Harnessing Biological Nitrogen Fixation in African Agriculture

Challenges and Opportunities

edited by
Sheunesu M. Mpepereki
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Fred T. Makonese

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Sixth International Conference of the African Association
for Biological Nitrogen Fixation
12–17 September, 1994, Harare, Zimbabwe
Selected Papers

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University of Zimbabwe Publications

CTA

ISBN 0-908307-58-6

First published in 1998 by
University of Zimbabwe Publications
P.O. Box MP 203
Mount Pleasant
Harare
Zimbabwe

Typeset byUniversity of Zimbabwe Publications
Printed in Zimbabwe by Mazongororo Paper Converters (Pvt.) Ltd

Part 5

Biological Nitrogen Fixation in Grain Legumes

5.4 Agricultural production in semi-arid regions: use of legume-based mixed cropping systems in Kenya

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Summary

Increasing pressure to feed an ever-expanding population has necessitated an extension of agricultural production in Kenya into marginal semi-arid regions. Crop productivity in these regions is limited not only by the supply of water and the efficiency of its use by the crop but also by the supply of nitrogen. Consequently, cropping systems based on legumes may be particularly appropriate for these areas. Currently, mixed cropping systems involving maize and beans are widely used, although there is a dearth of published information to support this practice. There are also few studies on the most suitable agronomic practices likely to increase agricultural production in these semi-arid areas.

Experiments performed in a semi-arid site at Kiboko, Kenya from 1990 to 1992, during both the long and the short rains, indicate little benefit of growing maize and bean in mixtures, except possibly when supplied with adequate amounts of water, or when water was supplied at the appropriate stage of plant development. At the study site, there was no response to inoculation under rainfed conditions and the beans did not fix atmospheric nitrogen, possibly as a result of high surface soil temperatures, or inadequate water supply.

More attention should be directed towards developing agronomic practices suited to these semi-arid environments, including development of genotypes adapted to these conditions. The significance of water shortages in the field on plants at different stages of development warrants further study.

Introduction

Due to an ever-expanding population, emphasis is being placed on the utilisation of Kenya's semi-arid marginal regions for agricultural production. In these regions, low levels of soil nutrients, such as nitrogen are common and rainfall is generally low and erratic. The probability of crops experiencing water deficits is common and ranges from 40 to 50%, using the drought index of Downing *et al.*, (1988), suggesting that crop failure due to periodic or prolonged water shortages is common.

The significance of growing crops as mixtures is not fully understood and their importance in the marginal areas has received little attention. Incorporation of N fixing legumes may spare some of the soil mineral N which can be used by the companion cereal crop. On the other hand, there may be direct transfer of N from the fixing legume plant, to the cereal. However, N fixation is a process that involves a higher energy and water cost to the fixing plant, in comparison to a plant that is assimilating soil mineral N. A nitrogen-fixing legume would thus have to satisfy the increased carbon demand required to support bacterial nitrogen fixation, whilst also supporting plant growth and reproduction.

The objectives of this study were firstly to study the effects of maize-bean intercrops on grain yield, and secondly to investigate the effects of selected *Rhizobium leguminosarum* biovar *phaseoli* strains on nitrogen fixation and grain yield of beans.

Materials and methods

Four experiments were set up between 1990 and 1991. In order to examine the first objective, maize, beans, and maize-bean mixtures were planted in 6 x 4 m plots. Soil moisture contents were determined during the growing season using the neutron probe technique. At final harvest grain yields were obtained from 1 m^2 predetermined plots, after drying in a force-draft oven at 70°C for 48 hrs. Land equivalent ratios (LERs) (Mead and Willey, 1980) were used to compare the performance of the crops in mixtures and a "t" test used to determine the significance of the LER's. To examine the second objective, bean seeds were inoculated with 6 *Rhizobium* strains using the filter mud as carrier. The ^{15}N-isotope dilution technique was used to assess nitrogen fixation, using maize as the reference crop.

Results and discussion

Grain yields in monocultures ranged from 1,3 to 1,9 t ha^{-1} in maize and from 1 to 1,2 t ha^{-1} in beans Table 5.4.1). Intercropped maize yields ranged from 0,81 to 1,4 t ha^{-1}, and from 0,5 to 1 t ha^{-1} in beans. Intercropping reduced yields in maize (18 to 40%) and beans (5 to 50%). Significant differences in the LER's were only obtained in LR91, where additional amounts of water were applied to prevent crop failure, indicating that, in these regions, intercropping may only be of significance under increased water supply for crop growth. The variability in the reduction may be explained by the water supplied and the timing, in relation to plant ontogeny.

Table 5.4.1: Grain yields (YLD) (g m^{-2}), and land equivalent ratios (LER) for maize and beans grown at Kiboko during the 1990 short rains (SR90), the 1991 long rains (LR91), and the 1991 short rains (SR91)

Cropping System	SR90 (257 mm)		LR91 (264 mm)		SR91 (254 mm)	
	LER	YLD	LER	YLD	LER	YLD
Sole maize	132,46	1,00	189	21 1,00	170,68	1,00
Intercropped maize	81,32	1,06 ns	140,72	1,70*	139,50	1,32 ns
Intercropped beans	53,26	1,06 ns	98,25	1,70*	61,66	1,32 ns
Sole beans	106,25	1,00	102,85	1,00	121,70	1,00
LSD (0,05)	58,84		19,64		52.00	

*, ns, indicate significance at 5% level, and not significant, respectively
Total rainfall (mm) per season is shown. LSD (0,05) indicates the least significant difference at the 5% level

Inoculation of beans with different rhizobial strains had no effect on dry matter production, or partitioning. Neither was there any inoculation effect on the seed yield, or the yield components (Table 5.4.2). Inoculation had no effect on the total amount of tissue nitrogen in any plant fraction at final harvest (Table 5.4.3). The total amount of N removed in standing biomass was greater in maize than in beans. The ^{15}N-atom % values, were generally low, representing 24,49 mg ^{15}N m^{-2} for beans and 35,14 mg 15N m^{-2} for maize. The ^{15}N-atom excess was actually greater in maize than in bean. This may be partly explained by a probably greater partitioning of the ^{15}N into the roots, or perhaps by the differences in the period of plant development, which is longer in maize,

Table 5.4.2. Yield of *Phaseolus vulgaris* inoculated with different strains of rhizobia at Kiboko in the 1990 short rains

Rhizobial strain	Pod (m^{-2})	No of seeds (m^{-2})	Biomass Total (gm^{-2})	Seeds (gm^{-2})	Harvest Index	1 000 seeds (g)
Control	173	259	161,8	70,3	0,430	266,9
9C	197	264	185,1	85,4	0,462	323,8
13C	171	265	177,2	79,7	0,477	298,3
18A	197	293	165,7	60,1	0,367	203,3
23	170	225	168,0	71,5	0,419	314,5
406	164	224	163,0	62,2	0,379	277,4
446	147	265	180,4	89,9	0,501	354,9
s.e.d.	18,5	37,9	19,7	13,4	0,039	37,6

s.e.d indicates the standard error of the difference; Pods and seed are given as numbers per m^2, whilst dry weight is given as standing biomass (Total) and seed in g m^{-2}

Table 5.4.3. Mean nitrogen content (g N m^{-2}) and ^{15}N atom % in the tissues of maize and beans inoculated with different rhizobial strains at final harvest

Rhizobial	Leaf and stem		Pod wall		Seed	
strain	g N	atom %	g N	atom %	g N	atom %
Control	0,92	0,507	0,57	0,494	3,01	0,529
9C	0,96	0,497	0,52	0,490	3,52	0,514
13C	0,96	0,530	0,49	0,515	3,29	0,534
18A	1,24	0,589	0,86	0,570	2,75	0,576
23	0,99	0,550	0,42	0,524	2,74	0,566
406	1,05	0,535	0,44	0,513	2,51	0,534
446	0,83	0,508	0,42	0,514	3,62	0,538
s.e.d.	0,171		0,805		0,501	
Maize	3,07	0,499	na	na	4,07	0,483

na = not applicable

in comparison to beans. The results indicate little evidence for nitrogen fixation under these conditions, although a qualitative assessment of the actual amount of nitrogen fixed could be complicated if maize is not a suitable reference crop. This data, together with other information (Kimani, 1994) indicate that there may be little nitrogen fixation under these conditions, and that there may be little benefit in terms of seed yield in growing plants as intercrops unless the crops are irrigated.

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ABOUT THE BOOK

This volume contains selected papers from the Sixth African Association for Biological Nitrogen Fixation conference proceedings which had the theme 'Agronomic, socio-economic and environmental benefits of biological nitrogen fixation (BNF) in Africa'. A number of papers explore in depth, the constraints and opportunities for successful exploitation of BNF in African agriculture. Microbiological, plant and environmental factors that limit BNF in African soils are reviewed. The socio-economic benefits of BNF for ordinary rural communities are illustrated by case studies from Cote d'Ivoire, Nigeria, Zambia and Zimbabwe. Several papers focus on the ecology and characteristics of rhizobia indigenous to African soils. The production, application and management of rhizobial inoculants in diverse African environments is also covered in this book. Agronomic performance of grain legumes under rhizobial inoculation and issues of nodulation promiscuity and quantification of BNF are the subject of several papers. Finally, the book examines the role of BNF in sustaining agro-forestry systems in a range of African environments. Overall, this book demonstrates that biological nitrogen fixation technologies offer low-cost alternatives for replenishing soil nitrogen for sustainable agriculture and forestry production in Africa.

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