WINTER GRAIN RESPONSE TO PHOSPHORUS VARIATION ON DIFFERENT SOIL TYPES UNDER PRECISION AGRICULTURE (PA)

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Abstract

Phosphorus (P) is an important nutrient required by every living plant and animal cell, and deficiencies in soils could cause limited crop production, thereby reducing profitability. P is also a primary nutrient essential for root development and crop production, and is needed in the tissues of a plant where cells rapidly divide and enlarge. Precision agriculture (PA) could assist the farmer in applying the ideal amount of P to a specific part of a field where it is required most. Variable rate technology (VRT) is a tool that can help with the development of strategies for fertiliser phosphate management.

On-field trials were conducted on a commercial farm in the Western Cape Province; As many as five soil types occur on each field studied, and three crops – wheat, canola and barley - are grown in rotation. One half of each field was planted using VRT (PA), while constant application (SR) was used on the other half. The objective was to determine the variation of winter grain yield response to P on different soil types.

Keywords: Precision agriculture, variable-rate phosphorus application, single rate phosphorus application, winter grain yield, South Africa.

1. Introduction

Swinton and Lowenberg-DeBoer (1998) reported that agriculture is becoming an industry based on knowledge, and that the ability to learn efficiently is a key factor in ensuring profitability in this sector. According to Gandonou, Stombaugh, Dillon and Shearer (2001), agriculture is increasingly turning into a computerized, information-based industry. The best example of this trend is the evolution of precision agriculture (PA). PA is an emerging technology that prescribes inputs based on site-specific soil and crop characteristics (Snyder, Schroeder, Havlin & Kluitenberg, 1996).

New intelligent technologies lead by the utilisation of information technologies, are changing traditional production processes. These intelligent technologies, in combination with the determination of "position and time", are much more complex than just dividing fields into management zones (Auernhammer, 2002). Khanna, Epouche and Hornbaker (1999) are of the opinion that the developments in computer, satellite and agricultural equipment technology enable farmers to undertake site-specific crop management instead of relying on whole-field management. This development enables farmers also to make more precise decisions about the application of inputs in order to avoid deficiencies and excesses in input-use. According to Maine, Nell, Alemu and Barker (2006), the standard rate of fertiliser application for individual cropping systems in South Africa is gradually being replaced by PA advice, based on the soil mineral nitrate of nitrogen (N) and phosphorus (P). Lowenberg-DeBoer and Erickson (2010) reported that PA is mostly adopted for its ability to increase the efficiency of inputs such as fertilisers, while still maintaining crop productivity.

P promotes growth in plants and animals and the importance of P cannot be over-emphasized in agriculture. Deficient P can cause low yield and poor quality crops and pastures. Rock phosphate is normally the sole source of P in nitrogen, phosphorus and potassium (N:P:K) fertilizer mixture (Florida Institute of Phosphate Research, 2004). Due to low availability of P in this native material, high transportation costs and the processing thereof, P becomes one of the most expensive crop inputs that require proper management.

2. Literature

One big challenge of P applications is that the analysis methods still need some attention and that there is low correlation between some of the methods (Le Roux, 2008 and Venter, 2008). The P fertilisation of soils has always been traditionally viewed as important as it is the most immobile of major plant nutrients and can only be absorbed by plants in a soluble form. The average total P level of soils around the world is low (one-tenth to one-fourth of N and one-twentieth of K). P in the soil is present either as inorganically fixed phosphates, as organically fixed P, or as P dissolved in the soil. Only the latter form of P is available for use by plants. The P concentration in the soil solution is normally in the range of 0,3 to 1 mg/kg-1 (approximately 0,3 to 1 kg of P_2O_5/ha). Non-labile P can range from 100 – 200 mg/kg-1 (1 000 - 2 000 kg P_2O_5 in the upper 15 cm of 1 hectare of soil). The soluble sources of P are fertilisers and manure. When these soluble sources are added to soils some of it are fixed, changed to unavailable forms (Grego, 2001, Florida Institute of Phosphate Research, 2004 & Yara, s.a.).

According to a study undertaken by Robinson (2005) near Cleveland, Mississippi, it was found that in some areas in farm fields the plants were stunted and these areas also did not yield well. By adding a yield monitor to a combine, the problem areas were identified. Soil samples indicated very low levels of P and the decision was taken to try a pre-plant application of Triple Super P. Satisfying the soil's P needs by applying chicken manure can cost the producer $12,00/lb pound of P applied. By applying the variable rate of P, the yield showed an increase. This fact emphasizes the importance of addressing the specific sites where the problems are experienced.

In another study undertaken in order to compare variable-rate (VRT) and uniform-rate (SR) P fertilization, it was found that P could be a major yield-limiting nutrient for some producers in many regions. VRT has the potential to reduce costs in areas where SR fertilization would over-apply fertiliser and to increase yield where fertiliser would be under-applied, but it seldom increased net returns because of increased costs of soil sampling and fertiliser application. VRT resulted in better P nutrient management because between 12 % and 41 % less fertiliser was applied and soil-test P variability was reduced compared with the SR fertilization method (Wittry & Mallarino, 2004).
The ultimate success of VRT is, according to Solohub, Van Kessel and Pennock (1996), dependent upon the economic advantage of implementing this technology into a farm-based management plan. There are four factors that control the profitability of such an approach: (1) the value of the commodity, (2) the savings in fertiliser costs, (3) the change in crop yield and (4) the cost associated with implementation.

3. Methodology

Data was collected by using the VRT application of P, in comparison with the SR application The study was conducted in collaboration with Mr Gildenhuys (on-farm trials) in the Heidelberg district in the Western Cape, South Africa. Four fields, totalling 106 ha, were identified as research fields for the study. The main crops included in the study were wheat, canola and barley (3rd year). In each field as many as five soil types were found. Each field was divided into two halves. One half was planted by making use of VRT, and the other half was planted by conforming to the traditional farm management system or the SR. The same crop was planted on both halves. Wheat, canola and barley were used in a crop rotation system.

In order to ensure a practical approach, the researcher conducted on-farm trials which represented the actual farming operations. In view of the fact that "small plot" trials differ from the real farming situation, it was important to conduct on-farm trials. The choice of variables (yield and P) in this study was guided by the researcher's field of interest, the problem to be solved and the physical on-farm situation. The most important variable in this study is yield, and the study also reflects on the relationship between yield (output) and fertiliser (input).

In this kind of study, it is important to make a distinction between independent and dependent variables. An independent variable is a variable that the researcher can manipulate (Leedy & Ormrod, 2005) while a dependant variable changes in response to an independent variable. P was identified as the independent variable in this study whereas yield was a dependant variable. Therefore P was manipulated by using different application rates as required by the soil potential and it was considered to be the cause of variation in yield. The effects of VRT and SR treatments of P on yield were the focus of the measurement. The yield was measured as the effect or result of the treatment with P.

4. Objective

The objective of this paper is to determine the variation of winter grain yield response to P on different soil types.

5. Results: Winter grain response to P variation on different soil types

PA poses several challenges to both models and modellers as it does not just require simulation of the mean, but also a simulation of spatial variation. Furthermore the model chosen should match the research objectives. For PA to succeed, one would expect the primary goal to be the ability of the model to simulate spatial variation with the accuracy of the model determining how good the conclusions will be. In the case of the application of PA, regression has been used as primary test in most model tests. When using the regression approach, the model will produce useful results if the simulated output represents 70 % to 80 % or more of the variation in the observed result (Sadler, Jones & Sudduth, 2007). One of the biggest challenges remain to link yields to soil conditions and to clearly establish the profitability of VRT fertiliser application. This complexity of yield response makes model specification difficult (Anselin, Bongiovanni & Lowenberg-DeBoer, 2004).

The spherical model for restricted maximum-likelihood (REML) is the most appropriate for each of the four fields for each of the three years, due to the fact that the akaike information criteria (AIC) is the smallest. The results achieved for each field for each year with the REML (spherical) model will be discussed separately in Tables 1 to 11. Soil type Glenrosa (Gs1) (S1) was used as base soil for discussion of all fields except for L2 where Gs3 (S3) was used as soil type Gs1 is not found in L2. The "Constant" represents the base soil and base treatment (SR) in kilograms (kg). The "Trt" coefficient is the yield difference between VRT and SR treatments for the base soil. The Si coefficients represent the difference between specified soil *i* and the base soil with SR treatment. The TRTSi interaction coefficient is the yield difference between VRT and SR for soil i versus the base soil ((Si:(VRT-SR) – Sbase (VRT-SR)). Table 1 presents the results of L2 (2004).

Table 1: Wheat response to P variation on different soil types: L2 (2004)

	Regression output			
	REML			
	Spherical			
	Cf	Std Err.	t-Value	Pr>|t|
Constant	1570.98	97.1020	16.18	-
Trt	-99.7969	82.0126	-1.22	0.2238
S6	-17.0635	64.3721	-0.27	0.7909
S7	-14.1341	49.5061	-0.29	0.7753
S12	-271.04	89.8425	-3.02	0.0026**
S13	-14.5565	75.2637	-0.19	0.8467
S14	-25.5085	71.4158	-0.36	0.7210
TRTS6	71.0820	106.56	0.67	0.5048
TRTS7	88.9119	74.5056	1.19	0.2329
TRTS12	300.21	143.88	2.09	0.0371*
TRTS13	108.90	100.85	1.08	0.2803
TRTS14	141.84	111.95	1.27	0.2053
LAMBDA	-	-	-	-

* = 0.05
** = 0.01

Table 1 shows that the yield for the Coega (Cg) soil type (S12) for the SR treatment has significant statistical results with the interaction towards the reference (Glenrosa, Gs3 soil) and the coefficient is -271,04 kg/ha. This means that Gs3 produced 271,04 kg/ha more wheat than the Cg soil with the SR treatment. TRTS12 is the interaction between VRT and S12 (for Cg) and show significant statistical results with a coefficient of 300,21 kg/ha. Therefore the Cg soil type produced 300,21 kg/ha more wheat than the Gs3 soil in the case of the VRT treatment (Cg: VRT–SR minus Gs3: VRT–SR). According to the results, the Cg soil reacted better with the VRT treatment. The other coefficients were not significant and are therefore not discussed. The total fertiliser cost with the VRT was ZAR85,67/ha (South African Rand) and with SR it was ZAR125,50/ha, resulting in a saving of ZAR39,83/ha. Table 2 shows the response of canola to P variation during 2005.

Table 2: Canola response to P variation on different soil types: L2 (2005)

	Regression output			
	REML			
	Spherical			
	Cf	Std Err.	t-Value	Pr>|t|
Constant	2762.43	131.07	21.08	-
Trt	-228.16	133.15	-1.71	0.0868
S6	10.6390	110.77	0.10	0.9235
S7	41.6905	86.9965	0.48	0.6318
S12	-239.84	152.98	-1.57	0.1171
S13	-53.835	131.50	-0.41	0.6823
S14	6.8077	121.08	0.06	0.9552
TRTS6	123.05	196.61	0.63	0.5315
TRTS7	94.1787	128.64	0.73	0.4642
TRTS12	71.9105	244.56	0.29	0.7688
TRTS13	97.3720	175.44	0.56	0.5789
TRTS14	165.12	194.22	0.85	0.3953
LAMBDA	-	-	-	-

* = 0.05
** = 0.01

According to Table 2, no significant statistical differences are evident with the different soil types and canola's response to the variation in P. The 2006 data were corrupted and could not be used. During 2005 a saving of ZAR2,59/ha was realized in total fertiliser cost between the VRT and SR treatments. The results of K3A during the three years are presented in Tables 3 to 5. The Glenrosa (Gs1) soil type was used as the reference on field K3A. Table 3 shows wheat response to P variation on different soil types during 2004.

Table 3: Wheat response to P variation on different soil types: K3A (2004)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	1453.23	163.71	8.88	-
Trt	143.01	95.1004	1.50	0.1328
S2	40.8241	77.9797	0.52	0.6007
S8	54.3059	89.0987	0.61	0.5423
TRTS2	51.8859	95.4362	0.54	0.5867
TRTS8	69.5550	111.88	0.62	0.5342
LAMBDA	-	-	-	-

* = 0.05
** = 0.01

Table 3 shows that no significant statistical differences are evident with the different soil types and wheat's response to P variation. The cost difference between the VRT and SR treatments was ZAR43,08/ha less with VRT. Table 4 shows the response of canola to P variation on different soil types in K3A during 2005.

Table 4: Canola response to P variation on different soil types: K3A (2005)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	3000.49	176.89	16.96	-
Trt	-142.37	135.60	-1.05	0.2939
S2	-110.05	104.76	-1.05	0.2936
S8	110.14	123.29	0.89	0.3718
TRTS2	289.76	128.32	2.26	0.0241*
TRTS8	395.86	152.06	2.60	0.0093**
LAMBDA	-	-	-	-

* = 0.05
**=0.01

The average yields on the Glenrosa (Gs2) (S2) and Gamoep (Gm) (S8) soil types tested statistically significant for the difference between VRT and SR treatments. TRTS2 show that Gs2 soil produced 289,76 kg/ha more canola yield with the VRT treatment and for TRTS8, the Gm soil yielded 395,86 kg/ha more canola with VRT. The total fertiliser cost with the VRT was ZAR112,23/ha and with SR it was ZAR129,120/ha, resulting in a saving of ZAR16,89/ha. Table 5 presents the results for K3A during 2006 when wheat was planted.

Table 5: Wheat response to P variation on different soil types: K3A (2006)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	4518.90	332.45	13.59	-
Trt	295.65	190.19	1.55	0.1203
S2	122.67	152.21	0.81	0.4204
S8	217.30	177.65	1.22	0.2214
TRTS2	-60.5589	190.18	-0.32	0.7502
TRTS8	-269.66	222.86	-1.21	0.2265
LAMBDA	-	-	-	-

* = 0.05
** = 0.01

No significant statistical differences are evident from Table 5 for the response of wheat to P variation on different soil types during 2006 on field K3A. The same was evident during 2004 when wheat was also planted. During 2005 canola was planted and significant statistical differences were evident for TRTS2 and TRTS8 (Table 4). During this year the fertiliser cost of VRT was ZAR53,89/ha more than SR. Table 6 shows canola's response to P during 2004 on K5.

Table 6: Canola response to P variation on different soil types: K5 (2004)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	1333.33	60.8810	21.90	-
Trt	25.4782	54.9464	0.46	0.6429
S4	94.2647	108.11	0.87	0.3833
S13	-202.07	72.2013	-2.80	0.0052**
TRTS4	136.20	112.21	-1.21	0.2250
TRTS13	211.91	108.92	1.95	0.0518*
LAMBDA	-	-	-	-

* = 0.05
**=0.01

Only the Etosha (Et) soil type (S13) shows significant statistical results. The Glenrosa (Gs1) soil type (the base soil type) resulted in 202,07 kg/ha more canola than the Et soil with the SR treatment. The VRT treatment on the Et soil show a positive coefficient and this means that the yield was 211,91 kg/ha more than with the Gs1 soil with VRT (Et: VRT–SR minus Gs1: VRT–SR). The cost saving on fertiliser with the VRT was ZAR3,84/ha. Table 7 shows the response of wheat to P variation on different soil types for K5 during 2005.

Table 7: Wheat response to P variation on different soil types: K5 (2005)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	5542.73	167.02	33.19	-
Trt	80.6799	151.64	0.53	0.5947
S4	-8.6146	315.70	-0.03	0.9782
S13	-175.16	180.44	-2.63	0.0085**
TRTS4	-184.49	324.99	-0.57	0.5703
TRTS13	375.84	290.53	1.29	0.1959
LAMBDA	-	-	-	-

* = 0.05
**=0.01

Table 7 shows that the only significant statistical difference is that of the Etosha (Et) soil type (S13) and the Glenrosa (Gs1) soil yielded 175,16 kg/ha more wheat with the SR treatment than the Et soil, but the fertiliser cost of VRT was ZAR32,15/ha less than SR. Table 8 summarises the results during 2006 on K5.

Table 8: Barley response to P variation on different soil types: K5 (2006)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	4405.22	398.60	11.05	-
Trt	-472.23	250.08	-1.89	0.0591
S4	-39.584	287.60	-0.14	0.8905
S13	-963.26	207.78	4.64	<0.0001***
TRTS4	25.4132	306.34	0.08	0.9339
TRTS13	1360.58	328.96	4.14	<0.0001***
LAMBDA	-	-	-	

* = 0.05
**=0.01
***=0.0001

As in the case of 2004 (Table 6) and 2005 (Table 7) the only significant statistical difference is evident with the Etosha (Et) soil type (S13). The SR treatment on the Et soil shows a negative coefficient and this means that the Glenrosa soil type produced 963,26 kg/ha more barley than the Et soil. With the VRT treatment (TRTS13) the coefficient is positive and this means that the Et soil produced 1 360,58 kg/ha more barley than the Glenrosa soil type with the VRT. When looking at the results it looks like the Et soil reacted better than the Glenrosa soil with the VRT treatment. The total fertiliser cost with the VRT was ZAR232,17/ha and with SR it was ZAR50,84/ha, resulting in ZAR181,87/ha higher fertiliser cost for VRT. Table 9 shows the results of K7A during 2004.

Table 9: Canola response to P variation on different soil types: K7A (2004)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	1210.82	136.23	8.89	-
Trt	129.12	82.3744	1.57	0.1172
S2	-19.715	45.7369	-1.09	0.2772
S4	-56.9582	82.1583	0.69	0.4882
S11	146.82	55.6569	2.64	0.0084**
TRTS2	-51.8126	98.9845	-0.52	0.6007
TRTS4	83.4732	93.8884	0.89	0.3741
TRTS11	-98.2111	82.3595	-1.19	02332
LAMBDA	-	-	-	-

* = 0.05
**=0.01

When looking at Table 9, the only significant statistical difference was obtained with the Cartref (Cf) soil type (S11) and the result showed that 146,82 kg/ha more canola yield was produced than the Glenrosa soil type under the SR treatment. The fertiliser cost difference between VRT and SR was ZAR74,82/ha more with VRT. Table 10 shows the response of wheat to P variation on different soil types during 2005 on K7A.

Table 10: Wheat response to P variation on different soil types: K7A (2005)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	5025.49	215.33	23.34	-
Trt	280.87	170.01	1.65	0.0987
S2	102.45	111.59	0.92	0.3587
S4	12.8689	197.37	0.07	0.9480
S11	136.70	141.49	0.97	0.3341
TRTS2	-248.79	219.30	-1.13	0.2567
TRTS4	31.7960	226.13	0.14	0.8882
TRTS11	-143.69	202.86	-0.71	0.4788
LAMBDA	-	-	-	-

* = 0.05
**=0.01

Table 10 shows that no significant statistical differences were obtained during 2005 with the response of wheat to P variation on different soil types for K7A. VRT resulted in a saving of ZAR21,23/ha in fertiliser cost. The response of barley to P variation during 2006 can be seen in Table 11.

Table 11: Barley response to P variation on different soil types: K7A (2006)

	Regression output			
	REML			
	Spherical			
	Cf	**Std Err.**	**t-Value**	**Pr>|t|**
Constant	2852.22	109.83	25.97	-
Trt	-43.4630	111.81	-0.39	0.6975
S2	-43.1446	73.2763	0.59	0.5561
S4	-48.3742	126.67	0.38	0.7026
S11	-91.4459	88.6752	-1.03	0.3026
TRTS2	187.37	142.37	1.32	0.1883
TRTS4	152.92	145.13	1.05	0.2922
TRTS11	251.85	130.39	1.93	0.0536
LAMBDA	-	-	-	-

* = 0.05
**=0.01

As was the case during 2005 with wheat, the results of the response of barley to P variation (Table 11) also show no significant statistical differences during 2006. The fertiliser cost was ZAR76,85/ha more with VRT. Annexure 1 gives a summary of the statistical mean yield and difference between VRT and SR fertiliser costs.

6. Conclusion

The spherical model for REML was the most appropriate for use in each of the four fields during the three years under review. The results of this study could not generate a general conclusion that yield response to fertiliser depends on a specific soil type, because yields and profits were higher in some soil types in certain years and lesser in other years. It can thus be concluded that yield responses to P and profits differ from year to year and also within the crop rotation system (wheat, canola and barley). The Glenrosa (Gs1 to Gs7) soil type was expected to perform better than the other soil types due to the fact that this soil is a higher potential soil for annual dry land crop production. However, this was not the case for all the fields under observation.

In field L2, the Glenrosa (Gs3) soil produced 271,04 kg/ha more wheat than the Coega (Cg) (S12) soil with the SR treatment in 2004. When the VRT treatment was used the Cg soil (TRTS12) produced 300,21 kg/ha more wheat than the Gs3 soil. According to the results, the Cg soil reacted better with the VRT treatment (see Table 1). In the same year, the Glenrosa (Gs1) soil resulted in 202,07 kg/ha more canola than the Etosha (Et) soil with the SR treatment in field K5. With the VRT treatment the Et soil produced 211,91 kg/ha more canola than Gs1 (Table 6).

Although three different crops were planted on field K5 during 2004, 2005 and 2006, statistical significance differences are evident for the same soil type namely Etosha (Et) (S13). The results during 2005 (Table 7) show that Gs1 produced 175,16 kg/ha more wheat than the Et soil with the SR treatment and in 2006 Gs1 produced 963,26 kg/ha more barley. When the VRT treatment was used during 2006 (Table 8) the Et soil (TRTS13) produced 1 360,58 kg/ha more barley than the Gs1 soil with the VRT treatment. The results of 2004 and 2006 shows that the Et (TRTS13) soil type reacted better than the Gs1 soil with the VRT treatment.

The results achieved on K7A indicated that during 2004 (Table 9) canola’s response to P show the only statistical significant difference on the Cartref (Cf) (S11) soil type and this soil produced 146,82 kg/ha more canola than the Glenrosa (Gs1) soil. The results achieved for 2005 and 2006 (Tables 10 and 11) showed that the response of wheat and barley to P was not statistical significant for any of the soil types.

The 2005 production year showed no statistical significant differences for canola response to P on different soil types (Table 2). However, the results of field K3A indicate that the only statistical significant difference is evident during 2005 (Table 4). Glenrosa (Gs2) (TRTS2) soil produced 289,76 kg/ha more canola when the VRT treatment was used and the Gamoep (Gm) (TRTS8) soil produced 395,86 kg/ha more canola.

It is thus evident that winter grain response to P on different soil types showed significant differences between the mean yields (kg/ha) achieved with the VRT and SR treatments and the best statistically results were achieved on L2 (2004) (Coega soil), K3A (2005) (Glenrsa and Gamoep soils) and K5 (2004 and 2006) (Etosha soil in both years).
The VRT resulted in fertiliser cost savings during all three production years on field L2. The results of field K3A and K5 showed cost savings in fertiliser during 2004 and 2005 with VRT, but during 2006 the fertiliser cost was more with VRT. The only saving in fertiliser cost on field K7A was during 2005. This means that three of the four fields showed fertiliser cost savings with VRT during two of the three production years. If less fertiliser is required with VRT, less interest will be paid on production credit and with higher yields achieved with VRT, more profit is made.

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ANNEXURE 1: STATISTICAL MEAN YIELD AND FERTILISER COSTS (FOUR FIELDS AND THREE YEARS)

YEAR AND FIELD	**MEAN YIELD (t/ha)**		**FERTILISER COSTS (ZAR*/ha)**	
2004	**VRT**	**SR**	**VRT**	**SR**
L2	1,62	1,59	85,67	125,50
K3A	1,89	1,69	127,60	170,68
K5	1,37	1,40	372,66	376,50
K7A	1,54	1,53	298,21	223,39
2005				
L2	2,57	2,86	131,91	134,50
K3A	3,14	3,00	112,23	129,12
K5	5,62	5,80	105,92	138,07
K7A	5,36	5,21	107,89	129,12
2006				
L2	0,00**	0,00**	53,53	54,56
K3A	5,20	4,83	109,69	55,80
K5	4,62	5,21	232,71	50,84
K7A	2,97	2,77	127,69	50,84

*South African Rand

**The yield data for 2006 went corrupt due to a faulty cable and could not be used