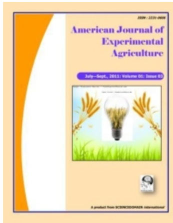

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Effects of Planting Sugarcane and Napier Grass on N Leaching from Lysimeters under High Application of Cattle Manure

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Authors' contributions

This work was carried out in collaboration between all authors. Authors SI and SY designed the study. Author SI performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SA and SI managed the analyses of the study. Author SI managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: Excess manure accumulated in livestock areas has been a concern in Japan where a great amount of nutrients such as nitrogen (N) has been imported from abroad contained in various agricultural commodities especially feeds for livestock animals. Aims of the present study is to look into the effects of planting sugarcane and napier grass on nitrate leaching from fields overdosed with excessive amount of manure application.
Study Design: A lysimeter experiment of 3 treatments with 2 replicates.
Place and Duration of Study: NARO-Shikoku Research Center (Kagawa, Japan), three years.
Methodology: (1) Monitoring of water samples drained from lysimeters during study period, (2) Sampling of planted crops and soils.
Results: The plots planted with either sugarcane or napier grass showed less drainage of water as well as less leaching of mineral N compared to control plots after summer when canopy was fully established. However, leaching of mineral N could not be completely prevented at the events of severe rainfalls except for the plots planted with napier grass.

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The reduced amount of drainage water for the plots planted with either sugarcane/napier grass was considered to be attributable to evapotranspiration of these crops. Both sugarcane and napier grass recovered a great amount of N in the above-ground part by the time of harvest. Yet, total N concentration of soil layers did not appear to have been affected by the presence of these crops compared to control plots.
Conclusion: It was concluded that planting sugarcane/napier grass was effective in the studied area in reducing leaching of mineral N especially by reducing drainage water.

Keywords: Nitrate leaching; lysimeter; evapotranspiration; sugarcane; napier grass.

1. INTRODUCTION

Nitrate concentration in groundwater is regulated by laws and regulations in different parts of the world [1-3]. Agriculture has been considered as a major source of nitrate leaching to surface and ground waters [4-6]. Pionke et al. [7] observed a nitrate-N concentration as high as 209 mg l^{-1} from drainage below the root zone in a horticultural area located in Western Australia. Fujiie et al. [8] pointed out that the reduction in nitrate leaching estimated in an area of Miyakojima-island during the period between 1977 and 2005 was partly attributable to the halved amount of fertilizer application between 1980 and 2006 indicating that agriculture was actually a major source of nitrate leaching in the studied area. Improved methods of fertilization such as split application and the use of slow releasing fertilizers have been recognized effective in reducing nitrate leaching [9-10].

However, there are situations where high rates of fertilization are practiced [11-12]. De Paz and Ramos [13] mentioned growers in Spain who apply excessive amount of fertilizers by paying little attention to local recommendations. Similar cases can be found in other parts of the world [14-15]. In Japan, vegetables and tea [16-17] are the crops that usually receive highest rates of fertilizer. Nishio [18] reported that amounts of unutilized nitrogen are especially high, more than 300 kg·ha^{-1}, in the case of celery, eggplants, cucumbers and tea. The growers apply high rates of fertilizer to these crops, as they are less likely to show negative response, such as yield decline, to heavy fertilization. In the case of tea, yield increased with the application of 1006 kg·ha^{-1} of mineral N. High rates of fertilizer application by vegetable growers are attributed to the relatively high economic value of commodities [19-20]. It is common that crops receiving high rates of chemical fertilizers are also applied with high rates of manure [21], another major causal factor of nitrate leaching [22-24].

In areas where livestock is intensively produced, the disposal of excess manure is a concern [25-26]. In Japan, livestock production once was closely linked to arable farming when scales of farms were small and manure was seen as a valuable source of nutrients. Concentration of livestock sector and spread use of chemical fertilizer brought about a situation where livestock sector became separated from arable farming [27-29] leading to manure shortage in arable farms [30], while excess manure being piled up in livestock farms [28]. Compared to chemical fertilizers, nutrients released from manure are much harder to control especially when applied at high rates continually [27,31]. As it has been rather common for growers to focus on the role of soil conditioner of manure paying less attention to the aspect of fertilizer, amounts of nutrients added to soils through manure application are very often omitted from calculation of nutrients balance [22,32] leading to the increased number of fields overdosed with excess nutrients [32-33]. In extreme cases, accumulated nutrients need to be removed by means of planting green manure crops or drained by a large amount of water in the case of glasshouse situations where natural drainage by rainfall cannot be expected. In any case, nitrogen-releasing effects of manure could last relatively a long period [34-35].

Outstanding ability of gramineae crops to take up N has been reported [25,36-38]. Sugarcane has been claimed to be promising as a double purpose crop, i.e. feed and cleaning crops for its ability to accumulate little amount of nitrate even when applied with high rates of N [39]. Effects of green manure crops and/or catch crops especially grown in winter on nitrate leaching have been studied relatively well. Thomsen and Christensen [40] and Thomsen [23] employed ryegrass as a catch crop in a series of lysimeter experiments and observed substantial reductions in nitrate leaching, although nitrate could be released again from the crop depending on methods and timings of incorporation. There seem, however, to be fewer studies so far that have looked into the effects of cultivating summer crops of gramineae such as sugarcane and napier grass on nitrate leaching from soils. It would serve agriculture as well as science to find out if the claimed ability of gramineae crops to take up large amount of N has significant meaning in terms of nitrate leaching from soils.

The objective of the present study is therefore to evaluate the effects of planting summer crops such as sugarcane and napier grass as well as a winter crop of triticale on the amount of drained water and that of leached nitrogen under the conditions of high application of cattle manure.

2. MATERIALS AND METHODS

A lysimeter experiment was conducted at National Agricultural Research Center for Western Region, Zentsuji (34º13'N, 133º46'E) during the period from December, 2007 until December, 2010. A lysimeter was the size of 2.9 m by 2 m with the depth of 1 m. Six lysimeters were employed for the experiment and gravel was spread over the bottom. Three lysimeters were filled with soil of granite origin in June, 2006 and sunflower grown, while the other three were filled in December, 2007. To each lysimeter, cattle manure of 10.0 $kg \cdot m^{-2}$ (100 $g \cdot m^{-2}$ of N) was applied in December, 2007 before commencing the experiment. During the experiment, cattle manure of 6.0 $kg \cdot m^{-2}$ (91 $g \cdot m^{-2}$ of N) and 5.2 $kg \cdot m^{-2}$ (78 $g \cdot m^{-2}$ of N) were applied to each plot and incorporated into the soil on 15 May and 22 July in 2009 respectively. In 2010, neither cattle manure nor chemical fertilizer was applied. In total of three years, 21.2 $kg \cdot m^{-2}$ of cattle manure and 269 $g \cdot m^{-2}$ of nitrogen were applied to each lysimeter supposing a high range of N rates possibly applied to some crops such as asparagus [21] and celery [18]. As senescence of leaves started being observed with napier grass from the prevailed dry condition in summer in 2010, irrigation of 34 mm was applied three times to each lysimeter on 24, 30 August and 9 September.

Treatments were consisted of the combination of a winter crop, triticale (X. Triticosecale Wittmark, cv. Ryekokko II) and summer crops, sugarcane (Saccharum spp. hybrid) and napier grass (*Pennisetum purpureum* Schumach. cv. Merkeron) (Table 1). Six lysimeters were assigned to three treatments creating two replicates for each treatment. The lysimeters filled with soil in 2006 were assigned to Rep. 1 and those in 2007 to Rep. 2. In 2008 and 2009, a half of the sugarcane plot was planted with seedlings of a sugar cultivar, NiF8, while the other half with those of KRFo93-1, the first feed cultivar of sugarcane bred for feed use in Japan [41]. In 2010, the whole plot was planted with seedlings of KRFo93-1. As to the control, plots were left with weeds in 2007/2008, while they were maintained bare by incorporating emerged weeds periodically in 2009 and 2010.

Table 1. Crop sequence in lysimeter experiments

Crop Sequence	2008		2009		2010	
Y1-Y2-Y3	Winter	Summer	Winter	Summer	Winter	Summer
C-C-C	untreated	untreated	bare soil	bare soil	bare soil	bare soil
TS-TS-TS	triticale (Ryekokko II)	sugarcane (NiF8, KRFo93-1)	triticale (Ryekokko II)	sugarcane (NiF8, KRFo93-1)	triticale (Ryekokko II)	sugarcane (KRFo93-1)
S-S-TN	untreated	sugarcane (NiF8, KRFo93-1)	bare soil	sugarcane (NiF8, KRFo93-1)	triticale (Ryekokko II)	Napier grass (Merkeron)

Y: year; C: control; T: triticale; S: sugarcane; N: napier grass

For each lysimeter, a drum of 84 litre volume was placed to collect the drained water. The depth of the water was measured to estimate the amount of drained water. Water samples were taken to estimate the amount of leached mineral nitrogen. After the measurement and collection of the samples, water was drained from the drum. Although water was carefully collected especially after the rainfall, there were a few occasions when water overflowed the drum. Aboveground plant materials were sampled at harvest of each crop (Table 2) and the fresh matter weight was determined. A subsample was oven-dried at 70ºC for 5 days and the dry matter weight determined.

Table 2. Planting, harvest and sampling dates of triticale, sugarcane, napier grass and weeds

Year	Crop	Triticale		Sugarcane/ Napier grass		Weeds
		P	H	P	H	Sp
2008	Control	-	-	-	-	5-Nov-08
	Triticale-Sugarcane	21-Dec-07	25-Apr-08	12-May-08	5-Nov-08	-
	Sugarcane	-	-			12-May-08
2009	Control	-	-	-	-	-
	Triticale-Sugarcane	15-Jan-09	15-May-09	19-May-09	25-Nov-09	15-May-09
	Sugarcane	-	-			-
2010	Control	-	-	-	-	-
	Triticale-Sugarcane	15-Jan-10	26-Apr-10	30-Apr-10	16-Nov-10	-
	Triticale-Napier grass					-

P: planting; H: harvest; Sp: sampling

2.1 Analysis of Samples

Sampled water was subjected to the analysis of nitrate-N and ammonium-N [42]. Dried plant materials were milled and filtered through 2 mm mesh (No. 1003-S; Yoshida Seisakusho, Tokyo, Japan).The milled plant samples were subjected to the analysis of total N concentration by the Dumas method with a Vario MAX CN (Elementar, Hanau, Germany). The nitrate-N concentration of sugarcane and napier grass plants was determined by Cataldo method [43].

2.2 Statistical Analysis

As the experiment was conducted in two replicates, results of both replicates were presented in figures and tables rather than showing a mean value with the standard deviation. Analysis of variance (ANOVA) was performed for some of the datasets using a statistical program of SPSS 13.0 (Tokyo).

3. RESULTS AND DISCUSSION

3.1 Weather

Daily mean temperature and total rainfall are given in Table 3. When the weather station near the experimental site was unable to record, the data sets recorded at the location, 3 km away from the site, were employed. In 2008, it rained very little during summer. High rainfalls recorded in July and August of 2009 and in July of 2010 were the events of a few days.

Table 3. Mean daily temperature and total rainfall over the three seasons

Month	2008		2009		2010	
	Temp. (ºC)	Rainfall (mm)	Temp. (ºC)	Rainfall (mm)	Temp. (ºC)	Rainfall (mm)
January	5.1	78	5.5	69	5.5	20
February	4.4	42	7.3	84	6.9	76
March	9.4	131	9.2	57	8.5	144
April	14.3	89	14.8	48	12.4	115
May	18.7	147	19.7*	48	18.2	97
June	21.9	150	23.3	91	22.9	194
July	28.1	12	26.6*	187*	26.8	137
August	27.6	46	27.4*	132*	29.1	67
September	23.9	138	23.3	33	25.7	78
October	18.7	109	18.2**	73	18.7	127
November	12.3	82	12.6	116	12.1	30
December	8.1	30	7.6	34	7.8	54
Mean	16.0	88	16.3	81	16.2	95

**Data recorded at Senyu area (3 km away from Ikano area); **excludes two missing dates*

3.2 Water Drainage and N Leaching

Amount of the drained water in each year is presented in Figs. 1a, 1b and 1c. Effects of planting triticale on leaching of water were hardly observed compared to control plots in 2009, while they were recognized in 2010. In 2007/2008, leaching was the least for one of the control plots. In 2009 and 2010, the plots planted with sugarcane or napier grass showed less leaching compared to control plots, i.e. bare soil, after summer until harvest. However, leaching of N could not be completely prevented at the events of severe rainfalls except for the plots planted with napier grass in 2010 (Table 4).

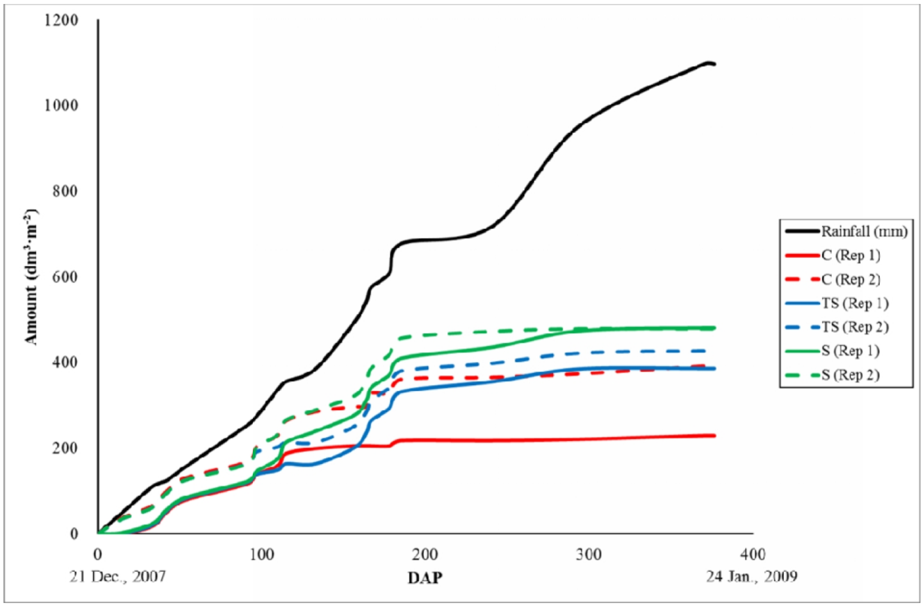

Fig. 1a. Accumulated rainfall (mm) and drained water ($dm^3 \cdot m^{-2}$) in 2007/2008
C: control; TS: triticale-sugarcane; S: sugarcane; DAP: days after planting; Rep: replicate

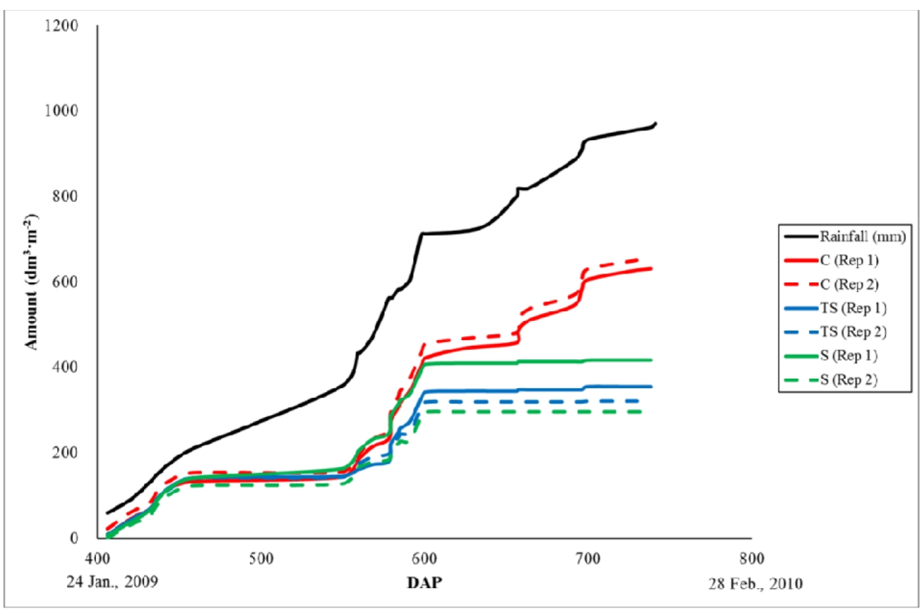

Fig. 1b. Accumulated rainfall (mm) and drained water ($dm^3 \cdot m^{-2}$) in 2009
C: control; TS: triticale-sugarcane; S: sugarcane; DAP: days after planting; Rep: replicate

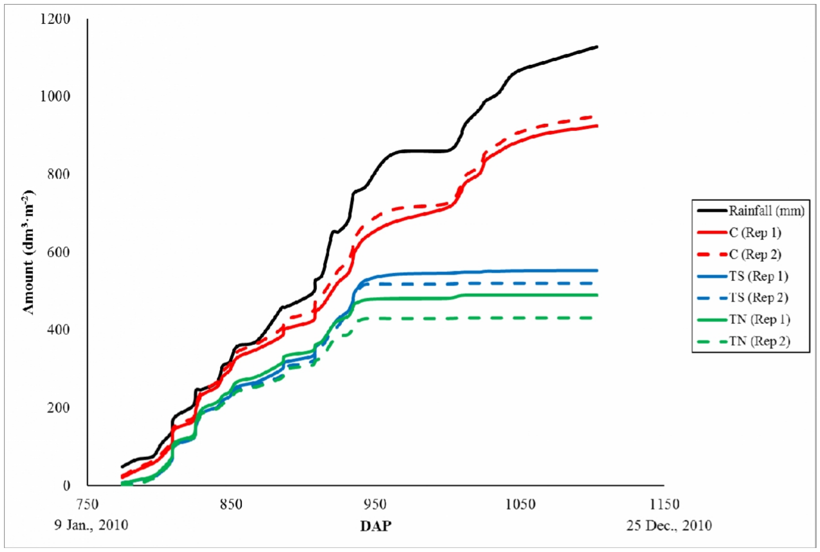

Fig. 1c. Accumulated rainfall (mm) and drained water ($dm^3 \cdot m^{-2}$) in 2010

C: control; TS: triticale-sugarcane; TN: triticale-napier grass; DAP: days after planting; Rep: replicate

Table 4. Amount of drained water and leached mineral N at events of severe rainfall

Severe Rainfall Events			Drained Water	Leached mineal N
Start Date	**End Date**	**Rainfall (mm)**	**(mm)**	**($g\ m^{-2}$)**
20-Jul-09	21-Jul-09	80	53.5	5.9a
9-Aug-09	10-Aug-09	102	57.9	5.3a
11-Jul-10	13-Jul-10	70	44.3	2.1b
Crop Sequence				
Control (C)			60.9a	5.9a
Summer Crop (S)			51.9ab	5.2a
Winter-Summer Crop (TS and TN)			45.5b	3.3b
P value				
Severe Rainfall Events			.063	.001
Crop Sequence			.031	.010

C: control; S: sugarcane; TS: triticale-sugarcane; TN: triticale-napier grass

The change in mineral N concentration of the drained water observed during the experimental period is presented in Fig. 2. Lysimeters of Rep 1 exhibited extremely high concentrations of the drained water compared to those of Rep 2. It took approximately 300 days for the discrepancy of the two replicates to disappear. Mineral N concentration was reduced to zero by the presence of napier grass from July 2010.

The cumulative amount of leached mineral N during the experimental period is presented in Figs. 3a, 3b and 3c. In 2007/2008, a similar discrepancy between the two replicates was observed (Fig. 3a) as was in the mineral N concentration of drained water. Both in 2009 and 2010, amounts of leached mineral N were significantly smaller for the lysimeters planted with sugarcane and napier grass compared to those assigned to control (Figs. 3b and 3c), (Table 5).

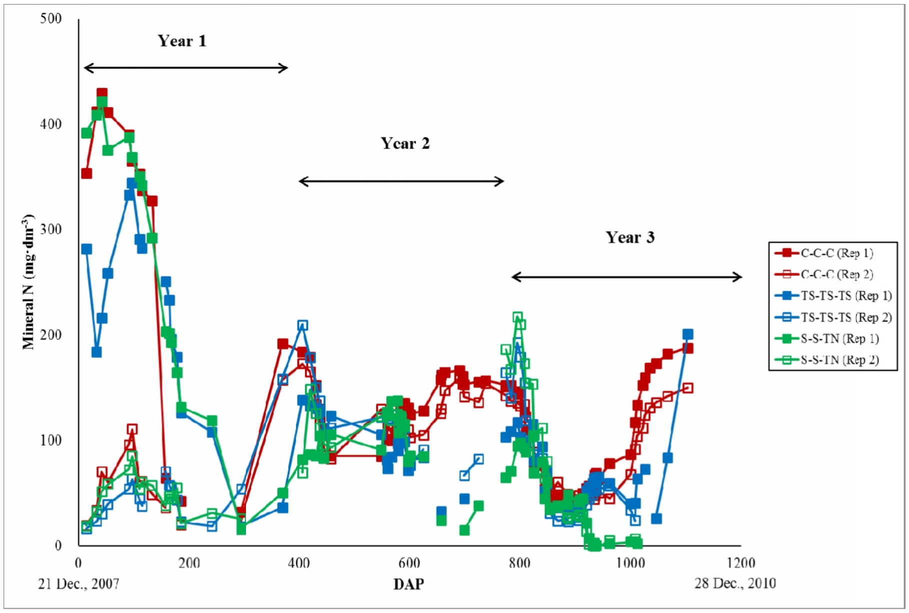

Fig. 2. Change in the concentration of mineral N in drained water during the experiment

C: control; TS: triticale-sugarcane; S: sugarcane; TN: triticale-napier grass; DAP: days after planting; Rep; replicate

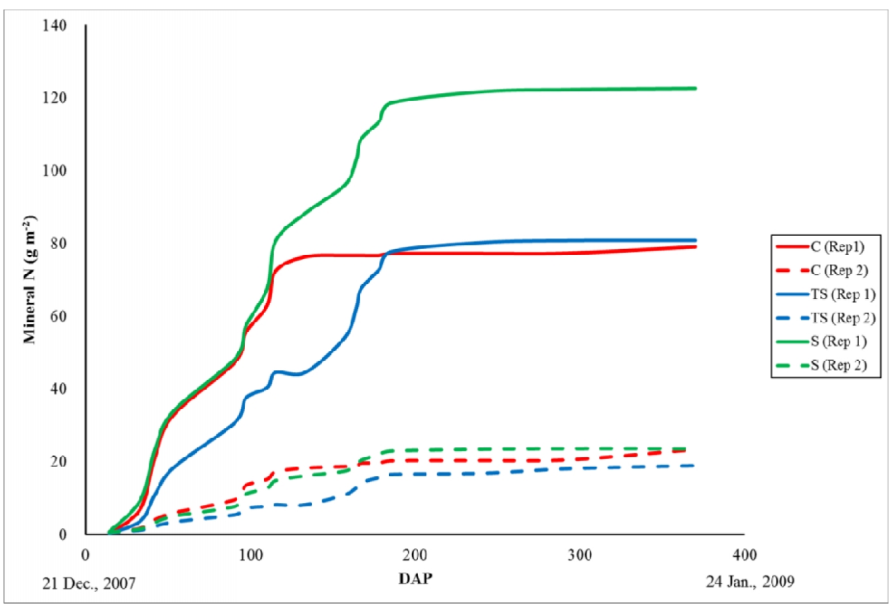

Fig. 3a. Accumulation of leached mineral N in 2007/2008

C: control; TS: triticale-sugarcane; S: sugarcane; DAP: days after planting; Rep: replicate

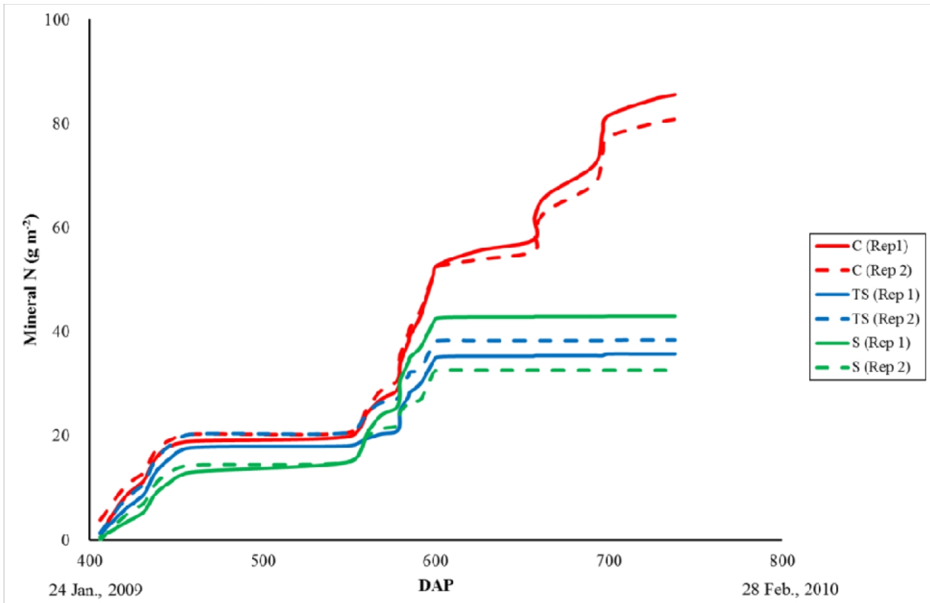

Fig. 3b. Accumulation of leached mineral N in 2009
C: control; TS: triticale-sugarcane; S: sugarcane; DAP: days after planting; Rep: replicate

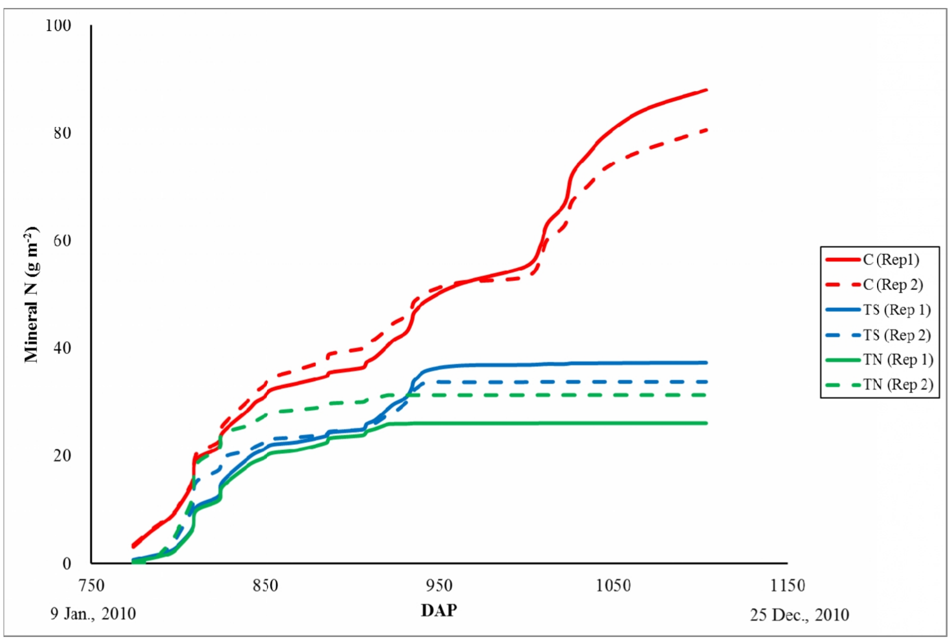

Fig. 3c. Accumulation of leached mineral N in 2010
C: control; TS: triticale-sugarcane; TN: triticale-napier grass; DAP: days after planting; Rep: replicate

Table 5. Drained water and leached mineral N

Year	Crop	Drained water (mm·year^{-1})	Leached mineral N (g·m^{-2}·year^{-1})
2009		446a	52.7
2010		663b	50.3
	Control (C)	790a	83.8a
	Summer (S)	465b	36.6b
	Winter-Summer (TS and TN)	408b	34.2b
***P* value**			
Year		.001	.458
Crop		< .001	< .001

C: control; S: sugarcane; TS: triticale-sugarcane; TN: triticale-napier grass

3.3 Growth, Yield and N Content of Crops

Height, above-ground dry matter weight and above-ground N yield of planted crops as well as weeds are presented in Table 6. Major weeds observed in control (C) and sugarcane plots (S) in 2008 were common lamb's-quarters (*Chenopodium album* L. var. *album*), henbit (*Lamium amplexicaule* L.), Japanese dock (*Rumex japonicas* Houtt.), water foxtail (*Alopecurus aequalis* Sobol. var. *amurensis* (Komar.) Ohwi) and field horsetail (*Equisetum arvense* L.). In 2010, napier grass suffered from drought typical to this area during summer resulting in leaf senescence. The combination of triticale and napier grass, however, recovered the greatest N in 2010. Although nitrate-N concentration of both sugarcane and napier grass did not exceed the critical level of 0.2 % for feed at dry matter basis, the values in 2010 was relatively higher than those in other years (data not shown).

3.4 N Content of Soils

For the original soil contained in the lysimeter and soils after the experiment, pH, C, Total N, nitrate-N and ammonium-N were presented (Table 7). The original soil was sampled in 2010 from the hill where the soil had been taken to fill the lysimeter in 2007. Nitrate-N in every soil layer was lower for the plots planted with napier grass in the year 3 (S-S-TN) compared to control plots (C-C-C) and the combination of triticale-sugarcane plots (TS-TS-TS). As the sampling and the analysis of the original soil were carried out in the third year of the experiments, comparison of inflow and outflow of nitrogen in each lysimeter was not attempted.

Table 6. Height, aboveground DMW and above-ground N yield of the harvested crops

Year	Treatment	Height (cm)		Above-ground DMW ($kg \cdot m^{-2}$)			Above-ground N Yield ($g \cdot m^{-2}$)			
		T	S/N	T	S/N	W	T	S/N	W	Total
2008	C	-	-	-	-	2.25-10.05	-	-	24-152	24-152
	TS	86-96	290-323	0.69-0.87	3.09-3.55	-	34-36	30-36	-	64-72
	S	-	305-322	-	3.52-4.36	0.29-0.53	-	32-41	12-16	47-53
2009	C	-	-	-	-	-	-	-	-	0
	TS	88-121	266-281	0.78-1.68	3.05-3.52	0.10	22-33	32-38	4	63-65
	S	-	281-285	-	3.85-3.86	-	-	38-39	-	38-39
2010	C	-	-	-	-	-	-	-	-	0
	TS	46-48	281-318	0.41-0.65*	3.62-4.35	-	13-23*	40	-	53-63
	TN	48-49	292-315	0.62-0.63*	4.91-5.38	-	18-23*	39-49	-	56-72

Results are presented as a range of two replicates.

Table 7. pH, C, total N, nitrate-N and ammonium-N in the original soil and the soils after the experiment

	Crop Sequence	Depth	pH	C	Total N	nitrate-N	ammonium-N
	Y1-Y2-Y3	**(cm)**		**(%)**	**(%)**	**($mg \cdot 100g^{-1}$)**	**($mg \cdot 100g^{-1}$)**
Original†		-	5.7	2.6	0.16	0.63	1.43
	C-C-C		6.1a	2.7a	0.17	4.23a	0.55
	TS-TS-TS		6.4b	3.0ab	0.19	3.23a	0.58
	S-S-TN		6.5b	3.1b	0.19	1.36b	0.37
		0-25	6.2a	3.3a	0.21a	3.21	0.48
		25-50	6.4b	2.7b	0.18b	2.62	0.52
		50-75	6.4ab	2.7b	0.17b	3.00	0.50
***P* value**							
Crop Sequence (CS)			.003	.016	.053	.002	.063
Depth (D)			.035	.003	.005	.556	.899

Y: year; C: control; T: triticale; S: sugarcane; N: napier grass
† not included in the statistical analysis
Means with the same letter within each component (Crop Sequence and Depth) are not significantly different.

3.5 Discussion

Planting sugarcane and napier grass was found effective in reducing the amount of drained water during summer (Figs. 1a, 1b and 1c). A hypothesis to arise is that water contained in the soil might have been reduced by evapotranspiration of the crop whether it was sugarcane or napier grass or even weeds, which would have provided soils with a higher capacity of holding water at events of rainfall. 1500 to 2500 mm of water has been reported to be required by sugarcane during its growth period [44], amounts greater than that of the rainfall observed in the present study. Although there are a number of studies that have looked at evapotranspiration of various crops including sugarcane [45-46], many of them were conducted to gain insight of water requirements of target crops for management of irrigation in semi-arid climates [47-48]. Efforts of reducing leaching losses of fertilizers can be seen in drought-prone areas as well. For areas of intensive cereal production in northern China, Islam et al. [49] proposed a use of superabsorbent polymer as soil amendment to reduce leaching losses.

As to ‘cleaning’ aspects of crops/plants, a number of studies can be found which have attempted to utilize plants to treat wastewaters [50-51] of especially municipal origin [52-53]. Bialowiec et al. [54], in a lysimeter experiment testing effectiveness of willow to treat polluted solutions, observed evapotranspiration of lysimeters planted with willow 3-14 times higher than evaporation of bare soil, which probably could also explain the observation of almost ceased drainage from the lysimeters planted with sugarcane and napier grass in the present study. Singh et al. [55] was unique in suggesting a system of treating waste waters by utilizing the transpiring ability of bamboo (*Dendrocalamus strictus*) characterized with high evapotranspiration rate. In the present study, it took approximately 3 months until the preventing effects of sugarcane on leaching started being observed probably due to its slow growth during early phase. Weeds showed a great nitrogen recovery in one of the two replicates (Table 6). However, constant effects are hard to expect from weeds where N recovery would vary greatly according to the type of weeds that emerge. Besides, leaving weeds uncontrolled would result in an expansion of seed banks in the soil, which would make it difficult to grow crops in following years to come.

In temperate regions, N leaching during winter has been well recognized and preventative measures such as planting catch crops have been practiced [23]. C3 cereal crops could take up a large quantity of N in suitable climates [56]. In the present study, triticale recovered a great amount of N comparable to that of sugarcane in 2008 and 2009. Triticale had a variable crop stand and its biomass yield was probably overestimated to some extent by limited sampling areas. The contribution of the crop both to the decreased water drainage and N leaching, however, was hard to recognize in 2009. In 2010, amounts of drained water and leached N appeared to have been reduced for the plots planted with triticale compared to control plots. The amount of rainfall in March and April in 2009 was approximately half of that in 2010 and there was little drainage of water in 2009 from any lysimeter. Triticale is therefore considered to have functioned as an effective cleaning crop in reducing N leaching, though the effects were smaller than those of sugarcane and napier grass.

Concentration of total N in soils did not appear to have been affected by the presence of any crop tested in the present study. A possibility that N leaching occurred not only in mineral forms but also in organic forms in the drained water could not be excluded [57], however, the fact that drained water was reduced to the level of near zero exhibited that planting cleaning crops was effective in preventing N leaching. Prevention of leaching by transpiration, the major finding of the present study, was effective at least partially for the events of severe rainfall in a short period of time (Table 4). Amount of annual rainfall observed in the studied area was less than 1000 mm, approximately two thirds of the average rainfall in the country. A further experiment is therefore required to study if transpiration of sugarcane/napiergrass would prevent N leaching in the areas of higher rainfall. As this study was carried out on lysimeters, containers where root growth is unnaturally restricted, a careful consideration is required in interpreting the results in the context of actual agricultural practices.

Looking at nitrogen recovery, aboveground part of sugarcane and napier grass contained comparable amounts of nitrogen, while concentration of mineral nitrogen contained in the drained water as well as nitrate left in the soil after harvest significantly differed for two crops. Despite that this was the observation made only in a single year, it gives us an impression that sugarcane and napier grass might have different mechanisms in acquiring nitrogen. Possibilities of nitrogen fixation by diazotrophs have been suggested for sugarcane by a number of researchers [58-60]. If this was the case, ability of sugarcane as a cleaning crop might need be downgraded.

Leaving out nitrogen fixation issue with sugarcane, napier grass is still considered to excel sugarcane in taking up nitrogen from soils under conditions of high fertilization. This is based on the observation made in our previous study [39] where field experiments of high fertilization were conducted in two years with sugarcane and napier grass. In the experiments, we observed nitrogen recovery of napier grass more than twice that of sugarcane for the plots applied with the N rate of 60 g m^{-2}, while difference was much smaller between two crops when the N rate was 30 g m^{-2} implying that sugarcane and napier grass have different capacity in taking up nitrogen. This might be related to another observation we had made in the previous study that sugarcane showed a tendency of accumulating less nitrate compared to napier grass when fertilized with high nitrogen. In the present study, neither sugarcane nor napier grass accumulated nitrate exceeding the critical level of 0.2% at dry matter basis for feed use.

From the above, sugarcane might have looked less competent as a cleaning crop compared to napier grass. This would not be necessary so, if usage of the harvested crop was taken into consideration. Harvested crops could be used for feed in the case of sugarcane where one has less worries about the accumulation of nitrate-N, although this does not exemplify concerns for possible accumulation of other nutrients such as potassium. Sugarcane probably would not be able to clean fields of over fertilization very quickly; however, it could reduce nitrate leaching substantially by evapotranspiration also giving higher chances for growers to utilize harvested crops. Napier grass is capable of reducing nitrate leaching by evapotranspiration as well. In addition, it would be quicker in cleaning up the target fields. On the other hand, it was more susceptible to drought compared to sugarcane and utilization of harvested crop would be considered more difficult. If it happens that undesirable levels or types of nutrients are contained, alternative use needs to be sought for. Biomass use is a possible option [61-62] especially when methods of treating cellulose rich materials have been studied intensively [63-64].

Although this study was originally commenced supposing situations where cleaning crops were expected to treat crop lands applied with over-dosed fertilizers including manure in agricultural areas of mostly vegetable and livestock production, recent upsurge of plant factories in the country based on hydroponics and light emitting diode (LED) makes us ponder a possibility that they might require some types of cleaning crops to treat wastewaters [65] in the future.

4. CONCLUSION

Sugarcane and napier grass were found to be effective in reducing the amount of N leaching from lysimeters overdosed with high rates of manure application. The effects were appeared to be chiefly brought about by the reduced drainage water from lysimeters planted with these crops compared to those left as bare soil. This implies that effects of a 'cleaning crop' could be evaluated not only from its ability of taking up N but also from that of minimizing drainage water at the time of rainfalls.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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