# Evaluating Mineral Concentration and Yield of Maize (*Zea mays* L.) Intercropped with Pulses on an Oxisol Soil in Swaziland


E. M. Ossom[1], M.G. Thwala[1], and R.L. Rhykerd[2]

[1]Faculty of Agriculture, University of Swaziland, Luyengo M205, Swaziland

[2]Department of Agriculture, Illinois State University, Normal, IL, U.S.A.



## Abstract

Farmers in the tropics do not usually practice monocropping, but commonly practice intercropping. These farmers are not certain of the specific benefits of crop mixtures. If growing maize with pulses would be beneficial, efforts should be made to determine which grain legume should be the companion crop. The objective of this investigation was to determine the effects of intercropping groundnut (*Arachis hypogaea* L.) or sugar bean (*Phaseolus vulgaris* L.) on crop mineral concentrations and maize yield. The field investigation was conducted on a acid highly weathered Oxisol in Swaziland. Maize was grown as a monocrop, and in association with sugar bean and groundnut. Five treatments were arranged in a randomized complete block design replicated four times. Results showed that there were no significant differences in the concentrations of nutrients in maize stems and leaves, though maize leaves contained higher concentrations of minerals than maize stems. However, these plant analyses revealed surprising low levels of N, P, K, S, and possibly B in maize and groundnut as would be expected when grown on an Oxisol soil. The reason for the considerably higher levels of these minerals in sugar bean in not known. Maize yields were: maize intercropped with groundnut, 6146 kg $ha^{-1}$; pure maize, 6298 kg $ha^{-1}$; maize intercropped with sugar bean, 5806 kg $ha^{-1}$. It is recommended that for increased total crop yields/plot, farmers intercrop maize with groundnut or sugar bean in preference to monocropping maize.


## Introduction

*Zea mays* L. (maize) is Swaziland's staple food. It is produced in most parts of the country, including the Lowveld; but it is common knowledge that maize is not a suitable crop for low rainfall, agro-ecological zones such as the Lowveld and dry Middleveld. It has been suggested that among the cereals, early-maturing varieties of sorghum and millet are much better adapted to these dry areas (Anon., 2004). More drought-tolerant crops such as sweetpotato (*Ipomoea batatas* L.), cassava (*Manihot esculenta* Pohl.), and various grain legumes are better suited to these dry regions. The continued dependence of Swaziland and other Southern Africa countries on maize as the major staple crop has seen prices of this crop skyrocket when the drought that began in 1991/1992 led to widespread maize crop failure and scarcity of maize (Edje, 1995). Probably, it is now time to review how maize is grown in the country so that the staple crop could be grown in a different manner in order to gain some advantages.

The need to increase food production is one of the major problems in the country where the physical area under cultivation cannot be increased beyond the 14% uncultivated land that is available. Anon. (2004) recommended that there is major scope to increase maize yields through better fertility and soil management in Swaziland. This would release more land for other, more high-value crops and would also facilitate better crop rotations. Swaziland soils were reported to be excessively acid, reducing the efficacy of applied fertilisers (Anon., 2004). It had been estimated that in Oxisols in Swaziland, the difference between cropped land under sugarcane since 1977 and uncultivated land was about 2.0 g organic carbon/kg of soil (Henry and Ellis, 1995). It is expedient to investigate cropping systems in the country so that a suitable system that would be adaptable to the poor soils and low rainfalls can be identified and recommended to peasant farmers. Growing of one type of crop in the same field and in the same season is known as monocropping. Growing a mixture of different crop species in the same field and in the same season is known as intercropping (Ruthernberg, 1980). Typical crop combinations in Swaziland include maize (*Zea mays* L.) intercropped with groundnut (*Arachis hypogaea* L.), with sugar bean (*Phaseolus vulgaris* L.), with sugarcane (*Saccharum officinarum* L.), or with jugo beans (*Vigna subterranea* L.). Some types of field bean or dry bean are known as sugar beans in Swaziland (Anon., 1991). Small-scale farmers are not certain of the specific, soil-related benefits of the crop mixtures.

Small-scale tropical farmers practise intercropping because of its advantages (Lamberts, 1980; Messiaen, 1994; (Mertin, 1981). Concerns were expressed about how environmental resources could be maximised in intercropping systems, and why output per unit area of land is usually higher (van Schoonhoven and Voysest, 1993).

## Objective

The objective of this investigation was to determine the effects of intercropping groundnut or sugar bean on soil chemical properties and grain yield of maize.

## Materials and Methods

**Experimental design**

The investigation was conducted at the Crop Production Department Experimental Farm at the University of Swaziland, Luyengo Campus (26.34oS, 31.10oE; 732.5 m above sea level; mean annual rainfall, 800 mm; mean temperature, mean temperature, 18 oC) in Swaziland, in 2003/2004 cropping season. The soil was a well-drained oxisol (Murdock, 1968). Initial fertility status of the soil was: organic matter, 3.5%; pH, 5.4; P, 18.0 mg/kg; K, 87.0 mg/kg; Mg, 145.0 mg/kg; Ca, 450.0 mg/kg. The experimental design was a randomized complete block design of five treatments replicated four times. Plot sizes were 5.5 m long and 5.0 m wide. Treatments (T) were as follows: T1, monocropped maize spaced at 90 cm (inter-row) x 25 cm (intra-row); T2, monocropped sugar bean at 90 cm x 10 cm; T3, monocropped groundnut at 90 cm x 10 cm; T4, maize (90 cm x 25 cm) mixed with sugar bean (90 cm x 10 cm); T5, maize (90 cm x 25 cm) mixed with groundnut (90 cm x 10 cm).

**Planting and fertilizer application**

All associated crops were planted along the same rows. Maize, (variety, SC 405) was sown at a spacing of 90 cm x 25 cm, giving a plant population of approximately 44,000 plants/ha. The two pulses, sugar bean, PAN 159, and groundnut, HARTS, were each planted at a spacing of 90 cm x 10 cm, resulting in a plant population of approximately 110,000 plants/ha. Weeding was done manually at four and 12 weeks after planting (WAP). Fertilizer application was made twice: basal dressing with 300 kg/ha (Anon., 1991) of a compound fertilizer, 2:3:2 (22) + Zn (by banding 15 cm away from the planting row), one day before planting. This was followed by a side dressing of N at 200 kg/ha of limestone ammonium nitrate (LAN, 28% N) at six WAP.

**Data collection and analysis**

Data were collected from four to 13 WAP, using four plants per plot. Crops were harvested at physiological maturity as follows: sugar bean, 14 WAP; maize or groundnut, 18 WAP. Grain yields were calculated at 12.5%, and 10.0% moisture content for maize and legumes, respectively. The income from each crop was determined by multiplying the current selling price/kilogramme by the yield/ha. After harvest, soil samples were collected from crop rows at 15-cm depth. These were air-dried for 48 hours on the laboratory bench, and later used for chemical analysis to determine the residual soil nutrients. Tissue and soil chemical analyses were done in a reputable laboratory in the United States, using standard analytical procedures (AOAC, 1990). Statistical analyses were carried out by the use of MSTAT-C statistical package, version 1.3 (Nissen, 1983). Mean comparisons were made using the F-protected LSD (Steel and Torrie, 1980) at $P \leq 0.05$.

## Results

- Treatments did not significantly affect soil OM, K, P, Mg, Ca, nitrate-N, pH and CEC (Table 1).
- Soil concentration of S were significantly higher in soils growing pure groundnut and maize-groundnut (Table 2).
- Treatments did not significantly affect soil micronutrient concentrations (Table 2).
- Treatments did not significantly affect soil base saturation content (Table 3).
- Although not statistically significant, intercrops of both maize and grain legumes yielded lower than their monocropped counterparts (Table 4).
- When groundnut was the companion crop to maize, the maize yielded 2% lower than monocropped maize. When intercropped with sugar bean, maize yielded 8% less than pure maize. Pure sugar bean yielded higher (839.4 kg/ha) than intercropped sugar bean (588.3 kg/ha) (Table 4).
- Monocropped groundnut yielded 100.5% higher than intercropped groundnut (Table 4).
- There was a positive but non-significant correlation (r = 0.62; r2 = 0.39; n = 20) between mass of groundnut pods/plant and pod yield/ha. The mass of 100 grains in maize was positively, but non-significantly correlated (r = 0.45; r2 = 0.20; n = 20) with maize yield. In groundnut, the mass of 100 grains positively, but non-significantly correlated (r = 0.42; r2 = 0.18; n = 20) with seed yield.

Table 1. Effects of legume-maize mixture on some soil properties.

| Cropping system | OM[1] | K | P | Mg | Ca | Nitrate N | pH | CEC[2] |
|---|---|---|---|---|---|---|---|---|
| | (%) | ---------------------mg/kg--------------------- | | | | | | cmol/kg |
| Pure maize | 3.4 | 83.3 | 28.0 | 128.8 | 362.5 | 1.3 | 5.6 | 4.6 |
| Pure sugar bean | 3.1 | 70.0 | 30.3 | 132.5 | 387.5 | 2.0 | 5.8 | 4.4 |
| Pure groundnut | 3.2 | 83.8 | 33.0 | 117.5 | 362.5 | 2.3 | 5.6 | 4.5 |
| Maize + sugar bean | 3.2 | 65.0 | 35.8 | 125.0 | 562.5 | 1.3 | 5.8 | 5.3 |
| Maize + groundnut | 3.1 | 55.8 | 44.0 | 115.0 | 425.0 | 2.3 | 5.3 | 5.6 |
| Means | 3.2 | 71.6 | 34.2 | 123.8 | 420.0 | 1.8 | 5.6 | 4.9 |
| $LSD^3_{(0.05)}$ | 0.4 | 36.0 | 31.7 | 115.8 | 199.4 | 1.6 | 0.4 | 1.7 |

[1]Organic matter
[2]Cation exchange capacity
[3]Least significant difference

Table 2. Influence of cropping system on soil sulfur and micronutrient concentrations.

| Cropping system | S | Zn | Mn | Fe | Cu | B |
|---|---|---|---|---|---|---|
| | ---------------------------------mg/kg--------------------------------- | | | | | |
| Pure maize | 11.3 | 2.8 | 22.3 | 1.0 | 1.4 | 0.5 |
| Pure sugar bean | 10.0 | 2.9 | 21.8 | 1.0 | 1.4 | 0.5 |
| Pure groundnut | 12.5 | 2.9 | 22.0 | 1.0 | 1.3 | 0.4 |
| Maize + sugar bean | 10.7 | 2.9 | 22.8 | 1.0 | 1.4 | 0.6 |
| Maize + groundnut | 12.0 | 3.2 | 22.5 | 1.0 | 1.3 | 0.4 |
| Means | 11.3 | 2.9 | 22.3 | 1.0 | 1.3 | 0.5 |
| $LSD^1_{(0.05)}$ | NA | 0.8 | 2.8 | NA | 0.2 | 0.1 |

[1]Least significant difference
NA, Not available

Table 3. Soil base saturation as influenced by crop association

| Cropping system | Basic cation K | Mg | Ca | Na |
|---|---|---|---|---|
| | --------------Saturation (%)----------- | | | |
| Pure maize | 4.7 | 23.5 | 39.8 | 4.0 |
| Pure sugar bean | 4.1 | 25.0 | 43.8 | 3.3 |
| Pure groundnut | 5.2 | 22.4 | 39.6 | 4.3 |
| Maize + sugar bean | 3.6 | 20.3 | 48.2 | 4.0 |
| Maize + groundnut | 2.9 | 17.7 | 38.0 | 6.0 |
| Means | 4.1 | 21.8 | 41.9 | 4.3 |
| $LSD^1_{(0.05)}$ | 2.6 | 5.4 | 9.5 | 2.1 |

[1]Least significant difference

Table 4. Maize and pulse grain yield and income/ha (Emalangeni[1]/ha) as influenced by intercropping.

| Cropping system | Maize yield (kg/ha) | Sugar bean yield (kg/ha) | Groundnut yield (kg/ha) | Total income/ha |
|---|---|---|---|---|
| Pure maize | 6289.0 | NA | NA | 6298.0 |
| Pure sugar bean | NA | 839.4 | NA | 5859.0 |
| Pure groundnut | NA | NA | 840.2 | 7015.7 |
| Maize + sugar bean | 5805.6 | 588.3 | NA | 9911.9 |
| Maize + groundnut | 6146.4 | NA | 419.0 | 9645.1 |
| Means | 6083.3 | 713.9 | 629.6 | 7745.9 |
| $LSD^1_{(0.05)}$ | 2657.8 | 564.9 | 391.8 | - |

[1]Least significant difference

## Discussion

There was a positive but non-significant correlation (r = 0.62; $r^2$ = 0.39; n = 20) between mass of groundnut pods/plant and pod yield/ha. The mass of 100 grains in maize was positively, but non-significantly correlated (r = 0.45; $r^2$ = 0.20; n = 20) with maize yield. In groundnut, the mass of 100 grains positively, but non-significantly correlated (r = 0.42; $r^2$ = 0.18; n = 20) with seed yield. That crop yields were reduced in mixtures was in agreement with the observations of Alford *et al.* (2003) and Lesoing *et al.* (1999). But the total crop yield/ha was greater in intercropped plots as was also observed by Sullivan (2000) who noted the yield advantage of intercrops over monocrops. In a different intercropping investigation, it was observed (O. T. Edje, University of Swaziland; personal communication, 2005) that when maize was grown in association with groundnut, there was poor pegging in groundnut, and this could lead to decreased groundnut yield; beans were regarded as being less sensitive to shading than groundnut.

Total income from the cropping systems suggested that farmers would benefit more by intercropping maize with groundnut, rather than using sugar bean as the companion crop. It might be pointed out that the selling price of maize had recently been reduced; otherwise, as the staple food crop, its price was attractive, and perhaps, the best in the South African Development Community (SADC) region. In intercropping, the higher price of groundnut (compared with the lower price of sugar bean) would be sufficient to entice farmers to grow more groundnut and maize, and so have increased production of a combination of maize and groundnut.

## Conclusions

Because greater income was obtained by intercropping, small-scale farmers are advised to intercrop maize with either sugar bean or groundnut in preference to monocropping maize.


## References

Alford, C. M., Krall, J. M., and Miller, S. D. (2003). Annual legumes for fall forage in the High Plains. *Agronomy Journal* 95:520-525. http://agron.scijournals.org/cgi/content/abstract/95/3/520. 30/10/04.

Anonymous. (1991). Field Crops Production. p.1-60. *In*: Pitts, C. W. (Ed.) Farmers' Handbook. Ministry of Agriculture and Cooperatives, Mbabane.

Anonymous. (2003). Groundnut. http://www.ikisan.com/links/ap_groundnutSoils%20And%20Climate.shtml 7/12/03.

Anonymous. (2004). Rapid Assessment of Agricultural Situation in Drought-Affected Areas of Swaziland. http://www.sahims.net/doclibrary/2005/01_january/26/Rapid%20Assessment%20of%20Agricultural%20Situation.pdf. 09/05/05.

Association of Official Analytical Chemists, AOAC. (1990). Official methods of analysis, 15th edn. Arlington, Virginia, U.S.A.

Edje, O. T. (1995). Response of maize and beans grown in monoculture and in association to placement method of kraal manure *UNISWA Journal of Agriculture* 4: 18-27.

Henry, P. C. and Ellis, R. D. (1995). Soil as a factor in sugarcane ratoon yield decline on an irrigated estate in Swaziland. Proceedings, International Society of Sugarcane Technologists pp. 236- 245.

Lamberts, M. L. (1980). Intercropping with potatoes. Unpublished MSc. Thesis, Cornell University, Ithaca, New York, U.S.A.

Leihner, D. (1983). Management and evaluation of intercropping systems with cassava. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia

Lesoing, G. W., and Francis, C.A. (1999). Strip intercropping effects on yield and yield components of corn, grain sorghum, and soybean. *Agronomy Journal* 91:807-813.

Mertin, J. V. (1981). Proceedings of the international workshop on groundnut. International Crops Institute for the Semi-Arid Tropics (ICRISAT), India, October 13-17, 1980.

Messiaen, C. M. (1994). The Tropical Vegetable Garden. Principles for improvement and increased production, with applications to the main vegetable types. British Library. London.

Murdock, G. (1968). Soils and land capability classification in Swaziland. Ministry of Agriculture and Cooperatives, Mbabane.

Nissen, O. (1983). MSTAT-C – A microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State University, East Lansing, Michigan.

Onwueme, I. C., and Sinha, T. D. (1991). Field crop production in tropical Africa. The Technical Centre for Agricultural and Rural Co-operation (CTA), Ede, The Netherlands.

Putnam, D. H., Oplinger, E. S., Teynor, T. M., Oelke, E. A., Kelling, K. A., and Doll, J. D. (1991). Peanut: Alternative field crops manual.

Ruthenberg, H. (1980). Farming systems in the tropics. 3rd edn. Clarendon Press, Oxford, England.

Steel, R. G. D., and Torrie, J. H. (1980). Principles and procedures of statistics: A biometrical approach, 2nd ed. McGraw-Hill, New York.

Sullivan, P. (2000). Intercropping Principles and Production Practices - Agronomy Systems Guide. Appropriate Technology Transfer For Rural Areas. http://www.attra.ncat.org/attra-pub/intercrop.html. 6/09/03.

Van Schoonhoven, A. and Voysest, O. (1993). Common beans research for crop improvement. Library Cataloguing in Publication Data, London, Great Britain.

Yamada, N. (1974). Biological nitrogen fixation – limitless resource supporting agriculture. (In Japanese) *Nettai Noken Shuho* 25:20-28.



## Acknowledgements

The authors are grateful to the University of Swaziland for providing the facilities for this investigation. We also thank Purdue University for assistance in chemical analysis. Lastly, we sincerely appreciate the editorial advice and co-operation of Dr. Charles L. Rhykerd, Professor Emeritus of Agronomy, Purdue University, West Lafayette, Indiana, U.S.A., in the preparation of this manuscript.