (>0.5t dostaw)	PLN/t	200.0
Fertilizer price (100-500 kg)	PLN/t	900.0
Fertilizer price (20-100 kg)	PLN/t	1 200.0
Fertilizer price (<20 kg opakowań)	PLN/t	1 500.0

FINANCIAL PARAMETERS	VARIANT			
	CHEAP	10%	100%	WAR
Discount rate, r	0.05	0.05	0.05	0.05
NPV (10 yrs), x 1000 PLN	258.77	385.95	1041.24	2606.20
IRR (10 yrs)	21.0%	27.0%	51.5%	97.0%
B/C (10 yrs)	1.4941	1.737	2.988	5.976
Payback time (yrs)	7	6	4	2

Conclusions

- Kitchen and garden waste has a great potential for the production of effective fertilizers
- These fertilizers are more effective in the cool season,
- Their fermentation 2 times improves the Fertilizer efficiency of the digestate (biogas residue) at the beginning of growth,
- But slightly corrects it as in total (>30% vs. > 20%),
- Sterilization (moderately) and dosing with EMs (slightly) further improves the efficiency of the fertilizer,
- The community is ready to use the fertilizers,
- The return on investment is 2 to 7 years

Thank you for your attention

Ksawery Kuligowski

kkuligowski@imp.gda.pl