Optimum phosphate and potassium levels in potato tops

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(*Accepted: 29.08.1983*)

Key words: plant analysis, mineral nutrition, foliar composition, potatoes, phosphorus response, potassium response, plant nutrient interpretation

Abstract. The feasibility of using chemical plant analysis for early diagnosis of phosphate and potassium deficiencies in potatoes was studied. Plant tops (leaves including stems) were sampled from fertilizer field experiments and analyzed for total N, P and K. The inverse relationship between plant N concentration and plant age was used for correcting plant P and K concentration to a standard N content, thus partly eliminating growth stage differences.

Maximum tuber yields were associated with leaf P above 0.5% and leaf K above 5%, both at 5% N in DM. With each percent decrease in N concentration the critical value for P decreases by about 0.1% and that for K by about 0.5%. Serious yield reductions may be found below 0.3% P and below 3% K, again at an N-level of 5%.

Over the past decades, foliar analysis of nutrients has been widely used as a method to determine fertilizer needs of crops in conjunction with or instead of soil analysis. Under conditions where the deficit is not severe and reductions in yield may occur despite the absence of distinct plant symptoms, plant analysis has been a useful tool for rapid diagnosis. Besides, the time for corrective measures is usually past when the symptoms appear.

The underlying principle is that each crop has critical minimum nutrient concentrations below which yield depressions occur. For practical purposes the method has proved particularly valuable for perennial crops, as these crops are grown for years on the same site and fertilizer dressings can be recommended for the period to come. This also holds for annual crops, if losses in yield resulting from nutrient deficiencies can be prevented in time by corrective topdressings. To avoid recurrence of the problem the results may also be used for crops grown for a second time in the rotation on the same field.

This paper deals with the optimum phosphate and potassium levels for potatoes, grown under field conditions in The Netherlands. This high-yielding and highly fertilizer-responsive crop with a high economic value shows, particularly for nitrogen and potassium, sonsiderable variation in plant tissue levels. Therefore, determination of the mineral composition would seem useful in reflecting the nutritional status of the crop. In regions where

Fertilizer Research 5: 203–211 (1984)

soil fertility studies have not been started yet and where possibilities for soil testing are restricted, foliar analysis could be considered, as it may give rapid information on the nutritional status and needs of the plant during growth.

Diagnostic methods based on plant analysis should be used with caution, as the mineral concentration of plant tissues depends, among other things, on age of sampling. With increasing plant age the concentrations of N, P and K expressed on a dry-matter basis generally decrease as a result of dilution due to the increased mass of plant material and reduction in the rate of uptake late in the season [2, 3, 5–7, 9–15, 19–22, 26, 27]. Besides, considerable changes in concentration occur between different plant parts, like petioles and leaf blades. Therefore, eatablishing critical values is difficult. For potatoes several workers report a wide range of critical levels, partly due to different times of sampling and different plant parts [1, 2, 4, 5, 8, 15–17, 23–27]. Those conditions must be taken into account when interpreting the results. To meet these difficulties to a certain extent, in the current investigation differences in physiological growth stage were partly eliminated by correcting plant foliage concentrations to a standard N concentration. The same procedure was adopted in an earlier study [18]. Besides, in this study whole plant tops (leaves including stems) instead of petioles or leaf blades were sampled for total analysis.

In the correction to a standard N concentration, also factors affecting the difference in concentration other than age of the crop have been included, for instance differences in nitrogen supply to the crop, but these factors cannot be distinguished in the correction. The correction is valid if no abnormal conditions concerning the nitrogen nutrition during growth occurred. It should be noted that, in our case, the correction was applied to data from experiments in which optimum nitrogen nutrition of the crop was aimed at. In the correction, however, the estimation of the age of the crop is obscured when the nitrogen supply was low or excessive.

Materials and methods

The plants analyzed were obtained from numerous P- and K-fertilizer field experiments located on five types of soil (sand, sand-peat mixtures, alluvial marine and fluvial clay, and loess) for many years. In the experiments, three or more rates of P or of K were applied. P was applied as superphosphate or triple superphosphate, K as potassium chloride, sulphate or nitrate, prior to planting, the rates ranging from 0 to 200 or 300, in some experiments to 500 kg P_2O_5 per ha and from 0 to 500, in some experiments to 1200 kg K_2O per ha. The other nutrients were applied at adequate levels. The following ware and industrial (starch) potato varieties were mainly grown: Bintje, Bevelander[1], Thorbecke[1] and Voran[1], and, in addition, 14 other varieties.

[1] No longer generally available

Tissue samples were taken from mid-June to mid-August and analyzed for total N, P and K in DM. The crop was harvested in September or October.

For each experimental field yield was plotted against the amounts of P and K applied and the maximum yield was determined by curve fitting (if necessary by extrapolation). Yields for the various fertilizer treatments (including the control) were expressed as a percentage of the maximum yield. For all experiments these relative yields were plotted against plant P and K concentrations in the tops.

Results

As may be expected, low plant P and K concentrations were found to be associated with yield reductions resulting from P or K deficiency, whereas a higher concentration usually gave higher yields. However, the relationship was affected by variation in the time of sampling, and, consequently, in stage of growth. Differences in physiological growth stage were partly eliminated by preliminary correction of the plant P and K concentrations to a standard N content. In this material N ranged from 2.5 to 7.5, P from 0.16 to 1 and K from 0.4 to 8%.

It can be judged from literature data that plant P and K concentrations gradually decrease with the reduction in N content as the criterion of stage of growth. Figure 1 shows the relations between leaf N and P as found by four authors. The average regression coefficient b = 0.088. For leaf N and K (Fig. 2), the slopes are similar in 8 out of 10 cases; the average regression coefficient b = 0.932. In the other two cases [10, 13] the K content did not

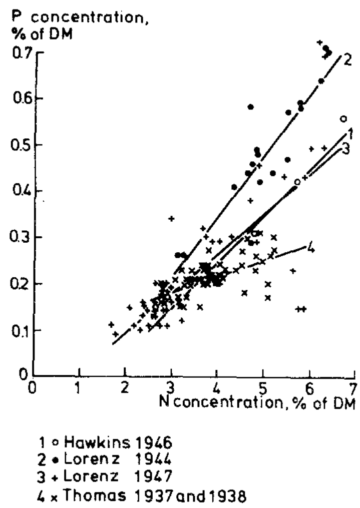

Figure 1. Relationships between nitrogen and phosphorus concentrations of potato (tops or leaves) according to literature data

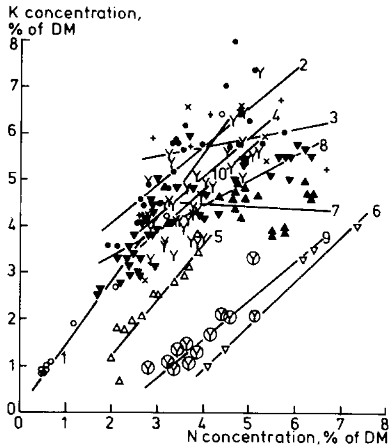

Figure 2. Relationships between nitrogen and potassium concentrations of potato (tops or leaves) according to literature data

increase with the N content, or only slightly so; no explanation for this was offered. If these data are included in the calculation, the average regression coefficient b becomes 0.762.

The assumption that leaf N, P and K decrease with ageing of the crop is acceptable also according to our own data. We therefore looked for a convenient correction factor for the effect of N on the P and K contents. First, the regression coefficient was calculated for P as well as for K, using the aggregate of experimental results. Then, to test the stability of the calculated coefficient, the data were grouped for P into 4, and for K into 5 relative yield levels. The regression lines for the various yield levels have nearly the same slope. This applies to P as well as to K. With each percent decrease in leaf N, leaf P decreases by 0.098% and leaf K by 0.456%. For P, this regression coefficient is almost identical to that calculated for the aggregate results ($b = 0.095$) and to that obtained from the literature ($b = 0.088$, Fig. 1). For K, the regression coefficient is larger than that calculated for the ungrouped data ($b = 0.276$), but smaller than that derived from the literature data ($b = 0.762$, Fig 2). For K we therefore applied a smaller correction than could be deduced from other authors' data.

To distinguish the regression models with one or more lines having the same or different slopes, F-tests were used to test differences among rest sums of squares. They are presented in Table 1 for P, in Table 2 for K. It is

Table 1. P–N regression models for relative yield levels. Discrimination among the linear models with F-tests

Models	Rest S.S.	d.f.	Differences S.S.	d.f.	M.S.	F
No line	5.1618	360				
			2.0881	1	2.0881	271^{xxx}
One line	3.0737	359				
			0.3118	3	0.1039	13.5^{xxx}
Four lines, one slope	2.7619	356				
			0.0402	3	0.0134	1.7^{-}
Four lines, four slopes	2.7217	353				
	Rest F-test		2.7217	353	0.0077	

Table 2. K–N regression models for relative yield levels. Discrimination among the linear models with F-tests

Models	Rest S.S.	d.f.	Differences S.S.	d.f.	M.S.	F
No line	2000.051	1072				
			62.753	1	62.753	62^{xxx}
One line	1937.298	1071				
			858.553	4	214.638	212^{xxx}
Five lines, one slope	1078.745	1067				
			1.818	4	0.455	0.45^{-}
Five lines, five slopes	1076.927	1063				
	Rest F-test		1076.927	1063	1.0131	

apparent that in both cases one regression line for all data is highly significant, but that the model with 4 yield levels for P with the same slope, and with 5 yield levels for K with the same slope, is distinctly preferable to one line. The models with 4 or 5 lines with different slopes give no improvement.

Using the above coefficients, P and K concentrations were corrected to a standard N level of 5%, by the following formulae:

$$\text{corrected P} = \text{actual P} - 0.098\,(N - 5)$$

$$\text{corrected K} = \text{actual K} - 0.456\,(N - 5)$$

The P and K concentrations were plotted against relative yields, before and after correction (Figs. 3a and b for P, 4a and b for K). It is evident that foliar P and K are correlated with crop yield. The correction gave a slight improvement, especially due to the fact that, at high relative yields, very low contents were shifted upward. Low concentrations after correction indicate serious yield depressions. Maximum tuber yields are associated with a corrected leaf P content exceeding 0.5% and a corrected leaf K content exceeding 5% at 5% N. These values can be considered the critical concentrations in potato tops. At corrected leaf K levels over 6%, yields decrease slightly due to

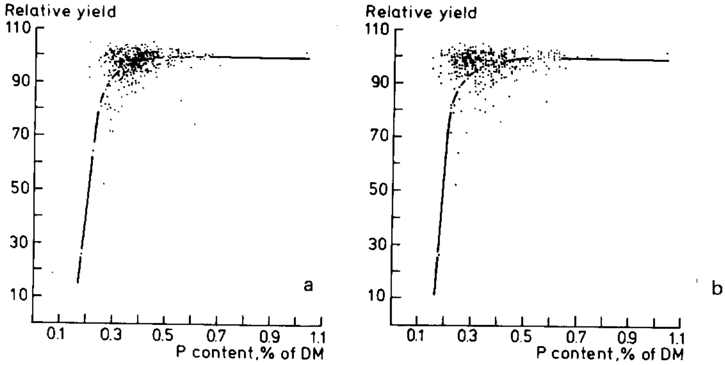

Figure 3. Relative tuber yield as related to phosphorus concentration of potato tops before (a) and after (b) correction to 5% N

potassium excess. Corrected leaf P levels ranging from 0.3 to 0.5% and corrected leaf K from 3 to 5% K are associated with mean yield reductions of up to 10%. Serious yield reduction may occur below these values. The lower the N concentrations, the lower these levels.

Scope of application

In this report no distinction is made between stems, petioles and leaf blades. Petioles and stems are generally higher in K and lower in N and P [8, 13, 16, 27]. Analysis of leaf blades provides a better insight into the yield/plant P relationship than analysis of petioles, because the former provides a wider range of values at low levels of P supply [8]. However, Loué [16] prefers petioles for determining the phosphate nutrition of potatoes. For potassium there is a close parallel between the concentration in leaves and that in petioles [16]. Therefore, both plant parts seem to be also very nearly equivalent for potassium. Lorenz [13] found that both leaf blades and stems plus petioles could be used with reasonable accuracy for total P and K.

As the season progresses, differences in P concentration due to phosphate fertilizing become smaller and in K concentration due to potassium fertilizing larger [5, 15, 19, 26, 27]. To make it possible to apply additional fertilizer, samples should be taken early, especially with a view to P analysis, and the results should be reported to the farmer as quickly as possible. This particularly holds for rapidly growing plants such as potatoes.

Topdressing can be applied in solid or in liquid form. In solid form it is necessary to incorporate the fertilizer into the soil by ridging, especially in the case of phosphate dressing, to ensure a good response. Sufficient rain is needed for uptake. Besides, the conditions must be favourable for prolonged growth, i.e. undisturbed root development and effective pest control.

Foliar K sprays can be more effective than soil application [18], but the

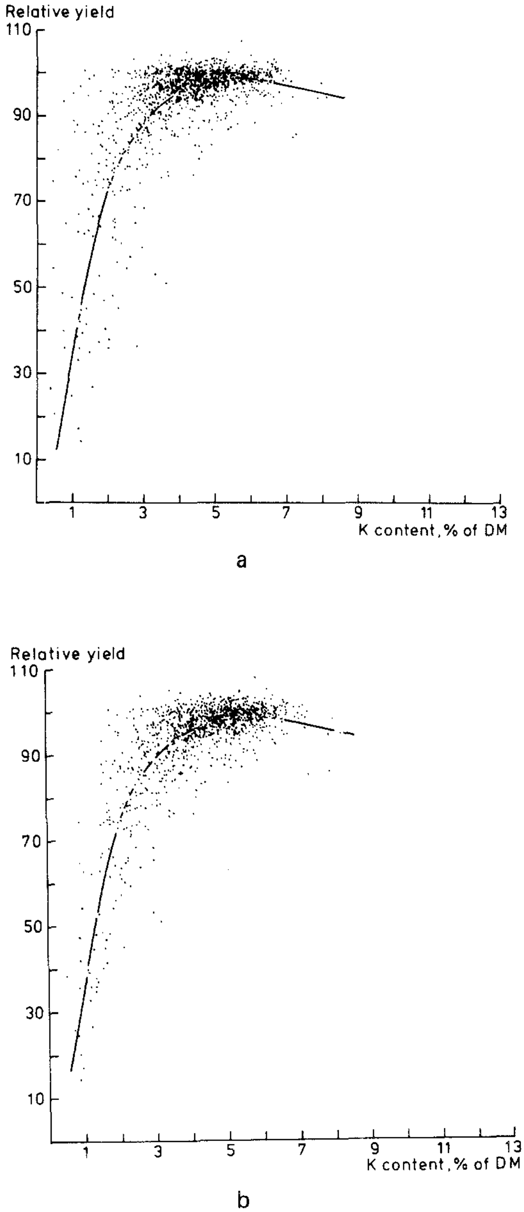

Figure 4. Relative tuber yield as related to potassium concentration of potato tops before (a) and after (b) correction to 5% N

drawback of spraying is that, to supply a sufficient quantity of the nutrient, the treatment must be repeated several times, because it is necessary to spray at low concentrations to avoid burning of leaves.

Acknowledgement

The authors are much indebted to Messrs J.T.N. Venekamp and J. Wolf (Institute for Soil Fertility) for their valuable assistance with the mathematical treatment of the results.

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