

Table of contents

Abstract	iii
Kurzfassung	iv
Table of contents	v
List of tables	viii
List of figures	viii
List of appendices	x
List of abbreviations	xiii
Acknowledgments	xv
1 Introduction	1
2 Review of literature	4
2.1 Fertilizer trend and usage	4
2.2 Nitrogen use efficiency	5
2.3 Ammonia volatilization	7
2.4 Management techniques to minimize ammonia losses	9
2.5 <i>Azolla</i>	10
2.5.1 Nitrogen fixed by <i>Azolla</i>	10
2.5.2 Release and availability of <i>Azolla</i> -N to rice	11
2.5.3 Effect of <i>Azolla</i> on grain yield and yield components	11
2.5.4 Other beneficial effects of <i>Azolla</i>	12
2.5.5 Critical factors affecting <i>Azolla</i> growth	13
2.5.6 Amount of <i>Azolla</i> inoculum and time of inoculation	14
2.5.7 The use of <i>Azolla</i> to improve N use efficiency	14
3 Materials and methods	16
3.1 Location	16
3.1.1 On-station field experiments	16
3.1.2 On-farm field experiments	18
3.2 Experimental layout and treatments	20
3.3 Planting materials	21
3.3.1 Rice plant	21
3.3.2 <i>Azolla</i>	22
3.4 Inorganic fertilizer	22

3.5	¹⁵ N balance determination.....	23
3.5.1	Microplot sampling.....	23
3.5.2	¹⁵ N analysis.....	24
3.6	Sampling methods and analyses.....	24
3.6.1	Floodwater measurements (1998-99 dry season)	24
3.6.2	Soil samples.....	26
3.6.3	<i>Azolla</i> samples	26
3.6.4	Plant samples	26
3.7	Statistical analysis.....	30
4	Results and discussion.....	31
4.1	Floodwater chemistry	31
4.1.1	Floodwater pH	31
4.1.2	Floodwater temperature.....	34
4.1.3	Floodwater total ammoniacal-N	39
4.1.4	Floodwater aqueous ammonia.....	42
4.1.5	Partial pressure of ammonia	43
4.2	¹⁵ N recovery	46
4.2.1	¹⁵ N recovery by the rice	46
4.2.2	¹⁵ N recovery by <i>Azolla</i>	49
4.2.3	¹⁵ N recovery in the soil.....	50
4.2.4	Total ¹⁵ N recovery in the <i>Azolla</i> -plant-soil system.....	51
4.2.5	¹⁵ N losses in the system.....	52
4.3	Apparent N recovery.....	53
4.4	Nitrogen uptake	54
4.4.1	On-station field experiments	54
4.4.2	On-farm field experiments	58
4.5	Tiller and panicle count	67
4.5.1	On-station field experiments	67
4.5.2	On-farm field experiments	69
4.6	Total dry matter yield at harvest.....	73
4.6.1	On-station field experiments	73
4.6.2	On-farm field experiments	74
4.7	Grain yield.....	75

4.7.1	On-station field experiments	75
4.7.2	On-farm field experiments	78
5	General discussion.....	85
5.1	Floodwater chemistry	86
5.2	¹⁵ N recovery	88
5.3	Total N uptake	89
5.4	Crop growth and yield	90
6	Conclusions.....	92
7	Recommendations	94
8	Summary.....	95
9	References.....	99
	Appendices	112