Research Findings

Photo 1. Symptoms of K deficiency on potato plant development in the field. Photo by W. Grzebisz.

Potassium as a Factor Driving Nitrogen Use Efficiency - The Case for Potatoes Cultivated on Light Soil

Grzebisz, W.[(1)], W. Szczepaniak[(1)], M. Biber[(1)], and K. Przygocka-Cyna[(1)]

Abstract
Potassium (K) is generally considered as a nutrient which significantly affects nitrogen use efficiency (NUE). This relationship was tested in a field experiment with rain-fed potatoes cultivated on a light soil. The experiment consisted of four K doses: 0, 80, 160, or 240 kg K_2O ha^{-1} and two N doses: 120 or 160 kg N ha^{-1}. The effect of residual K was tested against the background of 90 kg K_2O ha^{-1} applied to winter wheat sown consecutively. Potato yields responded positively to increasing K dose, especially in 2013, a year characterized by mild water stress in the summer months. A positive impact of K application on tuber yields was obtained in relation to the increased N dose. The harvested tuber yield showed a linear response to increasing N uptake but curvilinear to increasing K uptake, with an optimum at

[(1)]Poznan University of Life Sciences, Department of Agricultural Chemistry and Environmental Biogeochemistry, Poland
Corresponding author: witegr@up.poznan.pl

170 kg K ha^{-1}. Thus, potato fertilized with 160 K_2O ha^{-1} and with 160 kg N ha^{-1} reached highest productivity. However, the most efficient use of applied nutrients, as demonstrated by analyses of the agronomic index of NUE, was a fertilizer combination of 160 K_2O ha^{-1} and 120 kg N ha^{-1}. Elevated amounts of K fertilizer resulted in some increase of the soil K available pool. This pool in 2013, following the 2012 potato crop, was high enough to significantly increase the productivity of the consecutive winter wheat, but a similar effect did not occur in the winter of 2014.

Introduction

Potassium (K) is one of the seventeen mineral nutrients essential for growth and reproduction of all higher plants and is required in especially large amounts by crop plants. There are at least three levels of evaluation of K impact on plant growth. The first focuses on its pure physiological functions, which includes its importance in mitigating abiotic and biotic stresses. Potassium can now be considered as a primary mineral nutrient controlling crop plant response to various environmental stresses (Rengel and Damon, 2008; Zörb *et al.*, 2014). The second level of K evaluation in crop production is its impact on yield development during plant growth. Shortage of K, as has been recently been reported by Grzebisz *et al.* (2013), reduces the physiological sink size in crop plants. Supplying crop plants with adequate K, covering their needs during critical stages of yield formation, can at least partially overcome water shortage. The third level of K importance in crop production relates to its management in the soil-crop system. Since K mobility may vary among different soils, budgeting for K needs should be considered against the background of crop rotation (Grzebisz and Diatta, 2012).

Potassium, despite its importance for the cultivation of crop plants, is frequently omitted by farmers in their fertilizing plans, without considering the current soil K status. At the same time and too often, the dose of applied nitrogenous fertilizers is not adjusted, resulting in a widening N:K ratio in the soil. Such fertilizing policy has brought about serious unfavorable economic consequences not only at the farm level, but also within regional and countrywide systems. A classic example of this was in the Central European countries, which underwent an economic revolution during the last decade of the 20th Century, when the shift to the free-market economy resulted in an upsurge of production costs, with an emphasis on fertilizer price. Consequently, consumption of all fertilizers decreased drastically, particularly that of K and P. As a result, the N:K ratio of fertilizer application widened rapidly from 1:0.8 to 1:0.3. In some countries, like Poland and Hungary, this negative trend came to a halt at this level, but in others, it decreased even further to a ratio of 1:0.1 (Grzebisz *et al.*, 2010).

In crop cultivation oriented to high yields, K supply to growing plants plays a decisive role in productivity. The first consequence of low K supply is a decreasing rate of nitrate-nitrogen uptake, which in turn reduces plant growth. In addition, the dynamics of N uptake is not synchronized with crop growth. Consequently, its imbalanced supply depresses the basic yield components. Potassium shortage during the key stages of yield development leads to a decreased number of ears in cereals and/or number of grains per ear (Grzebisz *et al.*, 2013). In potatoes, it results in low stem biomass, reduced tuber number, and/or a low rate of tuber growth, and even tuber cracking (Photos 1 and 2).

Potato is one of the most important staple food crops throughout the world, also including warm areas. As a starch crop, potato needs to be adequately supplied with water and K. Therefore, highest yields are harvested on well fertilized and irrigated fields, almost complying with the tuber yield potentials. Under rain-fed conditions, typical to North and Central European countries, meeting the yield potential becomes complex. Here, tuber yields depend on three major factors: climate, soil fertility, and quality of crop management. Thus, the potential yield of potatoes in Ireland (wet Atlantic climate) is assessed at the level of 72.4 Mg ha^{-1} (Supit *et al.*, 2010). For Germany, which lies at the borderline between the wet Atlantic and humid continental climate, potato potential is estimated at the level of 60.9 Mg ha^{-1}. In countries

Photo 2. Symptoms of K deficiency on tuber development and quality (cracked vs. normal tubers). Photo by W. Grzebisz.

east of Germany, such as Poland and Bulgaria, potential yields are much lower, amounting to 39.7 and 31.6 Mg ha^{-1}, respectively, mainly due to their continental climate. Practically, however, tuber yields tend to be significantly lower than the potential (Table 1). Excluding the climatic factor, the differences between potential and practical yields, as well as between countries, can be attributed to soil quality and imbalanced nutrient management (Grzebisz and Diatta, 2012).

Table 1. Statistical characteristics of potato yield in Central-Eastern European countries, Mg ha^{-1}, mean for 2003-2012.

Characteristics	Czech R.	Germany	Hungary	Poland	Romania
Mean	25.57	41.78	24.24	18.35	14.15
SD[1]	2.94	3.68	2.88	3.84	1.72
CV[2] (%)	11.5	8.8	11.9	20.9	12.1

Note: [1]SD: Standard deviation; [2]CV: Coefficient of variation.

The key objective of this study was to demonstrate, using experimental findings, that optimizing fertilizer K and N rates can be an important factor increasing nitrogen use efficiency (NUE) and, at the same time, improving yields of potato grown on sandy soils. The secondary objective was to evaluate the residual effect of K fertilizer, remaining in the soil following a potato crop, on consecutive winter wheat productivity.

Materials and methods

The impact of K fertilization, as considered against the background of N supply and NUE, was investigated and evaluated in potato over two consecutive growing seasons: 2012 and 2013 for potato, and 2012/13 and 2013/14 for the residual K effect on winter wheat productivity. These studies were carried out on a private farm at Donatowo (52°05 N 16°52 E), 50 km west of Poznan, Poland. The field experiment was established on a soil originating from loamy sand underlined by sandy loam and classified as an Albic Luvisol. Soil K fertility level, as indicated by analysis for soil available K, was measured as satisfactory for producing a high yield of tubers (186 mg K_2O kg^{-1} soil in 2012 and 154 mg K_2O kg^{-1} soil in 2013). The content of available P was very high in both years and magnesium was very high in 2012 and high in 2013.

A factorial experiment was set up consisting of eight treatments with four doses of K_2O application (0, 80, 160, or 240 kg K_2O ha^{-1} and two doses of N application (120 or 160 kg N ha^{-1}), and an absolute control (without N and K application). Each of the treatments was replicated four times. The two tested crops were cultivated in rotation: potato (variety Bellarosa), followed by winter wheat (variety Muszelka). An individual plot size for potato was 100 m^2. Before planting, N in the form of ammonium nitrate - NH_4NO_3 (34% N) and K as potassium chloride (KCl) were applied to the soil. Phosphorus was applied as di-ammonium phosphate (DAP) according to soil analysis. The potato seed-tubers were sown during the third week of April. Harvest took place during the third week of September, from harvest sampling plots of 14 m^2. After the potato harvest, the plots were divided into two sub-plots of 37.5 m^2, treated with or without freshly applied K fertilizer as KCl at a rate of 90 kg K_2O ha^{-1}. Phosphorus was applied as DAP, according to soil analysis.

The winter wheat crop was sown during the first week of October, just after the potato harvest. Nitrogen in the form of NH_4NO_3 (34% N) was applied at a rate of 180 kg N ha^{-1}, split into three dressings and applied at i) spring regrowth (50%); ii) the beginning of shooting (25%); and, iii) at heading (25%). The crop was harvested at the end of July. Harvest sampling was exercised from 15 m^2 plots using a plot combine harvester. Total seed yield was adjusted to 14% moisture content.

Nitrogen concentration in plant samples was determined by the standard macro-Kjeldahl procedure on dried then finely ground plant material. Potassium concentrations in the dried and ground plant tissues were determined by flame photometry, following ashing of the dried plant material in a muffle furnace at 640°C, then releasing the K into solution using 33% nitric acid (HNO_3). Results are expressed on a dry matter basis. Amounts of nutrients in plant organs and entire plants were calculated by multiplication of tissue concentration and respective biomass. Measurement of residual available K in soil following the potato harvest was carried out using the Egner Rheim method: soil samples were extracted with 0.04M calcium lactate at a pH of 3.5-3.7 using hydrocloric acid (HCl). This method is particularly suitable for relatively acidic soils.

Nitrogen fertilizer use efficiency indices were expressed using the following equations:

- Agronomic N use efficiency (kg tubers kg^{-1} N):
  $AEN = (Y_{Ni} - Y_0)/N_d$
- Apparent N recovery (%):
  $NR = (NU_{Ni} - NU_0)/N_d \cdot 100$
- Physiological N use efficiency (kg tubers kg^{-1} N):
  $PhEN = (Y_{Ni} - Y_0)/(NU_{Ni} - NU_0)$

Unit potassium uptake (UKU) and unit nitrogen uptake (UNU) were calculated using the formula:

$UKU = KU_i/Y_{Ni}$ (kg K Mg^{-1} tubers);

$UNU = NU_i/Y_{Ni}$ (kg N Mg^{-1} tubers).

Where:

- Y_{Ni}: Yield of tubers harvested from determined doses of N (kg ha^{-1})
- Y_0: Yield of tubers harvested from the absolute control (kg ha^{-1})
- N_d: Nitrogen fertilizer dose (kg N ha^{-1})
- KU_i: Potassium uptake by crop from determined doses of K (kg ha^{-1})
- NU_i: Nitrogen uptake by crop from determined doses of N (kg ha^{-1})
- KU_0: Potassium uptake by the crop in the absolute control (kg ha^{-1})
- NU_0: Nitrogen uptake by the crop in the absolute control (kg ha^{-1})

The experimentally obtained data were subjected to the conventional analysis of variance using computer program STATISTICA 10. The differences between treatments were evaluated with Tukey's test.

Results and discussion

Yield of tubers

The course of weather conditions during potato vegetation is generally considered as the decisive factor for plant growth and tuber production (Supit *et al.*, 2010). During the study, 2012 (the first year) can be considered as wet. In three consecutive months, i.e., June, July and August, the total sum of precipitation was 312 mm. It was higher by 110 mm than the long-term average. In 2013, the course of weather was different; a wet June with 90 mm of precipitation was followed by two semi-dry months with a total sum of about 100 mm. In spite of the relatively adequate amount of precipitation during the season, its distribution was only moderately suitable for potato growth. In the summer months, the amount of precipitation was below the long-term averages and inadequate to cover water requirements of this crop during critical stages of tuber growth.

In both years, tuber yield was significantly affected by interaction between the P and N doses of application. In 2012, a year with ample water supply to plants during tuber growth, yield harvested in the absolute control treatment (no fertilizer application) amounted to 31 Mg ha^{-1} (Fig. 1). This level of yield implicitly indicates preliminary high soil fertility and very suitable conditions for potato growth. For comparison, the country average yield of potatoes during this year only amounted to 24.4 Mg ha^{-1}, which was the highest in the last decade (FAOSTAT, 2014).

Nevertheless, the contribution of fertilizer application at this basal situation was obvious; application of N alone, at 120 or 160 kg ha^{-1}, brought tuber yield above 40 Mg ha^{-1} (Fig. 1). Potassium (K_2O) application at 80 kg ha^{-1} resulted in a small addition in the tuber yield only at the higher N level. Further

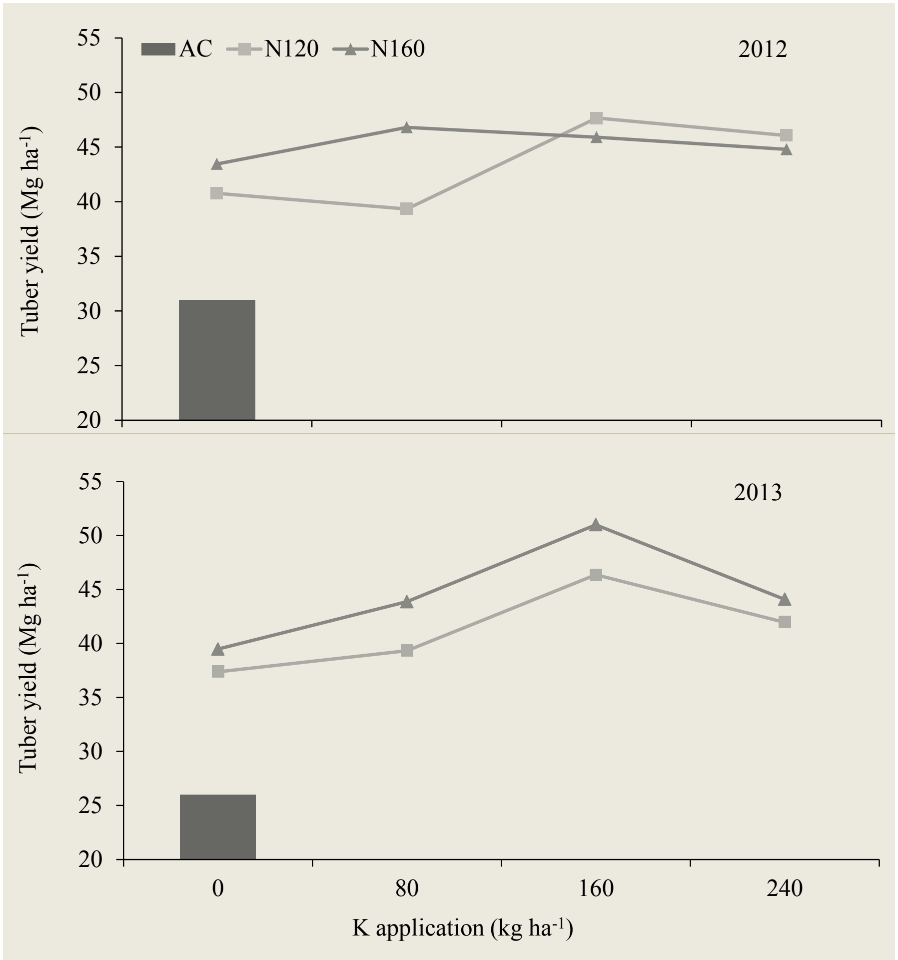

Fig. 1. Effect of K and N application on potato tuber yields in 2012 and 2013. AC: absolute control; N120 and N160: nitrogen application levels, kg N ha^{-1}.

increase of K application to 160 kg ha^{-1} elevated tuber yields to more than 45 Mg ha^{-1} at both N levels. Further increase of K application produced no further response. A detailed analysis of tuber fractions showed a dominance of large tubers, which contributed from 77% at the K control to 86% at the 240 K_2O ha^{-1} dose, when fertilized with 160 kg N ha^{-1}.

The second year of the study was less favorable for potato production. Yields harvested in the absolute control amounted to 27 Mg ha^{-1} (Fig. 1), compared to the country average yield of only 21.4 Mg ha^{-1} (FAOSTAT, 2014). However, tuber yield showed a significant response to fertilizer treatments. The harvested tuber yield gradually increased to a maximum (45 and 50 Mg ha^{-1}, at 120 and 160 kg N ha^{-1}, respectively) at 160 kg K_2O ha^{-1}, but declined significantly with further increase of fertilizer inputs. The significant impact shown here for N application at 160 kg ha^{-1} may be considered as optimal for high-yielding potato, regardless of the field location, as reported by Jamaati-e-Somarin *et al.* (2010) for Iran, Mustonen *et al.* (2010) for Finland and Tein *et al.* (2014) for Estonia.

The results presented here clearly explain controversies concerning impact of K fertilizing systems on potato tuber yields. In this study, experiments were conducted on light soil, but quite rich with available K. Thus, in the year with ample water supply during tuber growth and development (2012), yield positively responded to N application, which appeared the restrictive element. Contribution of K fertilizer was seldom significant (Fig. 1). An adequate supply of water and N was sufficient to exploit yield potential of the tested variety, assessed at the high level of 48 Mg ha^{-1}. Therefore, under favorable climatic conditions and satisfactory K soil availability, in agreement with reports for this crop in Great Britain (Allison *et al.*, 2001) and in Ethiopia (Ayalew and Beyene, 2011), further K application appears unnecessary. The same is also true with irrigated systems of potato production, as has been broadly documented by Hochmuth and Hanlon (2000).

On the contrary, for potatoes produced on sandy soils under unstable rain-fed conditions in 2013, where dependence on external supply of both fertilizers was obvious. A mild water stress in summer months implicitly underlined the impact of N application on tuber yield. However, an adequate administration of K fertilizer was required to fulfill the potential contribution of N availability. The same type of potato interactive response to K and N application has been observed by Sing and Lal (2012) in India. In that case, the optimum rates of N and K required to produce 40 Mg ha^{-1} of tubers were 225 kg N ha^{-1} and 150 kg K_2O ha^{-1}.

Nutritional status of plants at the stage of tubering

The stage of tubering is decisive for potato yields, as cardinal physiological factors, such as carbon source-sink relations and plant nutritional status, become deeply involved and interact. At this stage, N concentration in the whole plant was unaffected by either K or N application levels, in both years (Table 2), excluding a significant rise above the absolute control solely in 2012. The whole plant K concentration increased significantly in 2012 in response to the rising K (but not N) application level, but remained indifferent in 2013. Interestingly, mean N concentration in the whole plant was significantly smaller in 2012 (4.21%) than in 2013 (5.55%). On the contrary, mean K concentration in the whole plant was significantly greater in 2012 than in 2013, 4.86% vs. 3.60%, respectively.

Assuming adequate P availability, N:K ratio may serve as an indicator for the nutritional status of potato plants, with an optimum of around 0.88 (Haddock, 1961). During the wet 2012 summer, N:K ratio decreased from about 1 in plants that had received no K application to about 0.75 in plants with the higher level of K application (Table 2). The optimum ratio was obtained already at the low K application (80 K_2O ha^{-1}), indicating that optimal water status coincides with optimal nutritional status, and that nutritional requirements are at a minimum. Under the mild water stress during the 2013 summer, N:K ratio was stable and higher, 1.54, but still within the optimum range (Rosen,

Table 2. Nutrient concentration in the whole potato plant at tubering, % of DM.

K application	N application	2012			2013		
		N	K	N:K	N	K	N:K
kg K_2O ha^{-1}	*kg N ha^{-1}*	----------%----------			----------%----------		
0	120	4.23	4.00[a]	1.06	5.33	3.52	1.51
	160	4.30	3.88[a]	1.11	5.76	3.50	1.65
80	120	4.03	4.91[ab]	0.82	5.47	3.62	1.51
	160	4.49	4.81[ab]	0.93	5.57	3.68	1.51
160	120	4.12	5.46[b]	0.75	5.33	3.59	1.48
	160	4.46	5.55[b]	0.80	5.68	3.70	1.54
240	120	4.15	5.61[b]	0.74	5.35	3.82	1.40
	160	4.35	5.69[b]	0.76	6.11	3.79	1.61
Absolute control		3.72	3.87[a]	0.96	5.37	3.21	1.67
Means		4.21	4.86	0.88	5.55	3.60	1.54

Note: [a,b]: The same letter means a lack of significant difference between level of the treatment.

2001). The relatively high N:K ratio may indicate that under such circumstances, N uptake by potato plants was favored, while K acquisition encountered difficulties. Even though, there was a positive plant response to increasing K and N doses, finally leading to yield increase.

Nutrient accumulation in tubers

Nitrogen uptake significantly increased in response to N application (Fig. 2). This was clearly demonstrated in both years by the upsurge of N uptake to 75-120 kg N ha^{-1}) in plants fertilized solely with N, as compared with the absolute control (60-70 kg N ha^{-1}). In this respect, the interactions between K and N levels in N fertilized plants were less significant. In 2012, N uptake ranged at a narrow band between 95 to 120 kg N ha^{-1}; at the lower N application, N uptake gradually increased with the increasing K application, reaching a maximum at the highest K level. Nevertheless, at the higher N level, N uptake remained quite stable along the K application doses. In 2013, N uptake fluctuated a lot, particularly at the higher N application level. A significant peak was recorded, however, at K dose of 160 kg ha^{-1}. Nitrogen accumulated in the potato crop at harvest was linearly correlated with tuber yield (Fig. 2C). This relationship implicitly indicates that N, irrespective of year-to-year variability, was a factor limiting potato growth and yield.

On average, the total amount of K accumulated in potato was higher as compared to N (Fig. 3). Here, as well, the initial contribution of N fertilization was most significant for K uptake, as demonstrated by the absolute control. In both years, the higher N application level seemed to interrupt P uptake at the two upper levels of K application. The response of K uptake to its application level was unequivocal up to application level of 80 kg K ha^{-1}. The maximum K uptake in both years occurred at the combination of 120 and 160 kg ha^{-1}, N and K application levels, respectively,

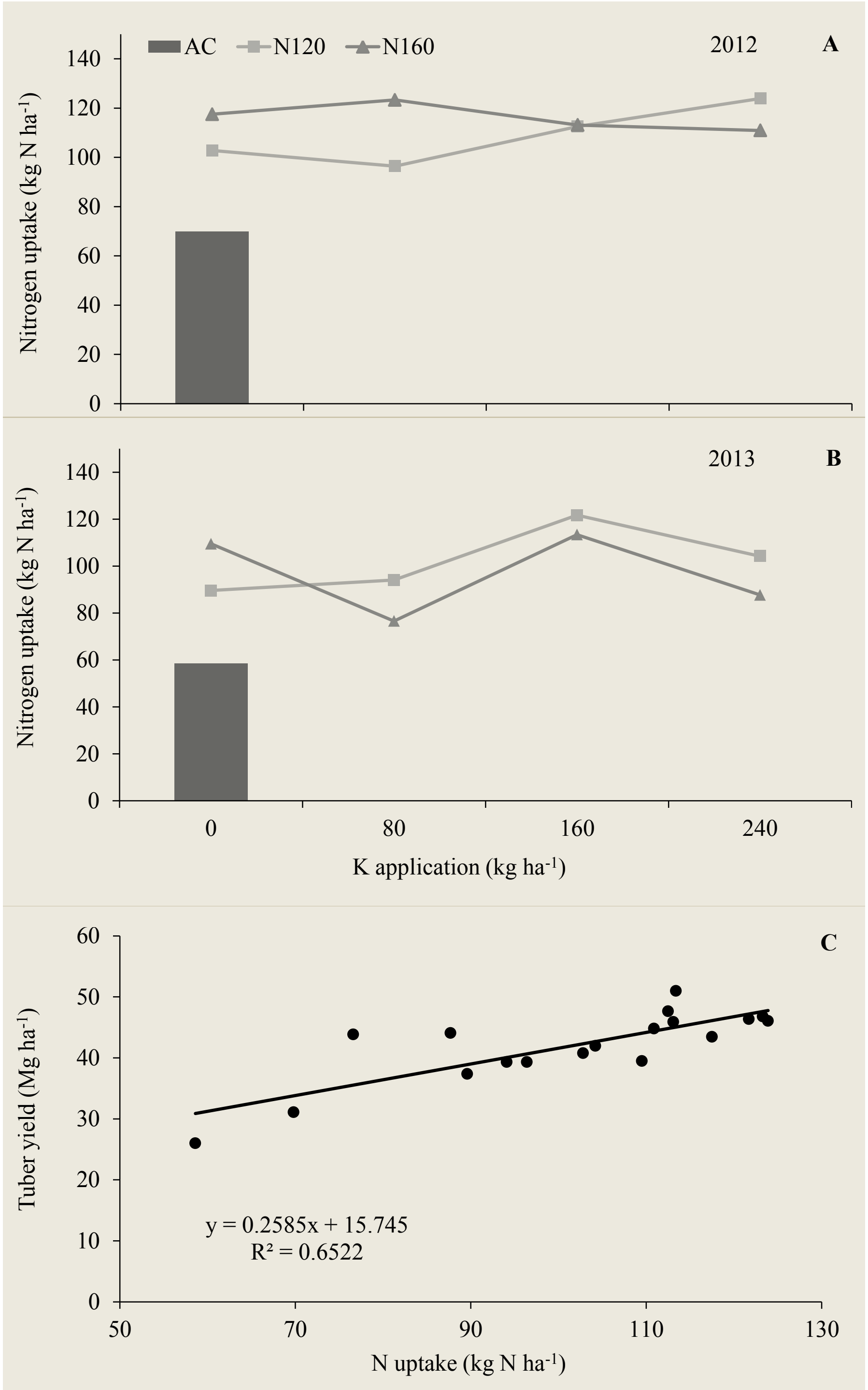

Fig. 2. Effects of K and N application on N uptake by potato crop in 2012 (A) and 2013 (B). Effect of N uptake (N_u) on tuber yields, irrespective of year and K application (C).

and thereafter it tended to decrease. The results obtained here clearly indicate a yield forming K effect. This effect was especially pronounced in 2013, which was less favorable for potato cultivation, as compared to 2012. The relationship

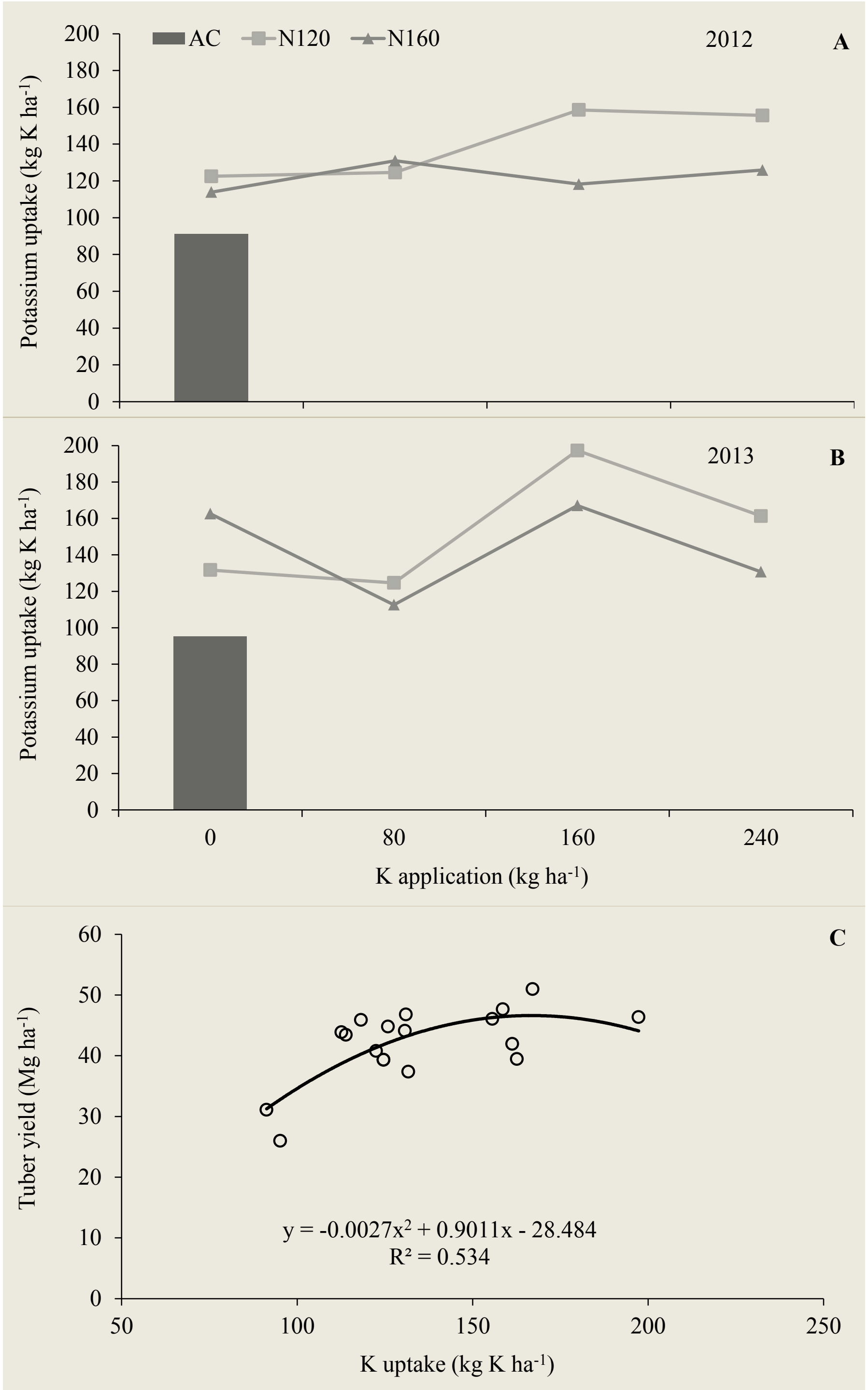

Fig. 3. Effects of K and N application on K uptake by potato crop in 2012 (A) and 2013 (B). Effect of K uptake (K_u) on tuber yields, irrespective of year and N application (C).

between the K amount accumulated by the potato crop at harvest and tuber yield was curvilinear, indicating for an optimum at 170 kg K ha^{-1} (Fig. 3C), beyond which tuber yield might decrease.

NUE indices

In agronomic practice, an important indicator of crop K requirement is the index known as Unit Nutrient Uptake (UNU). This describes the amount of a given nutrient per unit in the main product and additional amount in its by-product. For British conditions, as reported by Allison *et al.* (2001), the unit potassium uptake (UKU) value for high-yielding potato crop varies from 2.6 to 5.7 with the average of 4.2 kg K Mg^{-1} tubers. In the present study, UKU was much lower and year specific. In 2012, it varied from 2.6 to 3.4 kg K Mg^{-1} tubers. As shown in Fig. 4, slightly lower values were recorded in treatments fertilized with 160 kg N ha^{-1}. In 2013, the value of this parameter ranged from 2.6 to 4.1 kg K Mg^{-1} tubers. The higher N rate, except for the K control, resulted in an index decrease. The second index, unit nitrogen uptake (UNU), showed a year-to-year variability (Fig. 5). However, the index for the absolute control was at the same level for both years, amounting to 2.25 kg N Mg^{-1} tubers. The UNU indices in 2012 were slightly above this value, without any response to fertilizing treatments. A quite different situation was observed in 2013, when plants fertilized with 160 kg N ha^{-1} and K_2O obtained significantly smaller values.

Nitrogen use efficiency (NUE) is the most important indicator evaluating fertilizer application. Indices of physiological efficiency of nitrogen (PhEN) allow comparison of the effect of N application against the background of K application scale, i.e., increasing rates of K applied to potato crop. As shown in Table 3, PhEN indices were slightly higher in 2013 as compared to 2012. The interactive effect of K and N on this index was the highest for the 160 K_2O ha^{-1} application level. Maximum values were obtained for 120 and 160 kg N ha^{-1}, in 2012 and 2013, respectively. The second NUE index, N recovery (NR), describes the contribution of fertilizer N in total N uptake by the crop. In general, NR values were low,

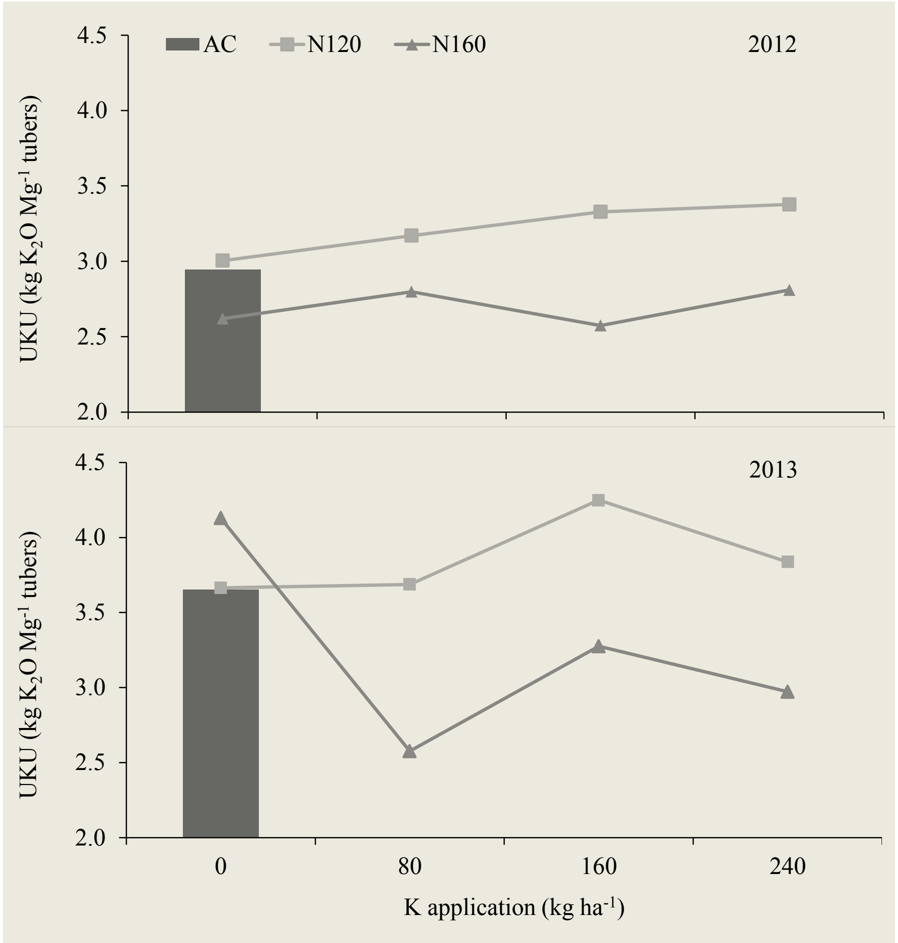

Fig. 4. Effects of K and N application on the efficiency of K uptake by potato crop in 2012 and 2013, as expressed by UKU (unit potassium uptake) (kg K_2O Mg^{-1} tubers).

Table 3. Indices of nitrogen use efficiency.

K rates	N rates	Physiological N efficiency (PhEN)		Nitrogen recovery (RN)		Agronomic N efficiency (AEN)	
		2012	2013	2012	2013	2012	2013
kg K_2O ha^{-1}	*kg N ha^{-1}*	*kg tubers kg^{-1} N_u*		----------%----------		*kg tubers kg^{-1} N_d*	
0	120	296.1	367.0	27.5	25.8	81.5	94.8
	160	261.4	229.0	29.8	36.8	77.9	84.2
80	120	313.3	376.2	22.2	29.5	69.5	111.0
	160	295.7	276.4	33.4	40.4	98.8	111.6
160	120	390.1	322.7	35.6	52.6	138.9	169.6
	160	344.3	458.7	27.1	34.1	93.2	156.2
240	120	278.4	350.1	45.1	38.0	125.6	133.0
	160	335.4	345.8	25.7	32.7	86.3	113.1
Means		314.3	340.7	30.8	36.2	96.5	121.7

Note: N_u: N uptake; N_d: N fertilizer dose.

especially in 2012. In both years, there was an obvious K x N interaction on NR; at low K inputs, NR was higher in the high N level, while the opposite occurred in the higher K inputs (Table 3). The third index, termed as agronomic use efficiency (AEN) describes the final effect of applied N fertilizer. Irrespective of the year, the highest productivity of N input occurred at the 160 K_2O ha^{-1}/ 120 kg N ha^{-1} combination. AEN values were significantly smaller at any other combination of N and K inputs.

Soil K status

It is well known that potato crop is highly sensitive to inadequate potassium supply, which is expressed mainly by a poorly developed root system. A post-harvest analysis of the soil showed some impact of the K fertilizing system on the status of available K. In general, available K slightly increased from about 16 to 26 mg K 100 g^{-1} soil, in accordance with increasing K application. Interestingly, the highest values in both years were recorded at the 160 K_2O ha^{-1}/120 kg N ha^{-1} treatments. This result may suggest that at the higher K application levels, the consecutive crop might benefit from a certain residual K, in spite of the high efficiency of potato production at that particular combination. It is notable, however, that K availability in the soil was limited to a depth of 60 cm only.

Residual effect of K fertilizer – winter wheat response

The effect of both residual and fresh applied K fertilizer was tested in winter wheat following the potato crop (Table 4). The effect of both sources of K was significant only in the first winter wheat crop, in 2013. The residual effect of K application was significant only at the highest level (240 kg ha^{-1}), contributing about 0.5 Mg wheat grains per ha. Nitrogen application regime in the 2012 potato crop seemed to have an even higher residual effect on the consecutive winter wheat crop; the difference in grain yield between 120 and 160 kg N ha^{-1} was about 1 Mg. The current K application was effective only on winter 2013, contributing about 0.5 Mg ha^{-1} to wheat grain yield (Table 4). The considerable differences between the two years may be partially explained by the efficiency of nutrient acquisition

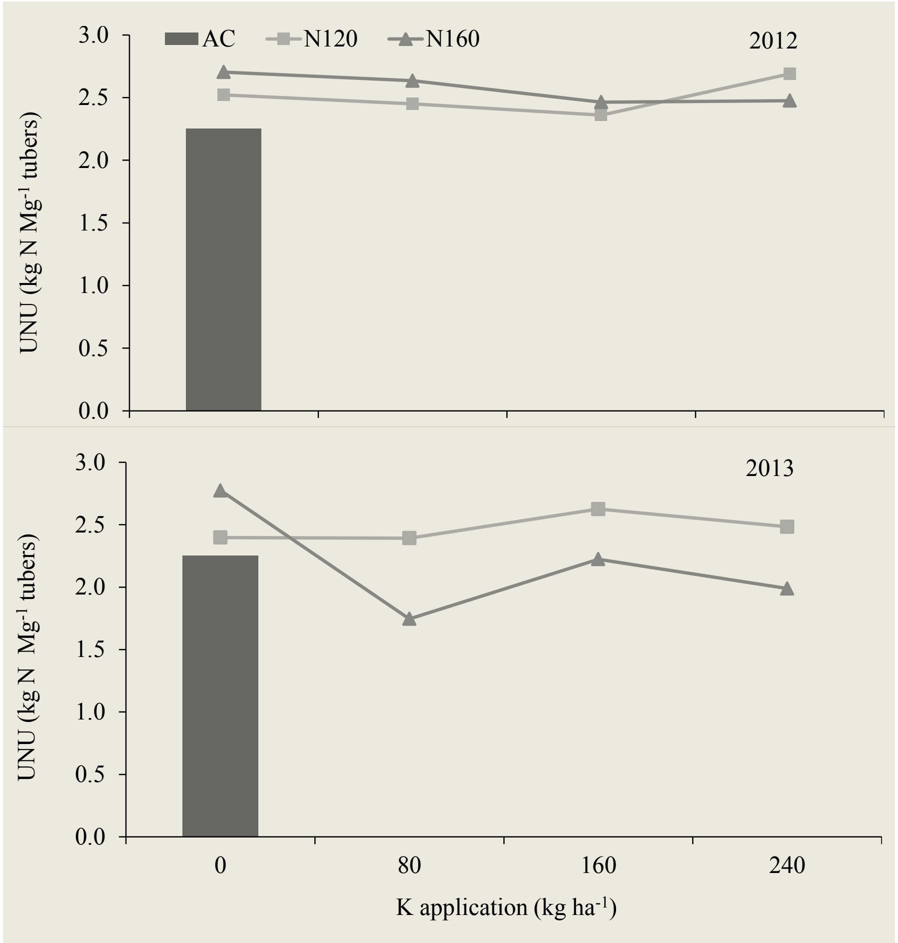

Fig. 5. Effects of K and N application on the efficiency of N uptake by potato crop in 2012 and 2013, as expressed by UNU (unit nitrogen uptake) (kg N Mg^{-1} tubers).

Table 4. Winter wheat response to the system of K fertilization, yield of grain, Mg ha^{-1}.

	2013	2014
K dose	--------kg K_2O ha^{-1}--------	
0	5,348[a]	6,716
80	5,398[a]	6,852
160	5,565[a]	6,845
240	6,099[b]	6,799
N dose	--------kg N ha^{-1}--------	
120	5,093[a]	6,731
160	6,112[b]	6,875
Freshly applied K dose for winter wheat	--------kg K_2O ha^{-1}--------	
0	5,355[a]	6,698
90	5,851[b]	6,908

Note: [a,b]: The same letter means a lack of significant difference between level of the treatment.

by the potato crop each year. In 2012, nutritional requirements of potato were smaller due to favorable climatic conditions, thus resulting in significant residual fertilizers in the soil. In 2013, the potato crop acquired more K than in 2012 (Fig. 4), probably leaving less residue for the consecutive crop. Nevertheless, more comprehensive evaluation of nutrients residual effects requires further consideration of other important factors, such as weather conditions during the consecutive crop.

Final conclusions

1. A comparison of yields harvested in two consecutive years, differing in weather conditions, clearly shows that the variety Bellarosa is highly sensitive to applied K fertilizer.
2. An appropriate K application may support potato crops under mild water stress.
3. Potassium and N possess significant interactions, thus careful optimization should be made with considerable adjustment to soil types in order to maximize tuber yields.
4. Excess K as well as N application may have positive residual effects on consecutive crops, depending on weather and other conditions.

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