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A Survey of Myanmar Rice Production and Constraints

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Abstract

Although modern high yielding varieties were introduced into Myanmar in the early 1980s, the national average of rice grain yield has stagnated at 3.2-3.4 t ha^{-1}. To identify yield constraints, input intensities and the general practices of rice cultivation in Myanmar, a survey was conducted during the wet seasons of 2001 and 2002. A total of 98 farmers from five townships in Upper Myanmar and 16 in Lower Myanmar representing the most important areas of rice production were questioned on their management practices, yields, and perceived yield constraints over the previous four years. There was a recent decrease in the overall average rate of fertilizer application, an increase in the prevalence of rice-legume cropping systems, and only localized insect pest or disease problems. Additionally, rice yields were found to be higher in Upper Myanmar, likely the results of more suitable weather conditions, better irrigation, and ready market access. Furthermore, a number of critical factors affecting production are identified and possible solutions discussed.

Keywords: Myanmar, Burma, rice diseases

1 Introduction

Agriculture in Myanmar, dominated by paddy rice cultivation, generates a direct or indirect economic livelihood for over 75% of the population. Rice is grown throughout the country by resource poor rural farmers and landless agricultural labourers on small farms averaging only 2.3 ha in size (Okamoto, 2004). Although a shift to high yielding rice varieties (HYVs) in the 1980s was meant to increase production, average grain yields have stagnated at around 3.0 t ha^{-1}. With an annual population growth rate of 2%, an increase in rice yield has become vital to both matching the rising caloric demand for this staple and to contributing to the income of the rural poor. Before production can be improved, the most critical factors affecting that production must be revealed. There exists only one recent comprehensive survey in the literature on rice production in Myanmar (Garcia *et al.*, 1998), but little is known about the actual inputs used

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and the overall constraints limiting rice productivity. Therefore, a survey was conducted in the two major rice-growing regions of Myanmar during the rainy seasons of 2001 and 2002 to provide a comprehensive overview of rice production and to understand its shortcomings. The cropping systems practiced by local farmers were examined to determine the yield variability among different rice growing regions, explain the effects of climate and crop management on rice yields, understand how disease and pest incidence is related to crop management and environmental conditions, identify yield constraints of rice production, and define possible approaches to remove those constraints. This in turn has multifaceted practical applications, as improved yields would benefit the nutrition and living standards of the predominantly rural population of Myanmar.

This paper is structurally divided into six sections. Section two explores the previously published literature to provide an overview of the recent history of rice production in Myanmar. Section three outlines the research design for the data collected. Section four draws on the data to present the key current cropping systems, seed sources, diseases and pests, and the status quo of agrochemical use to tease out yield constraining relationships. The final sections of this paper discuss yield constraints and possible solutions.

2 Rice Production in Myanmar: An Overview

At 676,552 km^2 the Union of Myanmar is the largest country in Southeast Asia. Due to its geographic size, Myanmar varies considerably both topographically and meteorologically. Annual precipitation and monthly mean maximum/minimum temperatures also show considerable variation over time and space, and are particularly affected by the summer monsoons. In general, the climate is cooler in the mountainous north and warmer in the southern Delta areas of the Ayeyarwady River, with monthly mean maximum temperatures from 24.1°C to 38.2°C in May, and monthly mean minimum temperatures from 2.3°C to 20.8°C in December. Most major rice growing areas, such as the Ayeyarwady, Yangon and Bago Divisions, are naturally provided with fertile deltaic alluvial soil and abundant monsoon rainfall.

Myanmar has a long tradition of rice production. In the years immediately prior to World War II it was the largest rice-producing nation in the world, and it continues to be one of the ten largest rice-producing countries in terms of total yield (IRRI, 2002). Traditionally, rice production occurred only as a monsoon crop in the rainy season (from the end of May through November). This changed during the late 1970s and early 80s with the government-sponsored Whole Township Paddy Production Program that introduced modern high yielding varieties (HYVs) of rice and thereby enhanced production possibilities.

Since that time over 60 HYVs, usually of the semi-dwarf type, have been introduced, and now comprise 70% of the total lowland rice area (Nguyen and Tran, 2002). Many of these can accommodate closer spacing, heavy nitrogen (N) fertilization, continuous cropping and/or are photoperiod insensitive. Overall, this adaptation of HYVs and the improvement of irrigation systems in some areas of the country has allowed for the cultivation of rice in the dry summer season and for double cropping. In particular, IR50 and IR 13240-108-2-2-3 now occupy 80% of the country's dry land cultivation area (Kaushik, 2001). By 2001/02, the total overall area sown with rice was roughly 7.3 Mio ha with 5.7 Mio ha under monsoon paddy and 1.6 Mio ha under irrigated summer paddy in rotation (MOAI, 2003).

Nonetheless, despite the cultivation of HYVs in many parts of the country, the expected increases in yield did not happen during the last decade (IRRI, 2002). Rather, the average rice yield has remained relatively stagnant at 3.2 t ha^{-1} in 1994, 3.3 t ha^{-1} in 2000, and 3.4 t ha^{-1} in 2002 (MOAI, 2003). In view of this, the purpose of this study was to examine biotic and abiotic constraints to production through an in-depth survey of the country's main rice growing regions.

3 Materials and Methods

Qualitative data were collected through 107 semi-structured interviews with farmers over a span of two years in the two main agroecological zones of rice production, that is in Lower and Upper Myanmar (Fig. 1). In the rainy season of 2001, 52 respondents in ten townships located in Lower Myanmar and in three townships in Upper Myanmar were interviewed. In 2002, 55 respondents from nine townships in Lower Myanmar and three townships in Upper Myanmar were interviewed. Among the farmers, four from Upper Myanmar (Pyinmana) and five from Lower Myanmar (Nyaungdon) were interviewed in both years to check the reliability of the survey data over time.

Respondents were chosen from townships incorporating rainfed and/or irrigated lowland rice production areas, as these regimes comprise approximately 90% of the country's rice production (Garcia *et al.*, 1998). In each township, a maximum of five respondents were selected. Criteria employed in this selection were that they cultivated the popular Manawthukha rice variety in relatively accessible fields.

The interview schedule was designed to obtain the following types of information:

(a) Field description: farm size, soil type, source of water supply,

(b) History of farm cropping systems over the last four years,

(c) Amount and type of organic and inorganic fertilizer applied over the last four years,

(d) Rice yields over the last three to four years,

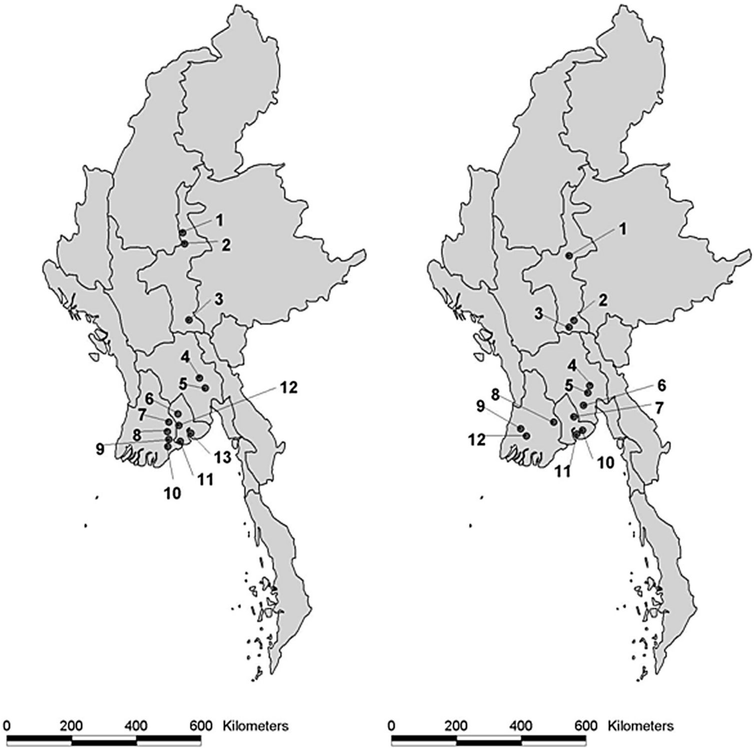
(e) Management practices in the seedbed and field: seed source, transplanting or direct seeding, weed management, pest and disease incidence and their management,

(f) Perceived yield limiting problems such as climate, soil, agronomic and/or socio-economic conditions.

3.1 Sampling pattern and methods of assessment

In addition to the interviews, one field per farm of the variety Manawthukha was surveyed to assess the disease and pest incidence or severity in both years. To this end, a "W" sampling pattern was used in each field following IRRI's integrated pest survey (Elazegui *et al.*, 1990). These assessments were conducted once for each field between heading and flowering of the rice plants. Assessments were spaced in 10 m intervals

Figure 1: Location of Survey Areas in Myanmar in 2001 and 2002.
Townships in 2001: 1: Mattaya; 2: Patheingyi; 3: Pyinmana; 4: Kyauktaga; 5: Nyaunglebin; 6: Htantabin; 7: Nyaungdon; 8: Maubin; 9: Kyaiklatt; 10: Phyapon; 11: Kungyangon; 12: Twantay; 13: Kyauktan.
In 2002: 1: Kyaukse; 2: Pyinmana; 3: Leway, 4: Nyaunglebin; 5: Daik-U; 6: Bago; 7: Hlegu; 8: Nyaungdon; 9: Pathein; 10: Thongwa; 11: Kyauktan; 12: Myaungmya.



starting at a hill at least 1 m away from the field border. A total of 12 hills were randomly chosen in each field.

For all diseases and parts observed, the total number of infected hills was recorded and expressed as the percentage of the total number of hills surveyed. Assessments were made in the following way:

(a) The severity of bacterial leaf blight (caused by *Xanthomonas oryzae* pv. *oryzae*) was determined as the percentage of leaf area affected on the uppermost three leaves of two randomly selected tillers per hill.

(b) The incidence of sheath rot (caused by *Sarocladium oryzae*) was determined by counting the number of infected tillers or panicles per hill and then expressed as the percentage of total tillers.

(c) Tiller height and uppermost lesion height were measured for rice sheath blight (caused by *Rhizoctonia solani*) and then expressed as a percentage ratio (i.e. relative lesion height) following IRRI 1988:
Relative lesion height (%) = (vertical height of the uppermost lesion on stem or leaf or sheath / plant height) $\times$ 100.

(d) The number of infected tillers with false smut (caused by *Ustilaginoidea virens*) was recorded and then expressed as the percentage of total tillers.

(e) The number of hills attacked by stem borers (*Sesamia inferens*, *Scripophaga incertulas* and *S. innotata*) and rice hispa (*Dicladispa armigera*) were counted and then expressed as percentages of total tillers.

(f) The severity of rice gall midge (*Orseolia oryzae*) was assessed by recording the number of infested hills and tillers and then expressing them as a percentage. Percentages of all infestation and infection were then calculated according to the Standard Evaluation System (SES) for rice (IRRI, 1988).

To measure yield, four 0.25 m^2 harvest-areas about 2 meters away from the surrounding borders were randomly marked as sampling areas. All above ground material was harvested and total fresh weight and grain yield were determined. A sub-sample of 100 g of fresh grain and straw were taken to determine dry weight. Grain yield at 14% moisture content was calculated according to the following formula:
Adjusted grain weight (at 14% moisture) $= A \times W$ where $W =$ weight of the harvested grain and $A = (100 - M)/86$ where M is the moisture content (%) of grains.

To determine the straw dry weight, the straw was dried in the sun to weight constancy.

3.2 Data analysis and processing

Data were analyzed using GenStat 5$^{\text{th}}$ edition (2001). Averages were compared by t-tests. Multiple and linear regression analyses were also used as required. For the fertilizer input comparison, type dependent conversion factors for nutrient concentrations in mineral fertilizers were employed. This method proved more difficult for farmyard manure (FYM), which likely had a different composition at each site. As such, an estimation of the N-content in FYM followed Dobermann and Fairhurst's list of average N concentrations of fresh and composted cattle manure (DOBERMANN *et al.*, 2000).

4 Results

4.1 Water, climate, and the environment

The survey data revealed that of the 21 townships represented in the study, twelve were rainfed and seven used sporadic supplementary irrigation taken from catchments. In two townships of Upper Myanmar all rice was irrigated. Untimely flooding was seen as a severe constraint to rice production, especially in Lower Myanmar, which experienced generally more rainfall during 2001 and 2002 than Upper Myanmar. Although this rainfall was within the normal range, inadequate drainage facilities adversely affected yields. Overall, farmers from townships of Upper Myanmar (mean yield = 5.66 t ha^{-1})

achieved higher yields than farmers from townships of Lower Myanmar (mean yield = 4.01 t ha^{-1}), possibly as a result of irrigation and better water management.

4.2 Crop rotations

The size of individual fields in this survey was found to range from 0.2 to 0.5 ha, with animal and human labour comprising the main energy sources for land preparation, transplanting, weeding, fertilization, water management and harvesting. Many farmers were found to practice double or triple cropping as an expressed means of increasing their income. Overall however, the majority of the surveyed farmers cultivated two crops per year with rice-rice, rice-blackgram (*Vigna mungo* L.) or rice-greengram (*Vigna radiata* L.) being the dominant cropping systems (Table 1). Relay cropping was common in some areas such as in Patheingyi Township in Upper Myanmar, where farmers broadcasted chickpea, blackgram or greengram about two weeks before harvesting the monsoon rice to obtain enough moisture for the second crop. Thus, good yields were achieved for both rice and this second crop.

Only in areas of Upper Myanmar where supplementary irrigation is available were triple crop rotations encountered. Some farmers from townships located in Upper Myanmar produced three crops per year with a legume (e.g. *Lens esculenta* Moench or *Cicer arietinum* L.) or an oil crop such as *Sesamum indicum* L. in the rotation. In addition, the cultivation of legumes depended on market access and the shifting price of legumes at the market. Patheingyi Township is a noteworthy example, as respondents often mentioned their proximity to the urban markets of Mandalay as a reason for the inclusion of legumes in the rotation.

4.3 Seed quality

Most farmers in both Upper and Lower Myanmar sowed seed from their own harvest or from neighbouring farms, rather than purchasing seed as recommended from the Myanmar Agriculture Service (MAS) (Fig. 2). Respondents mentioned that due to poor transportation and communication infrastructures certified seeds of improved rice varieties were often unobtainable. As a result, a considerable amount of varietal degeneration was found in all areas of rice cultivation surveyed, likely the result of farmers using seeds from their own harvest for extended time periods. Although the removal of off-types or abnormal panicles before harvest was found to be a common practice, overall stand uniformity was poor.

4.4 Fertilizers and agrochemical inputs

The rate of N applications during the rainy season decreased from 95 kg N in 1998 to 35 kg N in 2002 with an increasing number of farmers having stopped the application of N-fertilizer altogether during this period. Overall, application rates were considerably higher in Upper than in Lower Myanmar (Fig. 3a, b). Trends in P and K application were the same in Upper Myanmar whereas in Lower Myanmar the rates were always low. No relationship between farm size and N input was found. The majority of farmers surveyed (50-85% depending on the year) did not use farmyard manure (FYM), and

Table 1: Townships where interviews were conducted, number of respondents per village, cropping patterns and water management of interviewed farmers in Myanmar in 2001 and 2002.

	Township	*Village*	*Farmers*	*Cropping pattern* ‡	*Land form* §
			2001		
Upper Myanmar					
	Mattaya	Panya	5	R-R	I
	Patheingyi	Thamataw	3	R-C-Se	I
		Thantsenkone	2	R-C-Se/Su	I
	Pyinmana	Thittat	5*	R-R, R-R-G	R+I
Lower Myanmar					
	Htantabin	Ahasugyi	2	R, R-R	R
	Kungyangon	Kamapa	1	R-R	R
	Kyaiklatt	Ngapichaung	5	R-R	R
	Kyauktaga	Khingyi	5	R-G	R+I
	Kyauktan	Nyaungwine	3	R-G, R-C	R
	Maubin	Nyaungwine	5	R-R, R-G	R
	Nyaungdon	Samalaut	5†	R-G	R+I
	Nyaunglebin	Ahaleywa	3	R, R-G	R
		Shanywa	2	R-G	R+I
	Phyapon	Chaungtwin	5	R-R	I
	Twantay	Yangonpauk	1	R	R
Total	13		52		
			2002		
Upper Myanmar					
	Kyaukse	Htanaungpinhla	5	R-C-Se, R-R	R+I
	Leway	Mwayyolay	5	R-G, R-G-Su	R+I
	Pyinmana	Thittat	5*	R-R, R-R-G	R+I
Lower Myanmar					
	Bago	Mayin	5	R-G	R
	Daik-U	Bote	3	R-G	R
		Layse	2	R-G	R
	Hlegu	Wanetkone	5	R-R, R-G	R+I
	Kyauktan	Padawa	2	R-G	R
	Myaungmya	Phayachaung	5	R-R	R+I
	Nyaungdon	Samalaut	5†	R-G	R+I
	Nyaunglaybin	Kaukayt	1	R-G	R
		Sankalay	1	R-G	R
		Thayetkone	1	R-G	R
	Pathein	Myochaung	4	R-R	R+I
		Pyinkatoekone	1	R-G	R
	Thonegwa	Ahnaut	5	R-G	R
Total	12		55		

* Four of five farmers in Pyinmana were interviewed in both years;
† All five farmers in Nyaungdon were interviewed in both years;
‡ R = rice, G = blackgram or greengram, C = chickpea, Se = sesame, Su = sunflower;
§ I = irrigated, R = rainfed

Figure 2: Sources of seed of a total of 98 interviewed Myanmar farmers during 2001 and 2002.

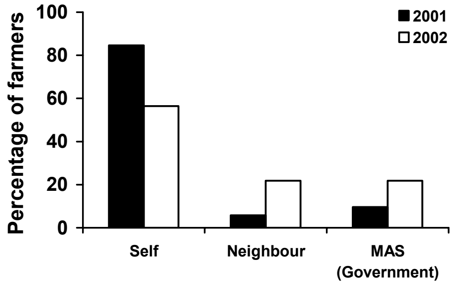
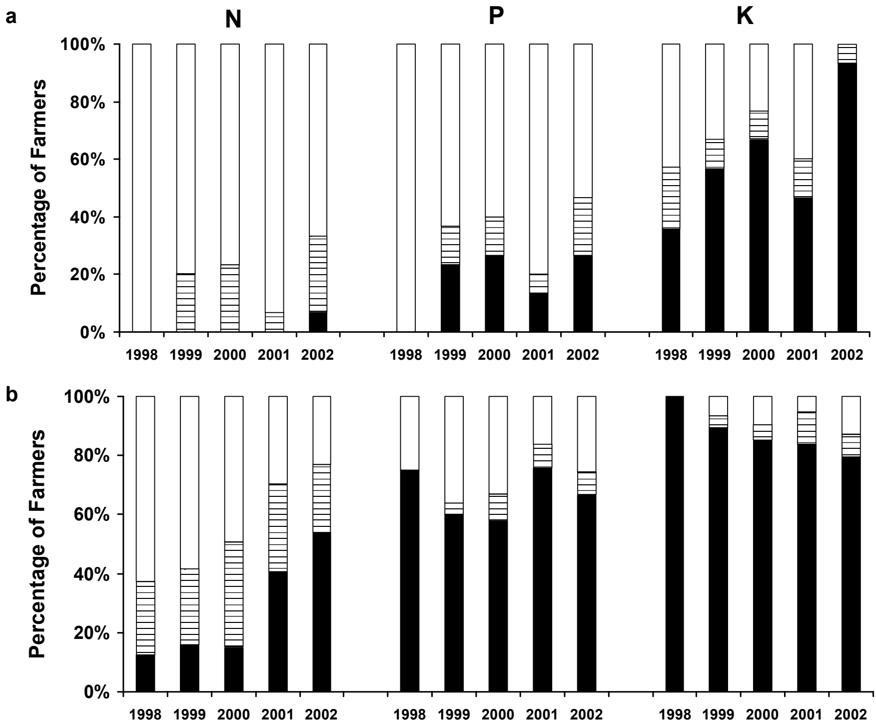


Figure 3: Percentage of farmers who applied the recommended rate (white sections), less than the recommended rate (striped sections) or none (black sections) in the wet season between 1998 and 2002 in (a) Upper and (b) Lower Myanmar. The recommended rates were 56 kg ha^{-1} N, 13 kg ha^{-1} P, and 20 kg ha^{-1} K. The number of respondents in Upper Myanmar was 14, 30, 30, 15, and 15 in 1998-2002 respectively, and 8, 75, 73, 37, and 39 in Lower Myanmar.



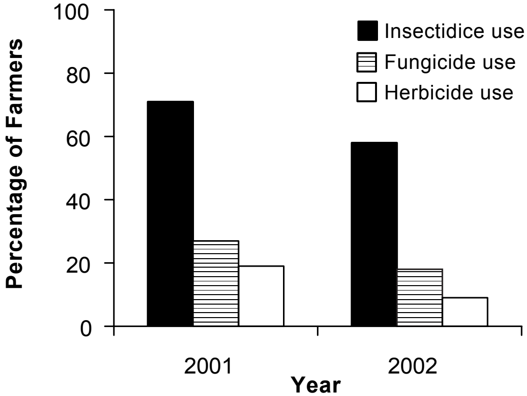
those who did only applied it at a rate of 2 –4 t ha^{-1} in addition to or as a substitute for chemical fertilizers.

The highest rates of fertilizer application were observed in the Mattaya and Patheingyi Townships in 2001 and in Kyaukse and Pyinmana in 2002, all townships in Upper Myanmar with irrigation facilities. Most farmers from the remaining townships utilized only limited amounts N fertilizers.

In both years, most farmers applied both chemical fertilizers and FYM to the seedbed at rates higher than those applied to transplanted fields. Farmers mentioned that they believed a heavy fertilization of the nursery would result in healthier seedlings, and this was often cited as being more effective than spreading small amounts of available manure over a larger area.

Overall, the percentage of farmers in both years who used some form of chemical insecticide was greater than for herbicides or fungicides (Fig. 4).

Figure 4: The percentage of farmers who used herbicides, fungicides and insecticides during 2001 (n=52) and 2002 (n=55)



4.5 Weed control

Only 52% of the interviewed respondents practised any form of weed control, although farmers faced difficulties with weed growth in both the rainy and dry seasons, often exaggerated by poor water management. The respondents of Upper Myanmar (73%) were more likely than those of Lower Myanmar (43%) to use weed control. Hand weeding was the most often employed method of control, as it allows for the selection of weeds useful for animal and human nutrition (Table 2). Although a variety of herbicides for rice production are available on the Myanmar market, they are little used and were often cited by respondents as being too expensive. Overall, farmers in all regions expressed only very basic knowledge about chemical weed control methods.

Table 2: Weed control practices of farmers surveyed in Myanmar in 2001 and 2002.

Township and Year	*Weed control (No. of farmers*)*		
	Hand weeding	*Herbicides*	*No weeding*
Upper Myanmar			
Kyaukse (02)	3	-	2
Leway (02)	3	-	2
Mattaya (01)	4	1	-
Patheingyi (01)	3	-	2
Pyinmana (01+ 02)	-	6	-
Lower Myanmar			
Kyaiklatt (01)	1	2	2
Maubin (01)	3	1	1
Myaungmya (02)	1	-	4
Nyaungdon (01 + 02)	5	-	-
Pathein (02)	1	-	4
Phyapon (01)	3	-	2
Bago (02)	-	-	5
Daik-U (02)	2	-	3
Kyauktaga (01)	5	-	-
Nyaunglebin (01)	-	-	5
Nyaunglebin (02)	2	-	1
Hlegu (02)	1	-	4
Htantabin (01)	-	-	2
Kyauktan (01)	2	1	-
Kyauktan (02)	-	-	2
Kungyangon (01)	-	-	1
Thongwa (02)	-	-	5
Twantay (01)	1	-	-
Total (98 farmers)	40	11	47
(%)	41	11	48

* Farmers interviewed in both 2001 and 2002 were counted only once.

4.6 Diseases

Generally, the damage level of diseases was quite low during the survey period. Rice sheath blight, bacterial leaf blight (BLB) and sheath rot were the most commonly found diseases in the surveyed areas, lesser so false smut and ufra disease. Less than 15% of the fields surveyed over the two years were found to be disease free (Fig. 5).

Most widespread (that is with the highest incidence) and severity was sheath blight, with around 60% of the fields being infected in both years. Within infected fields in 2001, incidences ranged from 8-100%. Sheath blight severity in 2001 was highest in Kyauktaga Township (43%) and in 2002 in Bago (58%).

Figure 5: Incidence of rice diseases in surveyed fields in 2001 and 2002.

Twenty and 15% of fields surveyed were infected with BLB in 2001 and 2002, respectively, with overall severities ranging between 1.4 and 55%. In both years, BLB was mostly observed in Lower Myanmar, for example, in Htandabin Township in 2001 (22% severity), and in 2002 in Bago (55%), Deik-U (34%) and Nyaungdon (42%) in Lower Myanmar, and only in Leway Township (41%) in Upper Myanmar. Although not a universal problem, if BLB occurred, it did so with a high incidence. Likewise sheath rot, with incidence ranging from 5 to 34%, was also more severe in Lower Myanmar in both years. Sheath rot occurred in approximately 50% of the fields in 2002 while in 2001 it was almost absent.

False smut and ufra disease were found only to be localized problems. False smut was observed in only 2 out of 52 fields in 2001 (in the Lower Myanmar Townships of Htantabin at 10% and in Nyaunglebin at 5% incidence). In 2002 however, incidence reached 12% in Kyaukse in Upper Myanmar and 25% in Kyauktan in Lower. Ufra was found only in Lower Myanmar during the 2002 rainy season, where its incidence, although not wide spread, reached high levels (for example, 68% in Myaungmya township). The negative effects of Ufra on rice yield could not be ascertained, as farmers harvested early to avoid future nematode problems.

No significant correlation between the amount of mineral N applied and incidence or severity of any disease was found (r 0.12 to 0.19).

Mean sheath blight severity in rice legume systems was found to be 19% (n=64), higher than in rice-rice systems (4.53%, n=37; $P < 0.001$; Fig.6).

4.7 Insect pests

Very few insect pests were observed in the fields surveyed. The most commonly found rice pests were stem borer (*Scirpophaga incertulas*), rice gall midge (*Orseolia oryzae*), Jassid (*Nephotettix apicalis*) and rice ear bug (*Leptocorisa* spp.) (Fig. 7).

The results of the survey also showed that although there were pests in some areas, the levels of their infestation was low, except for the gall midge. Although the incidence of

Figure 6: Incidences of bacterial leaf blight (BLB) and sheath blight in 2001 and 2002 in different cropping systems. Rice only is one single crop of rice per year while all other systems were some form of double cropping. Double counting was used 15 times for fields where both BLB and sheath blight were present.

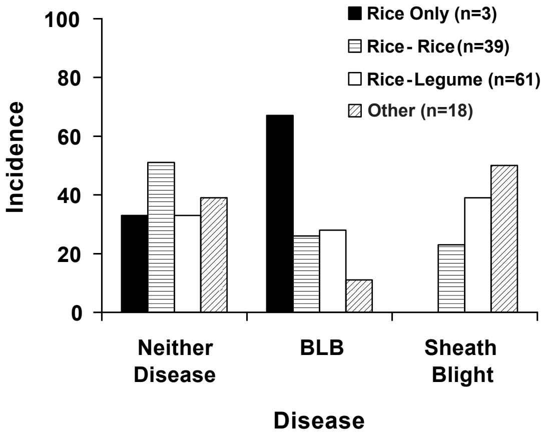
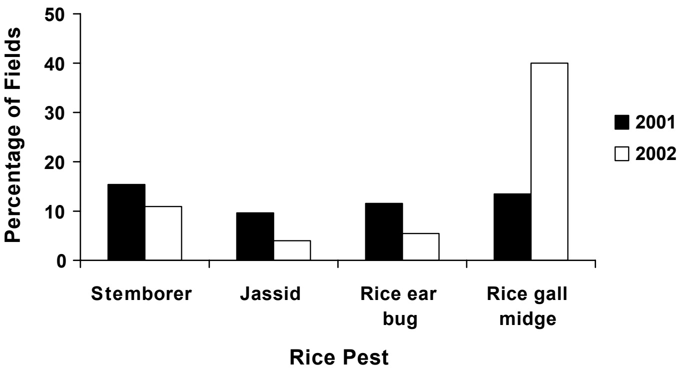


Figure 7: Percentage of fields infested with stemborer, jassid, rice ear bug and rice gall midge in 2001 and 2002.



this pest was low in 2001, a severe outbreak of rice gall midge occurred in 22 of the 55 surveyed fields, observed in Hlegu, Bago, Nyaunglebin and Daik-U townships where they clearly affected yields. Formerly, the rice gall midge was not a major rice pest in Myanmar. However, the abnormally heavy rains of the 2002 rainy season favoured the spread of the rice gall midge in those areas. The outbreak was found to have started in the seedbed before moving into the paddies.

4.8 Yields

Little difference was found between the yields reported by farmers and those measured during the survey. In most areas, average rice grain yields changed little over the period between 1998 and 2001/2, but showed considerable geographic variation. In 2002, for example, measured yields were generally higher in Upper Myanmar (3.7- 7.5 t ha^{-1}) than in Lower Myanmar (1.0-6.7 t ha^{-1}) during both rainy and dry seasons. Average total yields increased with the number of crops per year from 2.4 t ha^{-1} for single cropping (3 farmers) to 4.3 t ha^{-1} for double cropping (74 farmers) to 5.7 t ha^{-1} for triple cropping (15 farmers). The differences between triple and double cropped fields were highly significant ($P<0.001$, T-test). No comparison could were made for single crops because of the small sample size of respondents using such cropping systems.

The effects of crop rotation on rice yields were less clear and the number of crops from the same system was too low to conduct statistical comparisons for most pairs. When compared with T-tests, yields of double rice crops per year and rice-legume crop rotation were not significantly different (Table 3). Measured rice yields on irrigated land were 5.1 t ha^{-1} (25 farms), whereas on rainfed (54 farms) or rainfed and irrigated (13 farms) only 4.2 t ha^{-1}. Again, the large number of cropping systems involved did not justify a valid statistical comparison.

Measured yield levels of farmers using mineral fertilizer or manure were overall 36% ($P<0.001$) higher than of those who did not use fertilizers (Table 3). However, there was a huge variation in yields ranging from 1 to 5.3 t ha^{-1} for respondents who did not apply mineral N or FYM (33%) and from 1.8 to 6.7 t ha^{-1} for those who applied N either as urea, FYM, or both (67%). Multiple regression analysis suggested that at these yield levels the application of urea was only loosely correlated with rice yield. Application of K and rainfall appeared to affect the rice grain yield negatively, however:

$Y = 5.048 + 0.005\ \mathrm{N} - 0.22\ \mathrm{K} - 0.0004$ Rainfall, ($P< 0.001$, $r^2 + 0.21$)
Where Y = grain yield in kg ha^{-1}

The effects of weed control and insecticide application interacted with fertiliser application. While on farms that used fertilisers weed control increased yields by 29% ($P<0.001$) yields of unfertilised crops were somewhat reduced (10%) albeit not statistically significant. Similarly, when separating fertilizer users and non-users, insecticide applications enhanced the yields of those farmers who did use fertilizers by about 16%; this, however, was not statistically significant ($P=0.09$). In contrast, on farms where no fertilizers were applied, insecticide use appeared to be correlated with a yield reduction of 20% ($P=0.05$) (Table 3).

5 Discussion

Constraints to rice production in Myanmar seem to vary regionally but are tightly linked to the management practices and socioeconomic conditions of the farmers.

Throughout the various geographic regions surveyed, grain yield losses due to diseases and pests appeared for the most part to be insignificant. BLB should be an important disease of monsoon rice in the Bago and Ayeyarwady Divisions of Lower Myanmar

Table 3: Effects of management practices on rice yields measured in farmers' fields in Myanmar in 2001 and 2002.

Farmers Practice	*n*	*Mean yield (t ha^{-1})**	*P (t-Test)*
Cropping pattern			
Rice – rice	32	4.5 ± 1.76	0.35
Rice – legumes	41	4.2 ± 1.79	
Fertilizer			
User	62	4.9 ± 1.41	<0.001
Non-user	30	3.6 ± 1.13	
Weed Control			
Weeding	54	4.8 ± 1.95	<0.008
Non-weeding	36	4.0± 1.88	
Fertilizer users			
Weeding	41	5.3 ± 1.21	<0.001
Non-weeding	24	4.1 ± 1.46	
Fertilizer non-user			
Weeding	14	3.4 ± 0.88	0.38
Non-weeding	13	3.8 ± 1.31	
Insecticides			
User	57	4.6 ± 1.46	0.23
Non-user	35	4.2 ± 1.44	
Fertilizer users			
Insecticide user	42	5.1 ± 1.26	0.09
Non-user	20	4.4 ± 1.6	
Fertilizer non-user			
Insecticide user	15	3.2 ± 0.93	0.05
Non-user	15	4.0 ± 1.2	

* Data represent means followed by their standard deviation

with severity dependent on the variety of rice cultivated (GARCIA *et al.*, 1998). Indeed, Manawthuka was previously found susceptible to BLB under favourable conditions (HEIN *et al.*, 1993). However, during the seasons surveyed in this study, BLB was not severe in most of the regions.

The observed increased sheath blight incidence in rice-legume rotations agrees with the results of KIM *et al.* (1992), who reported that sheath blight was more severe in rotation systems (rice paddy and upland crops) than in continuous paddy fields. KIM *et al.* (1992) hypothesized that this was due to larger amounts of available N in the rotation plots. However, when grain legumes are harvested, N-balances are often negative leaving little to no additional N to the subsequent crop. Thus, it is unlikely that the increases in sheath blight infestation were due to N effects. More likely, the survival of the sclerotia of *R. solani* is reduced in the anaerobic paddy conditions given the absence of upland crops.

While agrochemical inputs were very low, their application was often done ineffectively. In particular, while weeds appeared the most severe problem in the field, farmers mostly used organophosphate insecticides.

Although dry season rice yields are higher than those in the rainy season, the rice double and triple cropping systems were limited to a few areas of Upper Myanmar with reliable irrigation. The popularity of rice-blackgram or rice-greengram cropping patterns can be partially explained by the minimal irrigation water or external input requirements of pulses. Also, in recent years, farmers preferred to grow legumes as a second crop instead of rice because of the high market value of the former. Farmers seemed to be aware of the role of legumes in enhancing soil fertility, but perhaps more importantly, pulses have become a genuine cash crop, with private sector exports climbing from 831,000 t in 2001/2 to 1,034,000 in 2001/2 (MOAI, 2003; Okamoto, 2004). It can therefore be hypothesized that such rice-legume cropping patterns will likely continue to shape the agroecosystems of Myanmar.

Reported and measured rice yields were generally higher in Upper Myanmar than in Lower Myanmar, likely the result of higher radiation and favourable socioeconomic conditions. The Mandalay Division of Upper Myanmar for example, enjoys a climate particularly suited to rice production, and access to year round irrigation water allows for the cultivation of three crops per year. In addition, spatial proximity to urban markets directly correlates with higher profits than what is obtainable to farmers in other regions. This additional income allows for the purchase and use of additional inputs to further enhance yields.

The most common problems of fertility are inadequate amounts and improperly applied mineral and organic fertilizers. Although respondents expressed the knowledge that fertilizer applications can positively affect their yield, the farmers of this survey, and in particular those of Lower Myanmar, generally used low rates of N, and almost no P or K during the rainy season. Likewise, the total amount of available FYM remains severely limited, as farmers possess few animals and little disposable income for off-farm purchasing.

In addition, a 1992 government reduction in the private importation of agricultural inputs has since resulted in a shortage of fertilizer supply and increased prices. Based on informal discussions with farmers, Naing (2004) estimated that expenses for fertilizer comprise over 25% of the total rice production cost. To exasperate the problem, this shortage of mineral fertilizer has occurred during the progressive adoption of HYVs of rice and the expansion of area under irrigated farming. Thus, and as oft mentioned by respondents, inadequate and costly inputs, weeding, high labour costs, poor drainage and untimely irrigation all together contribute to low crop yields, especially in Lower Myanmar.

The application of fertilizer to the seedbed at rates higher than for fields, most likely was of little use because such fertilization may lead only to enhanced shoot growth and thus results in earlier transplanting, but does not correlate with higher grain yields (Grist, 1975). While excessively high N-inputs may result in increased disease problems, moderate N inputs of up to 80 kg ha^{-1} split into four (that is basal, 2 weeks after transplanting, at panicle initiation and at flowering) increased yields substantially both in Lower and Upper Myanmar (Thein, 2004) without affecting disease levels (Naing, 2004).

While the mean yields were increased by 36% through fertilizer use, the huge variation in yields among farmers using fertilizers and the relatively weak correlation of N-inputs with yields clearly indicate that other factors other than N are important in limiting rice yields. The interactions of fertiliser use and weed control and insecticide applications with respect to yield (Table 3) are not straightforward to explain. Possibly, competition from weeds in stands that are not fertilised is lower due to overall plant density. However, no data are available to test this. As the overall incidence of insect pests was very low during this survey, it was surprising to see any affects of insecticide application on yield. As many insects are more attracted to better-fertilized crops, it appears logical that the effects of insecticide on yield should be more pronounced in fertilized crops. However, the fact that insecticides affected yields negatively when no fertilizers were applied cannot be explained.

In addition to a complete lack of weed control on almost 50% of the surveyed farms due to the cost of labour, weeding itself often could not be accomplished effectively due to direct seeding. This method impedes the later use of hoes and consequently, often only the aboveground parts of the weeds are removed, resulting in rapid re-infestation.

Even if fertilizer and weed management were optimized, another limiting factor is seed quality. Less than 20% of farmers use certified seed, and the low quality of seed used results in poor germination and infestations with seed borne diseases. The observed cases of false smut and ufra point to the need of improvements in the seed sector. Likewise, diseases such as bacterial leaf blight and sheath rot are also seed borne and can be a direct consequence of unclean seeds (Ou, 1985). Moreover, rice seed can be contaminated with weed seeds of similar maturity, further contributing to the observed weed problem.

6 Conclusions

This study shows that agronomic problems such as low rates of applied manure and chemical fertilizers, low seed quality and poor weed and water management appear to be the most serious limitations to rice production in Myanmar. In particular, the very low amounts of fertilizer that are currently applied to rice are probably the major reason for the low yields of rice in Myanmar. The use of fertilizers, particularly of N, is essential for increasing rice yield. In addition, sources of P and K are needed. While market opportunities determine which crops farmers grow, the cropping sequence per se had little to no effect on rice productivity. Based on our findings and recent research results the following recommendations can be made:

(a) While overall higher amounts of fertilizer are needed, the high fertilization of the seedbed uncovered in this study does not seem to be necessary.

(b) There is a need to improve weed management practices, especially to use hoes for more effective removal.

(c) Water management has to be improved to allow a more efficient management of the resource at the farm level.

(d) The seed production sector should be strengthened to supply quality seeds at affordable prices to farmers throughout the country. In addition, farmers should be trained to carefully select and manage their own seed production fields.

(e) In the current situation, it appears that most pesticide applications are unnecessary or counterproductive. Insecticides usually have a higher human toxicity than fungicides and herbicides, and when considering the rudimentary understanding of pesticides and pesticide safety expressed by respondents, the potential for health hazards are real. In view of their high cost and the associated health hazards especially when not applied with the proper precautions, any recommendation for their use appears unwise.

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