Nitrogen and potassium nutrition – a balancing act
Part 1: Plant and tuber growth

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The potato is a highly productive crop with rapid dry matter accumulation over a short period of time. However, it has a high nutrient demand and to ensure successful production, sufficient nutrients need to be supplied by means of a carefully designed fertiliser programme.

Due to their shallow, poorly developed root system and fast dry matter accumulation, potatoes have a rapid uptake of more nutrients within a short time compared to most other crops, such as cereals.

For sustainable potato production, nutrient management programmes must therefore be carefully planned and implemented to ensure that production conditions meet crop requirements in an effective manner. Production practices should be both economically and technically viable, but at the same time have little negative impact on the environment.

Management practices of N and K

Nitrogen (N) management practices have been studied thoroughly in the past, due to the high cost of N and increasing environmental concerns over the impact of leaching of N on the environment and pollution of groundwater resources. Although potatoes also have a high potassium (K) requirement, the management thereof has received less attention than that of N. Potassium plays an important role in growth and yield, and in potatoes it is particularly vital to tuber quality.

For a progressive crop lifecycle and sustainable potato production, best management practices should be developed for both N and K. In this regard, literature suggests that not only are the levels of nutrients in the soil of interest, but the interaction between nutrients such as N and K is also important since yield response to K can depend on the N status in the soil. For example, one study showed that the application of K without any N, resulted in no significant effect on potato yield.

For the full exploration of a crop's potential, it is necessary to provide a balanced nutrient programme, including optimal amounts and ratios of N to K to ensure high yield and the best quality potatoes. Fertiliser requirements of older South African potato cultivars such as BP1 and Up-to-Date, have been studied extensively and were used to develop the current fertiliser guidelines. However, little local research on potato nutrition has been conducted over the past decade, and there is a need to optimise fertiliser guidelines for some of the newer cultivars available.

Aspects such as nutrient ratios and the interaction effect of applied N and K, are often not taken into consideration in the current fertiliser guidelines. Furthermore, nutrient requirements may vary between cultivars, and yield and quality attributes of a specific cultivar may differ according to climate conditions and production practices.

Impact on short-season cultivars

A study was conducted with the aim of examining the effects of N and K levels, as well as ratios at constant phosphorous (P) levels on

Figure 1: A view of a replication of the field trial at UP's experimental farm, with cultivars Innovator (left) and Lanorma (right).

the growth, tuber yield, and quality of two more recently introduced, short-season potato cultivars – Lanorma and Innovator – under local conditions.

To study these, pot and field trials were conducted on the Hatfield Experimental Farm of the University of Pretoria (UP) with the following specific objectives:

- To investigate the effects of progressive levels of N and K on the growth, yield, and quality of the two selected cultivars.
- To determine whether there are optimal N to K fertiliser ratios for best tuber yield, size distribution, and quality.

Since the results of the pot and field trials were comparable, only the field trial results are presented in this article.

Table 1: Nutrient status of soil before starting the field trial.

Nutrient	mg/kg-1	cmol/kg-1	% of CEC
NO_3-	4.33	-	-
NH_4+	2.80	-	-
P	28.4	-	-
K	65.2	0.1672	5.4
Ca	405.5	2.0273	65.3
Na	1	0.0043	0.1
Mg	108.7	0.9059	29.2
Total CEC		3.1048	

Table 2: Fertiliser treatment combinations and corresponding N:K ratios.

Treatment number	N (kg/ha-1)	K (kg/ha-1)	N:K ratio
1	160	160	1.00
2	160	230	0.70
3	160	300	0.53
4	230	160	1.44
5	230	230	1.00
6	230	300	0.77
7	300	160	1.88
8	300	230	1.30
9	300	300	1.00
10	160	0	-

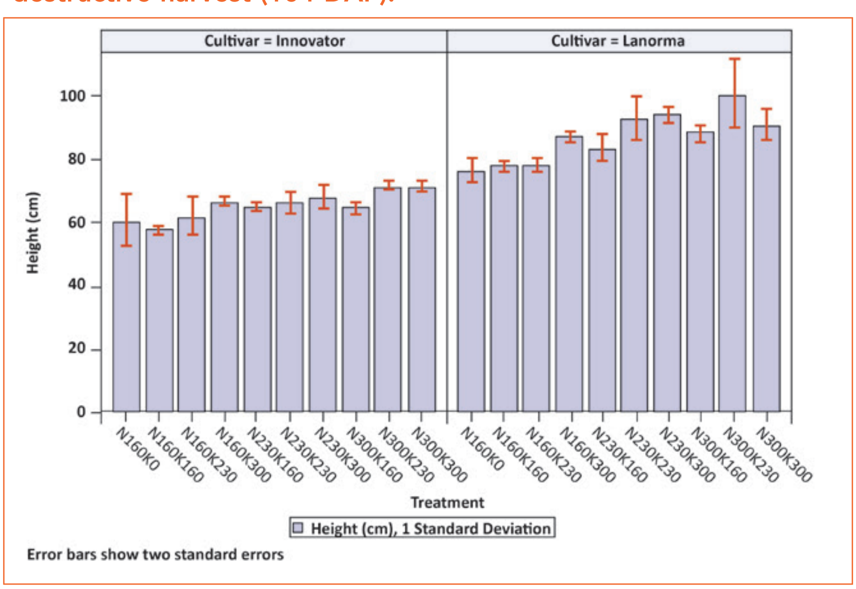
Methodology

The field trial was conducted during the 2016/17 summer season on sandy soil with low cation exchange capacity (CEC) of 3.1 as can be seen in *Table 1*. The same nutrient levels of 160, 230, and 300 kg/ha-1 were used for both N and K. The nine N x K treatment combinations provided seven N:K-level ratios. Ratios are expressed as the quantity of N (kg/ha-1) relative to the quantity of K (kg/ha-1). *Table 2* shows the fertiliser treatments and the corresponding N:K ratios.

A control treatment of 160 kg/ha-1 of N and 0 kg/ha-1 of K was also added to evaluate the responsiveness of the two cultivars to K. The experimental layout was a split-plot, randomised complete block design with 20 treatment combinations and three replications. Cultivars were allocated to the main plots and N x K treatment combinations to sub-plots.

Single superphosphate (14% P) was broadcast at a rate of 70 kg/ha-1 P prior to planting and was incorporated into the soil using a harrow disk. N and K fertiliser dressings were split into two, with the first half applied in the plant rows at planting, and the remainder as a top dressing at 14 days after emergence (DAE).

Figure 2: Plant height per treatment and per cultivar at the final destructive harvest (104 DAP).



The N source was limestone ammonium nitrate (LAN 28%), and potassium sulphate (K_2SO_4) was used as the K source.

Destructive growth analyses were performed four times during the growing season – at 41, 62, 83, and 104 days after planting (DAP). The following parameters were recorded: stolon length, tuber number, plant height, leaf dry mass, stem dry mass, and tuber dry mass. Tuber yield and quality tests were performed after crop senescence.

Results and discussion

This article focusses on crop growth responses to the different N x K treatment combinations and therefore, only the results from the growth analysis are presented and discussed. Final tuber yield and quality results will be presented in a following article. Since similar trends in crop response to treatments were observed across the four destructive harvests, only results from the final harvest (104 DAP) are presented.

Plant height response of the two cultivars to N and K treatments are presented in *Figure 2*. Lanorma plants were consistently taller than those of Innovator at corresponding N x K treatments. For both cultivars, plant height tended to increase with increments in both nutrients. Generally, plant height increased with a rise in N level at the same K level. It is also noteworthy that within each level of N, plant height generally increased with a rise in K levels – and thus a decrease in the N:K ratio.

Figure 3 shows the dry leaf mass per cultivar and treatment combination at the final destructive harvest (104 DAP). It is clear that, similar to plant height, dry leaf mass for both cultivars increased along with increases in N and K levels. It is known that the N rate affects leaf growth and number, thus higher N levels are expected to result in higher leaf mass.

Both cultivars, especially Innovator, had already started senescing at the time of the fourth harvest. This was more prominent with the low N treatments, which confirms that senescence commenced earlier for N-deficient treatments, while high N rates delayed crop senescence.

Stolons tended to be longer with an increase in N levels, although trends were not consistent. Lanorma had longer stolons (an average of 8.0 cm) than Innovator (4.5 cm), which seemed to initiate tubers just above and close to the mother tuber. The longer stolons of Lanorma, especially at high N rates, suggest that tubers may be borne close to the soil surface or the side of the ridge. Therefore, it is recommended that special care be taken when making and maintaining plant ridges to prevent exposure of tubers to sunlight, which could result in greening, tuber moth damage, and lower tuber quality.

Figure 3: Dry leaf mass per treatment and per cultivar at the final destructive harvest (104 DAP).

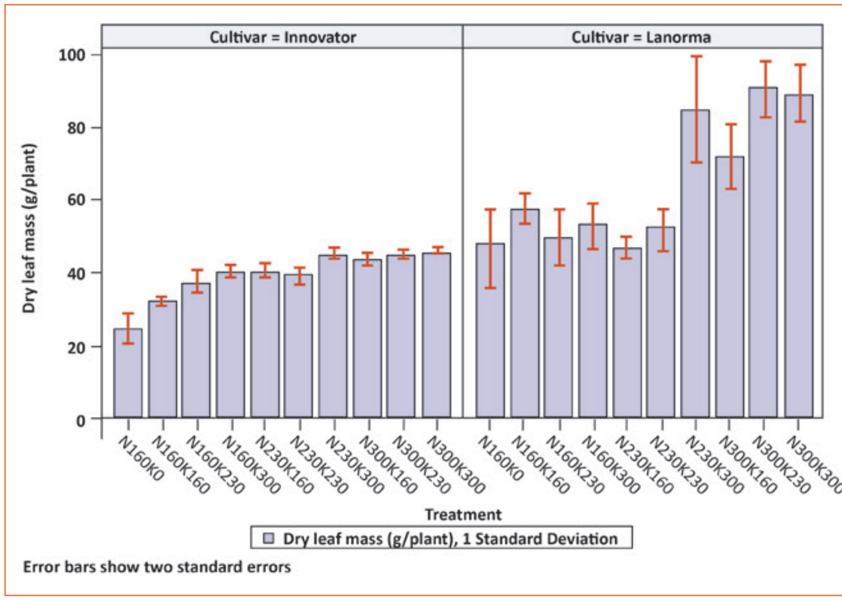


Figure 4: Dry tuber mass per treatment and per cultivar at the final destructive harvest (104 DAP).

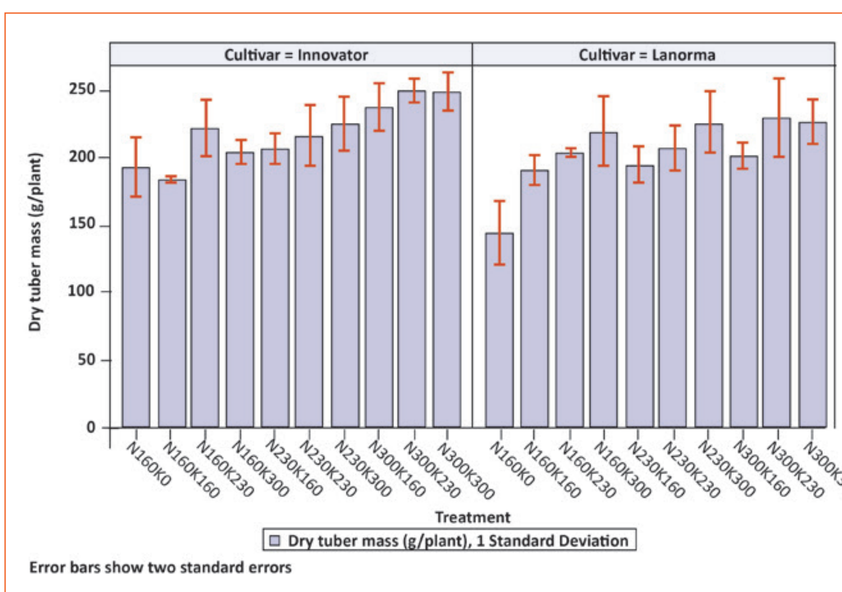


Table 3: Dry tuber yields (g/plant^{-1}) at different N and K levels (with corresponding N:K ratios) for cultivars Innovator and Lanorma at the final destructive harvest (104 DAP).

Treatment	N:K ratio	Innovator tuber yield	Lanorma tuber yield
N 160, K 160	1	183.77 e	190.27 c
N 160, K 230	0.70	221.97 bac	203.80 bac
N 160, K 300	0.53	204.50 edc	219.33 bac
N 230, K 160	1.44	206.50 edc	194.47 bc
N 230, K 230	1	215.93 bdc	206.8 bac
N 230, K 300	0.77	225.03 bac	225.73 ba
N 300, K 160	1.88	237.80 ba	201.23 bac
N 300, K 230	1.30	244.67 a	228.73 a
N 300, K 300	1	248.83 a	226.57 ba
N 160 only	-	191.57 ed	143.34 d
LSD		28.08	32.713
CV		7.56	9.4135

**Values followed by the same letter within a column are not significantly different.*

Both cultivars finished initiating tubers by the first harvest (41 DAP) and tuber numbers per plant remained fairly constant for the rest of the growing season (data is not presented). There were no clear fertiliser treatment effects on tuber numbers, but the two cultivars differed significantly in average tuber numbers across all fertiliser treatments, with 9.5 per plant for Lanorma and 6.8 for Innovator.

Lanorma and Innovator tuber yield

Regarding tuber yield per plant, Innovator displayed a trend of rapid dry tuber mass increase at higher N levels between the third and the fourth harvests. This suggests that for this early maturing cultivar, most assimilates were rapidly translocated to the tubers from early in the growing season and by the third harvest (83 DAP), most tuber filling had already occurred, while Lanorma continued tuber filling until the fourth harvest (104 DAP).

Tuber yields per plant displayed a tendency to increase as K was increased for each N level, as was the case for leaf dry mass, especially at the low (160 kg/ha^{-1}) and intermediate (230 kg/ha^{-1}) levels of N (*Figure 4*). However, at the highest N level of 300 kg/ha^{-1}, tuber yield only tended to increase with rising K levels up to 230 kg/ha^{-1}, whereafter yields levelled off for both cultivars.

For both cultivars, the N x K treatment combinations that delivered the highest dry tuber yields generally corresponded with N:K ratios ranging between 0.77 and 1.3 at the intermediate and highest levels of N (*Table 3*). However, at the lowest N and K levels, N:K ratios did not seem to have a clear effect on tuber yield, which might suggest that N:K ratios are more influential on yield when none of the two nutrients are severely deficient.

Summary and conclusions

- The two cultivars proved to differ in final plant height, with Lanorma having taller plants than Innovator for most of the growing season. For both cultivars, plant height tended to increase with increments in both N and K.
- Dry leaf mass for both cultivars increased with increments in N and K levels, and leaf mass tended to increase with each increment in K at a specific N level.
- Stolons showed a tendency to be longer with an increase in N levels, but the trends were not consistent. Lanorma had a longer average stolon length than Innovator, which may require more cautious management during ridging to avoid tuber exposure and damage.
- There were no clear fertiliser treatment effects on tuber numbers per plant, but Lanorma had on average significantly more (9.5) tubers per plant than Innovator (6.8).
- Although both Innovator and Lanorma are classified as short-season cultivars, clear differences in growth patterns were noted between the two.
- Tuber yields per plant generally increased with rising N and K levels. Dry tuber yields also tended to ~~multiply~~ as K was increased at each specific level of N, which implies that yields responded to changes in N:K ratios. The highest tuber yields were generally achieved at N:K ratios, ranging between 0.77 and 1.3 at the intermediate and highest N levels.
- N:K ratios were more influential on yield when N and K levels were not severely deficient.

These preliminary growth results suggest that fertiliser programmes should not only consider absolute N and K levels, but also the N:K ratios, as there is an interaction effect between the two nutrients. This effect will likely be more important for low CEC soils with low nutrient release capacity.

Final tuber yield and quality results for this study will be presented in a follow-up article.

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