

**ASSESSMENT OF SUITABILITY OF THE SOILS OF MADIIRA  
RESEARCH INSTITUTE, ARUSHA, TANZANIA, FOR THE  
PRODUCTION OF SOYBEANS AND MUNGBEANS**

**BY**

**MOSES RAPHAEL MLAHAGWA**

**FOR REFERENCE  
ONLY**

**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF  
THE REQUIREMENTS FOR THE DEGREE OF MASTER OF  
SCIENCE (SOIL SCIENCE AND LAND MANAGEMENT) OF THE  
SOKOINE UNIVERSITY OF AGRICULTURE**

**2001**

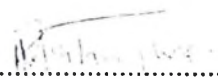
## ABSTRACT

A field study was conducted to assess the suitability of the soils of Madiira Research Institute farm for the introduction of growing and production of vegetable soybeans and mungbeans in Tanzania. The specific intention was to assess the fertility status of the soils, determine the plant uptake of the essential nutrient elements from the soils, and try to suggest measures and soil fertility management strategies for the sustainable and optimal production of vegetable soybean and mungbean production. Composite soil samples for the determination of the physical and chemical properties were sampled from two sites selected on the farm. About 400 m<sup>2</sup> of land for each site was plowed and then harrowed and each site was divided into three 8 m x 6 m plots/blocks for four soybeans and for five mungbeans, grown at a spacing of 30 cm x 10 cm and replicated three times respectively. Just before flowering nine plants of each line and from each block were harvested for dry matter yield determinations and total plant nutrient analysis. The other plants were left on the field to grow to maturity for grain yield determinations. The soils were found to be medium acidic, with medium CEC, OC, exchangeable Ca, and Mg, low levels of total N, and high levels of exchangeable K and Bray-1 P. The DTPA extractable Fe and Cu were above the critical limit, while Zn and Mn were medium. The plant analysis for soybeans showed that P and Zn correlated positively with the dry matter yields while total N, Ca, Mg, K, Fe, Cu and Mn correlated negatively with the same. Nitrogen, Mg, K, Fe, Cu and Mn correlated positively with grain yields while Ca, Zn and P correlated negatively with the same. The plant analysis

for mungbeans showed that N, Mg, K, Zn and Cu correlated positively with dry matter yields while P, Ca, Fe and Mn correlated negatively with the same. Nitrogen, Mg, K, Zn, Cu and Mn correlated positively with grain yields while Ca, Fe and P correlated negatively with the same. The soybean performances based on fresh grain yields were in the following order: GC 84051-32-1 > AGS 338 > AGS 329 > AGS 292 corresponding to 14730.0, 8861.6, 6447.0, and 6364.3 kg/ha respectively, while mungbean performances were: VC 6173(b-10) > VC 6148(50-12) > VC 6372(45-8) > VC 6379(23-2-1) > KANTI corresponding to 11178.0, 10549.3, 9167.6, 8547.0 and 6553.3 kg/ha respectively. The soils analytical data indicate that the soils are of medium fertility status, that is medium levels of CEC (16.2-16.8 cmol (+)/kg soil), OC (1.3-1.5%), Ca (8.0-8.1 cmol (+)/kg soil), Mg (2.7-3.0 cmol (+)/kg soil) and low levels of total N (0.19-0.22%), hence can support the growth of soybeans and mungbeans in the short term period. Recommendations are made to publicise the production of the best two high yielding soybean lines (i.e. GC 84051-32-1 and AGS 338) and mungbean lines (i.e. VC 6173(b-10) and VC 6148(50-12)). Seed inoculation for effective N<sub>2</sub>-fixation is recommended. On-site incorporation of the legume vegetable crop residues into the soils and further experiments and use of fertilizer rates are recommended for the sustainable soybean and mungbean production.

## DECLARATION

I, Moses Raphael Mlahagwa, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is a result of my own original work and has never been submitted for the award of a degree in any other University.

Signature: .....

Date: .....

**COPYRIGHT**

No part of this dissertation may be reproduced, stored in any retrieval system or transmitted in any form or by any means without the prior written permission of the author or the University in that behalf.

## ACKNOWLEDGEMENTS

My sincere gratitude to Dr J.P. Mrema of the Department of Soil Science of Sokoine University of Agriculture for his guidance and tireless supervision during preparation of the research, implementation and final write up of this dissertation. Sincere acknowledgements to the second supervisor, Dr M. Oluoch of the AVRDC, Arusha, who worked tirelessly guiding me in designing the field experiment and in doing the analytical work. My special gratitude to Dr Chadha, the Director of AVRDC for allowing me to conduct this research at the site and in using some of the AVRDC's materials and equipment.

I sincerely acknowledge and appreciate the NORAD-SUA programme for the financial assistance which I received during this study. I also wish to express my sincere thanks to the Ministry of Agriculture for granting me study leave to undertake MSc studies. I wish to thank all members of staff of the Department of Soil Science of Sokoine University of Agriculture and MSc students 1998/2000 intake of the Department of Soil Science of Sokoine University of Agriculture who in one way or another assisted me in the due course.

I am exceptionally indebted to my Lord and personal saviour Jesus Christ, whom through him I get the strength to do all things.

## **DEDICATION**

To Jane, my wife and friend; to my dear daughters, Makejoy, Makepeace (peace be with her) and Makerighteous, whose prayers, love and encouragement inspired me.

## TABLE OF CONTENTS

ABSTRACT .....	ii
DECLARATION .....	iv
COPYRIGHT .....	v
ACKNOWLEDGEMENTS .....	vi
DEDICATION .....	vii
TABLE OF CONTENTS .....	viii
LIST OF TABLES .....	xi
LIST OF APPENDICES .....	xii
CHAPTER ONE .....	1
1. INTRODUCTION .....	1
CHAPTER TWO .....	5
2. LITERATURE REVIEW .....	5
2.1 Factors influencing the growth of soybeans .....	5
2.1.1 Soil Factors .....	6
2.1.1.1 Soil texture and structure .....	6
2.1.1.2 Soil Acidity (soil pH) .....	6
2.1.2 Mineral nutrition of soybean .....	7
2.1.2.1 Nitrogen .....	7
2.1.2.2 Phosphorus .....	9
2.1.2.3 Potassium .....	10
2.1.2.4 Calcium .....	11
2.1.2.5 Magnesium .....	12
2.1.2.6 Micronutrients .....	12
2.1.2.6.1 Iron .....	13
2.1.2.6.2 Manganese .....	13
2.1.2.6.3 Copper .....	14
2.1.2.6.4 Zinc .....	14
2.1.3 Climatic Factors .....	14
2.1.3.1 Temperature .....	15
2.1.3.2 Photoperiod .....	16
2.1.3.3 Water .....	17
2.1.4 Plant Factors .....	17
2.2 Factors influencing the growth of mungbean .....	18
2.2.1 Soil factors .....	18
2.2.2 Mineral nutrition of mungbean .....	20
2.2.3 Plant Factors .....	21
2.2.4 Environmental factors .....	22
2.2.4.1 Temperature .....	22
2.2.4.2 Photoperiod .....	22

2.2.4.3 Rainfall .....	23
2.3 Contribution of soybean and mungbean to soil fertility .....	23
2.3.1 The influence of soybeans in soil fertility .....	24
2.3.2 The influence of mungbeans in soil fertility .....	25
2.4 Economic importance of soybeans and mungbeans .....	27
CHAPTER THREE .....	29
3. MATERIALS AND METHODS .....	29
3.1 Soil sampling .....	29
3.2 Soil analysis .....	30
3.3 The Field Experiment .....	30
3.4 Statistical analysis .....	32
CHAPTER FOUR .....	33
4. RESULTS AND DISCUSSION .....	33
4.1 Some of the physical and chemical properties of the two soils .....	33
4.1.1 Soil pH .....	33
4.1.2 Soil texture .....	35
4.1.3 Bulk density .....	35
4.1.4 Organic carbon .....	36
4.1.5 Total nitrogen .....	36
4.1.6 Available phosphorus .....	37
4.1.7 Cation exchange capacity (CEC) .....	38
4.1.8 Potassium .....	38
4.1.9 Calcium .....	39
4.1.10 Magnesium .....	39
4.1.11 Copper .....	40
4.1.12 Zinc .....	40
4.1.13 Manganese .....	40
4.1.14 Iron .....	41
4.2 Nutrient concentrations in plants .....	42
4.2.1 Nutrient concentrations in soybean plants .....	42
4.2.1.1 Nitrogen .....	42
4.2.1.2 Phosphorus .....	43
4.2.1.3 Potassium .....	44
4.2.1.4 Calcium .....	44
4.2.1.5 Magnesium .....	47
4.2.1.6 Iron .....	49
4.2.1.7 Zinc .....	49
4.2.1.8 Copper .....	50
4.2.1.9 Manganese .....	50
4.2.2 Nutrient concentrations in mungbean plants .....	51
4.2.2.1 Nitrogen .....	51
4.2.2.2 Phosphorus .....	52

4.2.2.3 Potassium .....	53
4.2.2.4 Calcium .....	53
4.2.2.5 Magnesium .....	56
4.2.2.6 Iron .....	58
4.2.2.7 Zinc .....	58
4.2.2.8 Copper .....	59
4.2.2.9 Manganese.....	59
4.3 Nutrient uptake of soybeans and mungbeans.....	59
4.3.1 Nutrient uptake of soybeans .....	59
4.3.2 Nutrient uptake of mungbeans.....	60
4.4. Correlation .....	61
4.4.1. Correlation between soil nutrient elements and fresh grain yields of soybeans .	61
4.4.2. Correlation between plant nutrient elements and grain yields of soybeans.....	62
4.4.3. Correlation between soil nutrient elements and plant nutrient elements in soybeans.....	63
4.4.4 Correlation between soil nutrient elements and grain yields of mungbeans .....	64
4.4.5. Correlation between plant nutrient elements and grain yields of mungbeans ....	66
4.4.6. Correlation between soil nutrient elements and plant nutrient elements of mungbeans.....	67
CHAPTER FIVE .....	69
5. CONCLUSIONS AND RECOMMENDATIONS .....	69
5.1 Conclusions.....	69
5.2 Recommendations.....	71
REFERENCES .....	74
APPENDICES .....	88

## LIST OF TABLES

<b>Table</b>	<b>Contents</b>	<b>Page</b>
1	Characteristics of the experimental soils of Madiira AVRDC farm...	34
2a	Overall means of plant nutrient contents, dry matter yields at flowering stage and fresh grain yields of soybeans.....	46
2b	Nutrient uptake and fresh grain yields of soybeans.....	48
3a	Overall means of plant nutrient contents, dry matter yields at flowering stage and fresh grain yields of mungbeans.....	55
3b	Nutrient uptake and fresh grain yields of mungbeans.....	57

**LIST OF APPENDICES**

<b>Appendix</b>	<b>Contents</b>	<b>Page</b>
1a	Regression and correlation between soil nutrient concentrations and fresh grain yields of soybeans.....	88
1b	Regression and correlation between plant nutrient concentrations and fresh grain yields of soybeans.....	89
1c	Regression and correlation between soil nutrient concentrations and plant nutrient concentrations of soybeans.....	90
2a	Regression and correlation between soil nutrient concentrations and fresh grain yields of mungbeans.....	91
2b	Regression and correlation between plant nutrient concentrations and fresh grain yields of mungbeans.....	92
2c	Regression and correlation between soil nutrient concentrations and plant nutrient concentrations of mungbeans.....	93

## CHAPTER ONE

### 1. INTRODUCTION

The current interest in soybean and mungbean production in Tanzania and Sub-Saharan Africa is due to the fact that these crops are potential vegetable legumes. Both, are known to play an important role in human and animal nutrition as well as for oil production. Furthermore, they are legumes with anticipated potential to contribute to the improvement of soil fertility and productivity if used as green manure, mulch, compost material or in intercropping.

Soybean (*Glycine max* (L.) Merrill) is one of the important grain legume crops. As a legume it is capable of utilizing atmospheric nitrogen through biological nitrogen fixation and is therefore much less dependent on synthetic nitrogenous fertilizers than most other crops. The introduction of soybean into crop rotations often breaks the build-up of pests and disease in cereals. Soybean has therefore become one of the favourite crops for crop rotation as observed in temperate countries (Haen, 1994). It is very common in Asia and is predominantly part of the rice-based farming system, and to a lesser extent, is grown with other upland crops (AVRDC, 1987).

It is fully recognized that lands suitable for soybean production are also suitable for other upland crops. In this context, it is envisaged that soybean will have to be grown either as an intercrop or in rotation with other crops (AVRDC, 1987).

Mungbean (*Vigna radiata* (L.) Wilczek) is an ancient and well-known crop in Asia, particularly in the Indian subcontinent, and now it is becoming popular in other continents as well. It is an excellent source of easily digestible protein of low flatulence which complements the staple rice diet in Asia. Mungbean is consumed as *dahl* (Asian term), bean sprouts, noodles, green beans, and boiled dry beans. Since it is a short-duration legume (maturing in 55 to 70 days), it fits well into many cropping systems, including rice and sugarcane under rainfed and irrigated conditions (Fernandez and Shanmugasunda, 1988). Mungbean's ability to fix atmospheric nitrogen (N<sub>2</sub>) in symbiotic association with bacteria of the genus *Bradyrhizobium* sp. (*Vigna*), is of extreme importance in soil fertility (Miller and Fernandez, 1988). These two legumes are about to be introduced in the North-Eastern Tanzania.

Interest in soybeans has grown rapidly and its increased production has been, perhaps the most striking characteristic of agricultural development in the last decade. During the last decade, the number of people engaged in soybean research in institutions has doubled, a vigorous soybean chemical industry has developed, soy protein in foods has been accepted and there has been a phenomenal growth in interest in the potential of

soybean for food use in tropical countries (Howell, 1975). At present some 500 million people, mainly in tropical countries, are seriously undernourished, and their number is expected to reach 628 million by the end year 2000 (Haen, 1994). In such countries the demand for affordable protein-and energy-rich foods is already high and will increase. Adoption and production of soybeans and mungbeans could meet that demand in such countries, Tanzania inclusive.

In certain areas, particularly in some tropical countries, chemical nitrogen fertilizer is not available or the farmer has no money to pay for it. Therefore, a well-planned cropping system which include legumes is essential to supply the nitrogen needed for the growth of non-legumes. The main drawback, however, is often the lack of adapted legumes (Tisdale and Nelson, 1970).

In order to optimize soybean and mungbean production in Tanzania, the soils in the areas where the two crops are intended to be introduced for multiplication and production have to be studied, the suitabilities of the soils for the growth of the two crops have to be assessed and correct production measures suggested accordingly. Very little or almost nothing has been studied in the north-eastern Tanzania to assess and evaluate the influence of the soils in relation to the performances of soybean and mungbean crops and in turn their influence to soil conditions.

As a broad objective, the study was carried therefore, to assess the suitability of the soils at AVRDC for the production and multiplication of soybeans and mungbeans.

Specifically this study intends to:

- i) assess the fertility status of the soils (nutrient supply) for the production of mungbeans and soybeans.
- ii) determine the nutrient uptake of the essential nutrient elements from the soils by the mungbeans and soybeans.
- iii) Suggest measures for the development of the crops at the area for the short, medium and long term soil fertility management strategies.

## CHAPTER TWO

### 2. LITERATURE REVIEW

#### 2.1 Factors influencing the growth of soybeans

Appropriate soil and crop management practices can increase and stabilize soybean yield in areas where dry spells occur. The soil should be managed to eliminate low fertility, high aluminium (Al) saturation, low calcium (Ca) levels throughout the profile and physical impediments. All these factors constitute adverse restrictions to root growth and functions (Neumaier and Nepomuceno, 1994). The soil should also be managed to increase the amount of available stored water. Neumaier and Nepomuceno (1994), recommended managing the soil to avoid compaction of the soil by using different implements each year to prevent the formation of a compacted layer.

Poor seedling emergence is one of the major problems in soybean production. Non-uniform seedling emergence may be due to crusting of the soil surface, making it difficult for cotyledons to penetrate through the surface, high soil temperature, especially during the dry season, inhibition of hypocotyl elongation and infection by pathogenic fungi of unmerged seedlings (AVRDC, 1987). Most of the above problems causing non-uniform seedling stands are directly and least of them indirectly related to soil

conditions.

## **2.1.1 Soil Factors**

### **2.1.1.1 Soil texture and structure**

Werner (1976), observed that soil texture and structure affect soybean rooting depth and hence the size of water reservoir from which the roots can draw. In some light textured soils with a plow pan or compact horizons, subsoiling directly under the row increases yield. On heavier soils subject to freezing and thawing or wetting and drying, subsoiling may be of little value. Roots in less favourable environments tend to die back. As conditions change during the season, successive generations of roots may proliferate alternately between surface and deeper soil layers.

### **2.1.1.2 Soil Acidity (soil pH)**

High acidity is common in many tropical soils and can be a stress to soybean. Acid soil toxicity is not a single factor but a complex of factors that may affect the growth of plants. The specific causes of poor plant growth on acid soils may vary with soil pH, clay mineral type and amount, organic matter content and kind, level of salts and particularly, with plant species or genotype (Foy *et al.*, 1978). Generally, the stress may be described as the direct effects of soil acidity and the related indirect effects of soil pH on other factors. At soil pH levels considered harmful to plants (pH < 5.0), Al, Mn and other mineral elements occur in toxic concentrations and the availabilities of essential

elements, particularly Ca, Mg, P and Mo, become suboptimal (Foy, 1984).

Soil pH also indirectly affects the kind, number and activities of micro-organisms involved in symbiotic N-fixation and organic-matter transformations. High acidity negatively affects all activities of *Bradyrhizobium japonicum*, from survival through to symbiotic efficiency (Borkert and Sfredo, 1994).

### **2.1.2 Mineral nutrition of soybean**

Kurtz (1976), observed that soybean, like other crops grow and produce well only when they have an adequate supply of the essential mineral nutrients. Few soils have, or maintain for long, the levels of mineral nutrients sufficient for maximum production. Any soybean grower who is seeking high production must meet the several requirements of the crop. One major category of requirements is an abundant but not excessive level of each mineral nutrient.

#### **2.1.2.1 Nitrogen**

Large amounts of N are required for good soybean production. For a yield of 3000 kg ha<sup>-1</sup>, 231 kg of N is required. Soybean plants can use N released by mineralization of soil organic matter (SOM), residual soil N, fertilizer N or atmospheric N<sub>2</sub>, which is converted to a usable form in root nodules through a symbiotic relationship between *Bradyrhizobium japonicum* bacteria and the soybean plant. While the soil is the primary

source of N for many crops, soybean obtains 65 to 85% of its needs through the symbiotic process. In most areas where soybean is now grown, production would be impractical without efficient symbiotic N<sub>2</sub> fixation. Without efficient N<sub>2</sub> fixation the feasibility of soybean production in new areas cannot be accurately evaluated (Borkert and Sfredo, 1994). Although the soybean is high in protein and requires large amounts of nitrogen, nitrogen fertilizers are not used extensively on this crop. Common practice in soybean growing areas is to depend on symbiotically fixed nitrogen, rather than fertilizer N to supplement nitrogen from the soil. The practice of depending on symbiotically fixed nitrogen rather than on chemical fertilizer nitrogen is justified by extensive field trials showing negligible and uneconomic responses of nodulated soybeans to the nitrogen fertilizers. Other observations indicate that soybeans do utilize fertilizer nitrogen if it is present in the soil. However, when soil or fertilizer nitrogen is utilized, symbiotic N-fixation is reduced correspondingly. Normally, nitrogen fertilizer substitutes for symbiotically fixed nitrogen without any increase in yield (Kurtz, 1976).

Depending on the plant species, development stage, and organ, the nitrogen content required for optimal growth varies between 2 and 5% of the plant dry weight. When the supply is suboptimal, growth is retarded; nitrogen is mobilized in mature leaves and retranslocated to areas of new growth (Marschner, 1986).

An increase in the nitrogen supply not only delays senescence and stimulates growth, but also changes plant morphology in a typical manner particularly if the nitrogen availability is high in the rooting medium during the early growth (Yoshida *et al.*, 1969). Shoot elongation is enhanced and root elongation inhibited (Klemm, 1966) as quoted by Marschner (1986), a shift which is unfavourable for nutrient acquisition and water uptake in later stages.

#### **2.1.2.2 Phosphorus**

Phosphorus management is critical to the production of soybean, particularly in acid soils with high P fixation. A lack of this element is doubly serious since it may prevent other nutrients from being absorbed by soybean plant. During late seed development, P is translocated from vegetative plant parts to the grains. At maturity, between 60 to 90% of the P taken up by the soybean plant is stored in the seeds (Borkert and Sfredo, 1994).

The phosphorus requirement for optimal growth is in the range of 0.3 to 0.5% of the plant dry weight during the vegetative stages of growth. Plants suffering from phosphorus deficiency exhibit retarded growth (Marschner, 1986). Terry and Ulrich (1973), reported that phosphorus has functions related to plant growth and metabolism of which a deficiency of it leads to a general reduction of most metabolic processes, including cell division and expansion, respiration and photosynthesis. Quebedeaux (1980) as quoted by Marschner (1986), reported the effect of phosphorus on partitioning

and that it is responsible, in part, for the insufficient photosynthate supply to nodulated roots of phosphorus-deficient legumes and the occurrence of nitrogen deficiency as dominant symptom in  $N_2$  fixing legumes receiving deficient levels of phosphorus.

### **2.1.2.3 Potassium**

Soybean uses large amounts of K and when K is deficient, maturation of soybean is retarded, seed quality is reduced and the incidence of seed disease is increased (Borkert and Sfredo, 1994). Potassium remains very mobile and moves readily from older tissues to the growing points of roots and shoots. At maturity, about half the total K in higher-yielding plants will be in the seed (Ohlrogge and Kamprath, 1968).

Potassium requirement for optimal plant growth is 2-5% of the dry weight of the vegetative parts, fleshy fruits and tubers. When K is deficient, growth is retarded and K is retranslocated from mature leaves and stems, and under conditions of severe deficiency these organs can become chlorotic and necrotic (Bussler, 1964) as quoted by Marschner (1986), lignification of vascular bundles is impaired, a factor that may also be responsible for the higher susceptibility of potassium deficient plants to lodging.

By increasing  $K^+$  supply to plant roots, it is relatively easy to increase the potassium content of various organs except grains and seeds, which maintain a relatively constant potassium content of 0.3% of the dry weight (Marschner, 1986). When the  $K^+$  supply is

abundant 'luxury consumption' of  $K^+$  often occurs, which deserves attention both for its effect on plant composition and for its possible interference with the uptake and physiological availability of  $Mg^{2+}$  and  $Ca^{2+}$ .

#### **2.1.2.4 Calcium**

Calcium serves many functions in soybean plants. The necessity of Ca for plant growth can easily be demonstrated by interrupting  $Ca^{2+}$  supply to the roots. Their growth rates are immediately reduced, and after some days the root tips become brown and gradually die (Mengel and Kirkby, 1987). Soybean often has a high Ca content, as a result of the high Ca levels in the soil solution than efficiency of active Ca uptake. The Ca concentration of the soil solution is generally about ten times higher than that of K. Low Ca uptake potential occurs because Ca can be absorbed only by young root tips in which the cell walls of the endodermis are still unsubserved (Mengel and Kirkby, 1987).

The calcium content of plants varies between 0.1 and > 5.0% of dry weight, depending on the growing conditions, plant species and plant organ. The calcium requirement for optimal growth is much lower in monocotyledons than in dicotyledons (Loneragan *et al.*, 1968; Loneragan and Snowball, 1969). Most of its activity is related to its capacity for co-ordination, by which it provides stable but reversible intermolecular linkages, predominantly in the cell walls and at the plasma membrane. These  $Ca^{2+}$  mediated linkages respond to local changes in environmental conditions and are part of the control

mechanism for growth and developmental processes (Marschner, 1986). Calcium is a non-toxic mineral nutrient even in high concentration and is very effective in detoxifying high concentrations of other mineral elements in plants (Hanson, 1984).

#### **2.1.2.5 Magnesium**

In the soil, Mg is present in solution, on the cation exchange complex and as a constituent of many minerals. Small amounts of Mg may also be combined with the soil's organic fraction (Barber, 1984). Although soybean contains less Mg than Ca, the percentage of Mg removed with grains is higher than that of Ca (Borkert and Sfredo, 1994). On average, the magnesium requirement for optimal plant growth is 0.5% of the dry weight of vegetative parts. Chlorosis of fully expanded leaves is the most obvious visible symptom of magnesium deficiency. In accordance with the function of  $Mg^{2+}$  in protein synthesis, the proportion of protein nitrogen is depressed and that of nonprotein nitrogen increased in Mg-deficient leaves (Marschner, 1986). As calculated on both unit leaf area and unit chlorophyll, the rate of photosynthesis is lower in magnesium-deficient plants than in normal plants, as is the respiration rate (Bottrill *et al.*, 1970; Terry and Ulrich, 1974).

#### **2.1.2.6 Micronutrients**

Micronutrients are absorbed in smaller quantities by soybeans than are N, P and K and sometimes Ca, Mg and S. Their role is equally as important and deficiencies of

micronutrients lead to severe depression in growth and yield. The solubility and consequently the availability of all micronutrients except Mo is low when soil pH is near neutrality (pH 7.0). However, most tropical soils should be managed in the 5.0 to 6.0 pH range for optimal availability of the micronutrients (Borkert and Sfredo, 1994).

#### **2.1.2.6.1 Iron**

Tisdale *et al.*, (1993) reported iron sufficient range in plant tissues as 50-250 ppm and < 50 ppm as deficient. Iron is an important constituent of the enzyme nitrogenase which is essential for N<sub>2</sub> fixation in N-fixing micro-organisms. It may also be capable of partial substitution for Mo as the metal cofactor necessary for the functioning of NO<sub>3</sub><sup>-</sup> reductase in soybeans.

#### **2.1.2.6.2 Manganese**

Manganese sufficient range in plant tissue is reported to be 20-500 ppm while 15-20 ppm is reported as deficient (Tisdale *et al.*, 1993). The involvement of Mn in photosynthesis particularly in the evolution of O<sub>2</sub> is well known. It also takes part in oxidation-reduction processes and in decarboxylation and hydrolysis reactions. Mn can substitute for Mg<sup>2+</sup> in many of the phosphorylating and group-transfer reactions. Although it is not specifically required, Mn is needed for maximal activity of many enzyme reactions in the citric acid cycle. However, plants are enjured by excessive amounts of Mn. Mn toxicity has also been found in soybeans on extremely acid soils

(Tisdale *et al.*, 1993).

#### **2.1.2.6.3 Copper**

Copper sufficient range in plant tissue is 5-20 ppm and < 4 ppm is deficient (Tisdale *et al.*, 1993). The element Cu is unique in its involvement in enzymes, and it cannot be substituted by any other metal ion. In many vegetable crops, the leaves lack turgor, become chlorotic, curl and flower production fails to take place where Cu is deficient.

#### **2.1.2.6.4 Zinc**

Tisdale *et al.*, (1993) has reported that > 400 ppm as a toxic range, 25-150 ppm as sufficient and < 20 ppm as deficient in plant tissue. Reduced growth hormone production in Zn-deficient plants causes the shortening of internodes and smaller than normal leaves. Zinc is involved in many enzymatic reactions, but it is not known whether it acts as a functional, structure or regulatory cofactor.

### **2.1.3 Climatic Factors**

Soybean development is sensitive to environmental factors. Water is the main factor influencing soybean productivity in time and space (Ravelo and Decker, 1979). Water use by soybean varies with climatic conditions, management practices and the life cycle of the cultivar and the crop's response to photoperiod and temperature defines the areas to which it is adapted (Farious, 1994). Mathematical models to express soybean

sensitivity to these factors have been developed (Summerfield *et al.*, 1989; Wilkerson *et al.*, 1989).

Summerfield *et al.*, (1989) focused on the effects of temperature and photoperiod on the development stages up to flowering, and a relatively simple picture of cultivar response to these environmental factors emerged. Hodges and French (1985), proposed four phases between planting and first flower: planting to emergence (temperature-dependent), emergence to the end of juvenile phase (temperature-dependent), end of juvenile phase to floral induction (day length-dependent), and floral development phase (temperature-dependent). The rate of development was also assumed to be sensitive to water stress, except during the third phase.

### **2.1.3.1 Temperature**

Soybean develops well under a wide range of temperatures, although regions in which the warmest mean monthly temperature is below 20<sup>0</sup>C are considered inappropriate for soybean (Farious, 1994). Very low soil temperatures during germination extend the period from planting to emergence. Seed germination occurs at temperatures from 5 to 40<sup>0</sup>C; however, for rapid germination the temperature should be around 30<sup>0</sup>C (Delouche, 1953). According to Cartter and Hartwig (1967), at 15.5<sup>0</sup>C emergence occurs in seven to ten days. In many tropical and subtropical areas, soil temperature at the time of planting is above 20<sup>0</sup>C, providing for seedling emergence in three to five days (Mota, 1978).

Farious (1994), observed that the number of days between planting and emergence decreased linearly as soil temperature at a depth of 5 cm increased. With an average of 12<sup>0</sup>C, emergence took 12 days, but with a temperature of 17<sup>0</sup>C emergence occurred in seven days.

Brown (1960), found a quadratic relationship between the rate of soybean development and air temperature. In this model, vegetative growth is slow or nil at temperatures of 10<sup>0</sup>C or less and optimum at 30<sup>0</sup>C, decreasing thereafter. Temperatures above 40<sup>0</sup>C are known to have adverse effects on growth rate, flower initiation and pod-set (Farious, 1994). Floral induction and reproductive development in soybean are particularly sensitive to night temperature with the optimum being between 21 and 27<sup>0</sup>C (Parker and Borthwick, 1943).

#### **2.1.3.2 Photoperiod**

Most soybean cultivars respond to photoperiod as quantitative short-day plants and are adapted for production in narrow band of latitudes (Farious, 1994). The soybean has a juvenile stage after emergence when it is especially sensitive to temperature and insensitive to day length (Hodges and French, 1985). Borthwick and Parker (1938b), reported that the induction of flowering in soybean is inhibited by a light intensity greater than 5.3 lux. Therefore, the soybean's biological day would be the duration of the light period with an intensity greater than 5.3 lux. This approximately corresponds to the

light intensity provided by the sun at 5° below the horizon (Farious, 1994).

### **2.1.3.3 Water**

Rainfall is the principal source of water for most of the world's soybean production, since only an extremely small number of farms have irrigation to supplement the water requirements of this crop (Farious, 1994). Soybean has two well-defined critical periods with respect to water requirements: these are planting to emergence and pod-filling. During germination, either an excess or deficit of moisture is detrimental to uniformity in distribution and number of plants per area, although an excess is much more limiting than a deficit (Farious, 1994). The water content of the soil during this period should not exceed 85% or be less than 50% of potential available soil water (Doorenbos and Kassam, 1986). A moisture deficit during the pod-filling period is more detrimental to yield than a deficit during flowering (Doss *et al.*, 1974; Sionit and Kramer, 1977). To achieve maximum yields, an adequate supply of water must be available during the critical seed-development period, either from frequent rains, irrigation or stored soil moisture (Farious, 1994).

### **2.1.4 Plant Factors**

The major constraints of soybean production and its development include lack of suitable location (specific cultivars to suit the location), low yield potential, susceptibility to diseases and insects, poor seed viability, susceptibility to drought and

high linolenic acid content (AVRDC, 1987).

Several researchers have reported varietal differences in photosynthesis. Egli *et al.*, (1970) and Dornhoff and Shibles (1970), and recent unpublished work at Urbana U.S.A have demonstrated that cultivar differences do in fact exist and are somewhat helpful in that those cultivars, with few exceptions, which exhibit higher photosynthate efficiencies in a canopy situation, are usually the leaders in regional yield tests.

Varieties differ greatly in capacity to withstand moisture stress. In studies under water stress conditions in Ohio U.S.A the yield of the most stress-resistant varieties was reduced by 20% and the least stress-resistant varieties by 40%. In Tennessee U.S.A it was shown that in 2 stress years out of 10, one variety produced 6.29 bu per inch of water (8.6 kg per mm of water) and another only 3.14 bu (4.5 kg) (Parks *et al.*, 1974).

## **2.2 Factors influencing the growth of mungbean**

### **2.2.1 Soil factors**

There is quite a large land area that could be used to grow a good mungbean crop without problems. However, mungbean grown on marginal land might face such adverse soil factors as unfavourable texture, reaction, fertility and moisture as reported by Tiaran *et al.*, (1985). According to the classification of land suitable for growing mungbean, attempts have been made to classify the suitability of soils for specific groups of grain

legumes. According to Panichapong and Vicharnsorn (1977), there are three broad suitability classes designated in Thailand. Classes 1 and 2 are generally suited and conditionally suited for bean cultivation, respectively, while soils and land types of class 3 are not considered suitable. Since the classification is too broad and general for application, more detailed investigation is needed (Claimon, 1983).

In the eighties, mungbean breeding work focused on disease resistance, pest resistance, tolerance to low pH, aluminum toxicity and moisture stress, nitrogen fixing ability, and adaptation to partial shade under coconut trees (Lantican and Navarro, 1988). Breeding for tolerance to low pH, aluminium toxicity, moisture stress and even nitrogen fixing ability seem to directly imply the effect or influence of soil conditions to the performance of the crop.

Fertilizer can increase mungbean yields, especially when grown on infertile soils. Results from mungbean fertilizer trials (Claimon, 1983) showed that potential yields and yield response to fertilizer application varied from region to region. This variation might be due to the influence of soils and environment. An assessment of the influence of nitrogen, phosphorus and potassium on the increase of mungbean yield revealed that on loamy soils mungbean responded to phosphorus and nitrogen more than to potassium, whereas on light-texture soils phosphorus and potassium played the same important role on yield increase (Claimon, 1983). Therefore, phosphorus is the most important nutrient

element for mungbeans grown on both light and medium textured soils.

### **2.2.2 Mineral nutrition of mungbean**

Mitra *et al.*, (1988) observed that nitrogen is the major limiting factor to mungbean yield, and Sinclair and de Wit (1975) documented that protein concentration in the mungbean seed ranges 24 to 26% on a dry weight basis and hence the N-requirement is high. It was estimated to be 26 mg N/g of photosynthate and that only 20 mg N/g can be available to the developing seed from the soil. Thus, from these data it is apparent that mungbean is not able to meet its N requirement by uptake from the soil or by fixation. Sinclair and de Wit (1975), reported that N requirement of the developing seed can be met by mobilization from foliage which in turn induces leaf senescence and abscission. This phenomenon has been described as “self destructive” and this has been cited as one cause for the low yield (Bhagwat *et al.*, 1979).

The N utilized for plant growth and that which accumulates in the seeds originates from the soil, fertilizer and from N<sub>2</sub> fixation. The amounts derived from these sources depend both on plant factors such as ability to absorb, translocate and metabolize available N as well as relative capacity or potential to fix N, and soil factors including soil texture, soil pH and availability of N. Studies in Queensland, Australia (Lawn and Ahn, 1985) using the cultivar Berken showed that with each ton (dry weight) of seed harvested, 40 to 42 kg N, 3 to 5 kg P, 12 to 14 kg K, 1.5 to 2.0 kg each of S and Mg and 1.0 to 1.5 kg Ca/ha

were removed from the field. Additional nutrient requirements are obviously necessary to sustain vegetative dry-matter production, and in situations where the vegetative matter is fed to animals, significantly more quantities of mineral nutrients may be removed from the field at harvest. Thus, there are several elements that are important for successful crop production but clearly, N is the most important contributor to yield of grain and dry matter in mungbean.

### **2.2.3 Plant Factors**

Many detailed studies, particularly by the geneticists have been based on the growing plants and on the grain. However in many situations, particularly in plant nutrition and management studies, little more than yield is measured. Information which is often gathered include disease and insect resistance, root characteristics, nodulation, date of first flower, pod height, leaf abscission, grain:stover ratio, stem cell senescence, photosynthesis, respiration, date of maturity, seed characteristics, oil and meal composition and many other data. Obviously, it would not be possible to make all these measurements in all experiments (Werner, 1976). The mentioned parameters seem to be directly related to the variety of the crop.

On mungbean production, Fernandez and Shanmugasundaram (1988) observed that the low yield potential, lack of yield stability, susceptibility to major diseases and pests, narrow adaptability due to photoperiod and temperature sensitivity, susceptibility to

abiotic stress; nonsynchronous pod maturity, pod shattering and field weathering are the most serious production constraints of the local mungbean cultivars in the tropics. All the mentioned parameters are directly related to the variety of the crop.

## **2.2.4 Environmental factors**

### **2.2.4.1 Temperature**

Environmental factors exert considerable influence on mungbean growth and yield in the tropics. Mungbean is described as a warm season crop, and growth is adversely affected by low temperature. Germination, emergence, seedling growth and flowering are also reported as temperature-sensitive. AVRDC (1981), reported mungbean as a warm-season crop and should be planted during the warm season in order to fully exploit its genetic potential.

Rawson and Craven (1979), reported varieties showing differential response to temperature. They noted that the yield per plant reached the maximum at 24<sup>0</sup>C (22<sup>0</sup>-27<sup>0</sup>C) rather than at the low temperature of 18<sup>0</sup>C (16<sup>0</sup>-21<sup>0</sup>C) or the high temperature of 33<sup>0</sup>C (31<sup>0</sup>-36<sup>0</sup>C) under controlled conditions.

### **2.2.4.2 Photoperiod**

Photoperiod and temperature are important environmental factors that influence the phenological development of mungbean at all growth stages and, therefore, determine

the adaptability of mungbean cultivars (Opena *et al.*, 1987). Mungbean is a short-day plant and warm season crop (Aggarwal and Poehlman, 1977). Although most mungbean lines flower in 12 to 13 hour photoperiods, flowering is progressively delayed as the photoperiod is extended (Lawn and Ahn, 1985).

#### **2.2.4.3 Rainfall**

Mungbean is one of the most important grain legumes of the arid and semiarid tropics. In India, it is generally grown either as a rainfed or irrigated crop. Therefore, the crop invariably suffers from moisture stress of different degree and duration depending upon the pattern of rainfall distribution or supply of irrigation water (Pannu and Singh, 1987). It is now well documented that plant water deficit affects practically every aspect of plant growth and yield by modifying anatomy, morphology, physiology, biochemistry and finally the productivity of the crop (Turner and Begg, 1981). Such studies, however, have been primarily confined to cereal crops, and very little research work is reported on mungbean (Phogat *et al.*, 1984a,b; Muchow, 1985). However Satyanarayana *et al.*, (1987), reported that under heavy rains mungbean suffers from preharvest sprouting of seeds in the pods of the standing crop causing severe damage to seed quality and yield.

### **2.3 Contribution of soybean and mungbean to soil fertility**

Soybean and mungbean are potential vegetable legumes. Legumes have been a mainstay of some rotations for many years. Apart from supplying large amounts of high quality

forage, an additional and valuable benefit has been the nitrogen supplied to succeeding crops. Maintaining an adequate supply of nitrogen is one of the most important problems of soil fertility. Tisdale and Nelson (1970), observed that legumes contribute to soil tilth, first through the organic matter of the roots and tops of the plants themselves and second by increased production of organic matter in the succeeding non legume crop by means of nitrogen supplied. From this point of view, these legumes are therefore anticipated to contribute to the improvement of soil fertility and productivity if used as green manures, mulch, compost material or for intercropping.

### **2.3.1 The influence of soybeans in soil fertility**

AVRDC (1987), reported soybean as one of the most important legume crops that is capable of utilizing atmospheric nitrogen through biological nitrogen fixation and much less dependent on synthetic nitrogenous fertilizer than most crops. Haen (1994), reported soybean as one of the favourite crops for crop rotation, while AVRDC (1987) proposed soybean to be grown either as an intercrop or in rotation with other crops.

#### **Soybean and N<sub>2</sub> fixation**

Nitrogen fixation by soybeans may start as early as the second week after planting. Vargas *et al.*, (1982) as cited by Cattelan and Hungria (1994), observed that the first nodules appeared five days after plant emergence and that the level of N<sub>2</sub> fixation was relatively high at 12 days after emergence. After this initial period, nodulation and N<sub>2</sub>

fixation increase until the full flowering stage; the fixation rate is then maintained or may decrease through pod formation, when nodules start to senesce and nitrogenase activity declines (Franco *et al.*, 1978 as cited by Cattelan and Hungria, 1994).

The amount of N<sub>2</sub> fixed by a soybean crop will vary with the prevailing conditions, but usually it is from 60 to 168 kg N ha<sup>-1</sup> (FAO, 1985). Cattelan and Hungria (1994), estimated that N<sub>2</sub> fixation provided 132 kg N ha<sup>-1</sup>, representing 57% of the total N absorbed by the soybean plants. When growth conditions are optimal the amount of fixed N<sub>2</sub> can be higher, and in an irrigated field Bergersen *et al.*, (1985) obtained 244 kg N ha<sup>-1</sup>, representing 67% of total N accumulated in shoots.

### **2.3.2 The influence of mungbeans in soil fertility**

Since mungbean is a short-duration legume (maturing in 55 to 70 days), it fits well into many cropping systems including rice and sugarcane under rainfed and irrigated conditions. Thus it increases small farmer's incomes whilst improving soil conditions (Fernandez and Shanmugasunda, 1988). Mungbean's ability to fix atmospheric nitrogen (N<sub>2</sub>) in association with bacteria of genus *Bradyrhizobium* sp. (*Vigna*), is of extreme importance and so mungbean is considered as a soil builder (Miller and Fernandez, 1988).

### **Mungbean and N<sub>2</sub> fixation**

The contribution of N<sub>2</sub> fixation to total plant N varies widely depending on the host plant, rhizobial populations, and edaphic factors affecting symbiosis. Reliable estimates of the amount of N fixed by mungbean are few. Results from a two-year rotation study in Thailand (Firth *et al.*, 1973) showed 58 to 107 kg N ha<sup>-1</sup> fixed. These estimates are probably higher than would be expected in farmers' fields where stands are often poor due to weed competition, wide spacing or pests. This study was conducted on a N-deficient soil which promotes fixation and is also typical of many mungbean growing situations. These values, while slightly higher, are consistent with an earlier long-term study in Oklahoma, USA (Harper and Gray, 1957) which showed that mungbean turned under as a green manure increased the yield of a subsequent oat crop by a magnitude equivalent to the addition of 70 kg N ha<sup>-1</sup>. Other reports (Morton *et al.*, 1982; Sinha, 1976) also estimated fixation by mungbean to range from 50 to 100 kg N ha<sup>-1</sup>. The value of mungbean as a N<sub>2</sub> fixing leguminous crop in rotation with non legume crops has not been well documented. There is need for definitive information on the net input of N from mungbean harvested for seed. If mungbean is to make a net N contribution, the amount of N removed in plant material, for example grain, must be less than that fixed by the crop. In situations where grains are harvested and crop residues are removed, a net N input into the soil from the mungbean crop can not be expected to be significant. In practice, however, the decision as to whether or not mungbean is grown in rotation with other crops is usually based more on how it fits into the cropping sequence and its

commercial value in that location rather than on its N<sub>2</sub> fixing potential.

As with other leguminous crops, biological N<sub>2</sub> fixation in mungbean is suppressed by N fertilization, which tends to suppress nodulation, and does not increase grain yield except in the absence of effective nodulation (Miller *et al.*, 1982). Mungbean is regarded as symbiotically promiscuous, with nodules produced when ineffective strains of the cowpea cross inoculation group of *Bradyrhizobium* sp. (Vigna) are present in the soil. For an introduced strain to be effective, it should produce N<sub>2</sub> fixing nodules over a wide range of soil conditions and be competitive in nodule formation and subsequent N<sub>2</sub> fixation with indigenous or native strains already present in the soil.

## **2.4 Economic importance of soybeans and mungbeans**

A good number of documents show that both soybean and mungbean crops play an important role in human and animal nutrition, soil fertility and cropping systems. In China, it has been documented that mungbean is presently cultivated over almost all arable land and due to its early maturity, lengthy seedling period, wide adaptation, tolerance to drought and poor soil and great nutritional and medicinal value, mungbean has long been a traditional favourite grain legume crop and has been widely utilized by Chinese people for several thousand years (Cereal Crop Institute, 1985; Dong and Li, 1982; Li and Cheng, 1983; Wang and Cheng, 1987). Miller and Fernandez (1988) reported that mungbean can also be utilized for human or animal consumption apart

from being used as a soil builder. In Thailand it has been reported that 65% of mungbean production is exported and the rest goes to domestic consumption (Areekul, 1988).

Panizzi and Mandarino (1994) suggested that soybean can now be grown in many parts of the world and has great potential to alleviate nutritional problems common in tropical regions. Soybean will directly help the world meet its food needs and will contribute towards eliminating poverty and enhancing the sustainability of production systems (Haen, 1994). The Tanzanian economy can benefit from such vegetable legumes as soybean and mungbean if introduced in the existing cropping or farming systems.

## **CHAPTER THREE**

### **3. MATERIALS AND METHODS**

Assessment of the suitability of the soils at AVRDC (Asian Vegetable Research and Development Centre)-Africa Region Programme, Arusha, Tanzania, for the growth and production of soybeans and mungbeans was undertaken based on soil analysis and field experiments. Soil and plant samples were collected from the farm and the analysis of the soil and plant material samples were done at SUA.

#### **3.1 Soil sampling**

Composite soil samples to a depth of 0-40 cm were collected from the sites intended for soybean and mungbean production. The soil samples were air-dried, ground and sieved through 2 mm sieve (Gee and Bauder, 1986) to obtain the fine earth fraction. In addition to the composite soil samples, core samples from the points where the sub-samples that constituted the composite soil sample for each of the soil site were taken for the determination of various soil physical properties.

### **3.2 Soil analysis**

Soil pH was determined in 1:2.5 soil:water suspensions using a pH meter (Maclean, 1982) and organic carbon was determined by the Walkley and Black method (Allison, 1965). Total nitrogen was determined by macro-Kjeldahl digestion followed by distillation as outlined by Bremner and Mulvaney (1982). Extractable P was determined according to the Bray 1 method (Bray and Kurtz, 1945) and colour development by the ascorbic acid method of Murphy and Riley (1962). Cation exchange capacity (CEC) was determined by the ammonium acetate saturation method (NSS, 1990), while exchangeable bases (K, Ca and Mg) in the ammonium acetate leachates were determined by atomic absorption spectrophotometry. Extractable Cu, Zn, Mn and Fe were determined by Diethylene-Triamine-Pentaacetic Acid (DPTA) procedure (Lindsay and Norvel, 1978). Particle size distribution was done by the Bouyoucos hydrometer method (Okalebo *et al.*, 1993) while the bulk density was determined by the core sample method (Blake and Hartge, 1982).

### **3.3 The Field Experiment**

A field experiment was conducted at the AVRDC-ARP, Arusha to assess the field performance of soybeans and mungbeans on two sites on the farm designated as sites A and B. Site A was a piece of land which was left uncultivated for one year while site B was a piece of land which had previously been under intensive vegetable production.

About 400 m<sup>2</sup> of land at each site was plowed and harrowed. The 400 m<sup>2</sup> harrowed piece of land for each site was divided into three blocks (each of 8 m x 6 m size) for planting four soybeans and three blocks for planting five mungbeans. Four soybean lines and five mungbean lines were grown at a spacing of 30 cm x 10 cm in their respective blocks, hence replicated three times. The four soybean lines grown were: AGS 329, AGS 338, AGS 292 and GC 84051-32-1, while the five mungbean lines were: VC 6148(50-12), VC 6379(23-2-1), KANTI, VC 6173(b-10) and VC 6372(45-8). The field experiment was conducted during warm season just before the main cropping season in Arusha. The crops were irrigated by surface irrigation.

Just before flowering nine, plants of each line and each block were randomly harvested (cut at a soil surface level) for dry matter yield determinations and total plant nutrient analysis. The other plants were left in the field to grow to maturity for fresh grain yield determinations. The sampled soybean and mungbean plants were thoroughly washed, dried to constant weights (70<sup>0</sup>C) to determine dry matter yield. Thereafter, it was ground into a fine powder which was used for the determination of nutrient element contents in the plants (macro and micro nutrients). The nutrient elements determined were; N, P, K, Ca, Mg, Fe, Cu, Zn and Mn.

The methods used in the determination of nutrient concentrations in the plant samples were as outlined by Jones and Case (1990). The nutrient concentrations in the plants

together with the dry matter yield were then used to compute the total uptake of the nutrient elements from the soil.

Just at full maturity (when the pods were still green or about to start turning yellow), nine soybean plants were randomly harvested from the three blocks (replications) at both sites A and B for grain yield determinations. Likewise, nine mungbean plants from the three blocks (replications) at both sites were randomly harvested at full maturity (when pods were fully dry) and grain yield determined. The grain yield for both soybeans and mungbeans were then computed.

### 3.4 Statistical analysis

The dry matter and grain yields data collected from the field experiments were analysed by the analysis of variance for the Split plot Complete Randomised Block Design using COHORT (co-stat) software programme. The statistical model used is as follows:

$$Y_i = \mu + \tau_i + b_i + \epsilon_i$$

Where  $Y_i$  = Yield due to  $i^{\text{th}}$  treatment

$\mu$  = Overall mean

$\tau_i$  = Treatment effect

$b_i$  = block effect

$\epsilon_i$  = Error term

## CHAPTER FOUR

### 4. RESULTS AND DISCUSSION

#### 4.1 Some of the physical and chemical properties of the two soils

The initial physical and chemical properties of the two soils in the study area of AVRDC farm are presented in Table 1.

##### 4.1.1 Soil pH

The mean soil pH determined in 1:2.5 soil:0.01 CaCl<sub>2</sub> suspensions for soils A and B were 5.8 and 6.0, respectively. According to the classification by Landon (1991), these soils are medium acid implying that they are somehow highly weathered. However, the soils are within the pH values ranging 5.5-7.0, which is the preferred range for most crops. Schwartz and Galves (1980), recommended a range of pH values for bean production to be 5.5-7.5. Knott (1980), reported that vegetables in the moderately tolerant group such as bean, tomato, pepper do well between pH values of 5.0-6.8 and specifically 5.5-7.0 for soybean. Therefore the soil pH values are favourable for the production of most vegetables, soybeans and mungbeans inclusive.

**Table 1. Characteristics of the experimental soils of Madiira AVRDC farm.**

Property and unit	Soil A Value	Soil B Value
pH (soil:water, 1:2.5)	6.70	6.70
pH (CaCl <sub>2</sub> )	5.80	6.00
pH (KCl)	5.50	5.50
Bulk density (g/cm <sup>3</sup> )	1.05	1.31
Organic carbon (%)	1.50	1.30
Total N (%)	0.22	0.19
Available P (µg/g)	36.40	44.10
CEC (cmol (+)/kg soil)	16.80	16.20
Exchangeable bases (cmol (+)/kg soil)		
Potassium	1.21	1.65
Magnesium	2.70	3.00
Calcium	8.10	8.00
Micronutrients (µg/g soil)		
Copper	12.00	11.50
Zinc	7.30	7.70
Manganese	90.60	64.10
Iron	77.90	70.30
Soil texture (soil separates, %)		
Sand	23.60	24.60
Silt	27.00	26.00
Clay	49.40	49.40
Textural class	CLAY	CLAY

#### **4.1.2 Soil texture**

The percentages for sand, silt and clay separates for soil A and B were 23.6, 27, 49.4 and 24.6, 26, 49.4, respectively. According to the classification by FAO (1977), the textural class for the soils is clay. The study area is a farm constantly dealing with vegetable research and production. The high percentage of clay in these soils may imply that previous chemical treatments done to the soil such as added copper through fungicides sprays and applied elements through fertilizer could have been retained by the soil colloids.

Fine to medium textured soils have been found to be good in moisture retention and nutrient retention (De Datta, 1981). The clay is important in water retention and nutrient supply to plants. Thus, based on soil texture soils of the study area are suitable for the production of vegetables, including the two legumes.

#### **4.1.3 Bulk density**

Soils A and B have bulk densities 1.05 and 1.31 g/cm<sup>3</sup>, respectively. These values fall within limits of 1.00 to 1.6 g/cm<sup>3</sup> identified by Brady and Weil (1996) for clay. According to Landon (1991), these values are reasonable for such soils. Values exceeding 1.8 g/cm<sup>3</sup> indicate soil compaction which affect crop root growth and water movement in the soil. The values measured are lower than the values for compacted soils, indicating that the soils are in good physical condition for the growth of crops.

#### **4.1.4 Organic carbon**

Soil organic carbon (SOC) content of the soils were, 1.3 and 1.5% for soil A and B, respectively. According to Landon (1991), these values are within the medium range of 1.26-2.5%. The medium levels of SOC could probably be associated with the continuous vegetable cultivation followed by limited incorporation of the vegetable residues and remains to the soil. The medium contents of organic carbon could also be attributed to the high rate of decomposition, mineralization and oxidation of the organic compounds and residues added to the soil, phenomena which are common in soils in tropical conditions (Smith and Sanchez, 1980). This occurs because of the high temperatures favourable to high microbial activities. The soil organic carbon contents in the soils may promote increased vegetable production, but this might be true only if the crop residues are incorporated into the soils.

#### **4.1.5 Total nitrogen**

The mean total nitrogen for the soils under study was 0.22 and 0.19% for soils A and B, respectively (Table 1). According to the classification by Landon (1991), the total N content of these soils are in low ranges. The low N content observed in soils could partly be attributed to nutrient mining by continuous cropping without additions of N. The other reason for low total N content observed in soils could have been attributed to the soil pH. The low total N contents in the two soils conform to the medium levels of organic matter (organic carbon) in the soil.

Nitrogen is a very important nutrient for vegetable production (Tindall, 1983). For optimum production of vegetables in this area, N containing fertilizer such as urea, calcium ammonium nitrate and sulphate of ammonia should be applied since the total N content of the soil is not enough to support good plant growth. The vegetable crop residues and remains should also be returned to the soils.

However, the common practice in soybean growing areas is to depend on symbiotically fixed nitrogen rather than fertilizer N to supplement nitrogen from the soil. This practice is justified by extensive field trials showing negligible and uneconomic responses of nodulated soybeans to nitrogen fertilizers. Kurtz (1976), reported on observations which indicate that soybean do utilize fertilizer nitrogen if it is present in the soil. However, when soil or fertilizer nitrogen is utilized symbiotic fixation is reduced correspondingly. Normally, nitrogen fertilizer substitutes for symbiotically fixed nitrogen without any increase in yield. As with other leguminous crops, biological N<sub>2</sub> fixation in mungbean is suppressed by N fertilization (Miller *et al.*, 1982), which tends to suppress nodulation and does not increase seed yields except in the absence of effective nodulation.

#### **4.1.6 Available phosphorus**

The available P in soil A and B are 36.4 and 44.1 mg P/kg soil, respectively. According to Landon (1991), this range is considered high. The high levels of P could be due to accumulation of the element in the soil from previous additions of P fertilizers since the

farm is constantly utilized for vegetable production and research. The other reason could be due to inherent high P amounts in the soil parent material. Such high P levels can induce Zn deficiency since high uptake rates of P are associated with the reduced uptake and translocation of Zn, Fe and Cu (Borkert and Sfredo, 1994).

#### **4.1.7 Cation exchange capacity (CEC)**

CEC of the soils were 16.2 and 16.8 cmol (+)/kg soil, for soils A and B, respectively. According to the classification by Landon (1991), the CEC levels were in the medium range and that the range which is satisfactory is 15-25 cmol (+)/kg soil. The medium levels of CEC could probably be associated with the reason that the soils are somewhat highly weathered with low organic matter content and the clay fraction dominated by 1:1 clay mineral type. However, the CEC values obtained for the two soils are within the reported satisfactory range and so quite satisfactory for vegetable production.

#### **4.1.8 Potassium**

The exchangeable K in the soils were 1.21 and 1.65 cmol (+)/kg soil for soils A and B, respectively. These values are within the high range (Landon, 1991). This might be due to inherent high K in the soil parent material and probably due to accumulation of the element resulting from additions of potassic fertilizers such as NPK and its retention by the clay components of the soils. When the K<sup>+</sup> supply is abundant, 'luxury consumption' of K<sup>+</sup> often occurs, which deserves attention both for its effect on plant composition and

for its possible interference with the uptake and physiological availability of  $Mg^{2+}$  and  $Ca^{2+}$  (Borkert and Sfredo, 1994).

#### **4.1.9 Calcium**

The mean exchangeable Ca for the soils is 8.1 cmol (+)/kg soil. According to Landon (1991), this is within the medium range. Landon (1991), suggested that when Ca is < 0.2 cmol (+)/kg, then Ca containing fertilizers should be applied for optimum production. However, the range of Ca observed for the two soils is medium and this implies that though the level is not within deficiency, there may still be a need to apply Ca fertilizer periodically for sustainable vegetable production since this level will likely tend to decrease with continuous vegetable cultivation.

#### **4.1.10 Magnesium**

The exchangeable Mg levels were 2.7 and 3.0 cmol (+)/kg soil for soil A and B, respectively. According to Landon (1991), this is classified as a medium range. Knott (1980) reported Mg levels less than 1.25 cmol (+)/kg as deficient for most vegetables including beans, tomatoes, cabbages and spinach. Schwartz and Coralles (1989) reported that 2.0 cmol (+)/kg soil is the proposed critical value for bean production. The Mg levels obtained for these soils are adequate for the production of vegetables.

#### **4.1.11 Copper**

The DTPA extractable copper levels were 12.0 and 11.5 mg/kg soil, for soils A and B, respectively. For DTPA extractable soil copper, 0.2 mg/kg soil, has been considered as the limit below which plants are likely to suffer from Cu deficiency (Viets and Lindsay, 1973; Lindsay and Novell, 1978). The values of Cu obtained in these soils are therefore above the proposed critical value. The high levels of copper could be due to accumulation and its retention by clay which is high in the farm soil. The accumulation of copper may have resulted from previous chemical treatments done to the soil such as added copper through pesticide sprays and fertilizers.

#### **4.1.12 Zinc**

The DTPA extractable zinc levels were 7.3 and 7.7 mg/kg soil for soils A and B, respectively. The proposed critical level for Zn (DTPA) in the soil is 0.4-0.6 mg/kg soil, and values greater than 10-20 mg/kg soil are regarded as excess (Sillanpaa, 1982). The values of Zn in these soils are therefore within the range which is neither deficient nor excess, but adequate for vegetable production of soybean and mungbean.

#### **4.1.13 Manganese**

The DTPA extractable manganese levels were 90.6 and 64.1 mg/kg soil for soils A and B, respectively. The proposed critical level for Mn (DTPA) in the soil ranges from 2-5 mg/kg soil, and values over 140-200 mg/kg soil are regarded as excess (Sillanpaa, 1982).

The values of Mn obtained in these soils are therefore within the range which is neither deficient nor excessive , but adequate for vegetable production.

#### **4.1.14 Iron**

The values of DTPA extractable iron were 77.9 and 70.3 mg/kg soil, for soils A and B, respectively. The proposed critical level for various crops ranges from 0.3-10 mg/kg soil (Lindsay and Cox, 1982). In both soils, Fe levels were above this critical range. The high levels of iron may be due to inherent high contents in the soil parent material, accumulation due to previous chemical treatments done to the soil and its retention by the clay component of the soil. Iron toxicity or deficiency may occur at low and high pH levels, respectively. In these soils, Fe toxicity may likely occur since the soils are medium acid.

## **4.2 Nutrient concentrations in plants**

### **4.2.1 Nutrient concentrations in soybean plants**

#### **4.2.1.1 Nitrogen**

The values of N content and uptake in soybean plants are shown in Table 2a and Table 2b, respectively. Nitrogen contents in the different soybean lines ranged from 1.96 to 2.73%. These values are below the optimum N concentration for this crop. Peck (1979) reported values of N below 3.25% as deficient for soybeans.

Since the mean total N in the soils under study was 0.2% (Table 1), and classified as low N levels (Landon, 1991), this result implies that these soils had insufficient N for the soybean plants. The nutrient availability in a soil is based on the concept that the content of a particular nutrient in the plant is greater the higher its availability in the soil (Mengel and Kirkby, 1987). However, the mineral content in the plant does not only depend on nutrient availability in the soil, but it is also affected by various other factors such as kind of plant organ/tissue, age of the plant, and the supply of the plant with other plant nutrients (Lund, 1970). The other reason for the low N content in plants may probably be due to inefficient utilization of atmospheric N<sub>2</sub> by the soybean plants themselves and the fact that the whole plant materials were analyzed as opposed to the newly formed mature leaves.

When plant analysis was done and mean plant N content over all the soybean lines compared, the four soybean lines were significantly different ( $P=0.05$ ) (Table 2a). This may probably be due to different abilities of lines in utilizing the atmospheric  $N_2$ , since both soils had low initial soil N contents.

#### **4.2.1.2 Phosphorus**

The P contents and uptake in the soybean plants are shown in Table 2a and Table 2b, respectively. The P contents in the different soybean lines ranged from 0.088 to 0.112%. These values are low (deficient) according to Peck (1979) who suggested that values less than 0.16% are low for soybeans.

The P contents in these soils ranged from 36.4 to 44.1  $\mu\text{g/g}$  soil (Table 1), and classified as high (Landon, 1991), implying that these soils had sufficient amounts of P for the soybean plants. However, the plant analysis for P content were contrary to the available P status in the soil based on the concept that the content of a particular nutrient in the plant is greater the higher its availability in the soil (Mengel and Kirkby, 1987). The fact that the whole plant materials were analyzed as opposed to the newly formed mature leaves might be the reason for the low P contents in plants. The other reason for the low P contents in the plants regardless of its high amounts in the soil, may probably be due to inefficiency of plants in taking up the nutrient element from the soil. The inefficiency of taking up the P element is probably due to low N contents in the soil. When the mean

plant P content over all the soybean lines were compared, the results show that there were no significant differences between soybean lines. This result could be interpreted to mean that the soybean lines had almost similar P-requirements and uptake from the soil.

#### **4.2.1.3 Potassium**

The K contents and uptake in soybean plants are shown in Table 2a and Table 2b, respectively. The K contents in the different soybean lines ranged from 1.71 to 2.22%. These values are sufficient according to Peck (1979) who suggested values ranging from 1.71-2.5% as sufficient for soybeans.

Since the K contents in the soils ranged from 1.21 to 1.65 cmol (+)/kg soil (Table 1) and classified as high (Landon, 1991), this result implies that these soils supplied sufficient amounts of K to the soybean plants (Mengel and Kirkby, 1987). When the mean plant K content over all the soybean lines were compared, there were highly significant differences ( $P=0.001$ ). This could be interpreted to mean that the soybean lines had varied K-requirements, and hence the varied amounts taken from the soils.

#### **4.2.1.4 Calcium**

The Ca contents and uptake in soybean plants are shown in Table 2a and Table 2b, respectively. Calcium contents in the different soybean lines ranged from 1.68 to 1.85%. These values are sufficient according to Peck (1979) who suggested values ranging from

0.36-2.0% are sufficient for soybeans.

Since the mean exchangeable Ca content in the soils was 8.0 cmol (+)/kg soil (Table 1), classified as medium Ca levels (Landon, 1991), this result implies that these soils had sufficient Ca for the soybean plants. When the mean plant Ca content over all the soybean lines were compared, there were highly significant differences ( $P=0.001$ ). This result could be interpreted to mean that the soybean lines had varied Ca-requirements and hence the varied amounts taken from the soils.

Table 2a: Overall means for plant nutrient contents, dry matter yield (g) per plant at flowering stage and fresh undried grain yield (g) per plant for soybeans.

Soybean line	Grain yield	Dry matter yield	N	Ca	Mg	K	P	Fe	Zn	Cu	Mn
			-----%----- -----µg/g-----								
AGS329	19.34b	11.15a	2.18bc	1.832a	0.86ab	1.86b	0.094a	650.40a	32.27a	8.87a	58.63a
AGS338	26.59b	12.57a	2.60ab	1.77a	0.89a	1.71b	0.094a	628.70a	32.90a	6.47a	51.13a
AGS292	19.09b	13.33a	1.96c	1.845a	0.837b	1.71b	0.112a	493.10a	35.42a	8.05a	47.02a
GC84051-32-1	44.19a	12.42a	2.73a	1.678b	0.86ab	2.22a	0.088a	630.10a	33.53a	8.73a	56.18a
CV%	24.68	22.01	17.11	3.27	4.61	8.12	22.12	19.62	16.95	27.68	21.95
F test for											
lines	***	ns	*	***	ns	***	ns	ns	ns	ns	ns
Soils	ns	***	ns	***	***	ns	*	***	ns	ns	ns

Means within the column followed by the same letter are not significantly different, based on DMRT

#### 4.2.1.5 Magnesium

The Mg contents and uptake in the soybean plants are shown in Table 2a and Table 2b, respectively. Magnesium contents in the different soybean lines ranged from 0.83 to 0.89%. These values are sufficient according to Peck (1979) who suggested 0.26-1.0% as sufficient for soybeans.

The mean exchangeable Mg contents in the soils ranged from 2.7 to 3.0 cmol (+)/kg soil (Table 1), classified as medium (Landon, 1991), implying that these soils supplied appreciable amounts of Mg to the soybean plants. However, when the mean plant Mg content over all the soybean lines were compared, the soybean lines were not significantly different. This could be interpreted to mean that the soybean lines had almost similar Mg-requirements which were met from uptake from the soil.

**Table 2b: Nutrient uptake and fresh (undried) grain yield of soybeans (kg ha<sup>-1</sup>).**

<b>Soybean line</b>	<b>N</b>	<b>P</b>	<b>Ca</b>	<b>Mg</b>	<b>K</b>	<b>Fe</b>	<b>Zn</b>	<b>Cu</b>	<b>Mn</b>	<b>yield</b>
AGS 329	81.00	3.40	68.10	31.90	69.10	2.40	0.12	0.03	0.22	6447.00
AGS 338	108.90	3.90	74.10	37.20	71.60	2.60	0.14	0.03	0.21	8861.60
AGS 292	87.00	4.90	81.90	37.10	75.90	2.19	0.16	0.04	0.20	6364.30
GC84051-32-1	113.00	3.60	69.40	35.50	91.90	2.60	0.14	0.04	0.23	14730.00

#### **4.2.1.6 Iron**

The Fe contents and uptake in the soybean plants are shown in Table 2a and Table 2b, respectively. Iron contents in the different soybean lines ranged from 493.13 to 650.43  $\mu\text{g/g}$  plant dry matter. These values are very high or excessive. Peck (1979), suggested values  $>500$   $\mu\text{g/g}$  plant dry matter are very high and can sometimes be toxic to soybeans. The high levels of iron contents in plants may be due its high availability from the soil since the measured soil Fe contents are also far above the critical range. The high levels of Fe could also have influenced an induced deficiency of other ions e.g. copper. When the mean plant Fe content over all the soybean lines were compared, there was no significant difference.

#### **4.2.1.7 Zinc**

The Zn contents and uptake in the soybean plants are shown in Table 2a and Table 2b, respectively. Zinc contents in the different soybean lines ranged from 32.27 to 33.53  $\mu\text{g/g}$  plant dry matter. These values are sufficient according to Peck (1979), who suggested values ranging from 21-50  $\mu\text{g/g}$  plant dry matter are sufficient for soybeans. When the mean plant Zn content over all the soybean lines were compared, there was no significant difference between the soybean lines.

#### **4.2.1.8 Copper**

The Cu contents and uptake in the soybean plants are shown in Table 2a and Table 2b, respectively. Cu contents in the different soybean lines ranged from 6.47 to 8.87  $\mu\text{g/g}$  plant dry matter. These values are low according to Peck (1979), who suggested values ranging from 5-9  $\mu\text{g/g}$  plant dry matter are low for soybeans.

The low Cu contents in the plants compared to the high levels of available Cu in the soil could be due to high levels of Fe in the soil and in the plants. Lucas and Knezek (1972), reported that, high levels of Fe can induce Cu deficiencies to plants. However, when the mean plant Cu content over all the soybean lines were compared, there were no significant differences between the soybean lines.

#### **4.2.1.9 Manganese**

The Mn contents and uptake in the soybean plants are shown in Table 2a and Table 2b, respectively. Manganese contents in the different soybean lines ranged from 47.02 to 58.63  $\mu\text{g/g}$  plant dry matter. These values are sufficient according to Peck (1979) who suggested values of 21-100  $\mu\text{g/g}$  plant dry matter as sufficient for soybeans. The Mn sufficiency in the soybean plants conform to the sufficient or medium levels of DTPA extractable Mn in the two soils. However, when the mean plant Mn content over all the soybean lines were compared, there were no significant differences between the soybean lines. This could be interpreted to mean that the soybean lines had almost similar Mn-

requirements and uptake from the soil.

## **4.2.2 Nutrient concentrations in mungbean plants**

### **4.2.2.1 Nitrogen**

The N contents and uptake in the mungbean plants are shown in Table 3a and Table 3b, respectively. The nitrogen contents in the different mungbean lines ranged from 2.15 to 2.49%. These values are below the optimum N contents for this crop. Tandon (1995) reported values of N ranging from 4.24-4.99% as being low for bean crops.

Since the mean total N in the soils was 0.2% (Table 1), classified as low (Landon, 1991), this result implies that these soils had insufficient N for the mungbean plants. Another reason for the low contents in the plants could be due to inefficiency of atmospheric N<sub>2</sub>-utilization by the mungbean plants themselves as well as the fact that the whole plant materials were analyzed as opposed to the newly formed mature leaves. According to Lund (1970), the mineral contents in the plant does not only depend on nutrient availability in the soil but is also affected by factors like age and kind or part of plant organ/tissue analysed. However, when the mean plant N content over all the mungbean lines were compared, there were no significant differences between the mungbean lines.

#### 4.2.2.2 Phosphorus

The P contents and uptake in the mungbean plants are shown in Table 3a and Table 3b, respectively. The P contents in the different mungbean lines ranged from 0.09 to 0.14%. These values are extremely low (deficient) according to Tandon (1995), who suggested that values of 0.25-0.34% are low for bean crops.

Since the P contents in the soils ranged from 36.4 to 44.1 mgP/kg soil (Table 1), classified as high (Landon, 1991), this result implies that these soils had sufficient amounts of P for the mungbean plants.

The fact that soils had higher available P contents while plant analysis showed extremely low (deficient) P content, might imply that the low levels of soil N resulted in a reduced uptake of soil P by the plants. Another reason for the low P contents in the plants could probably be due to negative interaction between Zn and P as well as the fact that the whole plant materials were analyzed as opposed to the newly formed mature leaves.

When the mean plant P content over all the mungbean lines were compared, there were highly significant differences ( $P=0.001$ ) probably due to differences in P-requirements between the mungbean lines.

#### **4.2.2.3 Potassium**

The K contents and uptake in the mungbean plants are shown in Table 3a and Table 3b, respectively. The K contents in the different mungbean lines ranged from 2.37 to 2.58%. These values are sufficient according to Tandon (1995), who suggested that values ranging from 2.25-4.0% are sufficient for bean crops.

Since the mean K contents in the soils ranged from 1.21 to 1.65 cmol (+)/kg soil (Table 1), classified as high (Landon, 1991), this result implies that these soils supplied sufficient amounts of K to the mungbean plants (Mengel and Kirkby, 1987).

However, when the mean plant K content over all the mungbean lines were compared, there were no significant differences between mungbean lines.

#### **4.2.2.4 Calcium**

The Ca contents and uptake in the mungbean plants are shown in Table 3a and Table 3b, respectively. Calcium contents in the different mungbean lines ranged from 1.75 to 1.89%. These values are sufficient according to Tandon (1995), who suggested that values ranging from 1.5-2.5% are sufficient for bean crops. This conforms to the values of exchangeable Ca in these soils. Since the mean Ca contents in these soils was 8.0 cmol (+)/kg soil (Table 1), classified as medium Ca levels (Landon, 1991), the result may imply that these soils had sufficient Ca for the mungbean plants. However, when

the mean plant Ca contents over all the mungbean lines were compared, there were no significant differences between the mungbean lines.

Table 3a. Overall means of plant nutrient contents, dry matter yield at flowering stage and grain yield (g) per plant for mungbeans

Mungbean lines	grain yield	Dry matter	N	Ca	Mg	K	P	Fe	Zn	Cu	Mn
			µg/g								
			%								
VC 6148-50-12	31.70ab	13.70a	2.37a	1.80ab	0.49a	2.49ab	0.09b	613.50bc	39.40a	8.17bc	56.88a
VC 6379-23-2-1	25.64b	13.90a	2.49a	1.86a	0.52a	2.45ab	0.11b	803.30a	34.03ab	10.55ab	58.73a
Kanti	19.66c	7.65b	2.16a	1.89a	0.49a	2.43ab	0.15a	804.40a	25.07b	7.32c	56.98a
VC 6173-(B-10)	33.54a	12.80a	2.29a	1.88a	0.50a	2.59a	0.10b	734.60ab	34.57ab	11.73a	57.53a
VC 6372-(45-8)	27.5ab	13.50a	2.21a	1.76b	0.48a	2.37b	0.09b	545.20c	29.10ab	11.00a	50.45a
CV%	17.17	13.58	15.62	4.34	9.53	5.03	13.02	19.07	25.88	20.71	11.90
F test for											
Lines	***	***	ns	ns	ns	ns	***	*	ns	**	ns
Soils	**	*	***	**	*	ns	ns	**	**	ns	***

Means within the column followed by the same letter are not significantly different, based on DMRT

#### 4.2.2.5 Magnesium

The Mg contents and uptake in the mungbean plants are shown in Table 3a and Table 3b, respectively. Magnesium contents in the different soybean lines ranged from 0.48 to 0.52%. These values are sufficient according to Tandon (1995) who suggested values ranging from 0.3-1.0% are sufficient for beans crops.

Since the mean Mg contents in these soils ranged from 2.7 to 3.0 cmol (+)/kg soil (Table 1), classified as medium (Landon, 1991), these data imply that these soils had adequate Mg for the mungbean plants. However, when the mean plant Mg content over all the mungbean lines were compared, there were no significant differences between the mungbean lines.

Table 3b: Nutrient uptake and grain yield of mungbean (kg ha<sup>-1</sup>)

Mungbean line	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	Yield
VC 6148(50-12)	108.90	4.20	114.00	84.90	22.80	2.80	0.18	0.04	0.26	10549.30
VC 6379(23-2-1)	116.20	4.90	114.00	86.60	24.20	3.73	0.16	0.05	0.27	8547.00
Kanti	55.00	3.60	61.80	48.20	12.36	2.05	0.06	0.02	0.15	6553.30
VC 6173(b-10)	97.30	4.30	110.10	79.80	21.30	3.10	0.14	0.04	0.24	11178.00
VC 6372(45-8)	99.20	4.20	106.60	78.80	21.60	2.45	0.13	0.05	0.22	9167.60

#### **4.2.2.6 Iron**

The Fe contents and uptake in mungbean plants are shown in Table 3a and Table 3b, respectively. Iron contents in the different mungbean lines ranged from 545.2 to 804.43  $\mu\text{g/g}$  plant dry matter. These values are high or excessive according to Tandon (1995) who suggested values  $>300$   $\mu\text{g/g}$  plant dry matter are high for bean crops. The high levels of iron contents in plants may be due to available contents in the soils which are far above the critical range. When the mean plant Fe content over all the mungbean lines were compared, there were significant differences ( $P=0.05$ ) between the mungbean lines. The reason could be due to that the mungbean lines had varied Fe-requirements and uptake from the soil.

#### **4.2.2.7 Zinc**

The Zn contents and uptake in the mungbean plants are shown in Table 3a and Table 3b, respectively. Zinc contents in the different mungbean lines ranged from 25.06 to 39.4  $\mu\text{g/g}$  plant dry matter. These values are sufficient according to Tandon (1995) who reported that values ranging from 20-200  $\mu\text{g/g}$  plant dry matter are sufficient for bean crops. When the mean plant Zn content over all the mungbean lines were compared, there were no significant differences between the mungbean lines.

#### **4.2.2.8 Copper**

The Cu contents and uptake in the mungbean plants are shown in Table 3a and Table 3b, respectively. The Cu contents in the different mungbean lines ranged from 7.31 to 11.73  $\mu\text{g/g}$  plant dry matter. These values are sufficient according to Tandon (1995) who suggested values ranging from 7-30  $\mu\text{g/g}$  plant dry matter are sufficient for bean crops. When the mean plant Cu content over all the mungbean lines were compared, there were highly significant differences ( $P=0.01$ ) between the mungbean lines.

#### **4.2.2.9 Manganese**

The Mn contents and uptake in mungbean plants are shown in Table 3a and Table 3b, respectively. Manganese contents in the different mungbean lines ranged from 50.45 to 58.73  $\mu\text{g/g}$  plant dry matter. These values are sufficient according to Tandon (1995), who suggested values ranging from 50-300  $\mu\text{g/g}$  plant dry matter are sufficient for bean crops. When the mean plant Mn content over all the soybean lines were compared, there were non significant differences between the mungbean lines.

### **4.3 Nutrient uptake of soybeans and mungbeans**

#### **4.3.1 Nutrient uptake of soybeans**

The nutrient uptake by the soybean lines are as shown in Table 2b. The data indicate in all the soybean lines, a relatively small amount of P was taken up when compared to other macronutrients (N, K, Ca and Mg). These data also show that a relatively small

amount of Cu was taken up compared to other micronutrients (Fe, Zn and Mn).

The relatively low uptake of phosphate might have been caused by low levels of N in the soil and high Zn levels, which reduced uptake of P. Likewise, the relatively small amounts of Cu taken up might probably be due to high levels of DTPA extractable Fe in the soil and in the plants, which induced Cu deficiency.

#### **4.3.2 Nutrient uptake of mungbeans**

The values for nutrient uptake by the mungbean lines are shown in Table 4b. Like soybeans, the results for all the mungbean lines show a relatively small amount of P was taken up when compared to other macronutrients (N, K, Ca and Mg). The relatively low uptake of phosphate might have been caused by low levels of N in the soil and high Zn levels, which reduced uptake of P. The results correspond with those of preliminary investigations on nutrient uptake of mungbean by Claimon (1987), showing a mungbean grain yield of 1025 kg ha<sup>-1</sup> requiring 6.2 kgP ha<sup>-1</sup>, 68.5 kgN ha<sup>-1</sup> and 26.8 kgK ha<sup>-1</sup>. According to Claimon (1987), the reason for the relatively low efficiency of P use was due to soil infertility and acidity. However, this is not the case with these soils since the soils are medium fertile, though the medium acidity of the soils could have attributed to the low uptake of the element.

These results also show that a relatively small amount of Cu was taken up compared to other micronutrients (Fe, Zn and Mn). Likewise, the relatively small amounts of Cu taken up might probably be due to high levels of DTPA extractable Fe in the soil and in the plants, which induced Cu deficiency.

#### **4.4. Correlation**

##### **4.4.1. Correlation between soil nutrient elements and fresh grain yields of soybeans**

The data on the correlation between available nutrient elements and yields of soybeans are presented in Appendix 1a. The soybean grain yields were positively correlated with the following soil nutrient elements; exchangeable Mg, K, Ca, DTPA extractable Zn and Mn indicating that an increase of each element in the soil would respectively increase yield. Borkert (1986); Cordeiro *et al.*, (1979); Bataglia and Mascarenhas (1977) as quoted by Borkert and Sfredo (1994), obtained similar relationships for Mn and Zn. The total N, DTPA extractable Fe, Cu and Bray-1 P, correlated negatively with the same, implying that an increase of each element in the soil would respectively decrease soybean grain yields. The negative correlation between total nitrogen and soybean seed yields imply that the total nitrogen in the soil is not a good index of nitrogen availability to the soybean plants. The negative correlation between Bray-1 P, DTPA extractable Cu and Fe with soybean grain yields could have been attributed to negative interactions between P, Cu, Fe and other nutrient ions in the soil and plants.

The correlation between CEC and soybean grain yields (Appendix 1a) is positive and this indicate that in practice soils with high CEC would normally be best suited for soybeans.

#### **4.4.2. Correlation between plant nutrient elements and grain yields of soybeans**

The correlation between plant nutrient content and grain yields of soybeans are presented in Appendix 1b. The soybean grain yields positively correlated with total N, Mg, K, Fe, Cu and Mn, while Ca, Zn, and P correlated negatively with the same.

The positive correlation between plant nutrient content of total N, Mg, K, Fe, Cu and Mn with soybean grain yields implies that the more the uptake of these elements by plants, the greater the likelihood of an increase in grain yields and vice versa. Since the content of total N in soil were low, the positive correlation between plant total N and soybean grain yields might have been due to N<sub>2</sub>-fixation.

The negative correlation between plant Ca, Zn and P with soybean grain yields implies that the higher the uptake of these elements by the plants, the decrease in soybean grain yields and vice versa. Borkert and Sfredo (1994) reported that soybean often has a higher Ca content as a result of high Ca levels in soil than efficiency of active uptake. The negative correlation between the plant P and Zn with soybean grain yield could have been attributed to negative interactions between Zn, P, Fe and other nutrient ions in the

soil and plants. Borkert and Sfredo (1994) reported that P management is critical to the production of soybean, particularly in acid soils with high P fixation. A deficiency of this element is doubly serious since it may prevent other nutrients from being absorbed by soybean plants. A combination of these factors may probably explain why there was a negative correlation between these elements and soybean grain yields.

#### **4.4.3. Correlation between soil nutrient elements and plant nutrient elements in soybeans**

The data on the correlation between soil nutrient elements and plant nutrient content in soybeans plants are presented in Appendix 1c. The soil nutrient elements which positively correlated with the same nutrient elements in plants were exchangeable Ca, Bray-1 P, DTPA Fe, Cu and Mn while the soil exchangeable Mg, K, soil total N and DTPA Zn correlated negatively with the same elements in plants.

The positive correlations between the soil exchangeable Ca, Bray-1 P, DTPA extractable Fe, Cu and Mn with the same elements in plants imply that the higher the contents of these elements in the soil, the higher the uptake of the same elements by the plants and vice versa. The soil exchangeable Ca, Bray-1 P, DTPA extractable Fe, Cu and Mn ranked medium to high, hence positive correlation with the same elements in the plants. Borkert and Sfredo (1994) found that Cu uptake in soybean is low and about half the Cu content of stems and leaves is removed with the grain while the amount of Mn removed

with soybean grain is one-third of the total absorbed by the plants.

The negative correlation between soil exchangeable Mg, K, soil total N and DTPA Zn with the same elements in the plants implies that the higher the contents of these elements in the soil, the lower the uptake of the same elements in the plants and vice versa. The negative correlation between soil exchangeable Mg and K with plant Mg and K respectively, might have probably been caused by a 'luxury consumption' of  $K^+$ , causing a possible interference with the uptake and physiological availability of  $Mg^{2+}$  and  $Ca^{2+}$ . The negative correlation between the DTPA extractable Zn and plant Zn might be due to the fact that species differ in their susceptibility to micronutrient deficiency/toxicity, due either to different requirement or ability of extracting the element from the soil (Viets and Lindsay, 1973).

#### **4.4.4 Correlation between soil nutrient elements and grain yields of mungbeans**

The data on the correlation between available nutrient elements and grain yields of mungbeans are presented in Appendix 2a. The mungbean grain yields were positively correlated with total N, exchangeable Mg and Ca, DTPA extractable Fe and Mn implying that an increase of these elements in the soil would cause increase in mungbean grain yields. Since the soil total N was low, the positive correlation between this element and the mungbean grain yield might have been due to  $N_2$ -fixation. Miller and Fernandez (1988) reported that the crop cannot produce optimal yield, whether biomass or grain

without an adequate supply of N for growth. As reported by Sinclair and de Wit (1975), the N requirement for grain development is high. From their study, it was apparent that mungbean is not able to meet the N demand of its grain from N uptake from the soil or from N<sub>2</sub>-fixation. Kuo *et al.*, (1978) found that optimal grain yield depends upon the duration of seed-filling which, in turn, depends upon the availability of nitrogen.

The exchangeable Mg and Ca and DTPA extractable Mn ranked medium in the soil, hence positive correlation with mungbean grain yields while the positive correlation between DTPA extractable Fe and mungbean grain yields is due to the fact that Fe is an important constituent of enzyme nitrogenase which is essential to N<sub>2</sub> fixation in N-fixing micro-organisms.

The exchangeable K, DTPA extractable Zn and Cu and Bray-1 P, correlated negatively with the same indicating that an increase of these elements in the soil would cause a decrease in mungbean grain yields and vice versa. The negative correlation between the soil nutrient elements with mungbean grain yields could have been attributed to negative interactions between Bray-1 P, DTPA extractable Zn and Cu and other nutrient ions in the soil and plants. Besides, the negative correlation between DTPA extractable Zn and mungbean grain yields may be supported by the fact that species differ in their susceptibility to micronutrient deficiency/toxicity due either to differential requirement or ability of extracting the element from the soil (Viets and Lindsay, 1973).

#### 4.4.5. Correlation between plant nutrient elements and grain yields of mungbeans

The data on the correlation between plant nutrient content and grain yields of mungbeans are presented in Appendix 2b. The mungbean grain yields were positively correlated with total N, Mg, K, Zn, Cu and Mn, while Ca, Fe, and P, correlated negatively with the same.

The positive correlation between the plant total N, Mg, K, Zn, Cu and Mn with mungbean grain yields implies that the higher the uptake of these elements by the plants, the greater the increase in grain yields and vice versa. The plant total N, Mg, K, Zn, Cu and Mn were found to be low to sufficient, hence positive correlation with mungbean grain yields. Flegmann *et al.*, (1975) reported that K is generally considered by horticulturists to be necessary for ensuring optimum yields of legumes in the presence of high levels of N and P. Zinc deficiency in plants might have occurred due to the negative interaction with other nutrients or factors. In this study, P levels in the soil were high and are likely to have induced Zn deficiency (Mengel and Kirkby, 1987).

Marschner (1986), reported that when the  $K^+$  supply is abundant, 'luxury consumption' of  $K^+$  often occurs. This observation deserves attention both for its effect on plant composition and for its possible interference with the uptake and physiological availability of  $Mg^{2+}$  and  $Ca^{2+}$ .

The negative correlation between plant Ca, Fe and P with mungbean grain yields implies that the higher the uptake of these elements by the plants, the lower the grain yields and vice versa. The negative correlation between plant Ca, Fe and P with mungbean grain yields might have been caused by the imbalances of soil nutrient elements like, N, P, K, Fe and Zn which causes suboptimal or abnormal amounts taken up by plants. For example in this study there may be an induced Zn deficiency due to high soil P levels.

#### **4.4.6. Correlation between soil nutrient elements and plant nutrient elements of mungbeans**

The data on the correlation between soil nutrient elements and plant nutrient content in mungbean plants are presented in Appendix 2c. The nutrient elements in the soil which positively correlated with the same nutrient elements in plants were; N, Ca, Fe, Mn and P indicating that the greater the contents of these elements in the soil, the higher the uptake of the same elements by the plant and vice versa.

Soil total N, exchangeable Ca, DTPA extractable Fe and Mn and Bray-1 P ranged from low to high, hence positive correlation with the same elements in the plants. Terry and Ulrich (1973), reported that phosphorus has functions related to plant growth and metabolism and a deficiency of it leads to a general reduction of most metabolic processes, including cell division and expansion, respiration and photosynthesis. Mitchel (1964), reported that Mn toxicity results when Mn levels are >1000 ppm in the dry

matter. The results suggest that there is still room for increasing Mn contents in the soil so as to increase it in plants.

The soil Mg, K, Zn, and Cu, correlated negatively with the same elements in plants implying that the higher the content of these elements in the soil, the lower the uptake of the same elements by the plants. This negative correlation might have been caused by the imbalances between soil nutrient elements. In this case, high levels of  $K^+$  might have had possible interference with the uptake and physiological availability of  $Mg^+$ . With regard to micronutrients, the negative correlation might be due to the fact that, species differ in their susceptibility to micronutrient deficiency/toxicity, due either to differential requirement or ability of extracting the element from the soil ((Viets and Lindsay, 1973).

## **CHAPTER FIVE**

### **5. CONCLUSIONS AND RECOMMENDATIONS**

#### **5.1 Conclusions**

This field study was conducted to assess the suitability of the soils at Asian Vegetable Research and Development Centre (AVRDC), Arusha, for the growth and production of soybeans and mungbeans. Specifically this study intended to assess the fertility status of the soils, determine the nutrient uptake of the essential nutrient elements from the soils and suggest measures and soil fertility management strategies for sustainable and optimal production of the two crops.

From the soil analytical data it was observed that the two soil types at AVRDC did not differ significantly both in physical and chemical properties. The soil analysis showed that the soils are medium fertile and suitable for grain legume production. The only limitation to soybean and mungbean production at AVRDC in the short and medium terms would be the medium CEC, OC, exchangeable Ca and Mg and the low levels of total N. Therefore, in order to sustain soybean and mungbean production at AVRDC, there is need to strictly monitor the levels of all the nutrients in the soils and replenish those removed by the plants.

With regard to nutrient uptake by the soybeans, the plant analysis showed that plant nutrient contents were low especially in total N, P and Cu but sufficient in Ca, Mg, K, Zn and Mn and high in Fe. There are possibilities of induced deficiencies of these elements due to imbalances of nutrient levels in these soils. Therefore, not only do the amounts need to be monitored, but also the balances among the various nutrient elements in order to avoid antagonisms.

The performances of soybean lines based on fresh (undried) grain yields at the two sites were in the following decreasing order of yields: GC 84051-32-1 > AGS 338 > AGS 329 > AGS 292 corresponding to 14730.0, 8861.6, 6447.0 and 6364.3 kg/ha, respectively. Based on the biological yield performances, soybean lines GC 84051-32-1 followed by AGS 338 should be grown at the site.

With regard to nutrient uptake by the mungbeans, the plant analysis showed that plant nutrient contents were low in total N, and P but sufficient in Ca, Mg, K, Zn Cu and Mn and high in Fe. Similarly as in the case of soybeans, relatively small amounts of P and Cu were taken up compared to other Macronutrients (N, K, Ca and Mg) and Micronutrients (Fe, Zn and Mn) respectively and therefore this insists monitoring of the balances among the various nutrient elements in order to avoid antagonisms.

The performances of mungbean lines based on grain yields were in the following decreasing order of yields: VC 6173(b-10) > VC 6148(50-12) > VC 6372(45-8) > VC 6379(23-2-1) > KANTI corresponding to 11178.0, 10549.3, 9167.6, 8547.0 and 6553.3 kg/ha, respectively. Basing on these performances, mungbean lines VC 6173(b-10) and VC 6148(50-12) are recommended for growing at the site since they are the high yielding lines as compared to the rest.

## **5.2 Recommendations**

Based on the findings obtained, the following are the recommendations.

(1) Production of N<sub>2</sub>-fixing vegetable/grain legume crops in such circumstances provides excellent opportunities for the production of high protein food sources without inputs of N fertilizer. Therefore, publicity on the production and use of soybeans and mungbeans as vegetables preferably by conducting on-farm demonstration plots/trials, is of importance. Basing on yielding potential, soybean lines GC 84051-32-1 and AGS 338 and mungbean lines VC 6173(b-10) and VC 6148(50-12) are the ones recommended for growing in the area so as to meet the human demand for affordable proteins and at the same time be utilized for animal consumption as well as soil builders.

(2) The soil or the seeds of soybeans and mungbeans should always be inoculated especially if the crops are being grown for the first time because the data shows that the crops were deficient in N. The soil was low in N and so the result suggests that the crops

were unable to meet their requirement from  $N_2$ -fixation in these soils.

(3) Except for nitrogen which can be obtained from the atmosphere through fixation and P due to its high levels in the soils, all the other nutrients need replenishment to replace removal from the system. Thus as an alternative for replenishing the removed nutrients due to nutrient mining from continuous cultivation of vegetable crops, application of different nutrients in the form of fertilizers and manures should be advocated. It might also be more efficient and profitable to encourage the farmers to use on-site plowed-in of crop residues of the vegetable legume crops instead of using other compost materials/manures.

(4) Neither macronutrient nor micronutrient fertilizers were applied in this study. Therefore, further research involving fertilizer application rates for all essential nutrients in the soils and plants (especially those needing replenishment of time to time as for this case) might be beneficial. Otherwise, with the current soil fertility status the already identified best lines for final distribution to farmers are as indicated in the recommendation number (1) above.

(5) The water used for irrigation at AVRDC, should be analyzed for plant nutrient contents as the water quality very much influences the plant nutrient contents both in the soils and soybean and mungbean plants. This is due to the fact that the source of

irrigation water at AVRDC passes through many other farmer`s fields who do practice different chemical treatments onto their farms.

## REFERENCES

- Aggarwal, V.D. and Pochlman, J.M. (1977) Effects of photoperiod and temperature on flowering in mungbean, *Euphytica* 26, 207-219.
- Allison, L.E. (1965) Organic carbon. In: *Methods of Soil Analysis* (edited by Black, C.A., Evans, D.D., White, J.L., Ensminger, L.E., Clack, F.E) Madison, Wisconsin, USA. *American Society of Agronomy Journal* 1367-1378.
- Areekul, S. (1988) In mungbean: *Proceedings of the 2<sup>nd</sup> international symposium*. (Edited by B.T. Mclean). 16<sup>th</sup> -20<sup>th</sup> November 1987, Bangkok, Thailand.
- AVRDC. (1987) AVRDC progress report 1985 Soybean variety improvement. Asian Vegetable Research and development Centre (AVRDC), Shanhua, Tainan.
- AVRDC (1981) AVRDC Progress Report 1979 Asian Vegetable Research and Development Centre (AVRDC), Shanhua, Tainan pp 337.
- Barber, S.A. (1984) *Soil nutrient bioavailability: a mechanistic approach*. New York, NY, USA, J. Wiley & Sons.
- Bergersen, F.J., Tuner, G.L., Gault, R.R., Chase, D.L., and Brockwell, J. (1985) The natural abundance of <sup>15</sup>N in an irrigated soybean crop and its use for the calculation of nitrogen fixation. *Australian Journal of Agricultural Research* 36, 411-423.
- Bhagwat, S.G., Bhatia, C.R., Gopalakrishna, T., Joshua, D.C., Mitra, R.K., Narahari, P., Pawar, S.E. and Thakare R.G. (1979) Increasing protein production in cereals

- and grain legumes. pp 225-236. In *Seed protein improvement in cereals and grain legumes*. Vol.II, IAEA, Viena.
- Black, G.R. and Hartge, K.H. (1986) Bulk density. In: *Methods of soil Analysis. Part 1*. 2<sup>nd</sup> edition. (Edited by Klute, A.) Agronomy monograph No 9. Soil Science Society of America. Madison, Wisconsin pp 364-376
- Borkert, C.M. and Sfredo, G.J. (1994) Fertilizing tropical soils for soybean. In *Tropical soybean: Improvement and production* (FAO plant production and protection series), Brazilian Agricultural Research Enterprise, National system Research Center 27, 175-196.
- Borthwick, H.A. & Parker, M.W. (1938) Photoperiodic perception in Bilox: soybeans. *Botany Gazette* 100, 374-387.
- Bottrill, D.E., Possingham, J.V., and Kriedemann, E.P. (1970) The effect of nutrient deficiencies on photosynthesis and respiration in spinach. *Plant soil*. 32, 424-438.
- Brady, N.C and Weil, R.R. (1996) *The nature and properties of soils*. 11th ed. Prentice Hall, Inc., Upper Saddle River, New Jersey. p739.
- Bray, R.H. and Kurtz, L.T. (1945) Determination of total, organic and available forms of phosphorus in soils. *Soil Science* 59, 39-45.
- Bremner, J.M. and Mulvaney, C.S. (1982) Total N determination. In: *Methods of soil analysis part 2*. Agronomy monograph no 9 (Edited by Page, A.L., R.H. Miller and D.R. Keeney). *American Society of Agronomy Inc*. Madison, Wisconsin pp

149-157.

- Brown, D.M. (1960) Soybean ecology. I Development temperature relationships from controlled environment studies. *Agronomy Journal* 52, 493-496.
- Carter, J.L. & Hartwig, E.E. (1967) The management of soybean. In A.G. Norman, ed. *The soybean*, p 162 - 221. New York, NY, USA, Academic Press.
- Cattelan, A.J., and Hungria, M. (1994) Nitrogen nutrition and inoculation. In *Tropical soybean: Improvement and production* (FAO plant production and protection series), Brazilian Agricultural Research Enterprise, National system Research Center 27, 201-208.
- Cereal Crop Institute, Henan Provincial Academy of agricultural & Forestry Sciences (1985) *The cultural practices of mungbean*. Henan Science & Technology Publishers. China. pp 1-13.
- Claimon, S. (1983) Mungbean soils and fertilizers research. In *Proceedings of first workshop on mungbean research*. Chai Nat Field Crop Research Center, Department of Agriculture. Thailand.
- De Datta, S.K. (1987) Nitrogen transformation processes in relation to improved culture practices for lowland rice. *Plant and soil* 100, 47-69
- Delouche, J.C. (1953) Influence of moisture and temperature levels on germination of corn, soybeans and watermelon. *Proceedings for Assessment of official seed Analysis* 43, 117-126.
- Dong, P.Y. and Li, Q.H. (1982) *The cultivation of edible legume crops*. Agriculture

Publishers, China. pp 55-60.

Doorenbos, Y. & Kassam, A.H. (1986) *Yield response to water*. FAO irrigation and drainage paper No. 33. Rome, FAO.

Dornhoff, G.M. and Shibles, R.M. (1970) Varietal differences in net photosynthesis of soybean leaves. *Crop Science* 10, 42-45.

Doss, B. P., Pearson, R.W. and Rogers, H.T. (1974) Effect of soil water stress at various growth stages on soybean yield. *Agronomy Journal* 66, 297-299.

Egli, D.B., Pendleton J.W. and Peters D.B. (1970) Photosynthetic rate of three soybean communities as related to carbon dioxide levels and solar radiation. *Agronomy Journal* 62, 411-414.

FAO (1977) *Guidelines for soil profile description* 2<sup>nd</sup> edition. FAO, Rome pp 66.

FAO (1985) *legume inoculants and their use*, pp.5. Nitrogen fixation for Tropical Agriculture Legumes Project (NIFTAL)-FAO, Rome.

Farious, J.R.B. (1994) Climatic requirements In: *Tropical soybean: Improvement and production*. FAO plant production and protection series, Brazilian Agricultural Research Enterprise, National system Research Center 27, 13-15.

Fernandez. G.C.J. and Shanmugasundaram (1988) The AVRDC mungbean improvement program: The past, present, and the future. In mungbean: *Proceedings of the 2<sup>nd</sup> international symposium*. (Edited by B.T. Mclean). 16<sup>th</sup> - 20<sup>th</sup> November 1987, Bangkok, Thailand. pp 58-62.

Firth, P., Thitipoca, H., Suthpradit, S., Wetselaar, R. and Beech, D.F. (1973) Nitrogen

- balance in the central plain of Thailand. *Soil Biology and Biochemistry* 5, 41-46.
- Flegmann, A.W., Raymond, A.T., George (1975) Soils and other growth media. The Macmillan Press Ltd. London and Basingstoke pp 131
- Foy, C.D. (1984) Physiological effects of hydrogen aluminium and manganese toxicities in acid soils. In F. Adams, Ed. *Soil acidity and liming Agronomy*. Madison, WI, USA, American Society of Agronomy 12, 57-97.
- Foy, C.D., Chaney, R.L. and White, M.C. (1978) The physiology of metal toxicity in plants. *Plant physiology* 29, 511-566.
- Gee, G.W. and Bauder, J.W. (1986) Particle size analysis. In: *methods of soil analysis*. Part 1. 2nd edition. (Edited by A. Klute). Agronomy monograph No. 9. Soil science society of America. Madison. Wisconsin. pp 383-412
- Grimme, H.K, Nemeth and Braunschweig, L.C. (1971) Some factors controlling K availability in soils. International symp. On soil fertility Evaluation proc., 1:33 New Delhi, India Soil Sci. Soc.
- Haen de H. (1994) Tropical soybean: Improvement and production (FAO plant production and protection series, No. 27), Brazilian Agricultural Research Enterprise, National system Research Center.
- Hanson, J.B. (1984) The function of calcium in plant nutrition. In: *advances in plant nutrition* (P.B. Tinker and A. Lauchli, eds.), pp 149-208. Praeger, New York.
- Harper, H.J, and Gray, F. (1957) Effect of seven annual legumes on the yield of corn and oats on Norge loam. *Agronomy journal* 49, 293-296.

- Hodges, T. and French, V. (1985) Soyphen: Soybean growth stages modelled from temperature, day length and water availability. *Agronomy Journal* 77, 500-505.
- Howell, R.W. (1975) World Soybean Research: *Proceedings of the world soybean research conference 3-8th august 1975. (Edited by Lowell D.H)*. The interstate Printers and Publishers, Inc. Danville, Illinois.
- Hymowitz, T. (1970) On the domestication of the soybean. *Econ. Bot* 24, 408-421.
- Jones, B.J.J.R. and Case, V.W. (1990) Sampling, handling and analyzing plant tissue samples. In: *Soil Testing and Plant Analysis*. Third edition (edited by Westerman. R.L.) Soil Science Society of America. In, Madison, Wisconsin pp 389-427.
- Kurtz, L.T. (1976) Fertilizer needs of the soybean. In World Soybean Research: *Proceedings of the world soybean research conference 3-8<sup>th</sup> august 1975*. p 85-100 (Edited by Lowell D.H). The interstate Printers and Publishers, Inc. Danville, Illinois.
- Landon, J.R. (Ed) (1991) Booker Tropical Soil Manual. A hand book for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-tropics. Longman, New York. pp 74
- Lantican, R.M. and Navarro, R.S. (1988) Breeding improved mungbeans for the Philippines. In mungbean: *Proceedings of the 2<sup>nd</sup> international symposium*. (Edited by B.T. Mclean). 16<sup>th</sup> -20<sup>th</sup> November 1987, Bangkok, Thailand. pp 98-101.

- Lawn, R.J and Ahn, C.S. (1985) Mungbean (*vigna radiata* (L.) Wilczek)/*vigna mungo* (L.) Hepper, pp 584-623. In: R.J. Summerfield and E.H. Roberts, eds. Grain legume crops. Collin, London.
- Lin, L.F. and Cheng, X.Z. (1983) The study of Chinese mungbean germplasm resources. *Crop Genetic Resources* 2, 12-16.
- Lindsay, W.L, and Novell, W.A (1978) Development of a DTPA micronutrient soil test. *Agronomy abstract* p 84.
- Lindsay, W.L., and Cox, F.R. (1982) Micronutrient soil testing for the tropics. In: micronutrients in the tropical food crop production (edited by Vlek, P.L.G) International fertilizer development centre. Muscle shoals, Alabama, USA.
- Loneragan, J.F., Snowball, K. and Simmons, W.J. (1968) Response of plants to calcium concentration in solution culture. *Aust. J. Agric. Res.* 19, 845-857.
- Loneragan, J.F. and Snowball, K. (1969) Calcium requirements of plants. *Australian J. Agric. Res.* 20, 465-478.
- Lucas, R.E. and Knezek, B.D. (1972) Climatic and soil conditions promoting micronutrient deficiencies in plants. In: Micronutrients in Agriculture (edited by Mortvedt, J.J., Giordano, P.M., Lindsay, W.L) Madison, Wisconsin, USA, *Soil Science Society of America* pp 265-288.
- Lund, Z.F. (1970) The effect of calcium and its relation to several cations in soybean root growth. *Soil Sci. Soc. Am. Proceedings* 34, 456-459.
- McLean, E.O. (1982) Soil pH and lime requirement. In: *Methods of soil analysis, Part 2*

- (Edited by Page, A.L., R.H. Miller and D.R. Keenly). *American Society of Agronomy*. Madison, Wisconsin 199-224.
- Marschner, H. (1986) Mineral nutrition of higher plants.. Academic Press Limited 24/28 Oval Road, London NW1 7DX.
- Mengel, K. And Kirkby, E.H.(1987) *Principles of plant nutrition*. International Potash Institute. Worblanfen-Bern, Switzerland.
- Miller, J.C. Jr., Scott, J.S., Zary, K.W, and O`Hair, S.K. (1982) The influence of available nitrate levels on nitrogen fixation in three cultivars of cowpea. *Agronomy journal* 74, 14-18.
- Miller. J.C. Jr, and Fernandez, G.C.J. (1988) Selecting and Breeding for enhanced N<sub>2</sub> Fixation. In mungbean: *Proceedings of the 2<sup>nd</sup> international symposium*. (Edited by B.T. Mclean). 16<sup>th</sup> -20<sup>th</sup> November 1987, Bangkok, Thailand. pp 111-121.
- Mitra, R., Pawar, S.E. and Bhatia, C.R. (1988) Nitrogen: The major limiting factor for mungbean yield. In mungbean: *Proceedings of the 2<sup>nd</sup> international symposium*. (Edited by B.T. Mclean). 16<sup>th</sup> -20<sup>th</sup> November 1987, Bangkok, Thailand. pp 244-249.
- Morton, J.F., Smith, R.E., Poehlman, J.M. (1982) The mungbean. Department of Agronomy and soils, University of Puerto Rico, Mayaguez. pp 136.
- Mota, F.S. (1978) *Soybean and weather*. Technical note 160. Geneva, Switzerland. World Meteorological Organization.
- Muchow, R.C. (1985) Stomatal behaviour in grain legumes grown under different soil

- water regimes in a semi-arid tropical environment. *Field crops Res.* 11, 291-307.
- Murphy, J. and Riley, J.P. (1962) A modified single solution method for determination of phosphate in natural water. *Analytical Chemical Acta* 27, 31-36.
- National Soil Service (1990) *National Soil Service Laboratory Procedures for Routine Soil Analysis*. Third Edition. Agricultural Research Institute, Mlingano Tanga, Tanzania.
- Neumaier, N. and Nepomuceno, A.L. (1994) Water management. In *Tropical soybean: Improvement and production* (FAO plant production and protection series), Brazilian Agricultural Research Enterprise, National system Research Center 27, 153-157.
- Ohlrogge, A.T. and Kamprath, E.J. (1968) Fertilizer use on soybean. In R.C. Dinauer, ed. *Changing patterns in fertilizer use*, Madison, WI, USA, Soil Science Society of America. pp 273-295.
- Okalebo, J.R., Gathua, K.W. and Woomer, P.L. (1993) *Laboratory methods of soil and plant analysis*. A working manual. Kenya Agricultural Research Institute, Soil Science East Africa and TSBF UNESCO-ROSTA. Marvel EPZ (Kenya) Ltd, Nairobi pp 88.
- Opena, R.T., Shanmugasundaram, S., Yoon, J.Y. and Fernandez, G.C.S. (1987) Crop improvement program to promote vegetable production in the tropics. p 1-17 In: W.N. Chang, R.T. Opena and J.B. Patersen, eds. *The breeding of horticultural crops*, Food and Fertilizer Technology Center for the Asian and Pacific Region.

Taipei. Taiwan.

- Panichapong, S. and Vicharnsorn, P. (1977) Soil suitability for beans. Paper presented at seminar on soybean research, 6-11th February 1977 at Chiang Mai University, Chiang Mai, Thailand.
- Panizzi, M.C., Mandarino, J.M.G. (1994) Soybean for human consumption: nutritional quality, processing and utilization. In *Tropical soybean: Improvement and production* (FAO plant production and protection series), Brazilian Agricultural Research Enterprise, National system Research Center 27, 241 - 250.
- Pannu, R.K. and Singh, D.P. (1987) Influence of water deficits on morpho-physical and yield behaviour of mungbean (*vigna radiata* (L.) Wilczek) (Edited by S. Shanmugasundaram) In: *Mungbean proceeding of the second international symposium* AVRDC Shanhua, Tainan.
- Parker, M.W. and Borthwick, H.A. (1943) Influence of temperature on photoperiodic reactions in leaf blades of Biloxi soybeans. *Bot. Gaz.*, 104, 612-629.
- Parks, W.L., Livingston, S. and Overton, J. (1974) Effects of water and light on soybean yield. *Soybean production, Marketing and use*. Tennessee Valley Authority, Muscle Shoals, Alabama.
- Peck, T.R. (1979) Plant analysis for production agriculture. In: *Soil plant analysis workshop*, Bridgeton, Mo, USA, Nov, p 1-45.
- Phogat, B.S., Singh, D.P. and Singh, P. (1984a) Response of cowpea and mungbean to irrigation. I. Effects on soil plant water relations, Evapotranspiration, Yield and

- water use efficiency. *Irrig. Sci* 5,47-60.
- Phogat, B.S., Singh, D.P. and Singh, P. (1984b) Response of cowpea and mungbean to irrigation. II. Effects on CO<sub>2</sub> exchange, radiation characteristics, growth and yield.. *Irrig. Sci* 5, 61-72.
- Ravelo, A.C. & Decker, W.L. (1979) Soybean weather analysis models. In *14th conference of Agricultural Forest Meteorology*. p. 72 - 74. Extended Abstr. Boston, MA, USA, American Meteorological Society.
- Rawson, H.M. and Craven, C.L. (1979) Variation between short duration mungbean cultivars (*vigna radiata* (L.) Wilczek) in response to temperature and photoperiod. *Indian J. Plant physiol* 22, 127-136.
- Richard, J. Delorit, R.J., Greub, L.J. and Ahlgren, H.L. (1984) 5th Edition, Crop production. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
- Satyanarayana, A., Seenaiiah, P. and Rao, Y.K. (1987) Radiation-induced resistance to preharvest sprouting in mungbean (*vigna radiata* (L.) Wilczek) (Edited by S. Shanmugasundaram) In: *Mungbean proceeding of the second international symposium* AVRDC Shanhua, Tainan.
- Schwartz, H.F., Galvez, E.G. (1980) Disease, insect, soil and climatic constraints of *Phaseolus vulgaris*. In: *Bean production problems* CIAT-Cali Columbia pp 341-362.
- Schwartz, H.F., Corrales, M.A.P. (1989) Nutritional disorders in beans. In: *Bean production problems in the tropics*. 2<sup>nd</sup> edition (Edited by Schwartz and Corrales)

- Cali, Columbia pp 570-604.
- Sillanpaa, M. (1982) Micronutrients and nutrient status of soils. A global study. Werner soder strom osakeyhtio, Rome, Italy: FAO Soils bulletin pp 17-96.
- Sinclair, T.R. and De Wit, C.T. (1975) Photosynthate and nitrogen requirements for seed production by various crops. *Science* 189, 565 - 567.
- Sinha, S.K (1976) Food legumes, Distribution, Adaptability, and Biology of Yield. FAO, Rome.
- Sionit, N. and Kramer, J.P. (1977) Effect of water stress during different stages of growth of soybeans. *Agronomy Journal* 69, 274-278.
- Smith, T.J and Sacher, P.A. (1980) Effect of lime silicate and phosphorous application to oxisol on phosphorous sorption and anion retention. *Soil Science Society of America Journal* 44, 500-505.
- Summerfield, R.J., Roberts, E.H. and Lawn, R.J. (1989) Measurement and prediction of flowering in soybean in fluctuating field environments. In A.J. Pascale, ed. *Actas iv Mundial de investigacion en soja*, Buenos Aires, 5-9 mar. pp 822-827. Buenos Aires, Argentina, Asociacion Argentina de la soja (AASOJA).
- Tandon, H.L.S (ed) (1995) Methods of analysis of soils, plants, waters and fertilizers. Fertilizer Development and Consultation Organization, New Delhi, India
- Terry, N and Ulrich, A. (1974) Effects of magnesium deficiency on the photosynthesis and respiration of leaves of sugar beet. *Plant physiol* 54, 379-381.
- Terry, N and Ulrich, A. (1973) Effects of phosphorus deficiency on the photosynthesis

- and respiration of leaves in sugar beet *Plant physiol* 51, 43-47.
- Tiaran, N., Pimsarn, S., Claimon, S. and Punpruk, P. (1985) Correction of nutrient deficiencies of legumes in Thailand. pp 54 - 55. In G.J. Persley, ed. Tropical legume improvement. ACIAR *Proceedings series* No. 8 Thai Dept. of Agriculture and ACIAR.
- Tisdale, S.L. and Nelson, W.L. (1975) *Soil fertility and fertilizers*. Third edition. Macmillan Publishing Co; In: New York pp 189-277.
- Tisdale, S.L., Nelson, W.L., Beaton, J.D. Havlin, J.L. (1993) 5<sup>th</sup> edition. *Soil fertility and fertilizers*. Prentice Hall, Upper Saddle River, New Jersey 07459.
- Turner, N.C and Begg, J.E. (1981) Plant-water relations and adaptation to stress. *Plant Soil* 58, 97-131.
- Viets, F.J. Jr and Lindsay, W.L. (1973) Testing soil for zinc, copper, manganese and iron. In: soil testing and plant analysis. (Edited by Walsh, L.M., and J.D Beaton,) Madison, *soil science society of America*. pp 153-172.
- Wang, Z.K. and Cheng, K.H. (1987) Mungbean cultivation. pp 52 Agricultural Publishers, Beijing, China.
- Werner. L.N. (1976) Soybean production. In World Soybean Research: *Proceedings of the world soybean research conference*. 3-8th august 1975.(Edited by Lowell D.H). The interstate Printers and Publishers, Inc. Danville, Illinois.
- Wilkerson, G.G., Jones, J.W., Boote, K.J. and Buol, G.S. (1989) Photoperiodically sensitive interval in time to flower of soybean. *Crop Science* 29, 721-726.

Yoshida, S., Navasero, S.A. and Ramrez, E.A. (1969) Effects of silica and nitrogen supply on some leaf characters of rice plant, *Plant soil.* 31,48-56.

## APPENDICES

**Appendix 1a: Regression and correlation between soil nutrients and yields of soybean plants**

Correlation	Intercept	Slope	R <sup>2</sup>	F-test	r	t-test
soil N Yield	56.415 (s.e)49.482	-169.015 (s.e)284.66	0.149	ns	-0.387	ns
soil Ca Yield	31.739 (s.e)214.36	-0.309 (s.e)14.896	0.000214	ns	0.401	ns
soil Mg Yield	16.662 (s.e)163.00	2.408 (s.e)36.849	0.002	ns	0.046	ns
soil K Yield	10.557 (s.e)51.112	14.721 (s.e)44.507	0.052	ns	0.228	ns
soil Fe Yield	314.296 (s.e)141.49	-3.784 (s.e)1.865	0.673	ns	-0.820	ns
soil Zn Yield	-23.996 (s.e)36.095	9.341 (s.e)6.508	0.507	ns	0.712	ns
soil Cu Yield	78.753 (s.e)354.05	-2.849 (s.e)19.6	0.010	ns	-0.102	ns
soil Mn Yield	-58.739 (s.e)45.881	1.447 (s.e)0.768	0.639	ns	0.799	ns
soil P Yield	35.957 (s.e)145.24	-0.169 (s.e)2.845	0.002	ns	-0.042	ns
Dry matter Yield	14.378 (s.e)114.21	1.045 (s.e)9.217	0.006	ns	0.079	ns
CEC meq Yield	-111.443 (s.e)99.721	9.408 (s.e)6.753	0.493	ns	0.702	ns

R<sup>2</sup> = Regression      (s.e) = Standard error +/-      r = Correlation

**Appendix 1b: Regression and correlation between plant nutrients and yields of soybeans**

Correlation	Intercept	Slope	R <sup>2</sup>	F-test	r	t-test
plant N Yield	-38.781 (s.e)29.146	27.912 (s.e)12.206	0.723	ns	0.85	ns
Plant Ca Yield	299.493 (s.e)29.519	-152.809 (s.e)16.561	0.977	*	-0.988	*
Plant Mg Yield	-53.296 (s.e)324.13	93.583 (s.e)376.26	0.03	ns	0.173	ns
Plant K Yield	-52.777 (s.e)31.95	42.709 (s.e)16.936	0.761	ns	0.872	ns
Plant Fe Yield	-9.588 (s.e)64.421	0.061 (s.e)0.107	0.142	ns	0.377	ns
Plant Zn Yield	57.669 (s.e)204.26	-0.906 (s.e)6.088	0.011	ns	-0.105	ns
Plant Cu Yield	13.832 (s.e)60.494	1.678 (s.e)7.481	0.025	ns	0.157	ns
Plant Mn Yield	-11.763 (s.e)81.151	0.734 (s.e)1.519	0.104	ns	0.323	ns
Plant P Yield	101.876 (s.e)57.401	-768.806 (s.e)589.22	0.459	ns	-0.678	

R<sup>2</sup> = Regression (s.e) = Standard error +/- r = Correlation

**Appendix 1c: Regression and correlation between soil nutrient and plant nutrient concentrations of soybeans**

Correlation	Intercept	Slope	R <sup>2</sup>	F-test	r	t-test
soil N plant N	3.477 (s.e)1.431	-6.444 (s.e)8.23	0.235	ns	-0.484	ns
soil Ca Plant Ca	1.796 (s.e)1.387	-0.001 (s.e)0.096	0.000056	ns	-0.008	ns
Soil Mg Plant Mg	1.271 (s.e)0.084	-0.093 (s.e)0.019	0.922	*	-0.96	*
Soil K Plant K	2.243 (s.e)1.039	-0.324 (s.e)0.905	0.06	ns	-0.245	ns
Soil Fe Plant Fe	142.246 (s.e)1484.1	6.043 (s.e)19.559	0.046	ns	0.213	ns
Soil Zn Plant Zn	37.729 (s.e)5.128	-0.765 (s.e)0.924	0.255	ns	-0.505	ns
Soil Cu Plant Cu	-18.137 (s.e)27.594	1.449 (s.e)1.528	0.31	ns	0.557	ns
Soil Mn Plant Mn	14.059 (s.e)18.948	0.659 (s.e)0.317	0.683	ns	0.827	ns
Soil P Plant P	0.094 (s.e)0.128	6.543 (s.e)0.003	0.00033	ns	0.018	ns

R<sup>2</sup> = Regression (s.e) = Standard error +/- r = Correlation

**Appendix 2a: Regression and Correlation between soil nutrients and yields of  
mungbean plants**

Correlation	Intercept	Slope	R <sup>2</sup>	F-test	r	t-test
soil N Yield	15.871 (s.e)15.879	39.885 (s.e)53.292	0.157	ns	0.397	ns
soil Ca Yield	35.999 (s.e)35.367	-0.546 (s.e)2.289	0.019	ns	0.352	ns
soil Mg Yield	21.375 (s.e)5.721	1.618 (s.e)13.168	0.005	ns	0.071	ns
soil K Yield	49.364 (s.e)24.172	-21.239 (s.e)23.461	0.215	ns	- 0.463	ns
soil Fe Yield	-25.625 (s.e)68.466	0.694 (s.e)0.892	0.168	ns	0.409	ns
soil Zn Yield	69.67 (s.e)32.588	-8.533 (s.e)6.593	0.358	ns	- 0.599	ns
soil Cu Yield	38.062 (s.e)18.383	0.685 (s.e)1.191	0.099	ns	- 0.315	ns
soil Mn Yield	-18.449 (s.e)68.084	0.667 (s.e)0.986	0.132	ns	0.364	ns
soil P Yield	98.309 (s.e)74.627	-1.567 (s.e)1.652	0.231	ns	- 0.480	ns
Dry matter Yield	9.099 (s.e)10.146	1.501 (s.e)0.808	0.535	ns	0.731	ns
CEC meq Yield	-16.329 (s.e)41.592	2.942 (s.e)2.781	0.272	ns	0.521	ns

R<sup>2</sup> = Regression      (s.e) = Standard error +/-      r = Correlation

**Appendix 2b: Regression and Correlation between plant nutrients and yields of mungbeans**

Correlation	Intercept	Slope	R <sup>2</sup>	F-test	r	t-test
plant N Yield	-3.552 (s.e)50.459	13.51 (s.e)21.855	0.113	ns	0.336	ns
Plant Ca Yield	57.126 (s.e)105.915	-15.981 (s.e)57.299	0.025	ns	-0.159	ns
Plant Mg Yield	-12.299 (s.e)95.412	80.147 (s.e)191.589	0.055	ns	0.235	ns
Plant K Yield	-83.377 (s.e)72.261	45.02 (s.e)29.302	0.44	ns	0.664	ns
Plant Fe Yield	42.594 (s.e)16.985	-0.021 (s.e)0.024	0.209	ns	-0.458	ns
Plant Zn Yield	1.721 (s.e)11.087	0.798 (s.e)0.338	0.65	ns	0.806	ns
Plant Cu Yield	12.197 (s.e)13.589	1.579 (s.e)1.373	0.306	ns	0.553	ns
Plant Mn Yield	27.527 (s.e)54.319	0.001 (s.e)0.907	0.0000006	ns	0.00075	ns
Plant P Yield	50.702 (s.e)8.774	-213.533 (s.e)79.855	0.704	ns	-0.839	ns

R<sup>2</sup> = Regression      (s.e) = Standard error +/-      r = Correlation

**Appendix 2c: Regression and Correlation between soil nutrients and plant nutrients of mungbeans**

Correlation	Intercept	Slope	R <sup>2</sup>	F-test	r	t-test
soil N	2.018	0.978	0.153	ns	0.391	ns
plant N	(s.e)0.396	(s.e)1.329				
soil Ca	1.614	0.015	0.146	ns	0.382	ns
PlantCa	(s.e)0.328	(s.e)0.021				
Soil Mg	0.576	-0.02	0.091	ns	-0.302	ns
Plant Mg	(s.e)0.142	(s.e)0.037				
Soil K	2.716	-0.245	0.131	ns	-0.362	ns
Plant K	(s.e)0.375	(s.e)0.364				
Soil Fe	115.667	7.619	0.044	ns	0.210	ns
Plant Fe	(s.c)1569.48	(s.e)20.44				
Soil Zn	44.714	-2.49	0.029	ns	-0.173	ns
Plant Zn	(s.e)40.49	(s.c)8.191				
Soil Cu	18.621	-0.581	0.581	ns	-0.762	ns
Plant Cu	(s.e)4.392	(s.e)0.285				
Soil Mn	-2.559	0.85	0.603	ns	0.777	ns
Plant Mn	(s.e)27.506	(s.e)0.398				
Soil P	-0.396	0.011	0.759	ns	0.871	ns
Plant P	(s.e)0.164	(s.e)0.004				

R<sup>2</sup> = Regression      (s.e) = Standard error +/-      r = Correlation