How farmers in Switzerland perceive fertilizers from recycled anthropogenic nutrients (urine)

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Abstract We studied acceptance of a urine-based fertilizer product using a mail survey of 467 Swiss farmers. We distinguished among four production types: organic or IP farming, and with or without vegetable production. Considering that the idea of urine-based fertilizers is new, acceptance among the answering farmers was surprisingly high, with 57% explicitly stating that they thought it was a good or very good idea, and 42% willing to purchase such a product. The farmers of different production types did not differ strongly in their attitude towards urine-based fertilizers. Especially IP and vegetable farmers, who purchased additional fertilizers anyway, seem willing to accept urine-based fertilizers, hereby preferring a grainy, odorless ammonium nitrate fertilizer. Absolutely essential is a hazard-free product: 30% of all farmers had concerns regarding micropollutants. Based on fertilizer data, we demonstrate an existing demand for the nutrients N, P, and K in Switzerland, which could be partially substituted by a recycled urine product. Finally, we discuss methodological requirements of social science surveys. To obtain representative data on an entire population in a mail survey, multiple contacts with respondents are necessary. We argue that information and participation of stakeholders at an early stage is essential for successful technology transfer.
Keywords Farmers; mail survey; participation; sustainable nutrient recycling; technology transfer; urine separation

Introduction

Phosphorus is a limited resource, and the known worldwide phosphate rock reserves will be exploited in ca. 300 years, given the present phosphorus exploitation rate (calculations based on Jasinski, 2000/2002). Therefore, sooner or later some sort of recycling from urban areas must take place. Known forms of recycling are sewage sludge (the only remaining form in northern Europe), treated wastewater, or direct application of urine and feces to agricultural land. At least in Switzerland, the reuse of sewage sludge will be prohibited in the near future (Chassot and Mühlethaler, 2001).

For many different reasons, including the possibility of nutrient recycling, urine separation is propagated as an improvement of wastewater management (e.g. Larsen *et al.*, 2001). Consumer acceptance, information and participation of the population are essential elements of such a technological innovation. These non-technical aspects, however, are often neglected both by science and by developers of new technologies (Chopyak and Levesque, 2002). An important aspect of NOVAQUATIS, a larger research project on urine separation (www.novaquatis.eawag.ch) is to involve stakeholders in an early phase of technology development. Accordingly, we defined a number of sub-projects with this aim. These projects include focus groups on consumer acceptance (Pahl-Wostl *et al.*, 2003),

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studies on farmer acceptance, and ongoing sociological investigations in pilot projects, which generate more long-term data both in private and institutional settings with NoMix toilets.

The study presented here is an explorative rather than confirmatory study to identify trends concerning the acceptance of a urine-based fertilizer by Swiss German farmers. A main goal was to develop methods for a larger, quantitative investigation, and to determine whether research in this direction would be feasible and effective. In Switzerland, agriculture is heavily subsidized, federal requirements strongly regulating the production type of agriculture receiving subsidies. Today, two production types are eligible: organic agriculture and the so-called 'integrated production', IP. The latter may be described as a 'best management practice' and has less stringent regulations than organic farming. Important features of IP farming are for instance balanced nutrient budgets. Farmers increasingly convert to one of these standards, and less than 40% practiced conventional farming in the year 2000. Different management practices have different nutrient requirements. Although the use of synthetic mineral fertilizer is prohibited in organic farming, especially vegetable farmers are dependent on additional nutrients. IP farmers are allowed to use synthetic mineral fertilizer, provided that the nutrient balance on the farm is in equilibrium. Livestock farmers often face a nutrient surplus from farm manure and may be less interested in any new fertilizer product.

Provided acceptance by farmers, a market for urine-based fertilizer exists undoubtedly. In Table 1, we compare data from different regions on the use of artificial fertilizer with data on the maximum possible production of nutrients from human urine. In Switzerland, the trend towards IP and organic farming, and the current Swiss efforts to lower nutrient losses from agriculture (Spiess, 1999) will presumably reduce the gap between nutrient demand from agriculture and the possible supply from separate urine handling.

Previous studies have shown that a farmer, as any other human being, is open to new ideas if there are no essential drawbacks to be expected. Farmers have often been criticized of being responsible for environmental problems, especially in rural areas. At least in Switzerland, this led to skepticism against or even rejection of environmental research by many farmers. Therefore, intensive and continuous communication between scientists and farmers is essential (Pongratz, 1992). However, sociocultural aspects of agriculture have only rarely been investigated (Lobao and Meyer, 2001). Therefore, an additional objective of our investigation is to gain experience in conducting social research studies with this population group.

Finally, we explore methodological requirements of such sociological investigations, thereby contributing to a knowledge transfer among engineers and scientists on sociocultural aspects of technological innovations. We hope to pave the way for more extensive

Table 1 Yearly per capita consumption of artificial fertilizer and potential production from urine

	Consumption of artificial fertilizer		
	N	P	K
	kg_N/p/y	kg_P/p/y	kg_K/p/y
Switzerland[1]	8.7	1.5	5.4
Western Europe[2]	26.3	4.0	8.4
World[2]	14.0	2.4	2.9
Max. potential production of fertilizer from urine[3]	3.2	0.3	0.8

[1] Year 1995 for 6.7 Mio. Swiss inhabitants. Fertilizer data are taken from Spiess (1999)

[2] Year 2000. Fertilizer data are taken from ifa (2001). Data on populations are taken from United Nations Population Division (2000)

[3] European data; based on Maurer and Larsen (2003)

studies on stakeholder involvement in technology development, which among others could increase the acceptance of waste-based fertilizers in European agriculture.

Materials and methods

Data collection

At the time of our study, 39,270 farmers in the German speaking part of Switzerland – which is the largest Swiss region – were registered as organic (10.2%) or IP (89.8%) farmers (Bundesamt für Statistik, 2000). We also distinguished among farmers with and without vegetable production. To achieve sufficient group size to allow comparisons, we used a stratified random sampling procedure: from the national farmer register, we randomly sampled 155 organic farmers with vegetable production (29% of all organic farmers with vegetables), 154 IP farmers with vegetables (6%), 79 organic farmers without vegetables (2%), and 79 IP farmers without vegetables (0.2%). We did not sample conventional farmers, as they are all believed to convert to IP or organic farming in the near future.

In January 2000, the study farmers received information on the urine separation project NOVAQUATIS together with the questionnaire. In February 2000 a reminder was sent again to the full sample, since the fully anonymous procedure we used did not allow tracking those who had not returned their answer. We asked for four groups of data: (1) personal, (2) farm details, (3) data on the acceptance of urine-based fertilizers, and (4) nutrient demands and type of fertilizer product needed (Table 2). Most questions were closed questions in a multiple-choice format, so that respondents had only to tick the appropriate answer.

Data analysis

First, we summarized responses over all farmer groups. Then we compared organic and IP farmers; farmers with and farmers without vegetable production; vegetable production (with/without) within the group of only organic and only IP farmers; and younger farmers (<45 yrs) with older ones (>45 yrs; hypothesizing that younger farmers are more progressive than older ones). We used χ^2-tests to determine differences among groups. Samples being small and most variables of ordinal scale only, we analyzed group differences in continuous variables (area of farm and vegetable fields/livestock units) with Mann-Whitney U tests. To assess correlations between different variables, we used Spearman's rho. We used the statistical software SPSS (release 10.1; SPSS Inc, Chicago, Illinois, USA).

Table 2 Overview of questions from questionnaire concerning urine-based fertilizer that was sent to 467 farmers in the German part of Switzerland

Data group	Description
Personal data	Sex, age, childhood spent on farm?
Farm details	Swiss canton, is agriculture main income?, production type (organic/IP)
	Reason for choice of production type (financial, practical, ethic)
	Date of change from conventional to current production type
	Size of farm (ha: crops, pastures, vegetable, others), livestock (cattle, pigs)
Acceptance of urine-based fertilizer	How do you like the idea of re-using urine as fertilizer?
	Should regulations change to allow urine-based fertilizer in organic farming?
	Would you use urine-based fertilizer?
	Additional comments and concerns
Nutrient demands/ product needed	Use of fertilizer (manure, artificial, or other additionally purchased)
	How large is nutrient demand (N, P, K, B, others)
	Preferred form of nitrogen fertilizer (urea, NH_4^+, NO_3^-, organically bound)
	How much would you pay for a urine-based fertilizer product?
	Would you use fertilizer with urine odor (or cattle/hog manure)?
	Preferred type of urine-based fertilizer (liquid or grainy)

Response

Of the 467 questionnaires, 127 (27%) were returned. Three returned questionnaires were empty and contained a remark that the idea of urine separation was completely ridiculous. Two farmers wrote that they did not wish to participate in the study. Given the short time available to carry out the survey (1 month), the response rate was acceptable and comparable to similar surveys using mail questionnaires (see below). The percentage of returned questionnaires differed highly significantly among the farmer groups, being highest among organic farmers (all: $N = 467$; $df = 1$; $P<0.001$; Table 3). This means, generalizations to the overall population of Swiss farmers should be avoided. However, comparisons between different groups are well possible, but also require some caution, since the returned sample could be biased (see below). The group of farmers that returned the questionnaire after receiving the reminder differed only in personal data (growing up on farm, main income from farm), but not in any of the questions concerning fertilizer acceptance.

Sample description

Most heads of farms were male (95%), 35–55 years old (67%), grew up on a farm (87%), and gained their main income with farming (90%). The size of farms ranged from 0.3 to 70 ha (mean 18.6; median 16.8 ha), and the area of vegetable land from 0.02 to 50 ha (mean 3; median 1 ha). The 102 farms with livestock (85%) had 1 to 60 animal units (mean 22; median 20).

The time of and reasons for converting to the current production type differed among organic and IP farmers: 39% of organic, but only 19% of IP farmers had converted to this production type before 1990 ($N = 119$; $df = 2$; $P<0.1$). Likewise, 51% of farmers with vegetables had converted before 1990 to their current production type (organic or IP), but only 15% of those without vegetables ($N = 199$; $df = 2$; $P<0.001$). A majority of organic farmers expressed ethical reasons for conversion (84%, and 92% of organic farmers with vegetable production), but only 44% of IP farmers ($N = 109$; $df = 1$; $P<0.001$). Financial motives for conversion were mentioned by 55% of IP, but only by 26% of organic farmers ($N = 111$; $df = 1$; $P<0.01$).

Results

Acceptance of a urine-based fertilizer

Over all groups, 57% of farmers had an explicitly positive attitude towards the idea of a urine-based fertilizer, and 33% thought it was a bad idea (Table 4A). Changing the regulations to allow the use of urine-based fertilizer in organic farming was welcomed by 43%, while 38% were against it (Table 4B). Of all farmers, 42% would purchase a urine-based fertilizer (Table 4C). We tried to track down reasons for not wanting to buy this fertilizer: of those that would not buy the fertilizer, 76% indicated that they had no need for it. Fifty-four % had indicated in question A that they regarded re-using urine in agriculture as a bad idea. Concerns about the quality of the fertilizer were mentioned in additional remarks by 46% of those that would not buy it (mostly fear of micropollutants, rarely hygienic aspects).

Table 3 Number and percentage (in parentheses) of returned questionnaires of the different farmer groups

	Organic farmers	IP farmers	Total with/without vegetables
With vegetable production	37 (24%)	18 (12%)	55 (18%)
Without vegetable production	41 (52%)	24 (30%)	65 (41%)
Total of organic/IP	78 (33%)	44[1] (19%)	

[1] Two questionnaires did not contain information on vegetable production

Table 4 Acceptance of a urine-based fertilizer over all farmers. We asked whether farmers regarded urine recycling as a good idea (A), whether regulations should change to allow the fertilizer in organic farming (B), and whether they would buy it (C). Of those that would not buy it, we show how many indicated no need for it, regarded it as a bad idea, or indicated concerns of some sort. We also present how many farmers wrote additional remarks and of those, how many had concerns regarding urine-based fertilizer (D)

		Percent	N[a]
A	**Idea**		
	Bad idea	33%	
	No opinion	10%	
	Good idea	46%	
	Very good idea	11%	125
B	**Change of regulations**		
	No	38%	
	No opinion	19%	
	Yes	43%	122
C	**Market chances**		
	Would buy fertilizer	42%	123
	No: no need for it	76%	67
	No: bad idea	54%	67
	No: quality concerns	46%	67
D	**Concerns**		
	Wrote additional remarks	59%	125
	Indicated concerns	82%	74

[a] Different sample sizes (N), because not all farmers answered all questions. Here, we did not include the missing answers

Of all 125 farmers, 59% wrote additional remarks, and the majority of these were concerns (Table 4D). Micropollutants such as hormones and other impurities caused by far the biggest worry, even though we had mentioned that the urine-based fertilizer would be treated to such a degree that it should not pose any toxicological or hygienic risks: doubts concerning micropollutants were mentioned in 51% of 74 remarks, which equals 30% of all 125 farmers. Other frequent concerns were feasibility (9% of 74), hygiene (7%), high costs (5%), missing acceptance by consumers of agricultural products (5%), and a negative attitude towards ideas that come 'from the city' and are burdened on farmers (9%). Of those with remarks, 9% explicitly wrote that they thought it was a ridiculous idea altogether (6% of all 125).

Opinions rarely differed among groups; here we present the few significant results only. The farmers older than 45 years were less indifferent towards the idea of urine-based fertilizer and the change of regulations than the younger ones: more older farmers had a distinctly negative or positive opinion (Figures 1A, B). More farmers without vegetables would change regulations to allow urine-based fertilizer in organic farming (Figure 1C). More organic than IP farmers indicated that they would not buy a urine-based fertilizer because they had no need for it (Figure 1D). Finally, more farmers that would not buy a urine-based fertilizer wrote additional remarks (Figure 1E). Concerns were mentioned more often in the remarks, when the farmers also indicated that they would not buy a urine-based fertilizer – in contrast, the farmers that would buy the fertilizer indicated fewer concerns (Figure 1F).

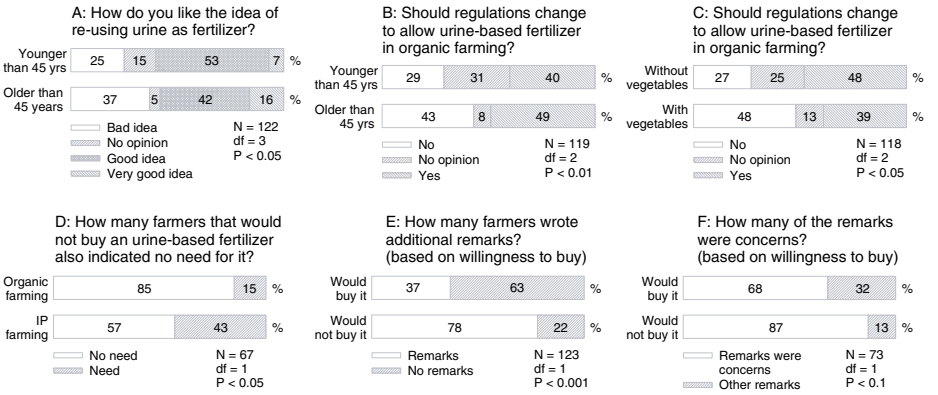

Figure 1 Significant differences among farmer groups concerning the acceptance of a urine-based fertilizer. We present the questions, the groups tested against each other (i.e. younger or older than 45 yrs; Figure 1A), responses to the possible answers (%), sample sizes (N), degrees of freedom for the χ^2 tests (df), and significance values (P)

Current use of fertilizer, nutrient demands and type of product needed

Over all groups, 38% of farmers bought additional fertilizers (Table 5A), with large significant differences among groups: more IP than organic farmers, more farmers with than without vegetables, and more vegetable farmers within only organic or only IP farmers purchased additional fertilizers (Figure 2A). Forty-six % of all farmers indicated a medium to large demand for N (Table 5B), the IP farmers indicating significantly more demand for N

Table 5 Use of additional fertilizers (A), nutrient demands (B), preferred form of nitrogen (C), acceptance of fertilizer with urine odor (D), and type of fertilizer product needed (E; percentage over all farmers)

		Percent
A	**Additional fertilizer used?**	
	Uses additional fertilizers	[a]49%
	Buys additional fertilizer	38%
B	**Nutrient demand**	
	Medium to large need for N	46%
	Medium to large need for P	28%
	Medium to large need for K	22%
	Medium to large need for B	18%
	Medium to large need for others	14%
C	**Preferred form of nitrogen**	
	Urea	14%
	NH_4^+	18%
	NO_3^-	18%
	Organically bound	25%
D	**Fertilizer with urine odor**	
	Would use it near house	12%
	Would use it on open field	31%
E	**Preferred type of fertilizer**	
	Has need for liquid fertilizer	11%
	Has need for grainy fertilizer	38%

[a] Sample size for all (N = 125); percentages inclusive missings; e.g., (A) 49% of all farmers indicated that they used additional fertilizer, and 51% that they did not or they gave no answer

than the organic farmers (Figure 2B). More IP farmers with vegetables than IP farmers without vegetables indicated a medium to large demand for K and B (Figure 2B).

The preferred form of nitrogen differed among some farmer groups: IP compared with organic farmers preferred NH_4^+ (Figure 2C). NO_3^- was preferred by more IP than organic farmers, by more farmers with than without vegetables, and also by many more IP farmers with vegetables than IP farmers without vegetables (Figure 2C). Organic farmers, and farmers without vegetables seemed to slightly prefer an organically bound slow-release fertilizer, but these preferences were not significant.

Of all farmers, only 35% would use a fertilizer with urine odor (near houses, in fields, or both), IP farmers being more willing to use it (especially in fields) than organic farmers (Figure 2D). Acceptance of cattle or hog manure was much higher: up to 100% of vegetable or IP farmers would use hog manure (with rather unpleasant odor) on fields. Farmers clearly preferred a grainy to a liquid fertilizer product (Table 5E; Figure 2D).

However, the price of a urine-based fertilizer would have to be moderate: only 4% of the farmers would pay more than for the fertilizer they are currently using, 34% would pay the same, 37% would pay 20% less, and 25% would pay 50% less. Regarding price, there were no differences among groups. Moreover, the older farmers did not differ from the younger ones in any of these variables.

Discussion

Attitude of farmers towards a urine-based fertilizer product

Considering that the idea of a urine-based fertilizer is new and possibly startling, acceptance among the answering farmers was surprisingly high, with 57% explicitly stating that

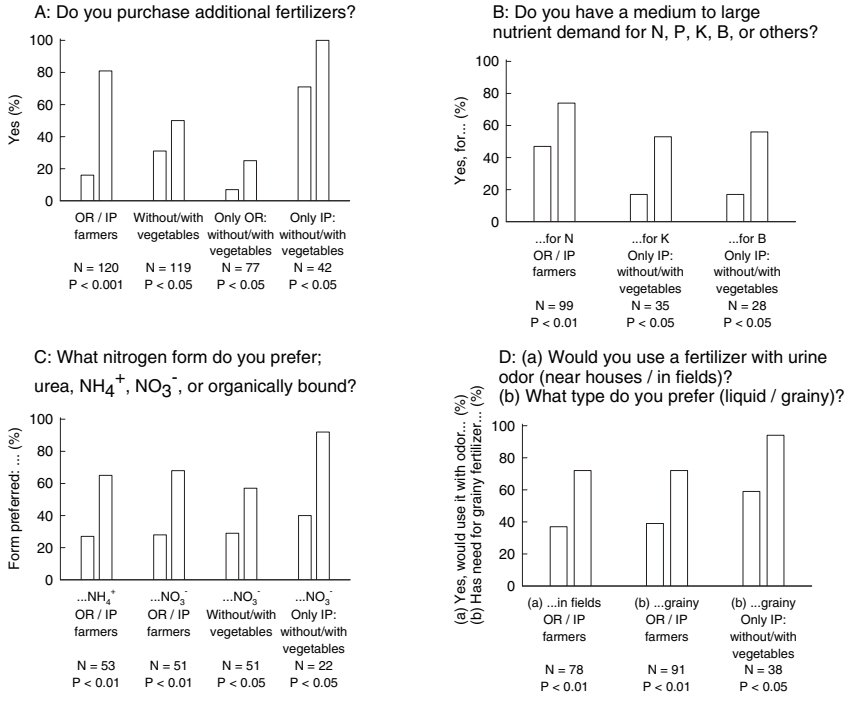

Figure 2 Significant differences among farmer groups concerning nutrient and fertilizer demands. We present the questions, the answers of the groups tested against each other (i.e., 16% of OR [organic], and 81% IP farmers purchased additional fertilizers; Figure 2A, 1st group), sample sizes (N), and significance values (P). The degree of freedom for the χ^2 test was always 1. Sample sizes differ, because not all farmers answered all questions

they thought it was a good or very good idea, and 42% willing to purchase such a product (Table 4). The farmer groups with different production types did not differ significantly in their attitude towards urine-based fertilizers. However, this might be an artifact of the biased sample, since probably primarily interested farmers answered (see below). Given certain quality criteria, farmers with a real nutrient demand (i.e. that purchased additional fertilizers anyway) would also buy a urine-based fertilizer product. Since a large majority of IP farmers – especially with vegetable production – purchases additional fertilizers, market chances would presumably be largest among this group. IP farmers were also less reluctant to apply fertilizer with urine odor compared with organic farmers. They strongly preferred a grainy nitrogen fertilizer in form of NH_4^+ or NO_3^-. Farmers were not willing to pay more than they paid for their current fertilizer product. Asking for the price can give an indirect estimation of attractiveness. Since only 34% of the farmers would even pay the same they currently paid, a urine-based fertilizer does not seem to be a highly desirable product at the moment. However, if one succeeds in producing a good quality, hazard free fertilizer, market chances seem to be good.

Concerns regarding micropollutants in urine

Concerns regarding the safety of a urine-based fertilizer were prominent, with 30% of all farmers remarking that they had doubts regarding residues such as hormones and pharmaceuticals. Such concerns were also mentioned by ca. 50% of farmers of any group that was not willing to purchase a urine-based fertilizer and seemed to be an important reason for rejecting the idea. Only 4% of all farmers mentioned hygiene as a problem. Apparently, farmers did not question the possibility of hygienizing a urine-based fertilizer, but did not believe in the technical feasibility of removing micropollutants. We hypothesize that this is due to a lack of positive experiences. Farmers in Switzerland – and Europe – were confronted with a paradigm change, especially regarding sewage sludge. Early recommendations strongly promoted the use of sewage sludge as fertilizer (Candinas, 1989). However, increasing awareness of environmental problems is now resulting in the total ban of re-use of this waste in Switzerland. Farmers are sensitized, and have been made responsible for various environmental problems, ranging from eutrophication to landscape destruction (Pongratz, 1992). This may result in total rejection of new ideas. Indeed, 6% of all farmers mentioned strong resentments against being burdened with problems 'from the cities'. Therefore, positive communication is essential. Moreover, the concerns regarding micropollutants are understandable. Without process engineering experience, it is not obvious why it should be possible to remove micropollutants from urine, but not from sewage sludge. Therefore, future communication with farmers must also emphasize technical knowledge transfer.

Nutrient demand in Swiss agriculture

Today, urine separation in Switzerland could substitute around 37% of N, 20% of P, and 15% of K from artificial fertilizers (Table 1). With increasing conversion from conventional to organic or IP farming, nutrient demands in agriculture will diminish, because organic agriculture applies by far less additional fertilizers. Therefore, a urine-based fertilizer could account for an even larger percentage of substitution. A popular argument against reusing nutrients in agriculture is the idea that agriculture generally faces a nutrient surplus. This applies to certain countries (e.g. The Netherlands; van Bruchem *et al.*, 1999), and to certain production types (livestock farming; Hall, 1999). Our survey clearly indicates that there *is* a nutrient demand for N (46% of all farmers), P (28%), and K (22%; Table 5), and that fertilizers *are* imported into Switzerland (Table 1). Surplus of nutrients is a regional problem due to transportation limitations. With liquid urine, we would face similar prob-

lems. In contrast, purified and solidified urine could easily be transported. We therefore believe that the existing nutrient demand could be partially supplied by a urine-based fertilizer product, which is additionally a sustainable alternative to artificial fertilizers.

Methodological considerations

A drawback of our study is that the project NOVAQUATIS is still in a very early phase. It is possible that some farmers did not take our idea of urine recycling seriously, which could be responsible, in part, for the relatively poor response rate. With ongoing implementation of larger pilot projects and increasing publicity, this should change. However, possibly farmers with currently indifferent opinions (because they did not take the idea seriously), might then also adopt a negative attitude.

Given that the response rate was rather low (27%) and differed significantly among farmer groups (Table 3), our study is not representative for Swiss farmers in general. Possibly, only farmers with increased interest in the very particular topic answered our questions (Dillman, 1991). In a study on farm work satisfaction, response rates also differed among conventional (60% returned) and organic farmers (80%), which was attributed to the relative salience of the study to the two groups (Rickson *et al.*, 1999). Work satisfaction is certainly much more relevant to all farmers than our topic, and is known to achieve better response (Heberlein and Baumgartner, 1978). Nevertheless, a better response would have been possible. In social research methodology low response to mail surveys is discussed extensively (Babbie, 2001; Schutt, 2001). Data collection with questionnaires can be implemented with three modes: (1) face-to-face interviews, (2) via telephone, or (3) with mail surveys. All three have their specific strengths and optimal application framework. In our study, due to restricted resources, neither telephone nor face-to-face interviews were possible, since the researcher needs even more time for each respondent than the respondent needs to answer the questions, especially in geographically dispersed areas (travel time). Hence, here mail survey is still the most promising method. Dillman (2000) postulates five important elements to achieve high response in mail surveys: (1) a respondent-friendly questionnaire, (2) up to five contacts with the recipient, (3) inclusion of stamped return envelopes, (4) personalized correspondence, and (5) a token financial incentive sent with the survey request. We followed (1), (3) and (4); (5) was not possible. Most importantly, increased response is possible with multiple contacts (Dillman, 1991). These need to be distinctive to attract different respondents at different times. Therefore, Dillman (2000) proposes: (1) a brief prenotice letter on the study, (2) a questionnaire mailing with detailed cover letter, (3) a postcard a few days later to thank for responding and reminding others to do so, (4) a second questionnaire to all non-respondents 2–4 weeks later, and (5) a phone reminder to the rest of the non-respondents. Evidently, steps (4) and (5) require an identification of each questionnaire, something that we did not want, because it could cause distrust among farmers. In short, increasing response in a mail survey is feasible, but requires a full set of measures and sufficient resources.

Conclusions

We conclude that there *is* a demand for the nutrients N, P, and K in Switzerland, which could be substituted, to a certain degree, by a recycled urine product. Those Swiss farmers that have a real need for additional fertilizers will most likely accept a urine-based fertilizer. Therefore, market chances would be especially high among IP and vegetable farmers. The fertilizer would have to be relatively cheap, odorless, of desired type (i.e. grainy ammonium nitrate), and – most importantly – free of micropollutants, since concerns regarding micropollutants seemed to be a prominent motive for rejection. Before actually introducing such an innovative product, stakeholder demands need to be assessed

in further detail. Our study further shows that additional measures are necessary to obtain representative data for an entire population (all Swiss German farmers in our case). Therefore, we propose that future surveys either use more time-consuming telephone interviews, or increase response rates of a mail survey by establishing multiple and varying contacts with the respondents. Finally, we believe that acceptance of a urine-based fertilizer will only be successful with ongoing information and participation of farmers and other stakeholders from the start.

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