Effect of Plant Spacing and Fertilizer on Yield, Purity, Chemical Constituents and Evapotranspiration of Sugar Beets in Kansas II. Chemical Constituents[1]

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The chemical constituents in sugar beets delivered to factories for processing have become a major concern in many producing areas of the United States. Their chemical make-up is determined by genetics, environment, and interactions between those two factors. Several investigators (3,5,19,22)[3] have demonstrated genetic control of many chemical characteristics. Field environment studies concerned with chemical composition have been conducted by many researchers most of whom varied moisture content of the soil and/or applied different fertilizers at different rates (4,5,6,7,8,9,10,12,14,16,17,18,19,20,21,23). Ogden et al. (16) and Herron et al. (12) reviewed many of these reports which have shown a close inverse relationship between nitrogen fertilization and sugar beet quality. Several experimenters (4,5,7,9,14, 17,19,20,23) have elucidated to some degree the effects of nitrogen fertilizer on nonsugars. All have shown that nitrogen constituents of sugar beet roots increase with increased nitrogen.

Complexing results are not surprising as soils are extremely variable and dynamic and are affected by micro and macro environments. Fertilizer results and recommendations, in general, are specifically applicable only to the general location in which tests were conducted. The investigation reported here was undertaken to:

1. Study effects of fertilizer treatments on several individual nonsugar constituents of sugar beets.

2. Study effects of varying plant populations on nonsugar constituents.

Materials and Methods

Experimental data were obtained from extensive field experiments at Garden City, Kansas, in 1959 and 1960, previously reported by Herron et al. (12). Sodium and potassium were de-

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[3] Numbers in parentheses refer to literature cited.

termined on the Beckman DU Spectrophotometer, utilizing the method proposed by Bauserman and Olson (1), and are reported as percent. Phosphate was estimated colorimetrically as molybdenum blue (13, 15) and is reported in parts per million. Galactinol and raffinose evaluations were determined by paper chromatography similar to that described by Brown (2). Amino acids were determined by paper chromatographic procedures reported by Hanzas (11). The total amino acid content is the sum of the individual amino acids found by paper chromatography. All paper chromatographic determinations are reported as percent of dry substance. Total nitrogen was determined by a modified micro-Kjeldahl nesslerization procedure (17), and is reported as percent of dry substance. Sugar and purity were analyzed by standard sugar analysis procedures.

The amounts of nitrogen were applied in an arithmetical progression, treatments were subdivided into their linear and quadratic effects as shown in Table 1.

Results and Discussion

Sixteen different chemical constituents were studied. Nitrogen produced the greatest effects on the constituents studied, as expected, because 11 of the 16 characters studied contained nitrogen atoms. Effects of nitrogen were not limited to compounds containing nitrogen atoms as it significantly affected 13 of the attributes studied in the 1959 test and 15 of those studied in the 1960 test (Tables 1 and 2). In all cases except for glutamic acid in the 1960 test, nitrogen effects were linear, i.e., as the rates of nitrogen fertilizer increased, the chemical constituents being studied increased proportionally. There were only three nitrogen quadratic effects and again only glutamic acid in the 1960 test showed a greater quadratic than linear effect.

Adding phosphorus fertilizer produced a significant increase in P_2O_5 content of beet roots both years and a significant increase in the aspartic acid content in 1960 (Table 2). Potassium caused a significant increase in the glutamic acid content of beets in 1959 but no other significant effects.

The three different population levels produced significant differences in both years for the elements: sodium, potassium and phosphorus, and the amino acids: glycine, valine, leucine and total amino acid. Significant differences among populations also were detected in the 1960 data for glutamine, gamma amino butyric acid and alanine. In all cases (Table 2) decreased plants per acre caused an increase in the above mentioned elements and amino acids, or as beets were spaced closer together they contained less per plot of the elements and the amino acids studied.

Table 1.—Levels of significance obtained for nitrogen, phosphate, potassium and populations for 16 different characters in the Kansas fertility and spacing tests.

Source of variation	Na.	Phos.	K	Raff.	Gal.	Total nit.	Aspar. acid	Glutamic	Asparagine	Glutamine	Gly.	G.A.B.A.	Alanine	Valine	Leucines	Total amino acids
								1959 Test								
Nit. L	***	NS	***	NS	NS	***	***	***	***	***	***	***	***	***	...	***
Nit. Q	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	**	NS	NS	NS	NS	NS
P	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
Nit. L x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nit. Q x P	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nit. L x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Nit. Q x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P x K	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	*	NS	NS	NS	NS	NS
Nit. L x P x K	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
Nit. Q x P x K	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Pop.	**	NS	***	NS	NS	*	NS	NS	NS	NS	*	NS	NS	***	**	*
Pop. x Fert.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
Pop. x P	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
Pop. x K	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x P x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x N x P x K	NS	NS	*	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 1 continued, next page.

Table 1.—Levels of significance obtained for nitrogen, phosphate, potassium and populations for 16 different characters in the Kansas fertility and spacing tests. *Continued*

1960 Test

Nit. L	***	**	***	NS	*	***	***	NS	***	***	***	***	***	***	***	**
Nit. Q	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
P	NS	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nit. L x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nit. Q x P	NS	NS	NS	NS	NS	NS	*	NS	*	*	NS	NS	NS	NS	NS	*
Nit. L x K	NS	NS	*	NS	NS	NS	NS	*	*	NS	**	*	**	*	NS	**
Nit. Q x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nit. L x P x K	NS	NS	NS	NS	NS	*	NS	NS	*	*	*	NS	*	NS	NS	*
Nit. Q x P x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop.	***	*	*	NS	NS	NS	NS	NS	NS	**	**	**	**	**	**	**
Pop. x Fert.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Pop. x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Pop. x P	**	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	*	NS	NS	
Pop. x K	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x N x P	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
Pop. x N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x P x K	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pop. x N x P x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non-significant
*** = Significant at the .1% level
** = Significant at the 1% level
* = Significant at the 5% level

Table 1 shows several significant first and second order interactions. The 1959 data also had two significant third order interactions. Although these interactions were statistically significant, their variances were relatively low, compared with those of the main effects and therefore are relatively unimportant. Several of the higher order interactions merely reflect significant interactions that occurred at lower levels. Data which produced the significant first order interactions are given in Table 3 and discussed below.

Effects of different fertilizers and populations are discussed under elements, carbohydrates, and nitrogenous constituents.

Chemical Elements

Effects of different fertilizers on sodium, potassium and phosphorus content of the beets varied (Table 2). As nitrogen fertilizers were increased, sodium and potassium contents of the beets significantly increased both years. Phosphorus content was significantly decreased by nitrogen in 1960. The trend was similar but not significant in 1959.

Phosphate fertilizer produced no significant change in the amount of sodium and potassium in the roots either year. However it significantly increased the amount of phosphorus content both years, which indicates that the more phosphorus applied, the more the beets absorb from the soil.

Potassium application did not significantly change the level of sodium, potassium or phosphorus in beets either year.

Different plant populations resulted in significant differences in sodium and potassium content of the beets both years, with lower populations and greater differences occurring together. The higher population (8-inch spacing compared with 16-inch spacing) lowered sodium and potassium content of beets indicating that the wider the spacing, the more sodium and potassium the plants absorbed from the soil. Phosphate in the 1960 test was significantly greater than in the 1959 test of greater population. This probably was a chance occurrence because it did not occur in 1959. The "F" value for 1960 barely reached significance.

Carbohydrates

Beets were analyzed for both raffinose and galactinol. A significant linear nitrogen response for 1960 is shown in Table 1. The galactinol content was lowest at the 0 nitrogen level and increased with increasing rates of nitrogen fertilizers. Raffinose was not significantly affected by changing rates of nitrogen. Potassium and phosphate applications did not significantly affect raffinose or galactinol contents either year. None of the three different spacings significantly influenced raffinose or galactinol content.

Table 2.—The average mean effects for nitrogen, phosphate, potassium and populations for 16 different characters in the Kansas fertility and spacing tests.

Nitrogen applied	Na.	Phos.	K	Raff.	Gal.	Total nit.	Aspar. acid	Glutamic	Asparagine	Glutamine	Gly.	G.A.B.A.	Alanine	Valine	Leucines	Total amino acids
								1959 Test								
0	.039	677	.214	.387	.253	.72	.127	.021	.116	.56	.083	.183	.053	.049	.084	1.25
80	.047	614	.227	.379	.244	.82	.151	.022	.151	.74	.113	.202	.070	.064	.105	1.60
140	.055	634	.245	.365	.266	.96	.182	.030	.184	1.00	.163	.242	.101	.085	.141	2.12
LSD (0.05)	.004	----	.008	----	----	.05	.015	.004	.024	.10	.013	.018	.015	.010	.015	.18
LSD (0.01)	.005	----	.011	----	----	.06	.021	.005	.033	.13	.018	.025	.020	.014	.020	.24
Degrees of freedom = 2 and 33																
Phosphate applied																
0	.046	587	.228	.385	.262	.81	.152	.023	.154	.76	.120	.211	.072	.065	.105	1.64
120	.048	696	.229	.369	.247	.85	.155	.026	.146	.78	.119	.206	.077	.067	.115	1.67
LSD (0.05)	----	75	----	----	----	----	----	----	----	----	----	----	----	----	----	----
LSD (0.01)	----	101	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Degrees of freedom = 1 and 33																
Potassium applied																
0	.046	657	.227	.383	.254	.82	.151	.022	.149	.76	.124	.205	.071	.066	.110	1.63
100	.048	627	.230	.372	.255	.84	.156	.027	.152	.78	.114	.213	.078	.067	.110	1.68
LSD (0.05)	----	----	----	----	----	----	----	.004	----	----	----	----	----	----	----	----
LSD (0.01)	----	----	----	----	----	----	----	.005	----	----	----	----	----	----	----	----
Degrees of freedom = 1 and 33																
Populations																
8″ Spacing	.044	635	.223	.389	.253	.81	.148	.023	.139	.73	.110	.205	.070	.058	.100	1.57
12″ Spacing	.047	667	.230	.364	.252	.84	.155	.023	.155	.77	.117	.205	.074	.069	.110	.165
16″ Spacing	.050	623	.233	.378	.258	.86	.156	.026	.156	.81	.131	.216	.080	.071	.119	1.74
LSD (0.05)	.003	----	.005	----	----	.03	----	----	----	----	.014	----	----	.007	.011	.13
LSD (0.01)	.004	----	.007	----	----	----	----	----	----	----	----	----	----	.009	.014	.18
Degrees of freedom = 2 and 72																

Table 2.—The average mean effects for nitrogen, phosphate, potassium and populations for 16 different characters in the Kansas fertility and spacing tests. *Continued*

Nitrogen applied	Na.	Phos.	K	Raff.	Gal.	Total nit.	Aspar. acid	Glu-tamic	Aspara-gine	Gluta-mine	Gly.	G.A.B.A.	Alanine	Valine	Leucines	Total amino acids
							1960 Test									
0	.031	713	.251	.280	.185	.71	.068	.019	.082	.367	.087	.117	.035	.043	.069	.87
60	.039	676	.262	.280	.193	.79	.071	.017	.096	.417	.102	.123	.046	.049	.076	.99
120	.045	622	.277	.279	.201	.92	.081	.023	.115	.499	.134	.142	.060	.060	.091	1.18
LSD (0.05)	.007	55	.009	----	.016	.06	.004	.004	.014	.045	.012	.011	.007	.007	.008	.09
LSD (0.01)	.009	79	.013	----	----	.09	.006	----	.018	.061	.017	.014	.010	.009	.012	.12
Degrees of freedom = 2 and 33																
Phosphate applied																
0	.039	644	.267	.288	.191	.80	.071	.021	.099	.429	.105	.127	.048	.052	.080	1.01
120	.038	697	.259	.272	.196	.81	.075	.019	.096	.426	.110	.128	.046	.050	.077	1.01
LSD (0.05)	----	48	----	----	----	----	.004	----	----	----	----	----	----	----	----	----
LSD (0.01)	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Degrees of freedom = 1 and 33																
Potassium applied																
0	.038	664	.261	.273	.194	.82	.072	.019	.099	.435	.109	.131	.048	.052	.080	1.02
100	.039	676	.265	.286	.193	.78	.074	.021	.096	.420	.106	.124	.046	.050	.077	1.00
LSD (0.05)	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
LSD (0.01)	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Degrees of freedom = 1 and 33																
Populations																
8" Spacing	.036	699	.258	.284	.194	.79	.072	.020	.094	.392	.101	.123	.044	.047	.074	.96
12" Spacing	.039	651	.264	.276	.188	.80	.071	.019	.098	.431	.106	.124	.045	.051	.079	1.00
16" Spacing	.042	660	.268	.279	.198	.82	.076	.020	.101	.460	.117	.135	.052	.054	.083	1.08
LSD (0.05)	.003	37	.007	----	----	----	----	----	----	.040	.008	.008	.005	.004	.005	.07
LSD (0.01)	.004	----	----	----	----	----	----	----	----	.054	.011	.010	.007	.005	.007	.09
Degrees of freedom = 2 and 72																

Total Nitrogen and Amino Acids

The total nitrogen content of all of the amino acids significantly increased with increased nitrogen applications. In 1959 all nitrogenous compounds tested showed a linear significant increase at the 0.1% level or .001 level. The glutamic acid and the glycine acid contents also showed a significant quadratic response, but the linear response accounted for a greater portion of the variation. In 1960 all linear responses except those for glutamic acid and total amino acid were significant at the 0.1% level. The total amino acid was significant at the 1% level; glutamic acid quadratic interactions, at the 5% level. In both years glutamic acid showed a significant quadratic effect. Although the values are significant, the amounts of glutamic acid in the beets (Table 2) were so small compared with other amino acids, importance of glutamic acid effects seems doubtful.

Phosphate applications produced only one significant effect for aspartic acid in 1960. Otherwise phosphate failed to affect significantly any nitrogenous character studied. Potassium applications significantly affected only glutamic acid and only in 1959. That both phosphorus and potassium affected only one amino acid and were not consistent both years indicate that those two fertilizers were not affecting the nitrogen content of the beets.

Effects of different populations on the total nitrogen and amino acid contents are shown in Table 2. The amount of nitrogen in the beets increased as spacing of beets increased from 8 to 16 inches, in nearly all cases, although some were not significant. Total amino acid content was significantly increased both years as beets were spaced farther apart. Sparse populations provide less competition for minerals and other soil elements so individual plants would be expected to gather more nitrogen and other mineral elements. Test results verify that hypothesis.

Significant First Order Interactions

There were several first order interactions in both years (Tables 1, 3, and 4). In 1959 (Table 3) only 7 significant interactions were found but 20 were found in 1960 (Table 4).

The 1959 data showed a significant N $\times$ P interaction for galactinol, due primarily to nitrogen. At the 0 rate of phosphate, galactinol was fairly high, but it dropped with application of 80 pounds of nitrogen, only to increase significantly with the 140-pound nitrogen rate. At the 120-pound phosphate rate, galactinol values were not significantly changed for any nitrogen rate.

Table 3.—Seven significant first order interactions which occurred in the 1959 test.

Galactinol

P \ N	0	80	140	Mean	
0	.263	.236	.287	.262	
120	.243	.251	.246	.247	NS
Mean	.253	.244	.266		

NS
N × P LSD (0.05) = .036

Glycine

K \ P	0	120	Mean	
0	.130	.119	.124	
100	.109	.120	.114	NS
Mean	.120	.119		

NS
P × K LSD (0.05) = .018

Sodium

Pop \ K	0	100	Mean	
1	.041	.048	.044	LSD (0.05)
2	.048	.047	.047	.003
3	.050	.050	.050	
Mean	.046	.048		

NS
K × P = Difference between 2 population means at the same level of K = .004.
Difference between 2 K means for the same population = .005.

Glycine

K \ N	0	80	140	Mean	
0	.082	.114	.176	.124	
100	.082	.112	.149	.114	NS
Mean	.082	.113	.163		

LSD (0.05) = .013
N × K LSD (0.05) = .018

Leucines

Pop \ N	0	80	140	Mean	
1	.076	.101	.123	.100	LSD (0.05)
2	.089	.109	.134	.110	.011
3	.087	.106	.165	.119	
Mean	.084	.105	.141		

LSD (0.05) = .015
N × Pop = Difference between 2 population means at the same level of N = .019.
Difference between 2 nitrogen means for the same population = .022.

Glutamic acid

K \ P	0	120	Mean	
0	.023	.022	.022	LSD (0.05)
100	.023	.031	.027	.003
Mean	.023	.026		

NS
P × K LSD (0.05) = .006

Asparagine

Pop \ P	0	120	Mean	
1	.129	.150	.139	
2	.164	.146	.155	NS
3	.169	.144	.156	
Mean	.154	.146		

NS
P × Pop = Difference between 2 population means at the same level of P = .028.
Difference between 2 P means for the same popultaion = .030.

The significant interaction of N $\times$ K for glycine was due to potash applications with a high nitrogen level. Glycine significantly increased with increased rates of nitrogen. Potash has no particular influence on glycine at the first two nitrogen levels, however at the 140-pound nitrogen rate, a 100-pound application of potash significantly restricted the build-up of glycine.

There were two significant interactions of P $\times$ K. Glutamic acid was not significantly affected by either P or K when used individually, but when used together glutamic acid content increased significantly. But glycine had the highest value at 0 rate of P and/or K, either of which seemed to reduce glycine content of beets. K, at 100 pounds per acre without P significantly reduced glycine content.

Population interacted significantly with all three fertilizers. Leucines showed a significant population $\times$ N interaction. Nitrogen significantly increased leucines in all three populations. However, the 12-inch population spacing showed more leucines at 0- and 80-pound nitrogen rates than the 16-inch spacing did. At the 140-pound nitrogen rate, greatest amount of glycine was in the widest spacing.

The significant interaction for asparagine due to population $\times$ P was primarily caused by the switch which took place at the 8-inch and 12-inch spacings and at 0- and 120-pound rates of P. Least asparagine occurred with 8-inch spacing and zero P rate. At the 12-inch spacing and 0-rate asparagine significantly increased and was higher than at the 120-pound P rate with 12-inch spacing. In general asparagine increased as population increased with no P applied. When P was applied, the trend was opposite although values differed only slightly and were not significant.

The significant interaction of population $\times$ K for sodium was due to the significant increase in sodium content from K applied to the 8-inch spacing; at the other two spacings no difference in sodium content was detected. Also sodium content increased significantly between 8-inch and the other two spacings when no K was applied. At the 100-pound K rate no significant differences were found in sodium content of the three populations.

Most of the interactions in 1959 were barely significant and may not be important biologically. The second and third order interactions appear to have little or no meaning and resulted primarily from first order interactions.

Table 4 shows the simple interactions detected from the 1960 data. There were four significant interactions of N $\times$ P for amino acids. With the 0 nitrogen rate values were approximately the same for both P levels. At the 60-pound N rate, P seems to have stimulated uptake of nitrogen, and all amino acid values were higher with the 120-pound N rate over P at 0. N at 120 pounds per acre, P reduced uptake of N so P at the 0 rate resulted in higher amounts of amino acids. This was true of all four N × P interactions.

Eight N × K interactions were significant (Table 4). Seven were amino acids; one was potassium. The interaction was produced by the 100-pound rate of K stimulating uptake of nitrogen and potassium at the 0 nitrogen rate. While at the 120 N rate, the 100-K rate reduced uptake of nitrogen ions compared with uptake at the zero-K rate. This complete reversal in all cases was the primary cause of the significant interactions. At the medium-(60 lb) nitrogen rate, amino acid values were approximately equal for both levels of K. That so many amino acids showed significant interactions of N × K definitely may have biological meaning even though they appeared in only the 1960 test. These interactions indicate that with high amounts of nitrogen, applying potash likely would raise beet quality because potash under those conditions seems to reduce the amount of amino acids in the beets.

Populations showed eight significant interactions with fertilizers: one each with nitrogen and potassium and six with phosphorus (Table 4). The significant N × population interaction resulted from the 12-inch spacing producing more glycine at 0-nitrogen rate and less at the 60-pound N rate, compared with the other two spacings.

Six interactions of P × populations were significant; five with amino acids and one with sodium. In all 8-inch spacings studied, attributes were higher at the zero-P rate than at the 120 P rate. The reverse was true with the 16-inch spacing; the 12-inch spacing gave highest interaction values at the 0 level. The reversals produced significant interactions, indicating that to obtain highest quality beets, one would plant high populations (8-inch spacing) and apply 120 pounds of phosphate fertilizer.

Most interactions in 1960 were somewhat like those in 1959, i.e., barely significant. But the 1960 interactions differed by following a definite trend. That there were 20 significant interactions in 1960 and that they followed definite trends indicates strongly that fertilizer elements used did not act independently and that chemical composition of beets depends on interactions among fertilizer elements applied. The data also show that fertilizer applied should be governed somewhat by beet populations.

Table 4.—Twenty significant first order interactions which occurred in the 1960 test.

Potassium

K \ N	0	60	120	Mean	
0	.246	.256	.282	.261	
100	.256	.268	.271	.265	NS
Mean	.251	.262	.277		

LSD (0.05) = .009
N × K LSD (0.05) = .013

Glutamic acid

K \ N	0	60	120	Mean	
0	.015	.017	.024	.019	
100	.023	.018	.021	.021	NS
Mean	.019	.017	.023		

LSD (0.05) = .004
N × K LSD (0.05) = .006

Asparagine

K \ N	0	60	120	Mean	
0	.078	.095	.124	.099	
100	.086	.096	.104	.096	NS
Mean	.082	.096	.115		

LSD (0.05) = .014
N × K LSD (0.05) = .019

Glycine

K \ N	0	60	120	Mean	
0	.080	.101	.146	.109	
100	.094	.103	.122	.106	NS
Mean	.087	.102	.134		

LSD (0.05) = .012
N × K LSD (0.05) = .018

Gamma amino butyric acid

K \ N	0	60	120	Mean	
0	.116	.122	.154	.131	
100	.118	.123	.131	.124	NS
Mean	.117	.123	.142		

LSD (0.05) = .011
N × K LSD (0.05) = .015

Alanine

K \ N	0	60	120	Mean	
0	.030	.048	.067	.048	
100	.040	.044	.054	.046	NS
Mean	.035	.046	.060		

LSD (0.05) = .007
N × K LSD (0.05) = .010

Valine

K \ N	0	60	120	Mean	
0	.040	.050	.064	.052	
100	.047	.048	.056	.050	NS
Mean	.043	.049	.060		

LSD (0.05) = .007
N × K LSD (0.05) = .009

Total amino acids

K \ N	0	60	120	Mean	
0	.83	.97	1.27	1.02	
100	.90	1.01	1.09	1.00	NS
Mean	.87	.99	1.18		

LSD (0.05) = .09
N × K LSD (0.05) = .13

Table 4.—Twenty significant first order interactions which occurred in the 1960 test. *Continued*

Sodium

Pop \ P	0	120	Mean	
1	.037	.033	.036	LSD (0.05)
2	.040	.037	.039	.003
3	.039	.044	.042	
Mean	.039	.038		
	NS			

P × Pop = Difference between 2 population means at the same level of P = .004.
Difference between 2 P means for the same population = .006.

Glutamine

Pop \ P	0	120	Mean	
1	.407	.376	.392	LSD (0.05)
2	.449	.414	.431	.040
3	.431	.490	.460	
Mean	.429	.426		
	NS			

P × Pop = Difference between 2 population means at the same level of P = .057.
Difference between 2 P means for the same population = .060.

Glycine

Pop \ P	0	120	Mean	
1	.104	.097	.101	LSD (0.05)
2	.102	.109	.106	.008
3	.109	.125	.117	
Mean	.105	.110		
	NS			

P × Pop = Difference between 2 population means at the same level of P = .012.
Difference between 2 P means for the same population = .014.

Gamma amino butyric acid

Pop \ P	0	120	Mean	
1	.124	.121	.123	LSD (0.05)
2	.128	.120	.124	.008
3	.128	.142	.135	
Mean	.127	.128		
	NS			

P × Pop = Difference between 2 population means at the same level of P = .010.
Difference between 2 P means for the same population = .012.

Alanine

Pop \ P	0	120	Mean	
1	.049	.040	.044	LSD (0.05)
2	.046	.044	.045	.005
3	.050	.054	.052	
Mean	.048	.046		
	NS			

P × Pop = Difference between 2 population means at the same level of P = .007.
Difference between 2 P means for the same population = .008.

Total amino acids

Pop \ P	0	120	Mean	
1	.98	.93	.96	LSD (0.05)
2	1.03	.97	1.00	.07
3	1.03	1.13	1.08	
Mean	1.01	1.01		
	NS			

P × Pop = Difference between 2 population means at the same level of P = .10.
Difference between 2 P means for the same population = .11.

Table 4.—Twenty significant first order interactions which occurred in the 1960 test. *Continued*

Asparatic acid

P \ N	0	60	120	Mean	
0	.066	.066	.081	.071	
120	.069	.075	.080	.075	NS
Mean	.068	.071	.081		

LSD (0.05) = .005
N × P LSD (0.05) = .006

Asparagine

P \ N	0	60	120	Mean	
0	.084	.088	.123	.099	
120	.079	.103	.106	.096	NS
Mean	.082	.096	.115		

LSD (0.05) = .014
N × P LSD (0.05) = .019

Glutamine

P \ N	0	60	120	Mean	
0	.372	.390	.524	.429	
120	.361	.444	.474	.426	NS
Mean	.367	.417	.499		

LSD (0.05) = .045
N × P LSD (0.05) = .064

Total amino acids

P \ N	0	60	120	Mean	
0	.89	.92	1.22	1.01	
120	.84	1.06	1.14	1.01	NS
Mean	.87	.99	1.18		

LSD (0.05) = .09
N × P LSD (0.05) = .13

Glycine

Pop \ N	0	60	120	Mean	
1	.079	.101	.122	.101	LSD (0.05)
2	.094	.091	.131	.106	.011
3	.088	.114	.149	.117	
Mean	.087	.102	.134		

LSD (0.05) = .012
N × Pop = Difference between 2 population means at the same level of nitrogen = .015.
Difference between 2 nitrogen means for the same population = .018.

Phosphate

Pop \ K	0	100	Mean	
1	719	680	699	LSD (0.05)
2	638	665	651	37
3	636	684	660	
Mean	664	676		

NS
K × Pop = Difference between 2 population means at the same level of K = 52.
Difference between 2 K means for the same population = 57.

High nitrogen rates affected some sugar beet constituents that influence sugar beet quality. Herron et al. (12), using the same experimental material, pointed out that nitrogen decreased sugar content and purity. In this test, several nonsugars, which are melassigenic, increased significantly with increased N. Our data confirm voluminous reports of nitrogen effects on sugar beet constituents and quality: mainly that excessive nitrogen definitely increases melassigenic components of beets.

Summary

Data presented show that the different fertilizers and different amounts of the same fertilizer drastically affect chemical composition of sugar beets. Effects of nitrogen fertilizers were most striking as N significantly increased nearly all characteristics studied. Phosphorus mainly affected the phosphate content of beets. Potassium showed no consistent main effects but both potassium and phosphorus showed significant interactions with nitrogen. Phosphorus and population also produced several significant interactions.

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