Effectiveness of P Fertilizer Placement Methods and N Fertilizer Sources on Fertilizer Utilization and Yield Characteristics of Sugarbeets *

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INTRODUCTION

Effectiveness of fertilizer usage is gaining interest lately in the effort to minimize pollution hazards and to increase fertilizer profitability. Effectiveness may be improved by selecting modes of placement (Barber 1977) and/or fertilizer sources which could make added nutrients more accessible to plant roots. No conclusive evidence has been obtained to date regarding phosphate placement methods for sugar beets. Early reports have indicated that phosphate banded close to the seed row, as compared to broadcasting the fertilizer, promoted top growth (Cooke 1949 and 1951), or increased P uptake (Olsen 1950, Schmehl et al 1952) by the young sugar beet plants. However, in those experiments the beneficial effect of shallow phosphate banding on plant growth has not persisted throughout the growing season. Favourable yield effects by banding NPK fertilizer near the seed have been reported in some experiments (Shotton 1962), but other experiments have shown (Larson 1954) that phosphate, incorporated by plowing, gave higher yields and greater P concentration in the folliage than did the former placement method. Still, in other field investigations (Romsdal and Schmehl 1963), there was no difference in sugar beet yield among several phosphate placement methods, although the addition of P fertilizer significantly increased, on the average, sugar beet yield.

The use of isotopically labelled fertilizers enables the investigator to get additional, direct and quantitative information with respect to the fate of the applied fertilizer. Recently it was reported (Anderson and Peterson 1978) that the uptake

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of ^{32}P-labelled phosphate by sugar beet seedlings was greatly enhanced when the fertilizer was placed 2 inches directly below the seed, as compared to side placement. However, no evidence is available regarding deep banding of ^{32}P-labelled phosphate. As to the differential effect of N fertilizer sources for sugar beet, it has been reported (Bretelet 1973) that nitrate is taken up more readily than ammonium, but this evidence has not been confirmed in field experiments. The aim of the present investigation was to study in field experiments, the effect of P fertilizer placement methods and of N fertilizer sources on plant nutrient concentration, fertilizer utilization, yield and quality of sugar beets, using isotopically labelled fertilizers.

MATERIALS AND METHODS

Experimental sites. Four field experiments were conducted in the sugar beet growing region of Platy, Central Macedonia, in the years 1976, 1977 and 1978. The plot soils which were selected as representative of the area, were deep, alluvial, calcareous, with moderate drainage, low in organic matter, and moderately supplied with available P. The texture was medium for two experiments, and medium to heavy for the rest (Table 1).

Table 1. Certain characteristics of the soils at the experimental sites and details of the experiments.

Year:	Experiment No. 1, 1976	Experiment No. 2, 1976	Experiment No. 3, 1977	Experiment No. 4, 1978
Location:	Episcopi Imathias	Platy	Episcopi Imathias	Nissi Imathias
Soil:				
Texture	SiCL	SiL	L	CL
pH	7.8	8.2	8.0	8.0
Eg. $CaCO_3$(%)	12.0	10.0	4.9	6.0
Org. C (%)	1.4	1.1	1.2	1.2
P Olsen (ppm)	10.2	8.8	10.6	5.6
Seed Variety	Kawemono	Kawemono	Kawemono	Kawemono
Date of Sowing	May 19	May 21	March 30	March 27
Date of Singling	June 20	June 19	May 17	May 8
Plant Density (thousand/ha)	95	95	99	101
Irrigation (numberxmm)	1x60	-	3x60	3x65
Date of harvest	Oct. 4	-	Sept. 9	Sept. 26

Design. The experimental design was a randomized complete block layout with four to six replications. Each plot ($10x3.5m^2$) consisted of seven rows with row spacing 50cm. On the row the final spacing between plants was 20cm.

Treatments. The methods and rates of fertilizer application of the placement experiments (1976 and 1977) appear in Table 2. Basal nitrogen (ammonium sulfate), at constant rate, and P (simple superphosphate 0-21-0) were applied before sowing, while topdress N (ammonium nitrate) was applied two weeks after emergence.

Table 2. Rates and methods of fertilizer application in the 1976-1977 sugarbeet experiments.

Treatment	kg/ha of applied fertilizer N	kg/ha of applied fertilizer P_2O_5	Method of fertilizer application
I	60+(60)	0	N broadcast and incorporation to a depth of 12 cm, P banded 12cm below the surface and 5 cm to the side of the seed row.
II	60+(60)	40	
III	60+(60)+	80	
IV	60+(60)	160	
V	60+(60)	80*	N and P broadcast and incorporation to a depth of 12cm.
VI	60+(60)	80	N and P banded 12cm below the surface and 5cm to the side of the seed row.
VII	60+(60)	80	N broadcast and incorporation to a depth of 12cm, P banding 8cm below the surface and 5cm to the side of the seed row.
VIII	60+(60)	80	N broadcast and incorporation to a depth of 12cm, P banding 22cm below the surface and 5 cm to the side of the seed row.

*The rate for this treatment in the 1977 experiment was 160 KG P_2O_5/ha.

In the experiment of N fertilizer sources (1978), P fertilizer was applied before sowing, while N was applied immediately after emergence. The tested sources were ammonium sulfate, ammonium nitrate (single labelling of ammonia and nitrate separately), urea and sodium nitrate. The tested rate was 120 Kg N/ha.

The ^{32}P (placement experiments) and ^{15}N (experiment with

N sources) labelled fertilizers were applied to small subplots, roughly 3m long and 1m wide, while unlabelled fertilizers, exactly in the same dose, were applied to the rest of the plot.

In all experiments the seed variety Kawemono was used, which is extensively employed also in growing practice. Irrigation, as well as chemical control of cercospora leaf spot, were provided according to need.

Methods. Soil samples to a depth of 60cm, at 15cm increments, were taken prior to fertilizer additions from each experiment. Plant samples (6-12 plants/plot) were taken at specific growth stages to determine fresh or dry (at 70°C) weights. For the chemical determinations generally accepted methods were used. Thus, available P was determined by Olsen's method, total N by standard Kjeldahl, and nitrate N of the petioles by the phenol disulfonic acid method. Abundance of ^{15}N was determined by an emmission mass spectrometer (Veb Statron NOI-5) and ^{32}P* was counted by an ICN Coru/mat 2700 liquid scintillation counter.

RESULTS AND DISCUSSION

Placement experiments. The data on percent P and also on percent P derived from fertilizer (Pf) in the dry matter of various plant parts are given in Tables 3, 4, and 5. It is clear from these data that the percent P in dry plant matter was generally decreasing with age, during the tested period, and the P content of the roots was lower than that of the leaves. For the various plant parts P fertilizer application had a favourable effect on their P content, at the early stages of growth, regardless of the placement method. The differences between control and the other treatments, statistically significant for most treatments at the early stages of growth, became non significant at later stages. As to the tested placement methods and rates, treatment V, which is broadcast and incorporation of the fertilizers at a depth of 12cm, gave, in both P rates, the lowest P content at the early stages of growth

*^{32}P labelled superphosphate was supplied by Tennessee Valley Authority, contract numbers TV-39740A and TV-43692A.

and very close to that of the control. The difference in P content between treatment V and the other tested placement methods, was, in most cases, statistically significant. However, banding P fertilizer in different depths (treatments III, VII, VIII) did not have a significant effect on the P content of various plant parts; neither did banding together ammonium sulfate and ordinary superphosphate (compare tr.III to tr.VI). Regarding the utilization of P fertilizer, the data of the above tables indicate that broadcast and incorporation of the fertilizers at a depth of 12cm gave the lowest value for percent P derived from fertilizer (Pf). The difference between Pf of treatment V and that of the other tested placement methods was, in most cases, statistically significant. Both these facts, i.e. the lowest % P and the lowest Pf of various plant parts of treatment V, suggest that surface broadcast and incorporation to a depth of 12cm was the least efficient of the tested placement methods with respect to phosphorus uptake at the early growth stages.

Table 3. Percent P (%P) and also percent P derived from fertilizer (Pf) in dry plant parts at different growth stages (Experiment No 1, 1976).

	4-permanent leaf stage (June 15)		10-12 permanent leaf stage (June 29)					
	Whole plants		Blades		Petioles		Roots	
Treatment	%P	Pf	%P	Pf	%P	Pf	%P	Pf
I	0.306	--	0.195	--	0.140	--	0.131	--
II	0.427	32.2	0.301	51.0	0.221	54.4	0.199	53.1
III	0.410	32.7	0.326	60.1	0.262	64.7	0.227	59.9
IV	0.450	40.3	0.391	81.1	0.266	89.2	0.246	77.8
V	0.320	27.0	0.222	25.6	0.175	25.5	0.177	23.1
VI	0.378	30.6	0.315	69.9	0.237	70.0	0.198	72.6
VII	0.436	37.4	0.292	74.2	0.244	74.3	0.203	61.4
VIII	0.407	28.2	0.334	62.7	0.253	65.1	0.207	51.2
LSD(0.05)	0.080	NS	0.041	25.3	0.058	24.9	0.041	26.7

Table 4. Percent P (%P) and also percent P derived from fertilizer (Pf) in dry plant parts at different growth stages (Experiment No 2, 1976).

Treatment	4-permanent leaf stage (June 17) Whole plants %P	Pf	10-12 permanent leaf stage (July 5) Blades %P	Pf	Petioles %P	Pf	Roots %P	Pf
I	0.350	--	0.283	--	0.229	--	0.224	--
II	0.418	19.2	0.291	12.3	0.237	12.4	0.288	7.8
III	0.450	35.5	0.328	11.0	0.264	14.0	0.240	11.9
IV	0.494	29.0	0.291	16.8	0.269	19.5	0.253	14.6
V	0.407	15.0	0.275	7.0	0.261	7.3	0.200	6.7
VI	0.451	32.2	0.267	27.0	0.267	25.2	0.229	22.6
VII	0.426	39.0	0.357	15.1	0.245	17.7	0.221	16.8
VIII	0.456	23.7	0.336	17.2	0.275	18.1	0.237	17.6
LSD(0.05)	0.07	13.2	NS	7.5	NS	12.4	NS	9.4

Table 5. Percent P (%P) and also percent P derived from fertilizer (Pf) in dry plant matter at different growth stages (Experiment No. 3, 1977).

Treatment	4-6 permanent leaf plants (May 4) Whole plants %P	Pf	10-12 permanent leaf plants (May 17) Whole plants %P	Pf	Fully developed plants (June 23) Tops %P	Pf	Roots %P	Pf
I	0.333	--	0.263	--	0.190	--	0.140	--
II	0.476	68.8	0.295	57.3	0.208	48.2	0.163	38.6
III	0.422	68.2	0.293	45.4	0.235	50.4	0.185	34.2
IV	0.480	72.4	0.313	59.0	0.229	46.5	0.171	45.7
V	0.392	42.9	0.269	26.3	0.239	33.0	0.168	23.2
VI	0.456	63.2	0.316	60.3	0.238	52.4	0.195	37.0
VII	0.401	55.5	0.331	44.6	0.235	37.5	0.186	31.2
VIII	0.473	71.9	0.323	54.8	0.240	25.0	0.202	35.3
LSD (0.05)	0.098	NS	0.050	21.2	NS	NS	NS	NS

This conclusion is in agreement with evidence reported in the literature (Romsdal and Schmehl 1963) indicating also that broadcast and disc incorporation of superphosphate fertilizer was the least effective method of placement with respect to P uptake at the early growth stages of sugar beet plants. It should be noticed that the data are inconclusive as to the effect of the rate of P fertilizer applciation and of the depth of banding on P fertilizer utilization.

The amount of available P was similar in all three fields (Table 1). Yet the amounts of P derived from fertilizer was different in the three experiments (Tables 3, 4, and 5), indicating different availability of the added fertilizer P and possibly a differentiated root growth in each case.

Table 6. Fresh weights (g/plant) of sugarbeet plants at 2 growth stages: Means of 5 replications (Experiment No 1) + .

Treatment	10-12 permnent leaf stage Whole plants	Fully developed plants (20-24 permanent leaves)	
		Tops	Roots
I	7.1	46.5	15.7
II	12.5	86.0	33.9
III	12.9	83.1	30.8
IV	13.0	86.7	30.9
V	10.0	82.4	33.4
VI	11.9	84.5	30.7
VII	11.2	72.2	32.8
VIII	12.9	96.7	38.1
LSD 0.05	NS	22.4	8.7

+Sampling dates 29 June and 23 July respectively.

Tables 6 and 7 give data regarding weights of sugar beet plants at the early stages of growth. It is clear from these data that addition of P fertilizer affected favourably plant growth at their early growth stages. However, no significant differences were observed for the various tested placement methods and the applied P fertilizer rates. At later growth stages the observed differences disappeared and no significant response was noticed at harvest (Table 8), with respect to root yield, sucrose content, and gross sugar yield. Apparently available soil P was not a limiting factor in these experiments where $NaHCO_3$-extractable soil P was 8.8ppm or higher (Table 1). Detailed calibration studies of the Olsen soil P

Table 7. Dry weights (g/plant) of sugarbeet plants at 2 growth stages: Means of 6 replications (Experiment No 3)+.

Treatment	4-6 permanent leaf stage	10-12 permanent leaf stage	
	Whole plants	Tops	Roots
I	0.38	2.28	0.74
II	0.47	2.58	0.88
III	0.64	2.47	0.93
IV	0.63	2.91	1.21
V	0.60	2.57	0.99
VI	0.55	3.32	1.19
VII	0.54	2.31	0.90
VIII	0.57	2.92	1.01
LSD 0.05	0.15	0.64	0.29[x]

+Sampling dates 4 May and 17 May respectively.
xSignificant at 0.10P.

test previously carried out in Greece (Analogides 1974) indicated that, when this test value was 10ppm, an average 90% yield, with respect to maximum should be expected. More recently (Westerman et al 1977) it was also reported that phosphorus fertilizer applications did not significantly increase sugar beet root yields when the $NaHCO_3$-extractable soil P was greater than 10ppm. It should be noticed that lack of response to P fertilization of Greek soils, and also low utilization of the applied P fertilizer, have been reported for other crops (Yassoglou et al 1968, Papanicolaou et al. 1977). They were attributed to the previous fertilization practices and also to the presence of $CaCO_3$ in the soil, which is common for most of the Greek soils.

Nitrogen sources. Data regarding N content of plant parts and also N fertilizer utilization are given in Table 9. It is clear from these data that the various N sources had no significant effect on the total N content of the various plant parts of sugar beet through its cycle. A more reliable index of nitrogen status for sugar beet is the NO_3-N content in the petioles of the recently matured leaves (Ulrich 1950, Ulrich and Hills 1967), with a critical value of 1000ppm. Despite of the fact that the control treatment was excessive in NO_3-N content, all

Table 8. Yields and quality of sugarbeets at harvest. Means of 5 and 6 replications for each experiment respectively.

	Experiment No 1			Experiment No 3		
Treatment	Roots t/ha	Sucrose %	Gross Sugar t/ha	Roots t/ha	Sucrose %	Gross Sugar t/ha
I	35.0	12.73	4.44	76.7	14.00	10.70
II	38.7	12.21	4.73	73.2	14.30	10.46
III	41.3	12.38	5.13	73.5	14.17	10.40
IV	38.3	12.34	4.72	73.5	13.60	9.98
V	41.2	12.43	5.12	74.5	14.03	10.45
VI	40.7	12.79	5.23	74.7	14.07	10.49
VII	37.6	12.95	4.85	72.8	13.83	10.07
VIII	39.8	12.58	5.00	72.7	14.13	10.25
LSD 0.05	NS	NS	NS	NS	NS	NS

tested sources of fertilizer N, increased this index. Great differences are observed in the percent nitrogen derived from fertilize (Nf) of the petioles. These data indicate better utilization of nitrates as compared to ammonium or urea (compare treatment VI to treatments II and III and treatment V to treatment IV). Such differences continue to exist till the final harvest and appear in the calculated percent utilization of labelled fertilizer. The highest utilization coefficient (30.8%) was obtained with sodium nitrate (treat. VI) and the lowest (18.8%) with ammonium nitrate having labelled ammonium. The observed more efficient utilization of nitrates and of sodium nitrate in particular, could be of considerable importance in fertilizer practice. It is noticed that the ammonium of ammonium nitrate appears to be utilized less efficiently than the ammonium of ammonium sulfate (utilization coefficients 18.8 and 24.3 respectively). Same is true for the nitrate of ammonium nitrate as compared to that of sodium nitrate (utilization coefficients 27.0 and 30.8 respectively). This discrepancy is probably due to the fact that labelled NH_4^+ of ammonium nitrate is taken up by the plant roots in the presence of equal amount of non labelled NO_3^--N. Similarly labelled NO_3^- is taken up in the presence of equal amount of non labelled NH_4^+-N. It is, thus, natural for the plant root to take up nitrogen from both

Table 9. N content and plant N derived from fertilizer (Nf) in plant parts and also percent utilization of N fertilizer (N sources experiment).

Treatment number	N Source	Petiole content *2			Total N% in		Nf		Percent utilization of labelled N fertilizer
		Total N%	NO_3-N (ppm)	Nf	roots	tops	roots	tops	
I	Control	1.62	9 970	–	1.09	2.88	–	–	–
II	Ammonium sulfate	1.63	13 136	17.26	1.16	3.12	12.28	8.00	24.3
III	Urea	1.47	11 741	17.02	1.10	2.84	10.88	7.20	22.7
IV	Ammonium nitrate *1	1.72	13 387	9.06	1.37	3.18	3.92	3.01	18.8
V	Ammonium nitrate *1	1.61	12 103	12.08	1.22	3.18	6.86	3.24	27.0
VI	Sodium nitrate	1.83	15 086	25.80	1.21	3.04	14.26	7.26	30.8
	LSD (0.05)	NS	3 843	5.1	NS	NS	4.60	3.15	

*1 Labelled part

*2 Sampling date July 17, 1978

available N sources with the observed result. It should also be noticed that the ratio $\frac{Nf\ root}{Nf\ top}$ is 1.5 for the treatments with labelled ammonium and urea and 2 for the treatments with labelled nitrates. This fact indicates also a slower rate of utilization of the applied nitrates compared to ammonium or urea.

Table 10. Yield and quality data from the N sources experiment.

Treatment (N Sources)	Yield in (Roots) t/ha	Sucrose % (S)	Gross Sugar t/ha	a-amino N mg/100 g	Ash per 100 ^{o}S	Juice Purity (Q)
I	86.80	13.50	11.70	95.56	4.01	82.90
II	83.10	13.19	10.99	113.84	4.52	81.70
III	80.20	13.04	10.44	103.08	4.37	82.20
IV	82.80	12.88	10.67	106.92	4.64	80.90
V	82.80	12.88	10.67	106.92	4.64	80.90
VI	90.80	12.45	11.33	115.86	5.02	80.00
LSD 0.05	NS	NS	NS	NS	0.55	NS

The data for crop yield and quality characteristics are given in Table 10. Irrespective of fertilizer sources, nitrogen did not increase root, or sugar yields, but tended to cause a detrimental effect on sucrose content, whose average level was low. These results are well justified on the basis of the excessive nitrogen status of the experimental site, as indicated by the NO_3-N index of the control. It is noted that earlier studies have shown (Analogides 1976) that an estimated 50% of the sugarbeet fields in the same area had a nitrogen status above adequate, owing to residual effects from continuous over-fertilization. With regard to effects on quality sodium nitrate gave the highest ash content and significantly higher than that of the control and the urea treatments.

SUMMARY

In field experiments during the years 1976, 1977, and 1978 the effect of P fertilizer placement and N fertilizer sources was studied using ^{32}P and ^{15}N labelled fertilizers. The plot soils were deep, alluvial, calcareous, low in organic matter, moderately supplied with available P, and having moderate drainage.

Application of P fertilizer exerted favourable effect on both, the P content and the fresh weight of plant parts at the early stages of growth. From the tested placement methods banding of P fertilizers, regardless of depth, affected the P content of plant parts more favourably than broadcast and in-corporation. The data on the utilization of P fertilizer indicate that banding P fertilizer in various depths gave higher Pf values for different plant parts than broadcast and incorporation. It is thus concluded that, among the tested methods of placement, surface broadcast and incorporation of P fertilizer contributed the least to the uptake and utilization of the nutrient by young sugar beet plants. However, further work is needed with soils low in available P in order to examine whether these effects are carried through final crop yield and P uptake.

The tested N sources did not have a significant effect on total N content of various plant parts. However, all of the tested forms affected favourably the nitrate content of petioles. Furthermore they affected the Nf values of the petioles as well as the Nf values of the various plant parts at harvest and the utilization coefficient of the applied fertilizer. Nitrates were utilized more efficiently than ammonia or urea. The highest utilization coefficient (30.8%) was obtained with sodium nitrate, and the lowest (18.8%) with ammonium labelled ammonium nitrate.

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