CROP ROTATION AS A SOIL FERTILITY IMPROVEMENT STRATEGY USING DIFFERENT LEGUMES ON A PEARL MILLET YIELD

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ABSTRACT

The soils of Namibia are naturally of marginal fertility. The declining soil fertility is therefore as a result of continuous mono-cropping and unreliable rains, which result in millet yields that are often poor. This study focused on improving soil fertility in order to enhance millet yields. An experimental trial to determine the impact and contribution of legumes to soil fertility, was conducted at Mannheim and Bagani Research Stations for six years and started in the growing season of 2005/2006. Crops used in the study are pearl millet (*Pennisetum glaucum*), lablab (*Lablab purpureus*), Jack bean (*Canavalia ensiformis*) and cowpea (*Vigna ungiculata*). A complete randomised block design with three replications was used. The trial was conducted under dry land conditions. A durational rotation of one to three years of growing pearl millet (Okashana no. 2) after a legume was assessed. The one to two year durational rotation performed best compared to one to one year and one to three years. The difference in the mean values among the different levels of treatments, is greater than would be expected by chance after allowing for effects of differences in replications. There is a statistically significant difference ($P = < 0{,}001$). The difference in the mean values among the different levels of replications is not great enough to exclude the possibility that the difference is due to random sampling variability after allowing for the effects of differences in treatments. There is not a statistically significant difference ($P = 0{,}387$).

INTRODUCTION

Nitrogen and phosphorus are known to be limited in the cultivated soils of the semi-arid northern communal areas of Namibia where pearl millet is the staple cereal. Due to the environmental and climatic conditions of the country, the area is characterised by soils of marginal fertility, known as sandy soils. Nutrient content and nutrient retention are normally low in sandy soils, thus causing a low inherent fertility status for agricultural production. Nutrients are easily leached out of the solum. The poor soil structure makes the soil very susceptible to wind erosion. This declining soil fertility as a result of continuous mono-cropping and unreliable rains, has the effect that pearl millet yields are often poor. Namibia has complex topography and diversified agricultural practices. By analysing the situation, it is known that soil fertility decline is due to uncontrollable soil erosion and improper soil management. The problem of soil fertility deterioration may worsen in future with crop intensity increasing, the use of high yielding crop varieties, low and unbalanced application of chemical fertilisers, and the decreasing use of organic manure. In light of the limited arable land resources, improved soil fertility is one of the key factors to increase the agricultural production of the nation.

There is a growing concern regarding the long-term sustainability of agriculture. Both the over and under application of fertilisers, and the poor management of resources have damaged the environment. Developed countries especially tend to over apply inorganic and organic fertilisers and this has led to the environmental contamination of water supplies and soils (Conway and Pretty 1991; Bumb and Baanante 1996; NRC 1989). In developing countries, on the other hand, harsh climatic conditions, population pressure, land constraints, and the decline of traditional soil management practices have in many places reduced soil fertility (Stoorvogel and Smaling 1990; Tandon 1998; Henao and Baanante 1999; Bumb and Baanante 1996). Owing to the fact that agriculture is a soil-based industry that extracts nutrients from the soil, effective and efficient approaches to reduce the removal, and aid the return of nutrients to the soil, will be required in order to maintain and increase crop productivity and sustain agriculture for the long term.

The overall strategy for increasing crop yields and sustaining them at a high level must include an integrated approach to the management of soil nutrients. An integrated approach recognises that soils are the storehouse of most of the plant nutrients essential for plant growth. At the same time the way in which nutrients are managed, will have a major impact on plant growth, soil fertility and agricultural sustainability. Crop rotation is a central component of all sustainable farming systems and offers the most effective, indirect method of minimising pest, disease and weed problems, in addition to maintaining and enhancing soil structure and fertility. It can limit the build-up of weeds that are favoured in single crop cultivation.

Crop rotation have many benefits, including increased soil microbial activity, which may increase nutrient availability. When crops are rotated, yields are usually 10 % to 15% higher than when grown in monoculture (Organic Agricultural Centre Canada, 2004). Rotations that include legumes and cereals help to ensure that the land is not exhausted. Nitrogen is the main nutrient element usually contained in commercial fertilisers used by farmers. It is required by plants in large quantities, and usually has the quickest and most pronounced impact on growth. Most plants absorb nitrogen in the form of nitrate and ammonium in soil. Air contains 78 % nitrogen, but most plants cannot access it. Legumes are therefore special in that they host nitrogen-fixing bacteria such as rhizobium that can convert atmospheric nitrogen into a form that can be used by the host plant. Legumes in rotation with cereals not only improve cereal productivity, but also economise on use of nitrogen: up to 40 kg nitrogen per hectare (Ali, Joshi, Pande, Asokan, Virmani, Kumar & Kandpal, 2000).

Legumes have been known for their soil ameliorative effect since time immemorial. They add substantial amounts of protein-rich biomass to the soil surface and rhizosphere, and thus keep the soil productive and healthy. In Namibia crop rotation is not common practice, especially in the communal areas. Thus, the main aim of this study is to determine the effects and contribution of durational crop rotation to soil fertility in order to increase and maintain the status of soil nutrients, which in turn will increase pearl millet production.

OBJECTIVES

- To determine the effects of crop rotation on the yield of pearl millet and other components.
- To identify appropriate and suitable leguminous crops, that are beneficial to soil fertility improvement and maintenance.
- To determine the appropriate sequencing and duration of crop rotation.

MATERIALS AND METHODS

Site information

Mannheim Research Station lies 15 km north and in the district of the town Tsumeb in the Oshikoto region – 19° 15' 0" south and 17° 42' 0" east. It has a sub-tropical climate with very hot summers and mild winters. The mean maximum temperature is 29,7 °C, while the mean minimum is 14,4 °C. Occasional thunderstorms occur during the summer rainfall months of October to March. The average rainfall is 555 mm per annum.

Bagani Research Station is in Bagani, 200 km east of the town Rundu in the Kavango region – 18° 7' 0" south and 21° 38' 0" east. Bagani also has a sub-tropical climate, but hot summers and cool to cold winters. The mean maximum temperature is 34 °C, while the mean minimum temperature is 15 °C. The average rainfall is 645 mm per annum.

Trial layout

An experimental trial to determine the impact and contribution of legumes to soil fertility was conducted at Mannheim Research Station. To improve pearl millet Okashana no. 2 a complete randomised block design with three replications was used. The trial was conducted under dry land conditions. A durational rotation of one to three years of growing millet after a legume was assessed. This was laid out as follows: millet – lablab, millet – Jack bean, millet – cowpea and a mono-crop millet as control. Jack bean and cowpea both had a spacing of 100 cm between rows and 30 cm within rows. Lablab was planted at a spacing of 120 cm between rows and 50 cm within the rows, and pearl millet at 75 cm between rows and 40 cm within rows. The plot had a 10 m row length and 6 m width, with 1 m spacing between plots and 2 m between replications. The net plot area size was 6 m x 10 m = 60 m^2, and the total plot area 69 m x 34 m = 2 346 m^2 = 0,23 ha. Soil conservation management was applied during the growing seasons. Crop residues and leguminous crops were used as cover crops to prevent soil run off. Microsoft Excel was used to analyse the data. Four crops were used in the trial: pearl millet variety Okashana no. 2 (*Pennisetum glaucum*), lablab (*Lablab purpureus*), Jack bean (*Canavalia ensiformis*) and Nakare, a variety of cowpea (*Vigna ungiculata*) with one to three years durational rotation resulting in 10 treatments.

The trial was planted at a depth of 2,5 cm for cowpea, lablab and Jack bean, and 2 cm for pearl millet. Seeds were planted densely and then thinned to one to two in the case of leguminous plants, and that of pearl millet to two to three per hill. Thinning was done by hand 14 to 21 days after emergence to prevent damage to the remaining plants. Weeding was carried out four times during the period by means of hand hoeing. Scouting for pests started within two weeks of emergence and was done on a daily basis. Vigilance was maintained throughout the flowering and grain formation stages. Harvesting was done when crops reached maturity.

Data collection and analysis

The parameters recorded were: Yield (t/ha), plant count, plant height, emergence date, and flowering and maturity date. Harvesting took place 102 days after planting for pearl millet, 156 days for Jack bean, 86 days for cowpea, and lablab was never harvested because it did not seed, especially at the Mannheim location.

At Bagani Research Station, it took pearl millet 85 days to reach maturity, 111 days for Jack bean, and 77 days for cowpea. Harvesting was carried out manually and the seed grain for all crops were weighed and recorded. Yields were then calculated using Microsoft Excel.

	No. of days to emergency		No. of days to flowering		No. of days to maturity	
	Mann-heim	Bagani	Mann-heim	Bagani	Mann-heim	Bagani
Pearl millet	10	7	22	41	102	85
Lablab	14	9	95	123		
Jack bean	17	9	48	60	156	111
Cowpea	10	9	32	54	86	77

RESULTS AND DISCUSSIONS

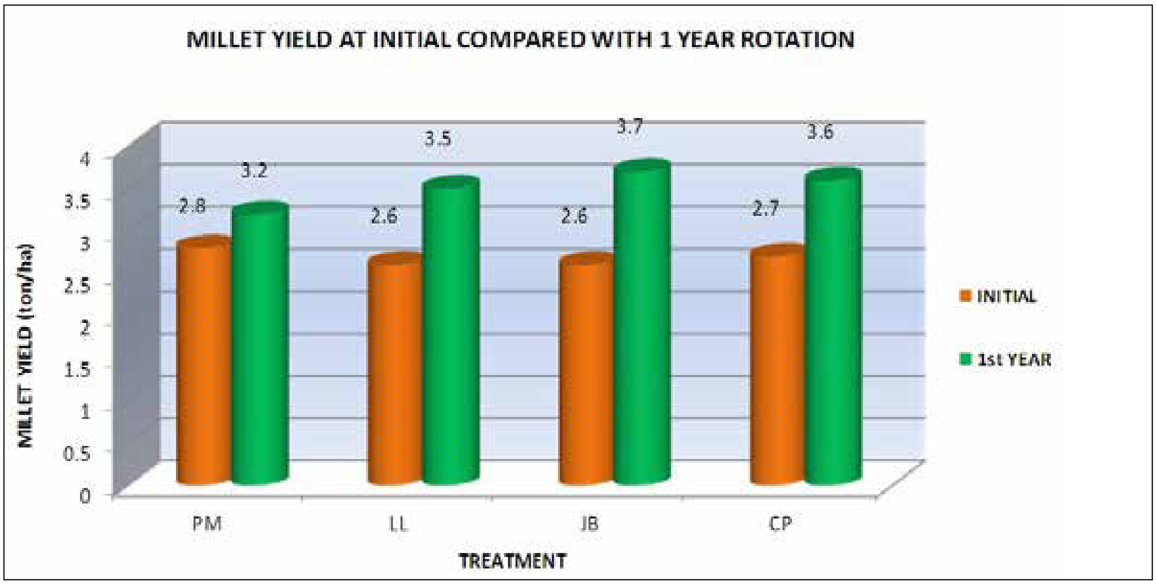

Figure 1. Millet yields on the one year rotation of millet with lablab (LL), Jack bean (JB) and cowpea (CP).

The initial millet yields were generally lower than that of one year rotation of millet (one year legume crop, one year millet) . These results could be attributed to the higher rainfall received during the growing season, which could have caused leaching of nutrients and water logging. The results of one year legume crop and one year pearl millet crop rotation indicate that planting pearl millet after a Jack bean yielded the highest at 3,7 t/ha. Planting pearl millet after cowpea recorded second at 3,6 t/ha, and lablab yielded the lowest at 3,5 t/ha.

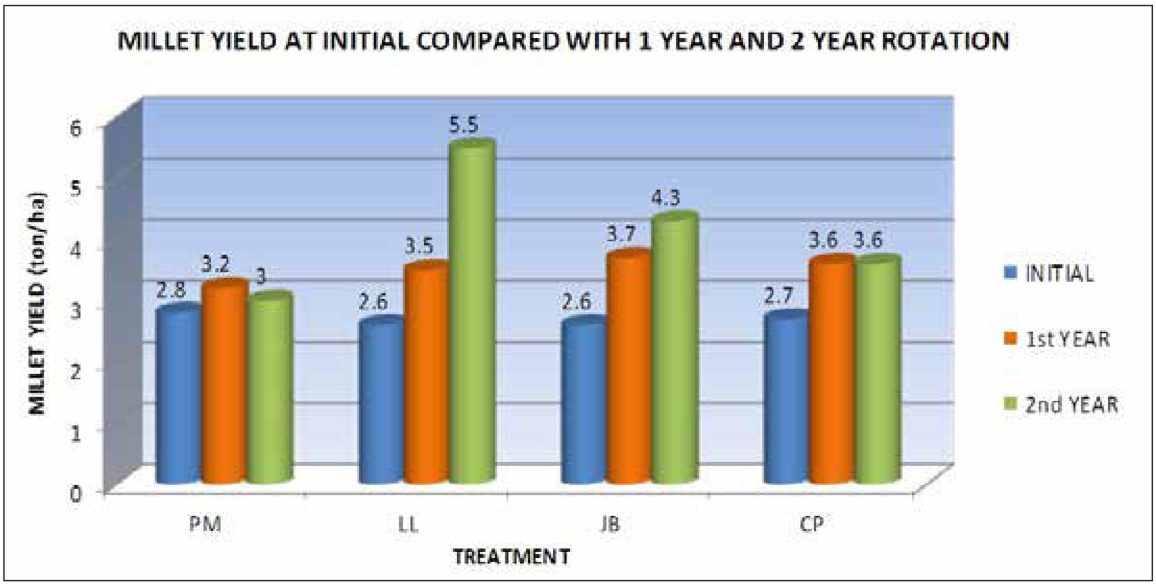

Figure 2. Initial millet yields compared with one year crop rotation (one year legume, one year millet), and two year crop rotation (one year legume, two years millet).

The results show that the second year of growing pearl millet after a legume, yielded higher than that of growing pearl millet one year after a legume, with the exception of cowpea which remained the same in both the two rotations. Pearl millet planted after lablab on the second year, yielded an exceptionally high recording of 5,5 t/ha, followed by Jack bean recording 4,3 t/ha, and lastly cowpea recording 3,6 t/ha. It is obvious that nitrogen is readily available for plants to uptake by the second year, thus the enhanced higher yields in one to two year rotation, to that of one to one year rotation.

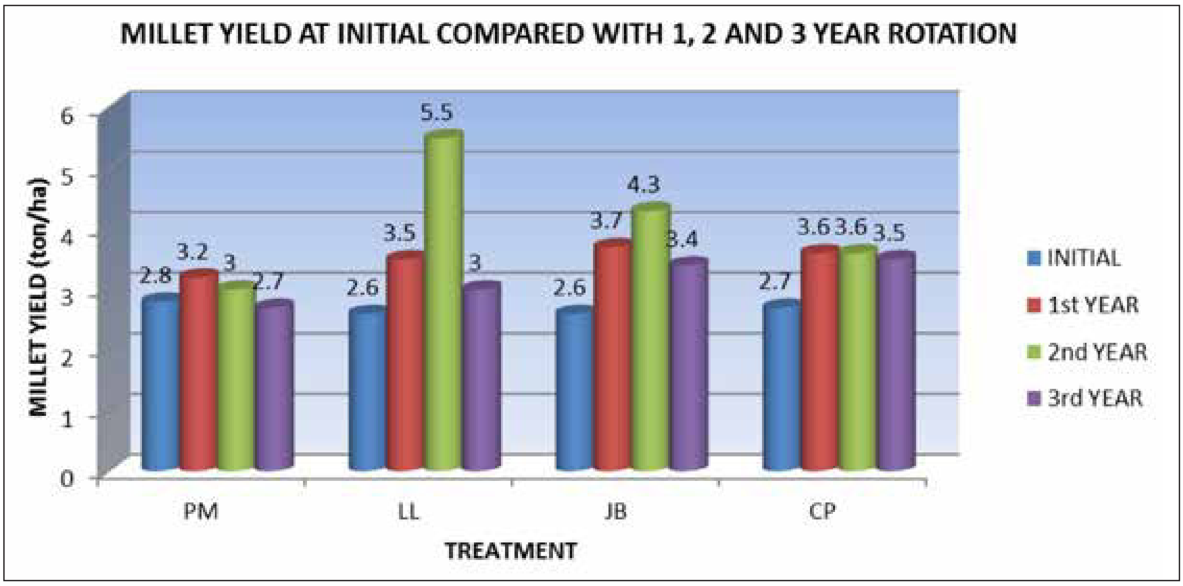

Figure 3. Initial millet yields compared with the one year (one year legume, one year millet), two year (one year legume, two years millet) and three year (one year legume, three years millet) crop rotation.

The result chart indicates that planting pearl millet for a third year after planting a leguminous crop, drastically decreases yields. This confirms that the availability of nutrients have diminished and need to be replaced. The yields that decreased most was lablab (– 2,5 t/ha) and Jack bean (– 0,9 t/ha) treatments. Cowpea treatment also recorded a decreased yield of –0,1 t/ha and mono-cropping pearl millet –0,3 t/ha. In the mono-crop treatment the trend shows that millet yields start to decrease from the second year round, which is not the case in all other treatments.

The difference in the mean values among the different levels of treatments is greater than what would be expected by chance, after allowing for effects of differences in replications. There is a statistically significant difference ($P = < 0{,}001$).

The difference in the mean values among the different levels of replications, is not great enough to exclude the possibility that the difference is just due to random sampling variability after allowing for the effects of differences in treatment. Statistically there is not a significant difference ($P = 0{,}387$).

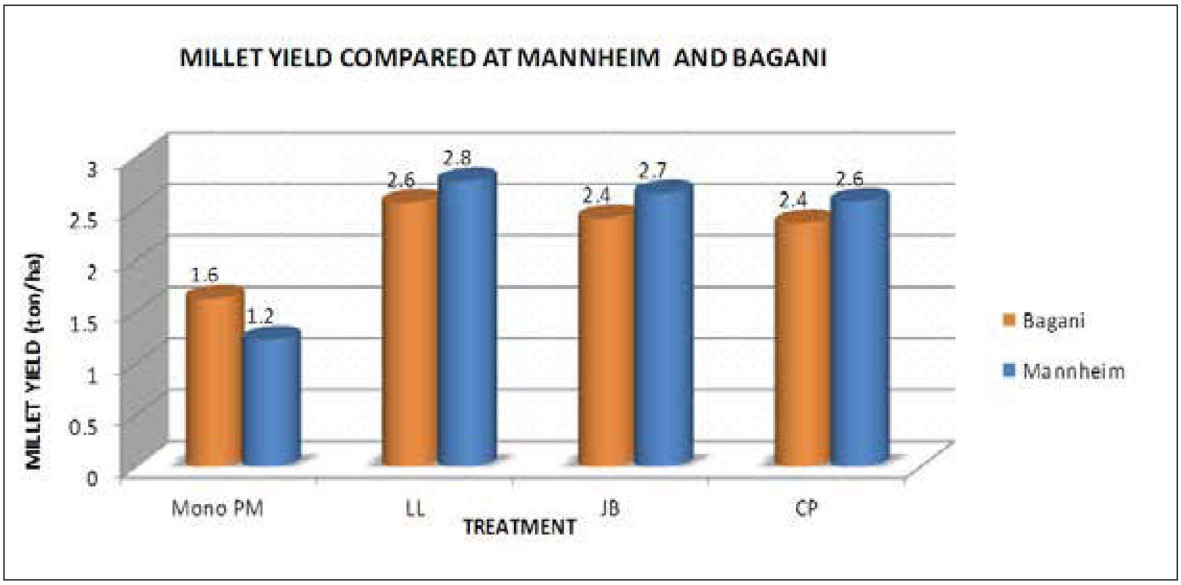

Figure 4. The comparison of average millet yields at two locations: Mannheim and Bagani.

Pearl millet in a rotation with legume crops such as lablab, Jack bean and cowpea was compared at two locations: Bagani and Mannheim Research Stations. The chart shows that yields were lower in a pearl millet mono-system than those obtained from a crop rotation system with legume crops in both locations. Pearl millet rotated with lablab yielded highest, followed by Jack bean and cowpea. The trend was the same at both locations. Rotated pearl millet yields were generally higher at Mannheim as compared to

Bagani. This could be as a result of poor fertility sandy soils at Bagani as compared to the loamy soils of Mannheim.

CONCLUSION AND RECOMMENDATIONS

The experimental trial (which is about comparing the effects of one to one, one to two and one to three year durational rotation of growing pearl millet after each of the three leguminous crops – lablab, Jack bean and cowpea) shows that lablab contributes significantly towards pearl millet yields, followed by Jack bean and lastly cowpea. The one to two year durational rotation performed best compared to the one to one and one to three year rotations. From the above results it is recommended that lablab as a legume crop, in combination with a one to two year durational rotation, can be used to improve pearl millet yields.

Improved soil and crop management practices (that increase the amount of plant residue returned to the soil, and adapt to the environmental conditions of northern Namibia) are needed to increase soil organic matter and the sustainability of farming systems.

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