RIU

Low-cost boost for crops in poor soils

Validated RNRRS Output.

A simple, low-cost way to boost crop yields in poor soils is now available. Farmers who till infertile land are often the poorest and can't afford fertilisers. Now, they can reap better harvests just by adding tiny amounts of nutrients to the water that they soak seeds in before sowing. Farmers in Bangladesh, India, Nepal and Pakistan added small amounts molybdenum, zinc, boron, phosphate and Rhizobia—the bacteria that help fix nitrogen—to priming water. In some cases, yields of chickpea, mungbean, maize and wheat improved by up to two-thirds. The simple 'nutrient priming' technology has almost unlimited potential. So many soils in less-developed countries are poor. Plus, the method can be used for many of the major tropical and sub-tropical crops.

Project Ref: **PSP30:**
Topic: **1. Improving Farmers Livelihoods: Better Crops, Systems & Pest Management**
Lead Organisation: **CAZS-NR, UK**
Source: **Plant Sciences Programme**

Document Contents:

Description

PSP30

Research into Use
NR International
Park House
Bradbourne Lane
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Kent
ME20 6SN
UK

Geographical regions included:

Bangladesh, India, Nepal, Pakistan,

Target Audiences for this content:

Crop farmers,

A. Description of the research output(s)

1. Working title of output or cluster of outputs.
In addition, you are free to suggest a shorter more imaginative working title/acronym of 20 words or less.

On-farm seed priming to improve plant nutrition in low fertility soil

or

'Nutrient seed priming'

2. Name of relevant RNRRS Programme(s) commissioning supporting research and also indicate other funding sources, if applicable.

Plant Sciences Research Programme (PSP).

3. Provide relevant R numbers (and/or programme development/dissemination reference numbers covering supporting research) along with the institutional partners (with individual contact persons (if appropriate)) involved in the project activities. As with the question above, this is primarily to allow for the legacy of the RNRRS to be acknowledged during the RIUP activities.

R7438, R8221, R8269

UK
CAZS Natural Resources, Bangor UK (Dr Dave Harris)

Pakistan
NWFPAU, Peshawar, Pakistan (Prof A. Rashid)

Bangladesh
PROVA, Rajshahi, Bangladesh (Mr A. M. Musa)

India
ICRISAT, Patancheru, AP, India (Dr J.V.D.K. Kumar Rao)
Catholic Relief Services, Hyderabad, India (Mr M. Kankal)

Nepal
FORWARD, Chitwan, Nepal (Mr N. N. Khanal)

*4. Describe the RNRRS output or cluster of outputs being proposed and when was it produced? **(max. 400 words)**. This requires a clear and concise description of the output(s) and the problem the output(s) aimed to address. Please incorporate and highlight (in bold) key words that would/could be used to select your output* *when held in a database.*

In marginal, rainfed areas, **patchy plant stands** often result from the failure of the crop to emerge quickly and uniformly. Yields of many crops are reduced because not enough seeds germinate and the plants that eventually emerge do so slowly and are susceptible to drought, pests and diseases. This is a particular problem for resource-poor farmers who can seldom command enough resources on a timely basis to ensure good establishment. Such farmers often also find it too expensive, or too risky, to apply sufficient, appropriate fertilizers to their crops to produce high yields. Huge areas of land in the world are deficient in macronutrients (e.g. **Nitrogen, Phosphorus**) and micronutrients (e.g. **Molybdenum, Boron, Zinc**, **Calcium**, Iron, etc.). A lack of these elements reduces yield and low densities of micronutrients such as Zn, Fe in grains adversely affect human and animal health. Although fertilizers can be used to mitigate effects of deficiencies on crop growth and foods can be supplemented to improve human and animal nutritional imbalances, such interventions are costly and their success is limited by poor infrastructure etc.

On-farm seed priming is a simple, low-cost, low-risk technology that hastens germination and seedling emergence and promotes vigorous early growth so that transient resources (soil moisture, nitrogen, etc.) are captured and utilised. Seed priming simply involves soaking seeds in **water**, usually ‘overnight’, surface-drying them to facilitate easy handling, then sowing them in the normal fashion. Seed priming, including all work funded by PSP, has recently been reviewed by Harris (2006). Crop plants grown from primed seeds generally emerge earlier and in greater numbers, grow more vigorously, flower and mature earlier and often yield better than those from non-primed seeds. This simple, low-cost, low-risk technology has been developed, tested, refined and promoted using a combination of *in vitro*, on-station and **participatory action research** with farmers during the period 1996-2006.

In addition, seed priming can be used to:

- Add ***Rhizobia*** inoculum to **legume** seeds (**chickpea, mungbean**) to promote fixation of atmospheric N;
- Provide small amounts of ‘starter’ P to crop seeds **(maize, wheat**, chickpea, **pearl millet**) to boost growth in low-P soils and to increase apparent recovery rates of expensive added P-fertilizer;
- Provide Mo to legumes (chickpea, mungbean) grown in **acidic soils** where Mo is unavailable so as to increase yield;
- Provide Zn to crop seeds (maize, wheat, chickpea) in **alkaline or other soils** where Zn is deficient, to increase yields and Zn nutrient density in grain.
- Provide B to crops (maize, wheat, chickpea) in B-deficient areas to increase yields.
- Improve the performance of seeds germinating in saline-affected soils

All the above interventions are highly **cost-effective** because only very dilute solutions of the materials are used for priming seeds. Work specifically on **nutrient seed priming** was done during the period 2002-2006.

5. What is the type of output(s) being described here?
Please tick one or more of the following options.

Product	***Technology***	***Service***	***Process or Methodology***	***Policy***	***Other Please specify***
	x				

6. What is the main commodity (ies) upon which the output(s) focussed? Could this output be applied to other commodities, if so, please comment

Nutrient seed priming has been developed and tested by PSP-funded research for maize, wheat, chickpea, mungbean and pearl millet so far but is potentially applicable to other crops once the appropriate optimum concentrations for priming solutions have been determined. There is some limited literature on the effects of nutrient priming with other crops but these generally have not been validated in the field.

7. What production system(s) does/could the output(s) focus upon?
Please tick one or more of the following options. Leave blank if not applicable

Semi-Arid	***High potential***	***Hillsides***	***Forest-Agriculture***	***Peri-urban***	***Land water***	***Tropical moist forest***	***Cross-cutting***
x	x	x	x	x			x

8. What farming system(s) does the output(s) focus upon?
Please tick one or more of the following options (see Annex B for definitions).
Leave blank if not applicable

Smallholder rainfed humid	***Irrigated***	***Wetland rice based***	***Smallholder rainfed highland***	***Smallholder rainfed dry/cold***	***Dualistic***	***Coastal artisanal fishing***
x	x	x	x	x		

*9. How could value be added to the output or additional constraints faced by poor people addressed by clustering this output with research outputs from other sources (RNRRS and non RNRRS)? (**max. 300 words**).*

Please specify what other outputs your output(s) could be clustered. At this point you should make reference to the circulated list of RNRRS outputs for which proformas are currently being prepared.

The application domain for this technology is so large (soils with low N, P, Mo, Zn, B, saline soils, acidic soils, alkaline soils, etc. and suitable for many of the major tropical and sub-tropical crops) that the potential for linkages with other research outputs is very great. Any work specifically relating to improving plant nutrition, crop establishment, integrated crop management, seed production or, more generally, initiatives to improve rural livelihoods and public health through better agricultural production could be linked to this output. A particularly appropriate linkage would be to explore the synergies between nutrient seed priming and the recent CGIAR Harvest Plus initiative to breed new varieties of crops that accumulate higher concentrations of beneficial micronutrients in grain.

Specifically, links with other RNRRS outputs could include:

- PSP, (all seed priming outputs);
- PSP, Transplanting sorghum and pearl millet in semi-arid regions (there are also opportunities to link with ongoing work in Bangladesh and Nepal, funded by USAID and Cornell University, to maximise seedling health for rice and vegetables and to fortify seeds by other means);
- PSP, Rice-fallow rabi cropping systems;
- PSP, PVS;
- LPP, Cultivation of African *dhaincha* and fodder *khesari* as animal feed in rice fields., R6610;
- NRSP, Integrated land management of Striga and low soil P, R7962 (it is possible that better P-nutrition early in the life of plants might increase resistance to Striga)
- CPP, Linking demand with supply of agricultural information, R8429, R8281

Validation

B. Validation of the research output(s)

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*10. **How** were the output(s) validated and **who** validated them?*

*Please provide brief description of method(s) used and consider application, replication, adaptation and/or adoption in the context of any partner organisation and user groups involved. In addressing the "who" component detail which group(s) did the validation e.g. end users, intermediary organisation, government department, aid organisation, private company etc... This section should also be used to detail, if applicable, to which social group, gender, income category the validation was applied and any increases in productivity observed during validation **(max. 500 words)**.*

Molybdenum and *Rhizobium*
In Bangladesh, validation of priming chickpea seeds with Mo and *Rhizobium* was managed by PROVA in collaboration with DAE. Multilocation on-farm trials at three sites showed that seed priming with Mo and *Rhizobium* increased grain yield by about 60%, the same as adding much larger amounts of Mo to the soil. Farmer evaluations in large plots at 50 locations in 5 *Upazillas* in 2004-05 demonstrated that farmers could implement the technology and that there was a significant yield increase (mean 21%) in all 5 *Upazillas*. A similar exercise with 50 farmers in 2005-06 gave a mean yield increase of 22%.

In **India**, pot trials using acidic soils in 2002-03 showed that *Rhizobium* added to chickpea seeds during seed priming increased the number of nodules and the level of nitrogenase activity in seedlings threefold, relative to the standard method of application. The response to priming chickpea seeds with 0.5 g Mo kg^{-1} seed $litre^{-1}$ of water was tested in 2003-04 by 48 farmers in acid-soil areas of Orissa, Chattisgarh, eastern Madhya Pradesh, Jharkhand and West Bengal states. The mean yield increase over a control without Mo was 22% using the ICCV 2 variety and 17% using KAK 2. Molybdenum content in chickpea grain increased up to 2.4-fold using Mo-primed seed. The main advantages of Mo application through seed priming are ease and uniformity of application and about a 30-fold cost saving.

In 188 on-farm trials during 2004-05 in the same states, priming improved chickpea nodulation by 62 percent. In a sub-set of 114 trials mean chickpea grain yield was increased by 9 percent and stover yield by 6 percent. Grain was sampled from a further sub-set of 63 trials and 54 showed increased concentrations of Mo.

In **Nepal**, priming with Mo increased nodulation and yield (23%) in mungbean in on-farm trials in the three years 2003-05. Positive results in chickpea and field pea need further verification.

Zinc

In **Pakistan** on Zn-deficient soils, after preliminary experiments established that the optimum concentration for priming wheat seeds with $ZnSO_4$ was 0.4% Zn, eight further on-station and on-farm trials produced a mean increase of 615 kg ha^{-1} in comparison with non-primed seed. The optimum concentration for priming chickpea seeds was much less, at 0.05% Zn. In nine trials, this treatment increased grain yield of chickpea from 1.1 t ha^{-1} to 1.6 t ha^{-1} in comparison with non-primed seed. Yield increases in individual trials ranged from 10-122%, with a mean of 48%. In seven trials with maize, mean grain yield was significantly increased from 3.0 t ha^{-1} in crops from non-primed seed to 3.8 t ha^{-1} (27%) using seeds primed with 1% Zn.

Boron

In Pakistan, the optimum concentration for priming maize was 10 mg L^{-1} B (as boric acid) which significantly increased mean grain yield by 23% from 3.9 to 4.8 ha^{-1}. For wheat, the mean increase using 20 mg B L^{-1} in three trials was 22%.

Salinity

In Pakistan, priming with water alone improved the performance of wheat by 41%, 28%, 24% and 22% in four trials in saline soils and that of chickpea by 21% (Rashid et al., 2002). In barley, grain yield was increased by priming by an average of 18% at three sites with saline soils (Rashid et al., 2006).

Phosphate

There is a known correlation between the amount/concentration of P in seeds and subsequent crop vigour and yield. Priming seeds with 1% P (as KH_2PO_4) between 2003-06 boosted their P content by 30% and, in five trials with maize in Pakistan, increased mean grain yield significantly from 3.2 t ha^{-1} to 3.9 t ha^{-1} (24%). In four additional trials, the effect of P-priming was consistent over a range of rates of application of P-fertilizer (Fig 1, below). A similar response was also demonstrated for wheat (Fig. 2, below).

Figure 1. Response of maize in Pakistan to seed priming with H_2O and P over a range of P-fertilizer rates (np = not primed).

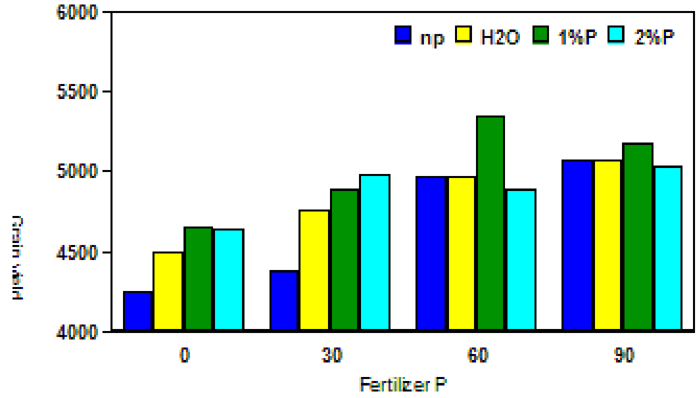
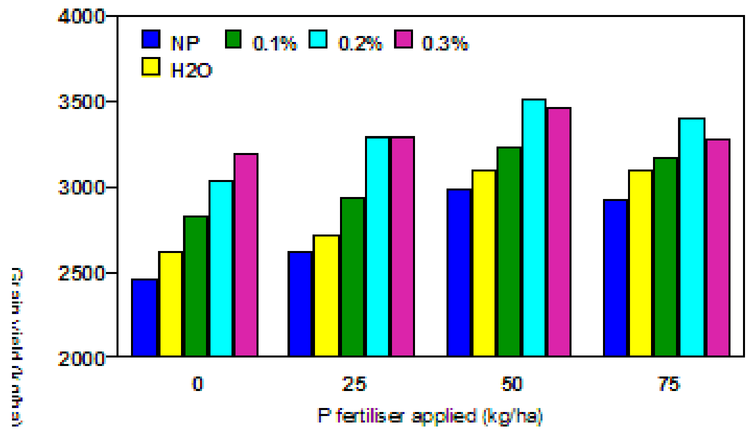


Figure 2. Response of wheat in Pakistan to seed priming with H_2O and P over a range of P-fertilizer rates (NP = not primed).



Although the principle of priming seeds with P was established using NaH_2PO_4 we have developed an even more cost-effective and practical protocol using a combination of two cheap and widely available materials - Na_2CO_3 (washing soda) and Single Super Phosphate fertilizer. Used to prime maize seeds before sowing, this mixture can give yield gains equivalent to priming with NaH_2PO_4.

*11. **Where and when** have the output(s) been validated?*

*Please indicate the places(s) and country(ies), any particular social group targeted and also indicate in which production system and farming system, using the options provided in questions 7 and 8 respectively, above **(max 300 words)**.*

See Question 10 for additional details.

In **Bangladesh**, validation has been ongoing with Mo/chickpea in the High Barind Tract (HBT) since 2002-03, targeted towards the resource-poor farmers of the rainfed rice fallows system (semi-arid, smallholder rainfed humid/dry). The same systems and farmer categories are targeted in the eastern states of **India** for chickpea and in **Nepal** for chickpea and mungbean. In **Pakistan**, maize/Zn, maize/P, maize/B, wheat/Zn, wheat/P and wheat/B have been validated in both high potential/irrigated and semi-arid, smallholder rainfed dry systems. Chickpea/Zn was found suitable for the semi-arid, smallholder rainfed dry system. Seed priming is low-cost and low-risk and so is suitable for all social groups (except the landless who may, nevertheless, benefit from additional opportunities afforded by greater yields).

Validation of nutrient priming in **Pakistan** was done at the Research Farm of NWFPAU, Peshawar and in on-farm trials in 8 Districts of NWFP (Peshawar, Nowshera, Mardan, Kohat, Karak, Lakki, Banu, D.I.Khan). On-farm trials involved close collaboration between project staff and farmers. Additional research on various aspects of seed priming was implemented by: Barani Agri. Research Station, Kohat; Barani Agri. Research Station, Karak; Sugar Research Station, Mardan; Central Cotton Council, D.I.Khan; Pakistan Oil Seed Board; Agri. Faculty Gomal University, D.I.Khan. Seed priming has been the subject of student theses at the following Universities: Agri. Uni. Peshawar; Agri. Uni. Faisalabad; Arid Agri. Uni., Rawalpindi; Gomal University, D.I.Khan.

Current Situation

C. Current situation

*12. **How and by whom** are the outputs currently being used? Please give a brief description **(max. 250 words)**.*

See Questions 10 and 11 for additional details.

In **Bangladesh**, priming with Mo + *Rhizobium* in acid surface soils of the HBT is now recommended for chickpea by PROVA and DAE. Further evaluations and demonstrations on a limited scale will continue in 2006-07 supported by other non-DFID-funded projects. After extensive testing (see question 10) CRS in **India** has adopted priming with Mo + *Rhizobium* for its forthcoming (2006-07) activities promoting rainfed *rabi* cropping in rice fallows. Around 200 tonnes of chickpea seeds with Mo and *Rhizobium* are being distributed/sold to resource-poor farmers in eastern India. Around 9000 farmers are currently growing chickpea as a new crop on land left fallow after rainfed rice.

In **Pakistan**, nutrient priming is a relatively recent innovation and there is little adoption yet by farmers, although the earlier technology of priming with water was quickly adopted by farmers in target areas after they had tested it for themselves. Similarly, in Nepal promotion of nutrient priming is at a relatively early stage and adoption is limited.

*13. **Where** are the outputs currently being used? As with Question 11 please indicate place(s) and countries where the outputs are being used **(max. 250 words).***

Farmers in Bangladesh, India and Nepal are priming chickpea with Mo and Rhizobium (see Questions 10, 11 and 12). Priming crops with zinc and with phosphate is just beginning in Pakistan.

14. What is the scale of current use? Indicating how quickly use was established and whether usage is still spreading ***(max 250 words).***

See Questions 12 and 13 for additional details.

In 2004-2005 around 1900 farmers in eastern India were involved in the CRS programme and, in 2005-2006, 6624 new farmers were inducted into the programme. Adoption has been rapid after farmers have tested the technology for themselves. Although access to inputs, including Mo and *Rhizobium*, is still being facilitated for many farmers by CRS this still represents substantial use of the technology package (including nutrient priming). Use of nutrient priming by farmers is at a relatively early stage in Pakistan, Bangladesh and Nepal but, based on the Indian experience, adoption can be rapid and widespread if the technology is included in a well-resourced and targeted promotional programme.

15. In your experience what programmes, platforms, policy, institutional structures exist that have assisted with the promotion and/or adoption of the output(s) proposed here and in terms of capacity strengthening what do you see as the key facts of success? ***(max 350 words).***

Institutional structures for promotion and extension of agricultural information exist in all four target countries (and in other countries where such a cross-cutting technology could be applied) but our experience with water priming (and with Mo and *Rhizobium* in the CRS programme) has been that potential institutional collaborators are generally unwilling to promote seed priming on evidence gathered elsewhere. In addition, nutrient (and water-) seed priming is often viewed as being too ‘simple’ to extend on its own. Successful adoption has been achieved when priming is promoted as part of a ‘package’ and the ‘integrated’ approaches (IPM, ICM, ICNM, etc., often implemented through Farmer Field Schools or something similar) offer a good platform for such an approach.

Current Promotion

D. Current promotion/uptake pathways

16. ***Where*** *is promotion currently taking place? Please indicate for each country specified detail what promotion is taking place, by whom and indicate the scale of current promotion* ***(max 200 words).***

There is a large ongoing promotional programme in eastern **India** for the chickpea production package that includes nutrient priming (see Question 14). Around 200 tonnes of chickpea seeds (plus Mo and *Rhizobium*) are being distributed by CRS and its partners in the forthcoming 2006-07 *rabi* season.

In **Bangladesh**, PROVA and DAE are continuing their programme of validation trials and demonstration plots in the HBT as part of another externally-funded project. A similar situation exists in **Nepal** where FORWARD are continuing with a limited testing and promotional programme in collaboration with some of the District Agricultural

Development Offices in the *Terai*. As far as we know, no formal promotional activities for nutrient priming are planned in **Pakistan**, although discussions are ongoing between NWFPAU researchers and the Outreach Directorate that coordinates research and extension activities.

There are a number of ongoing **generic activities** to promote seed priming widely. A website www.seedpriming.org is maintained and CAZS-NR receives many requests from visitors for additional information on seed priming, including that for nutrient priming. Several thousand copies of two colour brochures (DFID/PSP 2001; 2006) have been distributed to interested parties as well as many copies of specific research publications and customised protocols for testing seed priming. Seed priming has also been widely promoted during conference presentations around the world and at dedicated Technology Fairs (in Zimbabwe in December 2005 and in Uganda in February 2006).

17. What are the current barriers preventing or slowing the adoption of the output(s)? Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc. ***(max 200 words)****.*

Apart from the general issues relating to the need to use integrated approaches to promotion (see Question 15), local access to the materials used for nutrient priming can be difficult in rural areas. Although nutrient seed priming is highly cost effective relative to using fertilizers applied to the soil, accessibility and up-front cost of some of the materials used can be a bottleneck to adoption. We have used two approaches to address this issue. First, measuring the correct quantities, re-packaging and selling the small quantities of micronutrients needed by farmers offers opportunities for disadvantaged people (landless, widows, etc) to generate income. CRS have been pursuing this approach on a trial basis in eastern India but it is, in theory, applicable anywhere. However, a holistic approach to rural development is necessary, which is something that sectoral line agencies may find difficult.

A second approach has been pursued in Pakistan where cheaper, more readily available materials are being evaluated as an alternative source of P for priming. The need for commercialization of the supply of Mo and *Rhizobium* (and quality control) in Bangladesh and Nepal is a problem that will need to be addressed.

There is also an opportunity for seed producers to develop a value-added process if the technology can be refined to allow longer-term storage of nutrient-primed seeds.

The overarching constraint, of course, is lack of resources. For instance, although CRS and its partners in India could procure and distribute 200 tonnes of chickpea seeds this year without any external funding, their original target was for 600 tonnes of seed. Although the farmers are willing to bear the cost of seeds and inputs (recovered through a rolling fund) the up-front costs were simply too great for CRS to meet its original target.

18. What changes are needed to remove/reduce these barriers to adoption? This section could be used to identify perceived capacity related issues ***(max 200 words).***

There is already evidence that results-based advocacy by CRS, CAZS-NR and ICRISAT has persuaded the state government of Chhattisgarh to promote rainfed rabi cropping (including nutrient priming) by its Department of Agriculture. This is in addition to CRS' own ongoing efforts. This approach will be pursued with other state governments. A similar approach is being used in Bangladesh (see, for example, the Proceedings of a joint PSRP/ CPP/IRRI/BRRI/BARI meeting held in Dhaka, 6-8 Feb, 2006) to advocate an integrated approach to rural development.

A Business Development Services (BDS) approach to commercialization of resources such as Mo and *Rhizobium*, for which adoption and effective implementation of quality control legislation is essential. A commitment to the training of researchers, extensionists and farmers in integrated approaches is essential so that more widespread farmer evaluations and demonstrations can be accomplished.

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19. What lessons have you learnt about the best ways to get the outputs used by the largest number of poor people? ***(max 300 words).***

Direct involvement of farmers throughout the research-to-adoption process is essential as is access to (and acting upon) feedback from farmers – technologies are seldom adopted without being fine-tuned to local needs and circumstances. On-farm, farmer-participatory action research is essential, backed up by specific technical, problem-solving research as and when necessary.

We have always found a twin-track approach to dissemination to be effective, i.e. supporting local 'validation' where it is necessary (both in 'new' countries and crops and in areas where priming has only recently been introduced) and supporting extension activities to promote wider uptake with farmers in countries where local 'validation' has been completed.

Impacts On Poverty

E. Impacts on poverty to date

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20. Where have impact studies on poverty in relation to this output or cluster of outputs taken place? This should include any formal poverty impact studies (and it is appreciated that these will not be commonplace) and any less formal studies including any poverty mapping-type or monitoring work which allow for some analysis on impact on poverty to be made. Details of any cost-benefit analyses may also be detailed at this point. Please list studies here.

A recent study in India (Kankal et al., 2006) has surveyed the impact of the CRS rainfed *rabi* cropping initiative in eastern India. Although not specific to nutrient priming, the study concludes that the package has been effective in persuading large numbers of farmers to grow chickpea and reports case studies highlighting various beneficial effects on incomes and quality of life of the farming community.

There have been no impact studies yet specific to nutrient priming. However, a number of simple benefit: cost analyses have been done using information from research trials. Given the simple nature of seed priming, such analyses are deemed to be valid. As examples, using yield and cost data from Pakistan, benefit: cost ratio for wheat/Zn was about 360, for chickpea/Zn was 1500 (Harris et al., 2005) and for maize/Zn was 290. Benefit: cost ratio for priming with fresh water in saline areas was very large because extra cost was essentially zero. Priming wheat and maize with P was also very cost effective, exact values depending on the source of P used.

As long as steps are taken to facilitate access to priming materials and to provide appropriate training, nutrient priming could make substantial positive impacts on the livelihoods of poor farmers.

21. Based on the evidence in the studies listed above, for each country detail how the poor have benefited from the application and/or adoption of the output(s) ***(max. 500 words):***

- *What positive impacts on livelihoods have been recorded and over what time period have these impacts been observed? These impacts should be recorded against the capital assets (human, social, natural, physical and, financial) of the livelihoods framework;*
- *For whom i.e. which type of person (gender, poverty group (see glossary for definitions) has there been a positive impact;*
- *Indicate the number of people who have realised a positive impact on their livelihood;*
- *Using whatever appropriate indicator was used detail what was the average percentage increase recorded*

No impact analyses specific to nutrient priming have been done. Case studies in Kankal et al. (2006) demonstrate that chickpea cultivation in rice fallows is profitable, popular and accessible to men and women alike.

Environmental Impact

H. Environmental impact

24. What are the direct and indirect environmental benefits related to the output(s) and their outcome(s)? ***(max 300 words)***

This could include direct benefits from the application of the technology or policy action with local governments or multinational agencies to create environmentally sound policies or programmes. Any supporting and appropriate evidence can be provided in the form of an annex.

There are many environmental benefits associated with growing legumes, particularly as a second crop where none was possible before. These include: improved soil fertility through N-fixation and increased biomass; reduced soil erosion through longer duration of crop cover; increased agro-biodiversity; reduced incidence of pests and diseases (and thus use of pesticides) through rotation of crops. Nutrient priming with Mo and *Rhizobium* in, e.g. acid soils, can allow legumes to be grown where it was not possible before or can increase the profitability of poorly-performing legumes.

For all crops, nutrient priming will increase biomass and ground cover and increase fertilizer use efficiency, through more precise delivery of nutrients. For P, this could reduce surface- and groundwater pollution due to runoff and leaching of phosphate fertilizers.

Increased production per unit of land may dissuade people from cultivating more marginal, less suitable land.

25. Are there any adverse environmental impacts related to the output(s) and their outcome(s)? ***(max 100 words)***

Some of the materials used can be toxic to plants if seeds are exposed to high concentrations during the priming operation. Protocols for nutrient priming have been carefully developed with wide margins for error to minimise this risk. Nevertheless, training is essential to ensure maximum benefit with minimum risk.

There is little or no potential for risk to humans and animals through eating high concentrations of micronutrients in grain and fodder as accumulation in tissues is largely self-limiting. In addition, and as noted above, accidental use of toxic levels on seeds results in little or no growth and hence no opportunity for harm to consumers.

26. Do the outputs increase the capacity of poor people to cope with the effects of climate change, reduce the risks of natural disasters and increase their resilience? ***(max 200 words)***

A greater choice of farming options will improve the resilience of poor farmers to shocks due to climate change or other natural disasters. Nutrient priming can allow farmers to grow additional crops (e.g. legumes in marginal environments) and to produce crops more cost-effectively, thus minimising the risk of loss of investment.

Annex

References

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