Incorporating groundnut into the maize-based smallholder farming systems in semi-arid Limpopo province, RSA

Jude Odhiambo[A], Anthony M. Whitbread[B] and John N.G Hargreaves[C]

[A]University of Venda, Department of Soil Science, Private Bag X5050, Thohoyandou 0950, South Africa, Email Jude.Odhiambo@univen.ac.za
[B]CSIRO Sustainable Ecosystems, PMB2, Glen Osmond, SA 5064 Australia, Email anthony.whitbread@csiro.au
[C]CSIRO Sustainable Ecosystems, 203 Tor St, Toowoomba 4350 QLD Australia, Email john.hargreaves@csiro.au

Abstract
Incorporation of grain legumes into existing predominantly maize-based monoculture smallholder farming system may improve the productivity and sustainability of the system. This paper presents the results of a study conducted on-farm with the aim of evaluating the best groundnut cultivar for incorporation into the existing predominantly continuous maize cropping system. Treatments consisted of three groundnut (*Arachis hypogaea*) cultivars (Kwarts, Akwa and Kangwana red) and four phosphorus fertilizer rates (0, 15, 30 and 60 kg P/ha applied as superphosphate at planting) arranged in a completely randomized block design with three replications. Dry matter was measured at regular intervals and grain yield determined at maturity. The APSIM model was used to simulate growth and grain yield. Cultivar and P application had no effect on grain yield. Grain yield ranged from 554 to 649 and 1254 to 1503 kg/ha, in 2007/8 and 2008/9 seasons, respectively. A strong relationship (R^2=0.83) was recorded between observed and simulated grain yield. Long-term simulation with non-limiting P indicated that 50% of the seasons yielded >506 kg/ha grain. Low rainfall coupled with prolonged drought periods during growing season may have limited the potential response to P application.

Key Words
Groundnut, phosphorus, APSIM model, smallholder farmers, South Africa.

Introduction
Farming under smallholder systems in Limpopo province is characterized by a low level of production and small farm sizes of approximately 1.5 ha. The majority of these smallholder farms are located on infertile soils with any production primarily used for subsistence and little marketable surplus. An increasing pressure on the land resources is due population growth and has resulted in continuous cultivation and depletion of plant nutrients. Very few farmers can afford to purchase inorganic fertilizers due to their limited resources. Sole unfertilized maize is the dominant cropping system in this region. Legume intensification is often advocated to improve the productivity and sustainability of cereal based cropping systems in developing countries (Snapp *et al.* 1998). These technologies include agro-forestry systems, green manures, and legume intercrops or rotations. Experimentation has shown that these systems can enhance soil productivity through biological nitrogen fixation, carbon inputs and conservation of nutrients (Snapp *et al.* 1998). This paper presents the results of a study conducted on-farm with the aim of evaluating the best groundnut cultivar for incorporation into the existing predominantly continuous maize cropping system. The objectives of this study were to: (i) assess the effect of cultivar and phosphorus fertilizer application on grain yield of three groundnut cultivars over 2 seasons; and (ii) validate the performance of the APSIM model (Keating *et al.* 2003) to simulate the growth and yield of groundnut.

Materials and methods
A group of smallholder farmers from Bloodriver (23.817896°, 29.370232° 1244 m asl) near Polokwane in Limpopo Province South Africa had formed the Perkesbult Farmer Association and were experimenting with various grain legume options. At this location, a researcher managed field experiment was established in two seasons 2007/08 and 2008/09 (separate sites in each season) to evaluate three groundnut (*Arachis hypogaea*) cultivars (Kwarts, Akwa and Kangwana red) and four phosphorus fertilizer rates (0, 15, 30 and 60 kg P /ha applied as superphosphate at planting). The experiment was laid out as a complete randomized block design with three replications. Individual plot sizes measured 3 m x 3 m and seeds were planted at a spacing of 0.3 m x 0.6 m, to give a target population of 55556 plants/ha. Planting took place on 3 Jan 2008 and 18 Dec 2008. Data such as emergence, dry matter at 6-8 weeks after planting and flowering, grain yield at maturity were collected. Measured data was analyzed using SAS software. The APSIM model was used to

simulate grain yield production with soil being characterized according to the procedures of Dalgleish and Foale (1998) and the groundnut model parameterized according to Robertson *et al.* (2001). Existing groundnut cultivars available in APSIM were adjusted to match the phonological stages measured in the field experiments. To assess the goodness of fit of the simulations to measured data, the root mean square error (RMSE) between predicted and observed data was calculated as:

$$RMSE = [(\sum (O - P)^2/n)]^{0.5}$$

where O and P are the paired observed and predicted data and n is the number of observations.

Results and discussion

Crop production at this site is severely limited by low soil fertility, low soil water holding capacity and highly variable rainfall. Despite these limitations, smallholder farmers attempt to grow food crops such as maize, sorghum and a range of grain legumes, although crop failures are common and yield is usually low. The soil on which the experiments were located was a highly erodible coarse sand derived from granite (Plinthic soil with high base status), with a rooting depth of about 60cm and a plant available water capacity (PAWC) of 72 mm. Chemical fertility and carbon content is low (Table 1). According to weather records from Polokwane (about 20 km away) average annual rainfall is 475 mm with growing season rainfall (November to March) of 370 mm.

Table 1. Some soil physical and chemical properties of the soil at the experimental site.

pH	Sand	Silt	Clay	N	C	K	Ca	Mg	P
(H_2O)	------------%--------------			%	%	---------cmol(+)/kg--------			mg/kg
5.95	82.3	5.7	12	0.017	0.37	0.234	0.98	0.756	2.0

During the growing period, a total amount of 135 and 252 mm of rainfall was received in the 2007/8 and 2008/9 seasons, respectively. This resulted in grain yield ranging from 554 to 649 kg/ha in 2007/08 and 1254 to 1563 kg/ha in 2008/09 with no significant differences found between the cultivars or P application rates (Table 2).

Table 2. Effect of cultivar and P application rates on grain yield (kg/ha) of three groundnut cultivars in 2007/8 and 2008/9 seasons.

Factor	Grain yield (kg/ha)	
	2007/8 Season	2008/9 Season
Cultivar		
Kwarts	554a	1254a
Akwa	649a	1344a
Kangwana	567a	1563a
Phosphorus rate (kg/ha)		
0	507a	1112a
15	610a	1497a
30	621a	1615a
60	623a	1323a
F-test probabilities		
Cultivar	ns	ns
Phosphorus rate	ns	ns
Interaction (CxP)	ns	ns

Within Columns, means followed by the same letter are not significantly different at $P \leq 0.05$.

The observed and simulated grain yield at 60 kg P/ha in 2007/8 and 2008/9 seasons fall within the observed variation (RMSE = 168) (Figure 1). The linear regression between simulated and observed grain yield in 2007/8 and 2008/9 seasons when P is non-limiting had R^2 value of 83%, indicating a positive strong relationship (Figure 1). Crop production in this environment is highly risky due to low inherent soil fertility, low soil water holding capacity and highly variable rainfall. In simulations of maize growth without fertiliser N (1960-2009), it was found that there was complete crop failure in 60% of seasons (data not presented). This decreased to 30% of seasons with the application of 15 kg/ha of N fertiliser, but average grain yield remained below 1000 kg/ha. While growing grain legumes such as groundnuts results in >80% of seasons resulting in a successful crop, yield remains <506 kg/ha in 50% of seasons (Figure 2).

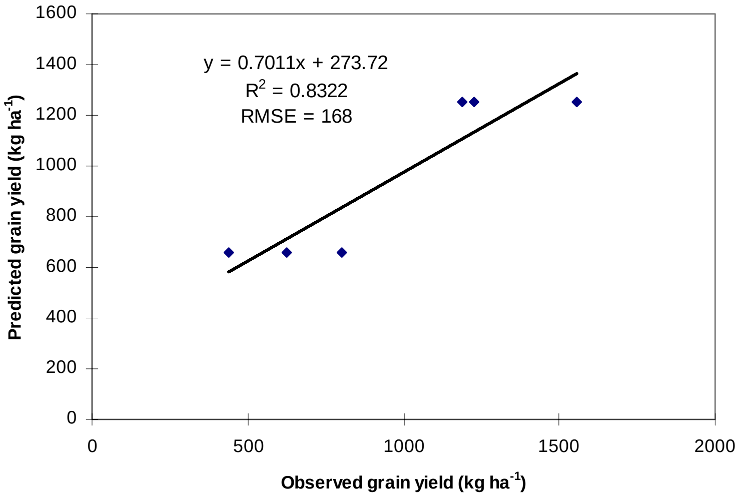

Figure 1. The relationship between the observed and predicted grain yield for 2007/8 and 2008/9 seasons at 60 kg/ha.

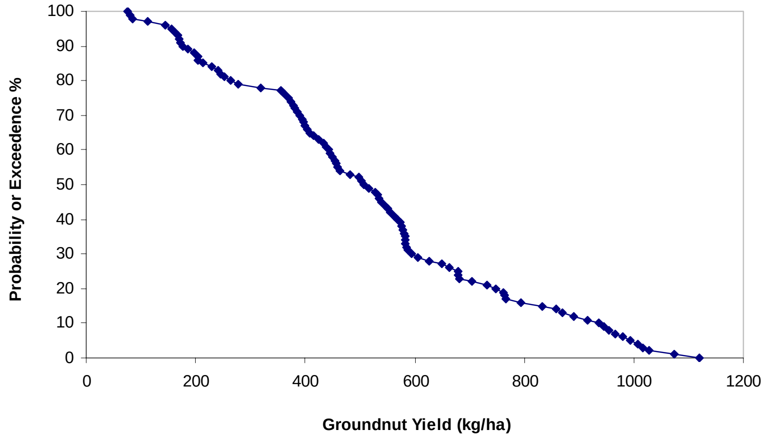

Figure 2. Long-term simulation (1961-2009) for grain yield with cultivar Kangwana when P is non-limiting.

Conclusion

Low rainfall, coupled with prolonged drought periods during the growing season may have limited the potential for response to P application. Cultivars Akwa and Kangwana are promising and may have the potential to produce better grain yield if there is sufficient rainfall. The APSIM model was able to simulate grain yield production with a fairly good degree of precision.

Acknowledgement

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