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Chapter 1

General introduction

1.1. Maize, green gram and rotation systems in Myanmar

Only 10 million ha of Myanmar's total surface of 68 million ha are used for agriculture which is mainly cereal-based (Table 1.1 and 1.2). Rice *(Oryza sativa L.)*, maize (*Zea mays L.*), food legumes, oilseeds, cotton (*Gossypium spp.*) and sugarcane (*Saccharum officinarum L.*) are very important commodities of this production sector in which sixty-four percent of Myanmar labour is employed (Thu Kha, 1993). The central part of the country is characterised by wide rivers and expansive plains of which the largest, the Ayeyarwady is navigable for 1600km of its length and its flood plains form the country's main agricultural area (Thein Han et al., 2001).

Table 1.1. Land utilization in Myanmar in 2003-2004
(Source: http://www.myanmar.com/Ministry/agriculture/generalagrisit.htm)

Type of Land	Million ha
Net sown acreage of crop land	10.27
Fallow land	0.51
Waste land	6.57
Forest reserve	15.29
Other forests	18.16
Land unsuitable for cropping	16.86
Total	**67.66**

Rice-based cropping systems are the most important in area covering 6 million ha while food legumes cover 20% of the total cultivated land whereby more than 13 legume crops are grown (Table 1.2). Cultivation of food legumes in Myanmar largely depends on soil moisture and temperature. Drought, excess moisture, high temperatures and adverse soil conditions are the common abiotic stresses limiting the productivity of food legumes in Myanmar (Thein Han et al., 2001). Nevertheless, the area dedicated to the cultivation of green gram (*Vigna radiata (L.) R. Wilczek*) increased from 48,3000 ha in 1988 to 770,000 ha in 2003-04 allowing it to reach 29% of the total production of grain legumes (Table 1.2). The exploitation of early-maturing varieties with synchronized flowering have allowed green gram to be introduced in rainfed maize, sesame (*Sesamum indicum L.*) and cotton based cropping systems dominating in the country's central dry zone. Most farmers grow green gram as a secondary crop without the application of mineral fertilizers.

Besides being an important export crop, legumes such as green gram provide much of the protein in the diet of Myanmar's people and are thought to improve the nitrogen (N) status of soils within rotations by adding symbiotically fixed N. For human nutrition, the protein composition of its seeds, especially their lysine content is of great importance. While this trait likely depends on genetic and plant nutritional aspects, little is known about the differences among green gram cultivars with respect to their amino acid composition and their response to the addition of phosphorus (P) fertilizers on low-P soils where P availability may govern the N-fixing capacity of legumes (Christiansen and Graham, 2002).

Maize (*Zea mays L.*) is the second most important cereal after rice in Myanmar. From 1993 to 2003 the area sown to maize increased from 133,400 ha to 300,000 ha with grain yields increases from 1534 kg ha^{-1} to 2500 kg ha^{-1} (FAO-RAPA, 2004). Maize growing in Myanmar has become popular over the last ten years due to its growing demand as a poultry feed and for export to neighbouring countries. However, maize yields remained low due to a variety of reasons such as poor seed quality and soil fertility constraints. Estimates indicate that growing hybrid varieties alone might lead to yield increases of 40% (Yee Yee Nwe et al., 2003).

One of the main constraints for maize production is N- and probably P-availability. Because of a general shortage of mineral fertilizers and their high price, which cannot be afforded by most farmers in Myanmar, there is a need to evaluate alternative methods for enhanced maize productivity. Crop rotation with legumes is widely practiced as an effective alleviation to N constraints in low external input systems. With the increasing importance of legumes in Myanmar agriculture on the one hand and shortages in mineral fertilizers on the other hand the establishment of effective legume-rotation schemes is an important question to be addressed by agricultural research.

Table 1.2. Area sown and production of various groups of crops in Myanmar, 2003-2004 (MOAI, 2004).

Crops	Area sown (1000 ha)	Production (1000 t)
Cereals		
Paddy rice	6543	23136
Maize	284	704
Sorghum	231	176
Wheat	95	124
Sub-total	*7153*	*24140*
Oilseed crops		
Groundnut	655	878
Sesame	1465	501
Sunflower	511	339
Oil palm	46	95
Sub-total	*2677*	*1813*
Food legumes		
Green gram	770	673
Black gram	732	740
Pigeon pea	524	485
Cowpea	140	123
Pigeon pea	524	485
Sub-total	*2690*	*2506*
Industrial crops		
Cotton	292	158
Sugarcane	275	7030
Rubber	189	40
Jute	33	26
Sub-total	*789*	*7254*
Food crops		
Chilly	164	260
Potato	33	403
Onion and garlic	27	838
Sub-total	*224*	*1501*
Total	***13,533***	***36210***

* The total is including 3,263,000 ha double crops

1.2. Aims and hypotheses

Based on the above research needs the aims of the work presented here were

(1) to examine the growth response of different green gram cultivars to P application and to compare the amino acid profile of their seeds

(2) to determine, if the often observed yield decline in continuous maize monocropping systems can be slowed down by the use of a green gram rotation.

The hypotheses underlying these aims were that (i) the available germplasm of local and improved greengram comprises a large variation with respect to its growth response to P and amino acid composition (particularly its lysine concentration) which could be exploited by future breeding programmes and (ii) that the yield decline in continuous maize systems is caused by a combination of low soil N, low P availability and increasing nematode infestation which could be partly alleviated by green gram as a rotation crop.

In chapter 2 of this dissertation, the relevant information for this study is reviewed as a basis for the experiments conducted under field conditions in Myanmar and under greenhouse conditions in Germany. In a first step, field-grown green gram landraces and improved green gram cultivars were screened for their P response and amino acid composition (Chapter 3). Subsequently, the effects of rotating green gram and maize on growth and yield parameters of both crops were investigated (Chapter 4). Rotations with and without the addition of farm yard manure and P fertilizer were compared to examine to what degree the expected N-related yield decline in a maize monocropping system under the low external input conditions of local farmers could be slowed down by a rotation with green gram. This approach also aimed at exploring the causes of possible yield-enhancing effects of green gram on maize.

In the final discussion (Chapter 5), the implication of the interactive effects of green gram cultivars and P-application for seed quality on the one hand and the yield dynamics within the maize-green gram cropping system on the other hand are discussed.

1.3. References

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Chapter 2

Literature review

2.1. Nutritional constraints in tropical soils of Myanmar

2.1.1. Availability and management of phosphorus in tropical soils

Phosphorus deficiency is one of the factors severely limiting crop production on tropical and sub-tropical soils (Fairhust et al., 1999). Many of the highly weathered tropical soils (Oxisols, Ultisols) are characterized by low total and available phosphorus (P) content, and a high P retention capacity (Friesen et al., 1997; von Uexküll, 1986). Also in SE Asia many soils are limited by low pH, low cation exchange capacity (CEC), low base saturation and a high P-fixing capacity (Pushparajah and Bachik, 1987). Correcting P deficiency with applications of P fertilizer is not always possible for resource-poor farmers in the tropics and subtropics, especially on soils with high P-fixing capacity (Horst et al., 2001).

Soil P dynamics and availability are determined by a combination of factors including soil properties and parent material, type of vegetation, environmental conditions and land management practices (Krämer and Green, 1999). In most ecosystems with increasing rainfall, the overall biomass production and rate of turnover increases with the soil organic matter content and the related availability of N. However, as soils are more and more leached and become more acid P availability is progressively limited by binding to or toxicity of Fe, Al and/or Mn (Breman and van Reuler, 2002).

To effectively enhance crop yields on P-limited soils, frequently large amounts of mineral P fertilizers or the application of organically bound, slow release P sources, such as manure (Eghball and Power, 1999) are needed. Often 90% of the applied mineral fertilizer P or more are not taken up by the crop but are retained in non-labile P sources (Stevenson and Cole, 1999). Consequently in the tropics, crop utilization of fertilizer P is usually low and rarely exceeds 20% of applied P in the year of application depending on the nature of the soils and crops concerned (Subba Rao et al., 1995). Soil P availability and efficiency of applied P may be improved through the use of knowledge-based management strategies which take into account a soil's P dynamics (Reddy et al., 1999). Under such conditions, the integration of crop species and/or crop cultivars that can make efficient use of the P supplied by the soil and maintenance fertilizer or manure applications represents a key element of sustainable cropping systems (Ae et al., 1990).

Mycorrhizae are known to enhance nutrient uptake, especially P, in many plant species (Harley, 1991). Karasawa et al. (2000) found P uptake and maize growth to be positively correlated with mycorrhizal colonization. For green gram N and P uptake was highest after inoculation with mycorrhiza in the presence of phosphate-solubilizing microorganisms (Singh and Kapoor, 1998). For the severely P deficient West African soils Bagayoko et al. (2000c) reported that P application led to large increases in early root growth, a prerequisite for early mycorrhizal infection and a subsequent significant contribution of mycorrhizae to enhanced plant growth and nutrient uptake. Tarafdar and Rao (1997) pointed out that VAM inoculation can increase phosphatase activity resulting in grain yield increases of 15-22% in arid-zone legumes. They attributed this to positive interactions between *Rhizobium* and micorrhizae. Mycorrhizal infection may be enhanced by crop rotation. Alvey et al. (2001) reported rotation-induced increases in mycorrhizal colonization of 10-15% during early cereal growth.

2.1.2. Nitrogen availability and management

Nitrogen is the most limiting element in agricultural production systems and often severely limits crop productivity (Gutteridge and Shelton, 1994). Many intensive cropping systems in humid and sub-humid tropical countries are characterized by continuous cropping of cereals, leading to serious erosion and productivity decline (Fischer et al., 2002). In sub-Saharan Africa, Asia and Latin America N losses under continuous cultivation are reported range from 20 to 70 kg ha^{-1} $year^{-1}$ (Giller and Cadisch, 1995). Potential sources of N to overcome this shortfall are: the mineralisation of soil organic matter, mineral fertilizers, animal manure, symbiotic N_2-fixation in legumes, and N fixation from free-living organisms associated with tropical grasses.

Breeding for improved nutrient use efficiency has been proposed to enhance crop yields in low-input agricultural systems (Clark and Duncan, 1991). Of these, N from soil is often insufficient to sustain plant growth especially in degraded tropical soils, often notoriously low in organic matter. Under such conditions the N release from decaying leaves and roots of a preceding legume crop can be a major component of the N pool available to plants (Härdter, 1989). Shah et al. (2003) showed that cereal grain and biomass yields can be increased by up to 350% through N addition from mineral N fertilizers or biological N-fixation.

2.1.3. Soil organic matter, soil pH

Soil organic matter is one of the most important regulators of numerous environmental constraints to crop productivity (Woomer et al., 1994). Soil organic matter is vital to the sustainable use of any soil because of its role in maintaining soil structure, water holding capacity, the microbial biomass and soil fauna, and in nutrient cycling (Goulding et al., 2001). Giller (2002) reported that increased soil organic matter content can improve N uptake due to better root growth and penetration as a result of improved soil physical properties and enhanced P uptake. Mineralization of decomposing residues is one major source of plant nutrients in highly weathered soils with little inherent mineral fertility (Sanchez et al., 1989). Unfortunately, due to their many competing uses as fuel, fodder and building material in many tropical cropping systems little or no crop residues are returned to the soil (Lal, 1986; Woomer and Ingram, 1990). Cultivation decreases soil organic matter stocks particularly in labile fractions (Chenu, et al. 2001). The storage of nutrients in soils is closely linked to the availability and turnover of organic matter derived from plants (Rees et al., 2001).

Manure application as one important way of maintaining soil organic matter levels can strongly buffer pH levels. The application of cattle feedlot manure or compost increased the soil surface (0-15 cm) pH while N application as NH_4NO_3 significantly reduced the pH from 6.4 to 5.6 (Eghball, 1999).

2.1.4. The role of legumes in a rotation

A crop rotation is defined as a system of farming in which a regular succession of different crops is planted on the same land area, as opposed to growing the same crop time after time (Singh and Jones, 2002). Crop rotation is one of the most important agronomic strategies in designing sustainable farming systems (Vereijken, 1997). A well-chosen rotation can help to naturally control yield limiting factors, such as pests, diseases, and deterioration of soil productivity. In continuous maize cropping nematode populations have been found to increase considerably leading to significant yield losses (Maqbool and Hashmi, 1986). Similar results have been reported by Bagaoyoko et al. (2000b) from a maize-groundnut system in West Africa. Under such conditions one beneficial effect of crop rotation was that the population of plant parasitic nematodes remained below the level of crop damage (Lopez-Fando and Bello, 1995). Particularly in rotations with leguminous plants the reduction of