NITROGEN AND POTASSIUM FERTILIZATION OF POTATOES: YIELD AND SPECIFIC GRAVITY[1]

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Abstract

Potassium and N fertilization is often required for maximum potato (*Solanum tuberosum* L.) production. Nitrogen, K, and K-sources (KCl, K_2SO_4) are known to affect yield and quality of potatoes but N and K interactions as affected by K-source have not been defined. This study evaluated the N*K and K-source interactions on Russet Burbank tuber yields and specific gravity (SG) in two irrigated field experiments. Nitrogen rates of 0, 112, 224 or 336 kg ha^{-1} were combined with selected K rates of 0, 112, 224 or 448 kg ha^{-1} as either KCl or K_2SO_4 in an incomplete factorial. A multiple linear regression model was fit to the data and used to predict yield and SG for a complete factorial for each K-source. Both N and K applications increased yields independent of K-source. Nitrogen decreased yields at the 336 kg ha^{-1} rate. Potassium increased yields up to 448 kg K ha^{-1}. Both K-sources decreased SG a similar amount with N application; without N, KCl decreased SG but K_2SO_4 did not. Nitrogen also decreased SG. Petiole NO_3-N and K concentrations were positively related to yields and negatively to specific gravities. The petiole K concentration 100 days after planting should be above 4.5 for highest tuber yields. The N*K*K-source interaction was important for yields at low available N and for SG at adequate N availabilities. This study showed that N or K fertilizers can be applied according to their respective soil test concentration and the crop's requirement, generally without consideration of K-source.

Compendio

Para una producción máxima de papa (*Solanum tuberosum* L.) se requiere frecuentemente de la fertilización nitrogenada y potásica. Se sabe que el nitrógeno (N), el potasio (K) y las fuentes de potasio (KCL, K_2SO_4) afectan el rendimiento y la calidad de la papa, pero las interacciones del N y el K en relación a la fuente de K no han sido definidas. Este estudio evaluó en dos experimentos de campo bajo irrigación las interacciones de N*K con la fuente de K sobre los rendimientos en tubérculos y la gravedad específica (GE) de Russet Burbank. Dosis de nitrógeno de 0, 112, 224 o 336 kg ha^{-1} se combinaron con dosis seleccionadas de K de 0, 112, 224 o 448 kg ha^{-1} como

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KCL o como K_2SO_4 en un factorial incompleto. Un modelo de regresión lineal múltiple fue adaptado a los datos y utilizado para pronosticar el rendimiento y la GE por un factorial completo para cada fuente de K. Tanto las aplicaciones de N como las de K incrementaron los rendimientos independientemente de la fuente de K. La dosis de 336 kg ha^{-1} de nitrógeno disminuyó los rendimientos. El potasio, hasta 448 kg ha^{-1}, aumentó los rendimientos. Ambas fuentes de K disminuyeron la GE en cantidades similares con la aplicación de N; sin N, el KCL disminuyó la GE, lo que no hizo el K_2PO_4. El N también disminuyó la GE. Las concentraciones de NO_3-N y de K en el peciolo estuvieron positivamente relacionadas a los rendimientos, y negativamente a las gravedads específicas. Las concentraciones de potasio en el peciolo, 100 días después de la siembra, debieron ser superiores a 4.5 para los más altos rendimientos en tubérculos. La interacción N* K* fuente de K fue importante para rendimientos a bajo contenido disponible de N y para GE a disponibilidades de N adecuadas. Este estudio muestra que los fertilizantes nitrogenados y potásicos pueden ser aplicados de acuerdo a su concentración en el suelo y los requerimientos del cultivo, sin considerar, generalmente, la fuente de potasio.

Introduction

Potassium acts as an osmoticum in plants and is important for the translocation of sugars and synthesis of starches in potatoes (1, 5, 15). Fertilizer K applications are often required for optimum potato yields because of a relatively high K requirement compared with other irrigated crops. Fertilizer K-source is known to affect tuber specific gravity (SG). McDole *et al.* (1978) showed that KCl applications above recommended rates decreased SG more than similar K_2SO_4 rates. Kunkel and Dow (1961) reported comparable KCl and K_2SO_4 effects on yield and quality; however, high SO_4-S concentrations in the irrigation water may have influenced their results. In similar studies on acid soils of western Washington, applying KCl lowered SG more than K_2SO_4 (12). Dubetz and Bole (1975) observed no K effect on yield, number of tubers, or weight of tubers at various N rates, but K decreased SG. Rowberry and Ketcheson (1978) reported that when K was withheld from a NPK experiment the quality of Kennebec potatoes decreased. This may only illustrate the "most limiting nutrient" principle rather than a physiological N*K interaction.

Fertilizer N applications are generally needed since the mineralization of soil organic N does not satisfy the N requirements of the potato plant (17). Nitrogen sources are not as critical as placement and timing on tuber yields and quality (26). Tuber SG decreases if more N is available than needed for growth particularly if available during late tuber bulking (12, 14). High petiole NO_3-N concentrations during late tuber bulking can be symptomatic of high N availabilities that reduce SG (15).

Potato plant N status can be evaluated by petiole analysis (13, 27). A concentration of 15,000 mg kg^{-1} NO_3-N should be maintained with in-season N applications until about 30 days before vine kill for Russet Burbank. Plant K concentration tends to decrease as the season advances (6, 28). The critical petiole K concentration for irrigated Russet Burbank potatoes at early tuber set, 45-55 DAP (days after planting), was estimated to be between 5 and 8% (9, 24). Rhue *et al.*(1986) reported that 4.5% K in whole leaf samples during late season was sufficient to maximize yields on an acid sandy soil; however, no correlation was made with petiole K concentration. A concentration between 3 to 5% K in petioles with leaves attached was sufficient for optimal yields (21). The petiole K and leaf K concentration relationship was also positive.

Nutrient management is a controllable input that potato growers utilize to ensure high tuber yields and quality. Both N and K fertilization are often required for maximum production. Optimum recommendations can only be made if the specific effects of K-sources and their interaction with N rates are known. The objective of this study was to evaluate the effects of N and K rates from two K-sources on yield and SG of Russet Burbank potatoes grown on a calcareous soil under irrigated conditions.

Materials and Methods

Field studies were conducted on a Millville silt loam soil (coarse-silty, carbonatic, mesic typic Rendolls) at the Greenville Experimental Station of the Utah Agricultural Experiment Station during 1988 and 1989. Spring soil samples taken to a depth of 30 cm from each replication before fertilizer application were analyzed for selected chemical properties (Table 1). In a preliminary study conducted within the same field in 1987, both N and K fertilizer treatments affected yield and quality. The irrigation water used at this location had very low NO_3-N, K, Cl, and SO_4-S concentrations (Table 1).

TABLE 1.—*Soil (0-30 cm) and irrigation water chemical properties at the experimental sites.*

Soil[a]		EC_e	pH	NO_3-N	K	P	Zn	O.M.	$CaCO_3$
		ds m^{-1}		mg kg^{-1}				%	
1988		1.6	7.9	23.1	59	5.4	1.1	1.2	40
1989		1.6	7.7	12.2	77	9.0	1.1	1.2	40
Water[b]	EC_e	pH	NO_3-N	Ca	Mg	Na	K	Cl	SO_4-S
	ds m^{-1}				$mmol_c$ L^{-1}				
	0.36	8.36	0.01	1.28	0.10	0.02	0.08	0.08	0.15

[a]EC_e and pH on saturated paste; NO_3-N with specific ion electrode (18); K and P extracted by $NaHCO_3$; Zn extracted by DTPA; O.M.= soil organic matter by Walkey-Black procedure; $CaCO_3$ is acid equivalent, respectively.

TABLE 2.—*Treatments, tuber yields and specific gravity of the 1988 and 1989 experiments.*

	Treatment			Yield		Specific Gravity	
No.	K source	K rate	N rate	1988	1989	1988	1989
		— kg ha^{-1} —		— mt ha^{-1} —			
1	---	0	0	25.4	34.9	1.079	1.091
2	---	0	224	27.1	47.6	1.077	1.088
3	KCl	112	112	36.2	49.9	1.079	1.092
4	KCl	112	336	30.5	45.2	1.073	1.081
5	KCl	224	0	27.9	34.1	1.076	1.087
6	KCl	224	224	36.6	49.5	1.077	1.084
7	KCl	448	112	37.6	55.5	1.075	1.088
8	KCl	448	336	33.8	52.7	1.071	1.078
9	K_2SO_4	112	112	38.3	47.6	1.075	1.092
10	K_2SO_4	112	336	32.9	52.9	1.073	1.085
11	K_2SO_4	224	0	28.8	40.4	1.080	1.090
12	K_2SO_4	224	224	31.2	51.6	1.072	1.086
13	K_2SO_4	448	112	38.0	50.5	1.076	1.088
14	K_2SO_4	448	336	35.4	49.4	1.070	1.079
Treatment significance			(Pr>F)	0.001	0.001	0.001	0.001
			LSD (P=0.05)	4.2	8.6	0.003	0.004
			Coefficient of Variation, %	9.2	13.0	0.20	0.24

Russet Burbank potato seed pieces (0.06 kg) were planted 24 cm apart at a depth of 20 cm the first week of May both years. Individual plots contained 6 rows, each 12.2 m long and 0.9 m between rows. Urea and either KCl or K_2SO_4 at the respective N and K rates (Table 2) were banded 15 cm to the side of the seed piece at planting. Phosphorus, 50 kg P ha^{-1} as $Ca(H_2PO_4)$, and S, 30 kg S ha^{-1} as $CaSO_4$, were broadcast preplant and incorporated over the entire plot area before planting.

Water was applied with small furrows in 1988 and with solid set sprinklers in 1989 when 40% of the plant available soil water was depleted from the root zone. Soil moisture was monitored during the growing season with tensiometers placed in the row at the seed piece depth. During 1989, the amount and frequency of irrigation was based on estimated ET (evapotranspiration). Actual water applications were measured with catch cans under the sprinklers.

Forty, fourth petioles from the growing tip were sampled from each plot 61, 79 and 106 DAP in 1988, and 74 and 101 DAP in 1989. The leaves were immediately stripped from the petiole and discarded. The petiole sample was dried at 60 C, ground, and stored until analyzed for inorganic chemical constituents. A subsample was extracted and NO_3-N determined in the extractant with a specific ion electrode (18). After dry ashing a subsample at 500 C for six hours, the residue was dissolved with HNO_3, and K determined by flame emission, P by a colorimetric procedure (11), and Cl (Method No. 12-117-07-1-A, mercuric thiocyanate) and S (Method No. 12-116-10-1-C, turbidimetric) by an automated ion analyzer (Lachat Instruments, 6645 West Mill Road, Milwaukee, WI 53218-1239, USA).

One 9.1 m (1988) or 10.7 m (1989) row between two border rows was harvested after vine removal in late September to estimate tuber yield and quality. Tubers were graded into U.S. #1's, #2's and culls, and weighed. Specific gravity was determined by the weight in water-weight in air method on a composite sample of #1 and #2 tubers.

The experiments were specifically designed to study the interactions between the independent variables (N and K) and potato yield and quality variables by response surfaces. The N and K rates varied from none to very high. Nitrogen and K rate combinations (Table 2) were selected using established fertilizer guides to help define the central region of the response surface (9, 17). Treatments were duplicated with KCl and K_2SO_4 as K-sources. A complete factorial experimental design would require 40 fertilizer treatments for all the N and K rate and K-source combinations. To minimize cost and the risk of uncontrollable field variability, an incomplete factorial with 14 treatments (Table 2) was used and replicated four times.

TABLE 3.—*Mean square (MS) from the analysis of variance for yield and specific gravity.*[a]

		Yield		Specific Gravity	
Source	df	MS 88	MS 89	MS 88 x 10^{-6}	MS 89 x 10^{-6}
Total	63	---	---	---	---
Replication	3	12.66	146.18**	27.86***	2.63
Treatment	15	87.15***	186.05***	34.93***	78.25***
Model (complete)[b]	11	85.68***	243.20***	49.63***	99.68***
Modified model (containing)					
"N" variables	6	54.49***	306.09***	61.99***	122.22***
"K" variables	6	92.29**	91.42**	23.02***	28.50***
"N*K" variables	2	10.18	24.39	26.22***	4.10
"Cl,SO_4" variables	6	4.93	46.17	17.69***	9.84
"Interactions" variables	8	44.32***	130.81**	14.75***	22.77***
Lack of fit (complete)	4	92.72***	28.88	3.51	14.61
Error	45	8.58	36.01	4.91	6.99

[a] *, **, *** indicate significance at the 0.10, 0.05, or 0.01 probability level, respectively.

[b] Contains variables of N, K, x, N^2, K^2, N*K, N*x, K*x, N^2*x, K^2*x,and N*K*x, where x is a categorical variable for Cl or SO_4.

Preliminary analyses of variance were calculated for potato yield and SG. Where significant treatment effects occurred (Tables 2 and 3), a multiple linear regression model (20) was fit to the treatment means (Table 4). Potassium source was introduced into the model as a categorical variable (+1 or -1 for KCl or K_2SO_4) to segregate source effects on yield and SG. All other variables were linear and quadratic combinations of N, K and K-source. This regression model was used to predict yield and SG for all cells in a complete 4N x 5K factorial for each K-source, which were subsequently used to develop the respective response surface. Treatments 1 and 2 (Table 2) were duplicated in the KCl and K_2SO_4 subsets for the respective response surface. This increased the degrees of freedom for treatments in the ANOVA to 15 (Table 3). The multiple linear regression model was a subdivision of the treatment degrees of freedom.

Incomplete factorial designs prohibit direct interpretation of the polynomial terms because the polynomial terms can be highly correlated, *e.g.*, N vs. N^2 (20). The following statistical procedure was used to overcome this disadvantage of the otherwise highly economical experimental design. After computing the complete regression model, selected variables (*e.g.*, all components involving N, six variables, in the complete model of Table 4) were removed and the sums of squares for the modified model determined. The difference between the complete and modified model sums of squares

TABLE 4.—*Partial regression coefficients in multiple linear equation used to interpolate missing cell values.*[a]

		Tuber yield, mt ha^{-1}		Specific gravity	
Coefficient	Variable	1988	1989	1988	1989
b_0	Constant	25.1***	34.6***	1.079***	1.091***
b_1	N	6.86***	13.73***	-6.606 x 10^{-4}	1.653 x 10^{-3}
b_2	K	3.94***	1.80	-9.632 x 10^{-4}	-1.126 x 10^{-3}
b_3	(Cl or SO_4)[b]	-0.61	0.13	-4.259 x 10^{-4}	8.954 x 10^{-5}
b_4	N^2	-2.26***	-3.32***	-2.744 x 10^{-4}	-1.356 x 10^{-3}***
b_5	K^2	-0.63**	7.56 x 10^{-2}	1.355 x 10^{-4}	9.632 x 10^{-5}
b_6	N*K	0.34	-0.32	-2.175 x 10^{-4}	-1.921 x 10^{-4}
b_7	N*(Cl or SO_4)	1.57	3.01	2.922 x 10^{-3}***	1.015 x 10^{-3}
b_8	K*(Cl or SO_4)	0.58	-2.62	2.441 x 10^{-4}	-1.259 x 10^{-3}
b_9	N^2*(Cl or SO_4)	-0.69	-1.45	-1.189 x 10^{-3}***	-5.262 x 10^{-4}
b_{10}	K^2*(Cl or SO_4)	-0.25	0.55	-3.652 x 10^{-4}*	2.293 x 10^{-4}
b_{11}	N*K*(Cl or SO_4)	0.28	0.60	6.698 x 10^{-4}**	2.016 x 10^{-4}
Coefficient of multiple determination, R^2		0.72***	0.96***	0.98***	0.95***

[a] *, **, *** indicates significance at the 0.10, 0.05 and 0.01 probability levels.

[b] Cl or SO_4 introduced in model as a categorical variable.

was taken as a measure of the deleted variables (Table 3). This technique does not determine the significance of individual variables in the modified models but rather gives an overall indication of the relative importance of the major components.

A stepwise linear regression procedure was used to relate petiole nutrient concentrations at each petiole sampling to tuber yield and SG. Initial independent variables were NO_3-N, K, S, Cl, $(NO_3\text{-N})^2$, K^2, and $(NO_3$-N)*Cl (*i.e.*, the respective nutrient concentration in the petiole). The $(NO_3$-N)*Cl interaction was included because this interaction occurs in petioles (10). It was not correlated to either Cl or NO_3-N (data not shown). The $(NO_3$-N)*K interaction was not included as an independent variable because NO_3-N was highly correlated to the interaction ($r \geq 0.80$). Both forward and backward selection procedures were used to determine the final model, using a F-ratio of 4.0 to select or reject a variable.

Results

Only total yields are presented and discussed since treatments did not significantly affect tuber grade distributions (data not shown). Significant treatment effects on tuber yield and SG occurred both years (Tables 2 & 3). Yields were larger and SG higher in 1989 than in 1988, possibly reflecting better soil moisture management with sprinkler irrigation. The multiple linear regression model was significant both years for yield and SG (Table 3). The "lack of fit" was only significant for yield in 1988. This partially occurred because of the unusual low yield in the K_2SO_4 subset with 224 kg ha^{-1} N and K. Careful examination of the data did not reveal the cause(s) for this anomaly. There was good agreement between the response surface estimated by the regression model and the observed treatment means (coefficient of multiple determination, Table 4). Further evidence for the accuracy of the regression model as a predictor of treatment effects is given in a comparison of predicted and observed yield and SG for the KCl treatment subset in 1988 as an example for all data sets (Table 5). These data may be compared with Figures 1 and 2 to help visualize the geometric distribution of the observed data within the region of the predicted data. The observed data sets consist of two over-lapping 2N x 2K factorials. As shown in Table 5, the standard error (SE) of the estimated mean tends to be smaller in the center of the 4N x 5K array because neighboring cells reinforce the predictability of a given cell, a type of "internal replication." Typically, cells on the edges and corners of the region have less reinforcement and larger SE's.

Yield

Yields where 224 kg N ha^{-1} was applied without K fertilization were higher than the control treatment (0N, 0K), particularly in 1989 (Table 2, Fig. 1). When K was applied with N, either as KCl or K_2SO_4, yields were higher than

TABLE 5.—*Geometric distribution of the observed (Ob), estimated (Es), and the standard error (SE) of the estimated mean for tuber yield and specific gravity across the response surface of the 1988 KCl subset.*

	N rate, kg ha^{-1}											
	0			112			224			336		
K rate	Ob	Es	SE	Ob	Es	SE	Ob	Es	SE	Ob	Es	SE
kg ha^{-1}	Yield, mt ha^{-1}											
0	25.4	24.5	2.53	—	30.0	2.23	27.1	29.6	2.33	—	23.2	4.07
112	—	28.2	2.04	36.2	34.3	1.88	—	34.5	1.76	30.5	28.7	2.54
224	27.9	30.0	2.42	—	36.8	2.07	36.6	37.6	2.17	—	32.5	2.33
336	—	30.2	3.20	—	37.5	1.91	—	38.9	2.08	—	34.4	2.33
448	—	28.5	5.00	37.6	36.4	2.64	—	38.5	2.26	33.8	34.6	2.68
	Specific Gravity											
0	1.079	1.079	0.0011	—	1.080	0.0008	1.077	1.077	0.0009	—	1.072	0.0015
112	—	1.078	0.0008	1.079	1.079	0.0007	—	1.077	0.0007	1.073	1.073	0.0010
224	1.076	1.076	0.0009	—	1.078	0.0008	1.077	1.077	0.0008	—	1.073	0.0009
336	—	1.074	0.0015	—	1.077	0.0009	—	1.076	0.0010	—	1.072	0.0011
448	—	1.072	0.0019	1.075	1.075	0.0010	—	1.074	0.0009	1.071	1.071	0.0010

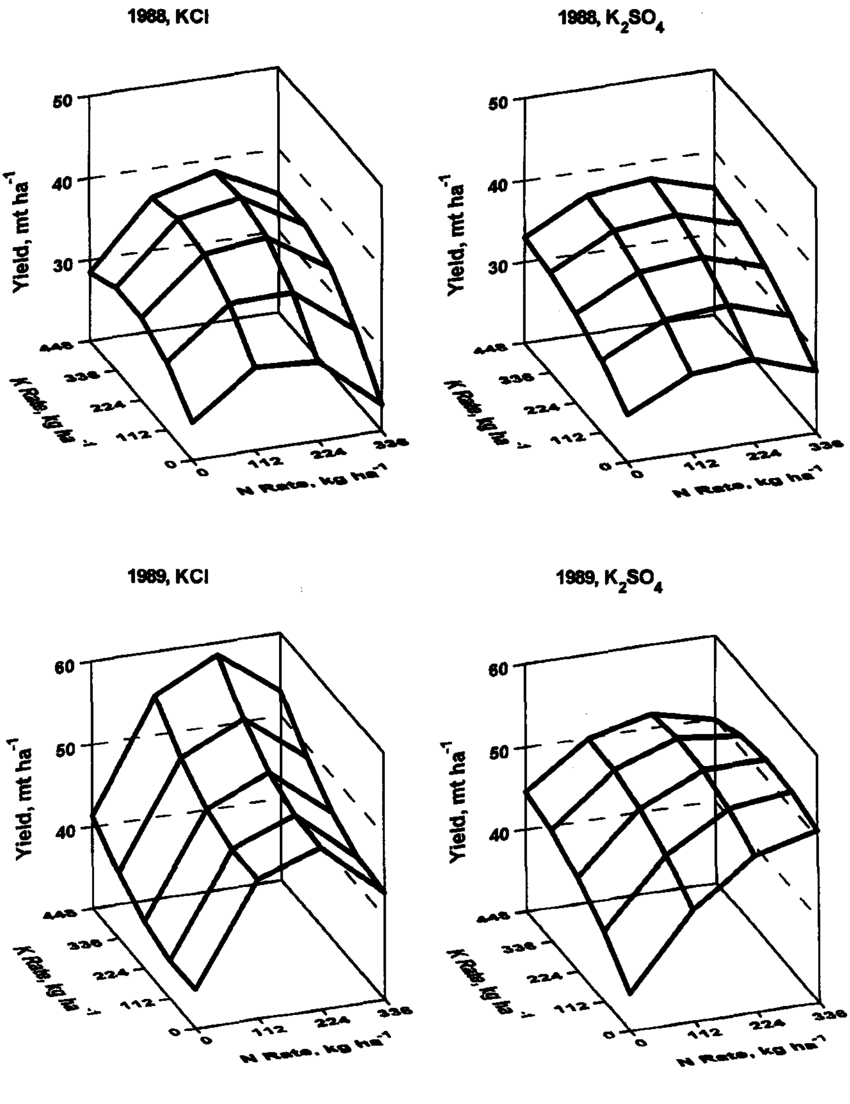

FIG. 1. Tuber yield response surfaces for N and K rates by K-sources in 1988 and 1989.

with N alone, with maximum yields near 112 and 224 kg N ha^{-1} for 1988 and 1989, respectively (Fig. 1). Yields from applying 112 kg N ha^{-1} were among the highest when combined with either 112 or 448 kg K ha^{-1} from either K-source (Table 2). The highest N application, 336 kg ha^{-1}, tended to decrease yields. Partial linear and quadratic regression coefficients for N were significant both years (Table 4). The partial regression coefficients for the N*K and the N*K-source interactions for yields were not significant either year.

Potassium effects on yield without N depended upon K-source. Yields with K_2SO_4 were 0.9 and 6.3 mt ha^{-1} larger than those with KCl in 1988 and 1989, respectively (Table 2). In 1989 when the residual soil NO_3-N was low (Table 1), yields with 224 kg K ha^{-1} as KCl without applied N were slightly lower than the control. Because the irrigation water was low in SO_4-S (Table 1), $CaSO_4$ was applied uniformly to all plots before seed bed preparation so these effects cannot be explained in terms of S deficiency. The K-source effects are interpreted in terms of an ion uptake antagonism between NO_3^- and Cl^-. This interaction is elaborated in a companion paper (7).

Potassium applications increased yields both years when N was applied. The partial linear and quadratic K regression coefficients for tuber yield were significant in 1988 but not in 1989 (Table 4). Soil test K was slightly higher in 1989 than in 1988 (Table 1). Average tuber yields increased 1.7 and 3.3 mt ha^{-1} in 1988 and 1989, respectively, when K increased from 112 to 448 kg ha^{-1}.

Specific gravity

The highest SG was always associated with the lowest N and K rates, 112 kg N or K ha^{-1} (Table 2, Fig. 2). Nitrogen application above this rate decreased SG both years. An interaction occurred between N and K-sources in 1988 (Fig. 2). This was supported by significant partial linear and quadratic regression coefficients for N*K-source effects in 1988 (Table 4). The anomaly between K-sources in 1988 was not readily explained except as mentioned previously under yields. There was no interaction for K rate or source with N on SG in 1989. Without N, 224 kg K ha^{-1} as KCl lowered SG while K_2SO_4 did not (Table 2). Specific gravities of tubers from the two K-sources within the same year were nearly equivalent when N was applied. Potassium and N effects on SG appear to be largely independent and additive when both present.

Petiole analysis vs yield and specific gravity

Significant treatment effects (Pr>F 0.001) on petiole NO_3-N and K concentrations were obtained in all samplings both years (ANOVA table not shown). All coefficients of multiple determination (R^2) for the stepwise linear regression models were significant for yield and SG (Table 6). The R^2 for yields generally decreased at later samplings. This may demonstrate that petiole NO_3-N and K concentrations at earlier samplings are better indicators of final tuber yields since both decrease with plant maturity. This would be particularly applicable when all the N and K fertilizers are applied preplant.

In 1988, linear NO_3-N and K variables, and the quadratic NO_3-N variable were selected at 61 DAP for the yield relationship, while only K was selected at 79 and 106 DAP (Table 6). In 1989, NO_3-N was selected in both samplings, along with the (NO_3-N)*Cl and K^2 variables at 74 and 101 DAP,

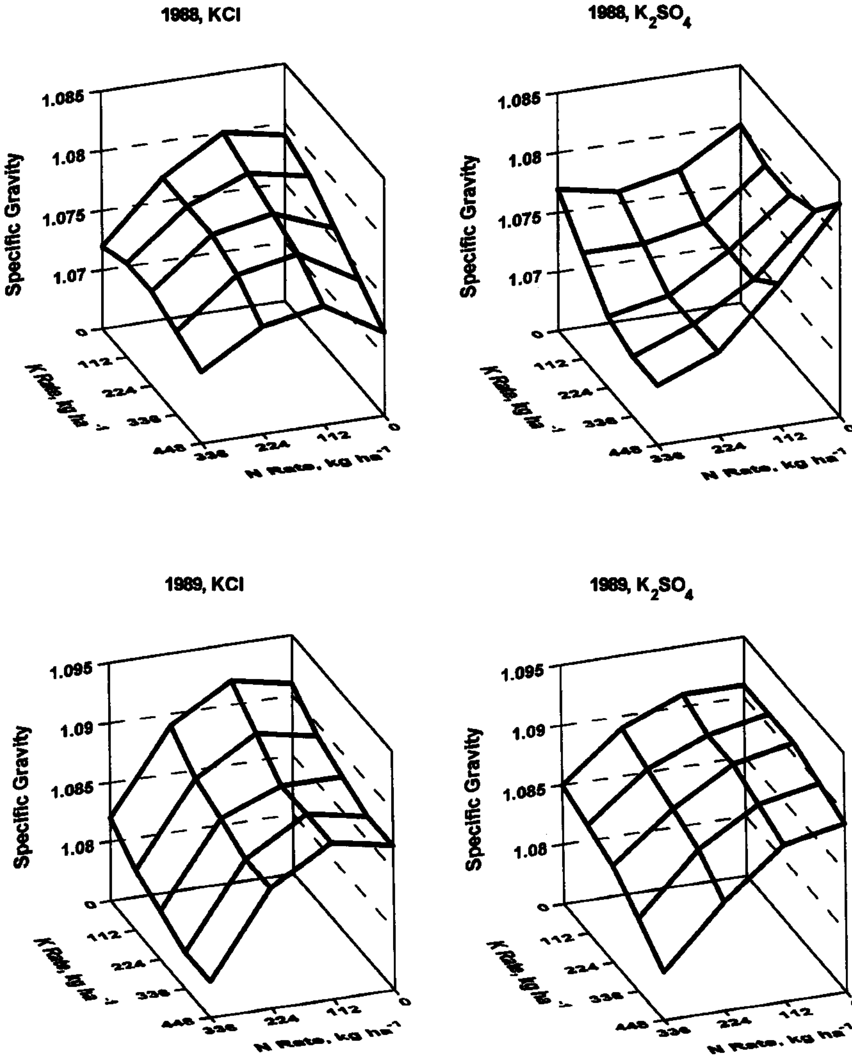

FIG. 2. Specific gravity response surfaces for N and K rates by K-sources in 1988 and 1989.

respectively. The data scatter did not allow a rigorous identification of critical petiole K concentrations at any sampling; however, yields were not appreciably increased above 5% K petiole (Fig. 3). Splitting the data into two groups with a statistical procedure (2) showed that a critical concentration might be at about 5% and 4.5% K at 79 and 106 DAP in 1988, respectively. This was slightly lower than previously reported for Russet Burbank 45-55 DAP (9, 24).

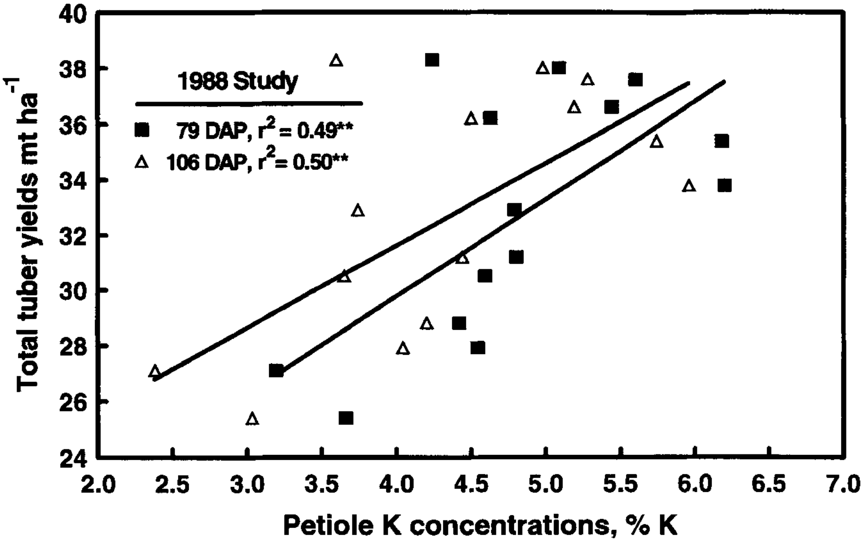

FIG. 3. The relationship between petiole K concentration and tuber yield for the second and third petiole sampling in 1988.

Only NO_3-N and K concentrations were selected for the SG relationship in 1988 (Table 6). In 1989 at 74 DAP, the quadratic variables for NO_3-N and K, and the linear variables for NO_3-N and S were selected; while at 101 DAP, K and (NO_3-N)*Cl, and the quadratic variable of NO_3-N were selected. All coefficients for the selected variables were negative, except for NO_3-N and S in the first samplings. The (NO_3-N)*Cl variable apparently contained additional information not in the NO_3-N or Cl. Chloride appears to have a minor or indirect role in 1989.

Discussion and Conclusions

A response to both N and K fertilization was anticipated in these studies because the initial soil test NO_3-N and K concentrations were low (9, 17) (Table 1). It was also anticipated that 448 kg K ha^{-1} would be more than sufficient for maximum yields since the fertilizer guides only recommended 224 kg K ha^{-1}. The soil at this location has a $CaCO_3$ acid equivalent of about 40% that is dominated by dolomite ($CaMg(CO_3)_2$). This may increase the K fertilizer requirement if a sufficient amount of exchangeable and soluble Mg^{++} is present, since Mg^{++} competes with K^+ for uptake by plants (3). This indicates that the K fertilizer recommendations should be reevaluated, especially for this growing environment. The relationships between Ca, Mg and K are further discussed in a companion paper on petiole nutrient con-

TABLE 6.—*Regression equation selected by stepwise regression procedure for yield or specific gravity relative to potato petiole NO_3-N, K, S and Cl concentrations at indicated days after planting (DAP) in 1988 and 1989.*[a]

	DAP	Constant	Regression equation[b]	R^2
Yield, 1988	61	-21.9	$5.20 \times 10^{-3} * N + 2.75 * K - 1.72 \times 10^{-7} * N^2$	0.72**
	79	15.7	$3.52 * K$	0.49**
	106	19.6	$2.98 * K$	0.50**
Yield, 1989	74	35.9	$5.04 \times 10^{-4} * N - 2.43^{-4} * (N * Cl)$	0.76**
	101	35.0	$2.64 \times 10^{-3} * N - 1.60 \times 10^{-7} * N^2 + 0.28 * K^2$	0.46**
S.G., 1988	61	1.074	$1.775 \times 10^{-6} * N - 7.750 \times 10^{-11} * N^2 - 1.160 \times 10^{-4} * K^2$	0.68**
	79	1.086	$-3.220 \times 10^{-7} * N - 1.995 \times 10^{-3} * K$	0.61**
	106	1.084	$-4.113 \times 10^{-7} * N - 1.412 \times 10^{-3} * K$	0.55**
S.G., 1989	74	1.091	$4.831 \times 10^{-7} * N + 0.049 * S - 4.367 \times 10^{-11} * N^2 - 1.930 \times 10^{-3} * K^2$	0.87**
	101	1.100	$-2.221 \times 10^{-3} * K - 2.115 \times 10^{-11} * N^2 - 1.753 \times 10^{-7} * (N * Cl)$	0.89**

[a]**Indicates significance at the 0.01 probability level.
[b]N as mg NO_3-N kg^{-1}; K as %K; S as %S; Cl as %Cl.

centrations (7).

Since the environment of these studies had a low Cl background (Table 1), it was anticipated that there might be a N*K*K-source interaction. Increasing Cl is known to depress petiole NO_3-N concentration but not protein N concentration in the leaves (10, 19). It is not known if a Cl application from either water or fertilizer sources increases the N fertilizer requirement or changes the petiole NO_3-N concentration needed for best yields. Average tuber yields in this study were slightly larger where K_2SO_4 was applied compared with KCl (41.4 vs. 40.8 mt ha^{-1}), however this difference was not significant using a paired *t*-test. Without applied N and relatively low initial soil NO_3-N concentrations in 1989, yields with KCl were lower than those with K_2SO_4 (Table 2). When N was applied, there was no difference between K-sources even at the highest K rate. The partial regression coefficients for the N*K-source and N*K*K-source variables were significant for only SG in 1988 (Table 4). This was also supported by the modified model results (Table 3). In addition, the petiole (NO_3-N)*Cl interaction was only selected by the stepwise regression analysis for yield and SG in 1989. These data suggest that yields are affected by the N*K*K-source interaction when available NO_3-N is low. At adequate NO_3-N availabilities, SG will be affected by the N*K*K-source interaction more than yields.

Response surfaces calculated with multiple regression equations for tuber yields and SG illustrates both main effects and interactions of N and K with K-sources (Figs. 1 and 2). This relationship does not separate the N, K or K-source effects nor their interactions. Modified models containing only "N" or "K" variables were significant for yields and SG (Table 3). The models having "N*K" interactions or "K-source" variables were significant for only SG in 1988; while all models containing all the "interactions" were significant for both yields and SG. The "interactions" model contained variables that were probably intercorrelated within and with main effect information. This analysis agrees with the actual data in Table 2 and the calculated response surfaces (Figs. 1 and 2).

The N fertilizer requirement for best yields was not dependent upon K-source nor was the K-source fertilizer requirement dependent upon N rate. If both are initially low, then the nutritional needs of each must be satisfied for best yields. In this study, N depressed SG more than K, while K-source did not influence SG as much as K itself. Nitrogen and K effects on SG were additive. Both petiole NO_3-N and K concentrations were both related to yields and SG but complex interactions appeared to obscure their relationships. Other papers have addressed the N and K rates, and K-source effects on petiole and tuber chemistries (7, 25).

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