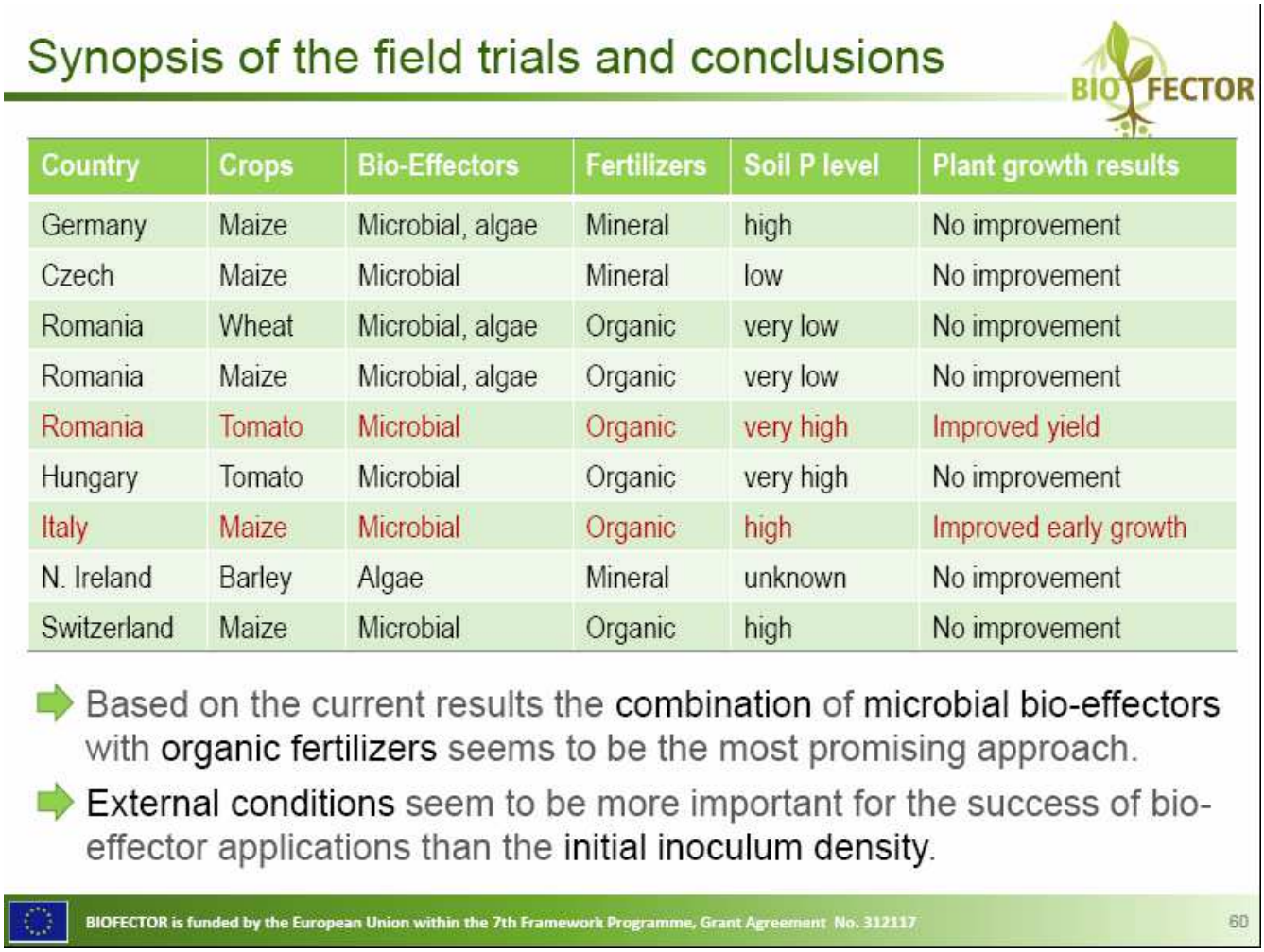
Table 1: Overview of the main results in BIOFECTOR pot experiments 2013-2015

Country	Crops	Bio-Effectors	Target	Soil P / nutrient level	Plant growth responses
ROOT GROWTH, MYCORRHIZA, P-ACQUISITION (18 Experiments, 11 positive)					
Germany UHOH JKI 4 experiments	Maize	BE1-3, *Pseudomonas jessenii*	Root growth stimulation Promotion of AM	Moderate P fertilisation	Root/plant growth stimulation Improved nutrient acquisition (P and others): in 3 out of 4 exp. Increased acid phosphatase act.
Germany UHOH 2 experiments	Maize	BE1-3 and combinations	Root growth stimulation Promotion of AM	Low P fertilisation	No or only marginal effects
Germany UHOH	Maize 2 cultivars	BE1-3, Trichoderma WG, Trichoderma OMG08, Vitalin-T50, Bacillus atrophaeus, B.simplex R41, Bacillus sp, BFDC, Phylazonit,MegaNit, Bactofil	Root growth stimulation Promotion of AM	Low P High P	No effects (Heat stress)
Germany UHOH JKI 5 experiments	Tomato	BE1-3, *Pseudomonas jessenii*	Root growth stimulation Promotion of AM	Moderate P fetilisation	Root/plant growth stimulation Improved nutrient acquisition (P and others) in 3 out of 5 exp. Increased acid phosphatase act
Germany UHOH	Tomato	*Pseudomonas jessenii* (heat in-activated and active)	Root growth stimulation	Moderate P fetilisation	Root/plant growth stimulation Improved P acquisition even with heat-inactivated inoculum
Germany, Italy, Ireland UHOH AGRIGES BIOAT 3 experiments	Maize	BE1-3+ 8 Sea weed extract products	Pe-biotic effects of seaweed extracts	sufficient	Plant growth stimulation in 2 out of 3 exp.
Ireland, Bioatlantis 2 Experiments	Tomato Lettuce	Swaweed extracts Superfifty, Florescence, Alga95	Plant growth stimulation	Sufficient Peat culture substrate	Plant growth stimulation
RECYLING FERTILISERS (34 Experiments, 12 positive)					
WP05/06 Partners 34 Experiments	Maize Tomato Wheat	24 microbial BEs belonging to 14 fungal and bacterial genera (*Azotobacter, Azospirillum, Cellvibrio*, *Bacillus*, *Burkholderia*, *Paenibacillus*, *Pseudomonas*, *Rhodococcus*, *Streptomyces*, *Trichoderma*, *Penicillium*, *Piriformospora*, *Glomus* ,*Rhizophagus*	**Organic and inorganic recycling fertilisers** (ashes, slags, Rock-P, composts, manures, digestates Sewage sludge) **Native paringly soluble soil P sources**	Low P soils	No response in the majority of experiments. Positive effects outlined below

Positive Results:		Seaweed extract: Nematec, Humic acids			
Germany UHOH	Maize Wheat	BE1-3, Combifector A *Paenibacillus mucigel-anosus*, Vitalin SP11,	Rock-P, Ashes	Low P soil	Plant growth stimulation Improved nutrient acquisition (P and others) in 3 out 13 experiments. So far only improved rock-P utilization with stabilized ammonium as N-form
Italy UNINA, Switzerland, FIBL	Maize	BE2-3, Combifector A, Humic acids, Nematec Mycorrhiza	Manures, Fresh digestate	Low P soil	Plant growth stimulation in 6 out of 6 experiments
Romania BUAS Gernany UHOH	Tomato	BE 2-3, BFDC (*Penicillium*)	Manures	Sufficient	Plant growth stimulation in 3 out of 5 experiments
FERTIGATION & FERTILISER PLACEMENT (5 Experiments, 3-4 positive)					
Israel ARO	Tomato	BE3-4	Mineral fertigation Compost	Low-high	Increased yield in BE4 treatments
Israel ARO 2 Expriments	Tomato	BE1-4	Mineral fertigation	Low-high P	Increased biomass and yield
Germany UHOH 2 Experiments	Maize	BE2	Ammonium placement	Low-high P	Increased biomass and P acquisition in the low P treatment
STRESS TOLERANCE (8 Experiments, 5 positive)					
Israel ARO	Tomato	BE1-4	Salinity Fertigation	sufficient	No significant effects
Italy UNINA 2 Experiments	Tomato	*Azotobacter chrococcum* BE4, AlgavytZnMn	Salinity	Low high	No effects with Azotobacter Plant strengthening effect of BE4 and Algavyt (seaweed extracts) at moderate salinity levels
Germany UHOH Denmark UCPH 3 Experiments	Maize	BE 2-4, Cold resistant *Bacillus simplex* Zn/Mn, Algavyt ZnMn, Algafect	Cold stress Low soil temp	sufficient	Improved root and shoot growth In ZnMn treatments and ZnMn-rich seaweed extracts Positive results in 3 out of 3 experiments
Germany UHOH Denmark UCPH 2 Experiments	Maize	BE2-4, Bacillus simplex R42, Penicillium bilaii, Vitalin T50 ZnMn	Cold stress Low soil temp	Low P	No improvement
Germany UHOH	Maize	BE2-3	Drought Stress	Moderate P	Growth stimulation at moderate drought (50% WHC) No effect at severe drought (30% WHC)

TOTAL 65 Experiments: 30 positive (red)

Table 2: Summary of field trials: BIOFECTOR Mid-Term Report 01.09.2013-28.02.2015



Synopsis of the field trials and conclusions

BIOFECTOR

Country	Crops	Bio-Effectors	Fertilizers	Soil P level	Plant growth results
Germany	Maize	Microbial, algae	Mineral	high	No improvement
Czech	Maize	Microbial	Mineral	low	No improvement
Romania	Wheat	Microbial, algae	Organic	very low	No improvement
Romania	Maize	Microbial, algae	Organic	very low	No improvement
Romania	Tomato	Microbial	Organic	very high	Improved yield
Hungary	Tomato	Microbial	Organic	very high	No improvement
Italy	Maize	Microbial	Organic	high	Improved early growth
N. Ireland	Barley	Algae	Mineral	unknown	No improvement
Switzerland	Maize	Microbial	Organic	high	No improvement

- Based on the current results the combination of microbial bio-effectors with organic fertilizers seems to be the most promising approach.
- External conditions seem to be more important for the success of bio-effector applications than the initial inoculum density.

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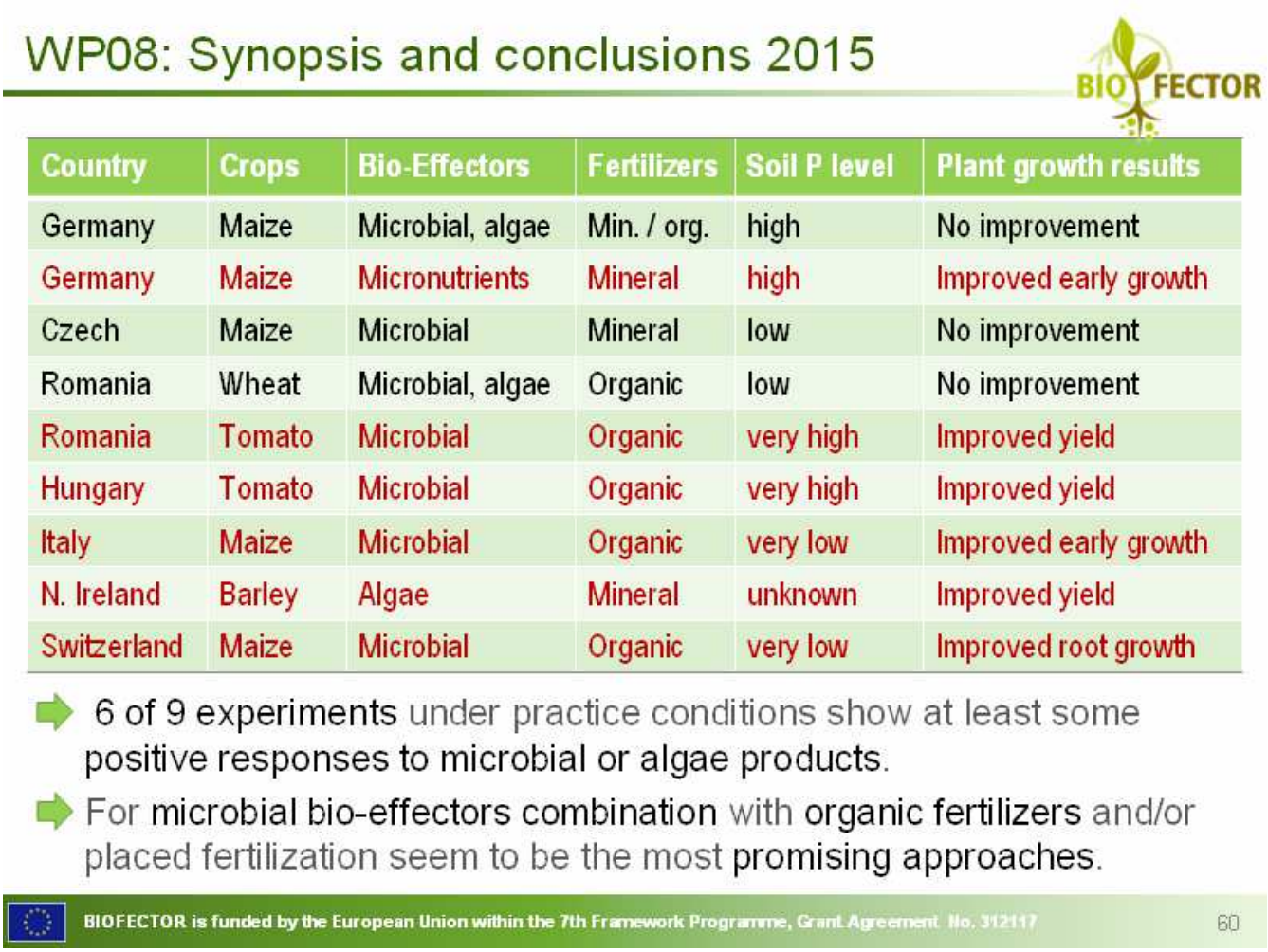
Positive results marked in red

Table 3: Summary of field trials 2015



WP08: Synopsis and conclusions 2015

Country	Crops	Bio-Effectors	Fertilizers	Soil P level	Plant growth results
Germany	Maize	Microbial, algae	Min. / org.	high	No improvement
Germany	Maize	Micronutrients	Mineral	high	Improved early growth
Czech	Maize	Microbial	Mineral	low	No improvement
Romania	Wheat	Microbial, algae	Organic	low	No improvement
Romania	Tomato	Microbial	Organic	very high	Improved yield
Hungary	Tomato	Microbial	Organic	very high	Improved yield
Italy	Maize	Microbial	Organic	very low	Improved early growth
N. Ireland	Barley	Algae	Mineral	unknown	Improved yield
Switzerland	Maize	Microbial	Organic	very low	Improved root growth

- 6 of 9 experiments under practice conditions show at least some positive responses to microbial or algae products.
- For microbial bio-effectors combination with organic fertilizers and/or placed fertilization seem to be the most promising approaches.

Positive results marked in red

Major Achievements

- Field and greenhouse production experiments under practice conditions have been conducted with tomato, wheat and maize.

➡ Bio-effector treatments repeatedly achieved strong yield increased in tomato under different production conditions.

  ➡ **Dual application**, i.e. at seedling stage and transplanting, and the combination with **organic fertilizers** seem to be critical factors.

➡ Evidence that **band and/or seed treatment** could be **efficient** and **product saving** delivery strategies for microbial bio-effectors

  ➡ Prospects for the **technical and economic feasibility** bio-effector applications in maize and wheat production.

➡ **Effective algae** products could be an interesting option in **wheat**.

Issues and open questions

1. So far, no evidence for consistent yield or quality improvements by bio-effector treatments in maize production.

➡ What is the role of environmental factors in the field?

2. Combination and/or placement of bio-effectors, ammonium, organic fertilizers.

➡ How can results from pot experiments or effects on root growth be translated into agronomic benefits?

3. Root colonization rates by microbial bio-effectors appear to decrease in the order broad cast > band > seed application.

➡ What are effective colonization densities?

➡ Can improved product formulations help?

Issues to be addressed in the 2016/17 work programme

Organic Recycling Fertilisers
(positive results with manure-based ORFs and fresh digestates but not with compost)

Mode of Action
Pot experiments
(WP03/06)

Hypothesis:
- BEs are particularly effective with ammonium-rich ORFs.

- Ammonium as a key cmpound for the interaction

Field Testing (WP05/06/08)

Including risks assessment related with antibiotic-resistant bacteria in ORFs (expression of antibiotic resistance genes)

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Inorganic Recycling Fertilisers

positive results mainly in combination with stabilised ammonium-based fertilisation

Field Testing
WP05/06/08)

Mode of Action
Pot experiments (WP03)

Hypothesis:

- Ammonium triggers both root-induced and microbial P mobilisation via rhizosphere acidification
- Ammonium stimulates auxin production in microbial BEs ans or plants
- Ammonium triggers root-induced P mobilisation enabling the host plant to supprt microbial root colonisation and stimulation of root growth

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Fertiliser placement

Root attraction by organic and inorganic feriliser depots improves root colonisation by BEs.

BE-induced root growth stimulation improves exploitation of fertiliser depots

Field Testing
(WP07/08)

Mode of Action
Pot experiments
(WP03/07)

- Investigations of rhizosphere chemistry) pH, phosphatases, carboxylates in depot root zones with and without BEs
- BE tracing
- Changes in nutrient availabiliry in the depot rhizosphere

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Abiotic Stress

Positive results with Zn/Mn & Zn/Mn seaweed extracts and selected MOs to improve cold resistance in maize

Seaweed extracts also as plant strengtheners with priming effects on production of stress protectants

Mode of Action
Pot experiments
(WP03/04)

Linking BE application with metabolism and gene expression of stress protectants

Field Testing (WP04/08)
(cold stress maize, drought, salinity tomato)

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Integrating BE application into agricultural practice

(Developing more efficient and economic inoculation techniques by combination with sowing, underfoot placement and depot fertilisation)

Field Testing (WP07/08/09)

More challenging enviroments required with reduced fertility to demonstrate not only root colonisation efficiency but also BE effects on plant growth and final yield

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WHICH BEs ???

Good performence of standard BEs Proradix and FZB42 in many comparative studies (tracing tools available)

Comparison with promising product combinations (WP02) (Combifector A, Artichoc-Humic Acids)

Seaweed extracts: BE4 (Superfifty), Algavyt ZnMn

In special cases also comparison with selected novel products (e,g. cold-resistant BE strains, Nematec, Manek, Si etc)

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