A COMPARISON OF SELECTED POTASSIUM FERTILIZER FORMULATIONS ON RUSSET BURBANK POTATOES

An evaluation of the effects of three potassium products on emergence, plant stand, early vigor, tissue nutrition, yield and quality in a commercial field in the central portion of the Columbia Basin in Washington State.

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by
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THE INFLUENCE OF POTASSIUM FORMULATION ON POTATO PRODUCTIVITY

A LITERATURE REVIEW OF THREE POSASSIUM FERTILIZER FORMULATIONS

Ongoing refinements in potato production are progressively reducing the growers margin for error. Today's more vigorous and productive crops place increasing demands against all of the growth requisites. Of major concern is the adequate and timely supply from residual soil fertility and applied nutrients to satisfy the developing plants needs. To complicate matters, the requirements for essential nutrients change considerably through the course of a growing season. Generally the greatest concerns focus on peak demand periods. Whenever nutrient demand exceeds the crops fertilizer uptake, the production potential is diminished. An appropriate selection from the available nutrient formulations is also becoming increasingly important to the success of the crop. This consideration is especially relevant for potassium fertilizers. While no potassium formulation has more negative than positive properties, there are clearly some types with more desirable benefit/risk ratios in specific crop situations. With increasing frequency we are finding unusually high fertilizer rates being applied where exceptional yields are expected. The effectiveness of potassium as a fertilizer depends in part on the form and formulation in which it is applied. Many potassium fertilizers are formulated as salts. The potential concern for elevated soil salts is an agronomic consideration that should not be ignored. Accumulations of dissolved ions that have little or no role in plant nutrition may directly interfere with the osmotic functions of nutrient uptake and translocation. For this reason the salt index of various potassium fertilizers merits a careful review. Potassium sulfate (K_2SO_4) has is a 52% equivalent of K_2O and a fertilizer salt index of 45. With Potassium nitrate, (KNO_3) there is a 47% equivalent of K_2O, and it has a salt index of 74. This 64% increase in salt index is significant. Muriate of potassium or potassium chloride (KCl) has a 60% equivalent K_2O and a salt index of 116. KCl thus has a salt index that is 152% higher than K_2SO_4 and 57% higher than KNO_3. The soluble salts in soils and the salt index of the fertilizer selected are always interrelated considerations. The salt index is a measures of a soluble materials potential to change the dissolved ion concentration or osmotic pressure of the soil solution. Fertilizer materials with high salt index's have the greatest effect on raising the soil solutions osmotic pressure and therefore the highest potential for phytotoxic "burn". By selecting a lower salt index formulation, the potential for salt induced yield and quality reduction is minimized. Also the higher the fertilizer application rate, the more important these considerations become. This is especially true where warm arid climates and high soil evaporation losses occur.

Fertility availability to the plant is influenced in part by the salt index of the formulation. Since "plants drink, they don't eat" all nutrients must dissolve before they become available. Furthermore, all nutrients move into the plant across selectively permeable membranes in water as dissolved ions. This is in direct response to the magnitude of existing osmotic pressure gradients. "Salts" as dissolved ions can also change the osmotic potential of the soil solution. If the osmotic pressure within the cell gets too high, neither is water taken into the root nor are the dissolved nutrient ions. If the salt concentration gets too high, water may actually be withdrawn producing a fertilizer "burn". All things considered, the rates of application must be lower with fertilizer forms with a high salt index. The elevated sodium content in irrigation water is another important concern in salt management strategies.

There is considerable evidence of an inhibitory effect on potassium uptake as chloride ions concentration increases. This antagonistic relationship is not present when sulfate or nitrate formulations are selected. Yield and quality responses are also better with sulfate and nitrate formulations, not so much because of the nitrate or sulfate presence. but because of the negative effects of chloride ions at the higher levels.

Nutrient balance and interaction is always an important consideration. When a need for high K levels exists we may need to make special allowances for interactions with potassium fertilizers. Calcium, magnesium, boron and molybdenum uptake may be reduced because of antagonistic interactions with potassium. Conversely high K levels are known to enhance Zn, Mn and Cu uptake. Potassium also tends to enhance nitrogen use and interact synergistically with phosphorus. Chlorides however tend to inhibit potassium uptake.

Injury caused by chloride ions occurs in sensitive crops at the 3,000 to 5,000 ppm range. The potato plant is generally considered to be moderately sensitive to chloride ions. The potato is also a relatively high user of potassium. Considering these factors together it may be wise to select carefully the formulation(s) of potassium fertilizer to be applied to a potato crop. By carefully managing the nutrient balance, plants will generally be able to assimilate adequate quantities of all the essential nutrients as long as sufficient soil levels are maintained. In other words, the effectiveness of potassium as a nutritional element is related to the crops need being satisfied on a daily basis and also the interaction(s) with the carrier ion with which it is formulated. These considerations are further complicated by the requirements of the specific crop, moisture and evaporation conditions and existing soil salt properties.

When undisturbed, potassium exists in the soil in a balanced and stable equilibrium. The chemistry and physical properties of the soil itself effects this relationship. The potassium equilibrium is composed of the SOLUBLE (available, dissolved ions);

EXCHANGEABLE (unavailable, electrically bonded on soil particle surfaces) and FIXED (unavailable, bound within the mineral structure of the soil particles) forms. During the growing season when plants are present this equilibrium is continually out of balance due in large part to root system potassium withdrawals. This interaction is therefore in an ongoing dynamic flux. It is governed most by the soil characteristics, the rate of addition (fertilizer applications) and withdrawal (plant uptake). All the potassium we apply enters the equilibrium in the SOLUBLE form and then largely ties up on the soil particle surfaces as EXCHANGEABLE potassium. While plants may have brief access to in season K applications before tie up occurs, the most important benefits are from the new equilibrium that will provide proportionately more available potassium and for extended periods. Potassium does not limit growth or vigor as long as the available, i.e. SOLUBLE, supply exceeds the level of assimilation demand which satisfies the plants needs. As plants continue to remove soluble potassium, the equilibrium shifts to restore that which is removed by the root system. When the conversion from EXCHANGEABLE to SOLUBLE does not satisfy the plants need we may see a deficiency condition develop. Good agronomics will then dictate that we apply some form of potassium fertilizer to the field. This balance in fertility is the growers attempt to meet the crops needs and at the same time maintain the best economic return on the fertilizer investment. Since more than 40% of crop yield is provided by applied fertilizers, correct decisions about rate, timing, form and formulations are critically important.

Potassium's primary function in the plant is to optimize the functions of photosynthesis. We are also concerned with activating enzymes to accelerate growth, regulating energy and water relations and the assimilation and translocation of nutrients and carbohydrates. Potassium is recognized as having more influence on crop quality than any other individual nutrient element. Furthermore, because crop performance is the objective and profit our primary measure of success, we tend to look at this aspect with particular interest.

Irrigation practices are also important since all nutrients are taken into the plant in the form of dissolved ions. The ion solutions in our soils are subject, in varying degrees to relocation whenever an over watering situation occurs. This may move our available nutrients out of reach to our plants root system. When soils are over-irrigated, i.e. saturated, some of the dissolved nutrients may be washed away from their equilibrated positions. Based on solubilities, the potential for K_2SO_4 to leach is half that of KCl and KNO_3. The soil equilibriums for potassium will be restored from the non-soluble reserves but there is a delay while this process occurs. This equilibrium recovery varies considerably with different soils. During this lag time the amount of soluble potassium necessary to satisfy crop needs may be temporarily inadequate. The overall effect is predictably one of reduced productivity and lost profit. Considerable evidence indicates that whenever a deficiency in soil potassium availability occurs, there is limited benefit to applying a single large application. Very high rates, that may be uneconomical (greater than 500 lbs/a), can however make corrections to potassium supply in the short term. A much better option may be to apply small amounts of soluble K frequently through the irrigation water in order to remain on the desirable side of the cost/benefit relationship. Fertilizer formulation solubility therefore becomes an important consideration since we are in effect supplementing the soil reserves with the additional nutrient needed in an available form. Application timing and rate must match the plants need by the amount that this need exceeds the soils current potassium release rate. The results demonstrate that the smaller and the more frequent these additions are made, the more efficient the results. It also suggests that preplant rates in some situations can be reduced and that in some situations the total amount applied can be lower for an equal or better result.

The relative effectiveness of potassium fertilizer formulations in terms of potato yield, specific gravity and starch accumulation favors K_2SO_4 over KNO_3 and KNO_3 over KCl. The effectiveness of potassium therefore depends on both the formulation and the crop to which it is applied. It is generally believed the poorer responses associated with muriates is due to the negative effects of chlorides rather than the positive benefits of sulfates or nitrates. It is further noted that the consequences of elevated chloride ions is greatest on course soil types and in situations where arid climates and high soil surface water losses as upward percolation exists. While the information about potassium fertilizer formulation and potato crops comes from throughout the world there is little data currently available from the Columbia Basin in Washington State. To address this issue a replicated and randomized trial was undertaken in the central part of the basin area during summer of 1992 to compare Russet Burbank potato crop performances with the three most common potassium fertilizer formulations used commercially in the Pacific Northwest.

METHODS AND PROCEDURES

A field site was selected that had an unusually low potassium soil test value. This field was deliberately selected to enhance the opportunity for performance differences between applied potassium formulations to be exhibited. A location well into the selected field (more than 600 feet from the perimeter) was chosen for its topographic and soil type uniformity. The perimeter of the plot site was measured and staked prior to the commercial preplant broadcast fertilizer application to the remainder of this 100 acre pivot irrigated field. The broadcast application and the test treatments were applied on April 20th. These were incorporated using a tightly set finishing disc to minimize the movement of the applied fertilizers during the incorporating process. Following this tillage operation, the borders of the replicated and randomized test blocks were remeasured and staked. On April 27th the plot rows were individually opened, the 10 inch seed interval marked and the seed was hand planted. Four rows each twenty five feet in length of each 30 foot treatment area was planted with 30 seed pieces on 10 inch spacings and 34 inch row centers. The soil covering the seed was shaped by hand tools to exactly duplicate the size and shape of the hill created by the growers mechanical planter. Seed piece depth was 6 1/2 inches below the top of the hill's soil surface. Every effort was made to duplicate the commercial situation of the field. After planting was complete, with the exception of stand counts on May 21st, the extensive petiole sampling beginning July 6th and ending September 18^{th} and the split KNO_3 applications (July 15^{th}-31^{st} and August 14^{th}), nothing culturally was done within the plot site that did not occur in the remainder of the field until harvest. That is to say the plots were cared for under good commercial agronomic practices to make the results more relevant to commercial potato production. Weekly petiole sampling consisted of collecting 40 petioles (10 from each replicated block) fourth from the top of the stem, leaves removed and placed in ID coded paper sample bags. All samples were delivered to the lab within one hour of being collected. All were collected before 10 AM in the morning and were transported to the lab in an ice chest.

The plots were harvested on October 9^{th} with a single row potato lifter after vine senescence. All the remaining vines were removed by hand prior to digging. The center two rows of each four row block were dug for yield and grade evaluation. The harvested crop was hand sacked, tagged and taken to a USDA grade facility where it was evaluated by USDA inspectors using USDA process grade criteria on October 16^{th}. The balance of plot rows and the field was harvested after the plot harvest was complete by the commercial grower; Johnson Agriprises Inc.

The growers preplant fertility program applied to test field (except for the test plot site) based on soil test and projected crop need.

Nitrogen	140 lbs/a
Phosphorus	150 lbs/a
Potassium	225 lbs/a
Sulfur	50 lbs/a
Zinc	5 lbs/a
Boron	1 lb/a

Figure 1

POTASSIUM FORMULATION EVALUATED

Treatment 1	KCl	100% preplant applied April 20th
Treatment 2	K_2SO_4	100% preplant applied April 20th
Treatment 3	KNO_3	100% preplant applied April 20th
Treatment 4	KNO_3	50% preplant applied 16.7% applied July 15th 16.7% applied July 31st 16.7% applied August 14th

Figure 2

PLOT LAYOUT

NORTH

3	1	4	2	REP 1
2	3	4	1	REP 2
1	3	2	4	REP 3
4	2	1	3	REP 4

SOUTH

Treatment Code:

1 = KCl
2 = K_2SO_4
3 = KNO_3
4 = KNO_3 (split)

Each treatment block was 30 ft long X 11' 4" wide or 339.0 sq ft. 339.9 sq ft X 4 replications = 1360 sq ft or .003 acres

Diagram 1

PLANT POPULATIONS

	TOTALS
Treatment 1	237
Treatment 2	235
Treatment 3	236
Treatment 4	236
OVERALL TOTAL	944

Percent Stand 944/960 = 98.33%

Figure 3

STAND COUNTS AT 4" GROWTH STAGE

21 MAY 1992

	REP 1	REP 2	REP 3	REP 4
Treatment 1	30*30	29 29	30 30	30 29
Treatment 2	29 30	28 29	30 30	30 29
Treatment 3	29 30	29 29	29 30	30 30
Treatment 4	29 30	29 28	30 30	30 30

*Plant count per 30 seed pieces planted.

Figure 4

RESULTS AND DISCUSSION

The established plant population in the plot site was 98.33% of the seed planted. Figure 3. This is based on stand counts made on May 21st when the plants were approximately four inches tall. Figure 4. Of the 960 seed pieces planted 944 emerged. Missing plants were due equally to three pathogens _Fusarium_ sp., _Rhizoctonia_ sp., and _Pithium_ sp. and losses were distributed very equitably between the four treatments and the four replications. In other words, the loss in stand, small as it was, was randomly distributed throughout the plot site and not related to the treatments.

Early vigor and plant development was examined closely and found not to be different between treatments or replications.

Petiole sampling began July 6th when the plants were 12 to 14 inches tall. The collection of petioles was delayed to this stage of growth because the seed pieces planted were relatively large (2.5 oz. average) and seed this large is recognized as having an important influence on crop nutrient status at least through the 10 to 12 inch plant height. All treatments had first sample NO_3-nitrogen petiole levels above 20,000 ppm with the exception of the split KNO_3 treatment. Figures 5 through 8, Tables 1 through 4. Petiole levels increased in all treatments for the next two weeks. After that, all treatments exhibited a characteristic (normal) downward trend through September 18th when sampling ended. Petiole sample collection was discontinued at that time due to the maturation progress of the potato vines. In other words, there wasn't enough healthy tissue remaining to collect a credible and representative sample.

The phosphorus tissue levels was measured a PO_4-P percentage. Figures 9 through 12, Table 5. The phosphorus levels were slightly higher for the split potassium nitrate treatment from the start. In eight of the eleven weeks the KNO_3 split treatment was equal to or higher than any other treatment. The potassium chloride treatment had equal to or the highest phosphorus levels in five of the eleven sample periods. The potassium sulfate and potassium nitrate treatments each had one highest value in the eleven weekly samples. It is interesting to note that the phosphorus tissue level showed a distinctly elevated value the week after each of the three mid-season KNO_3 split applications.

The potassium level in the tissue sample analysis also produced some interesting results. Figures 13 through 16, Table 6. The tissue levels were highest in the potassium chloride plots during the first three sample periods. With the exception of the final sample period, the potassium nitrate treatment either individually or together with another formulation had the highest tissue potassium level for the last seven weeks. The split potassium nitrate treatment consistently maintained the highest potassium levels through most of the growing season.

The sulfur levels in the tissue analyses show the potassium sulfate treatment had the highest sulfur levels in four of the first five sample periods and again in the last three sample periods. Figures 17 through 20, Table 7. The potassium chloride treatments were highest or equal to the highest levels after August 1st. Sulfur levels were consistently lower in the potassium nitrate treatments by comparison.

The yield and quality performances of the plants in the four tested treatments exhibited some very useful relationships. Figures 21 through 23, Table 8. This performance, when measured in yield and quality parameters, indicates that all the potassium formulation applied entirely pre-plant incorporated were significantly better than the KNO_3 split applications. The 100% PPI potassium nitrate produced a crop with a value $275.39 per acre higher than the KNO_3 split treatment. The KNO_3 and K_2SO_4 yields were very nearly equal with only a one half percent yield or $24.23 per acre in crop value difference in this trial. The internal defects in the K_2SO_4 treatment was significantly higher than any of the other treatments which were not different from one another. Figure 24.

The poorest performance of the three 100% K pre-plant incorporated treatments was the muriate of potassium formulation. The KCl plots averaged .89 tons/acre or $111.46 less crop value per acre than did the K_2SO_4 treatment and $87.23 less than the KNO_3 plots.

The harvested tuber size distributions showed no consistent or important differences of economic significance. Figure 25 through 28, Table 9. The effect of potassium formulation on tuber specific gravity shows the K_2SO_4 and KNO_3 split had the best averages. Figure 29, Table 10. The KCl treatment had the lowest dry matter results. As expected the smallest tubers had the lowest specific gravities. This is the most likely direct result of immaturity. The 4 to 6 oz. potatoes had in all cases higher gravities than the 2 to 4 oz. tubers and in all cases lower gravities than either the 6 to 10 oz. or the 10 to 14 oz. size categories. The largest tuber size, the 10 to 14 oz. group, had equal to or higher gravity properties as compared to the 6 to 10 oz. sizes. The differences occurring in this trial are commercially significant and of monetary consequence to the grower.

The sugar content of the harvested tubers as measured by fry color on the USDA color chart showed the KNO_3 treatments had significantly more 1 and 2 color fry strips than did KCl and K_2SO_4. Table 11. While samples graded directly out of field seldom exhibited sugar levels of concern there may be reason to wonder what the outcome might be after an extended storage exposure. This was not done as the entire sample was consumed as the grade evaluation was done.

PETIOLE ANALYSIS DATA

Treatment 1 - KCl 100% PPI

	NO_3-N (PPM)	S (%)	P (%)	K (%)
7/06	20,750	.21	.36	10.0
7/15	22,250	.26	.45	19.9
7/24	22,875	.30	.55	12.7
7/31	17,050	.27	.36	11.3
8/07	16,500	.29	.36	10.4
8/14	14,125	.32	.33	10.6
8/21	12,125	.31	.43	8.7
8/28	8,500	.21	.22	8.6
9/04	9,000	.22	.21	9.3
9/11	7,750	.25	.17	8.8
9/18	4,725	.19	.14	7.9

Table 1

Treatment 2 - K_2SO_4 100% PPI

	NO_3-N (PPM)	S (%)	P (%)	K (%)
7/06	20,125	.22	.37	9.7
7/15	23,450	.26	.38	10.9
7/24	25,950	.37	.50	12.0
7/31	21,950	.33	.32	11.6
8/07	19,750	.29	.30	10.1
8/14	15,250	.28	.42	10.9
8/21	12,955	.23	.23	9.5
8/28	10,000	.20	.27	9.3
9/04	9,550	.22	.21	8.9
9/11	5,450	.25	.15	8.5
9/18	4,675	.20	.13	8.0

Table 2

PETIOLE ANALYSIS DATA

Treatment 3 - KNO_3 100% PPI

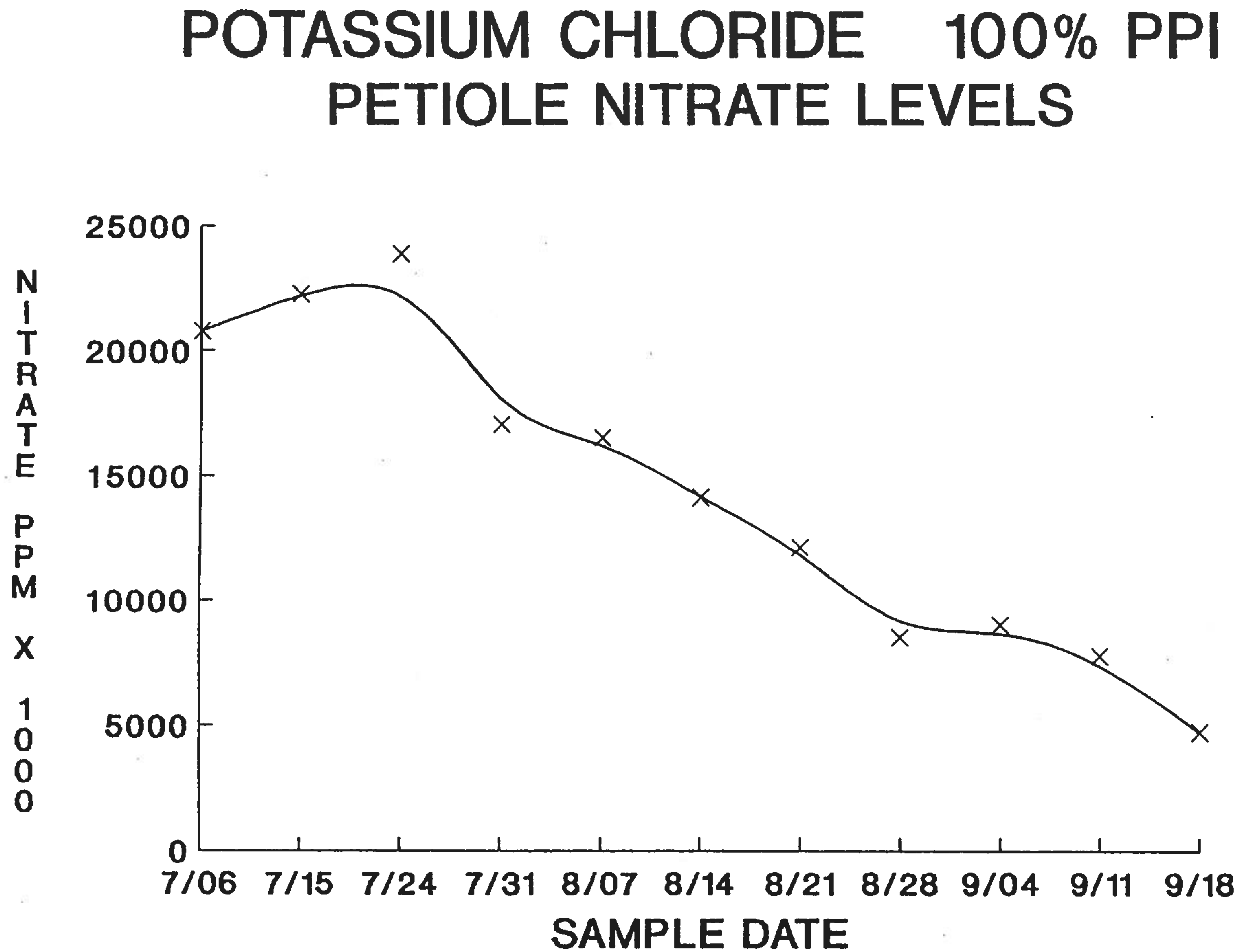
	NO_3-N (PPM)	S (%)	P (%)	K (%)
7/06	21,000	.25	.41	9.6
7/15	21,000	.25	.32	10.7
7/24	25,850	.28	.48	12.2
7/31	21,100	.29	.30	11.1
8/07	21,125	.29	.43	10.7
8/14	19,075	.30	.30	11.4
8/21	14,550	.26	.32	9.8
8/28	9,350	.26	.29	9.6
9/04	8,000	.19	.17	9.1
9/11	5,325	.20	.16	8.5
9/18	4,750	.19	.13	7.9

Table 3

Treatment 4 - KNO_3 Split (50% PPI and three 16.7% applications)

	NO_3-N (PPM)	S (%)	P (%)	K (%)
7/06	19,000	.24	.42	9.8
7/15	20,550	.26	.40	10.5
7/24	25,000	.30	.57	12.0
7/31	19,125	.30	.38	10.8
8/07	20,375	.27	.50	12.4
8/14	16,500	.27	.26	10.8
8/21	12,125	.25	.43	11.3
8/28	8,500	.23	.22	9.6
9/04	9,000	.22	.21	9.3
9/11	7,750	.20	.17	8.8
9/18	4,725	.19	.14	7.9

Table 4



POTASSIUM CHLORIDE 100% PPI
PETIOLE NITRATE LEVELS
NITRATE PPM X 1000
25000
20000
15000
10000
5000
0
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

Figure 5

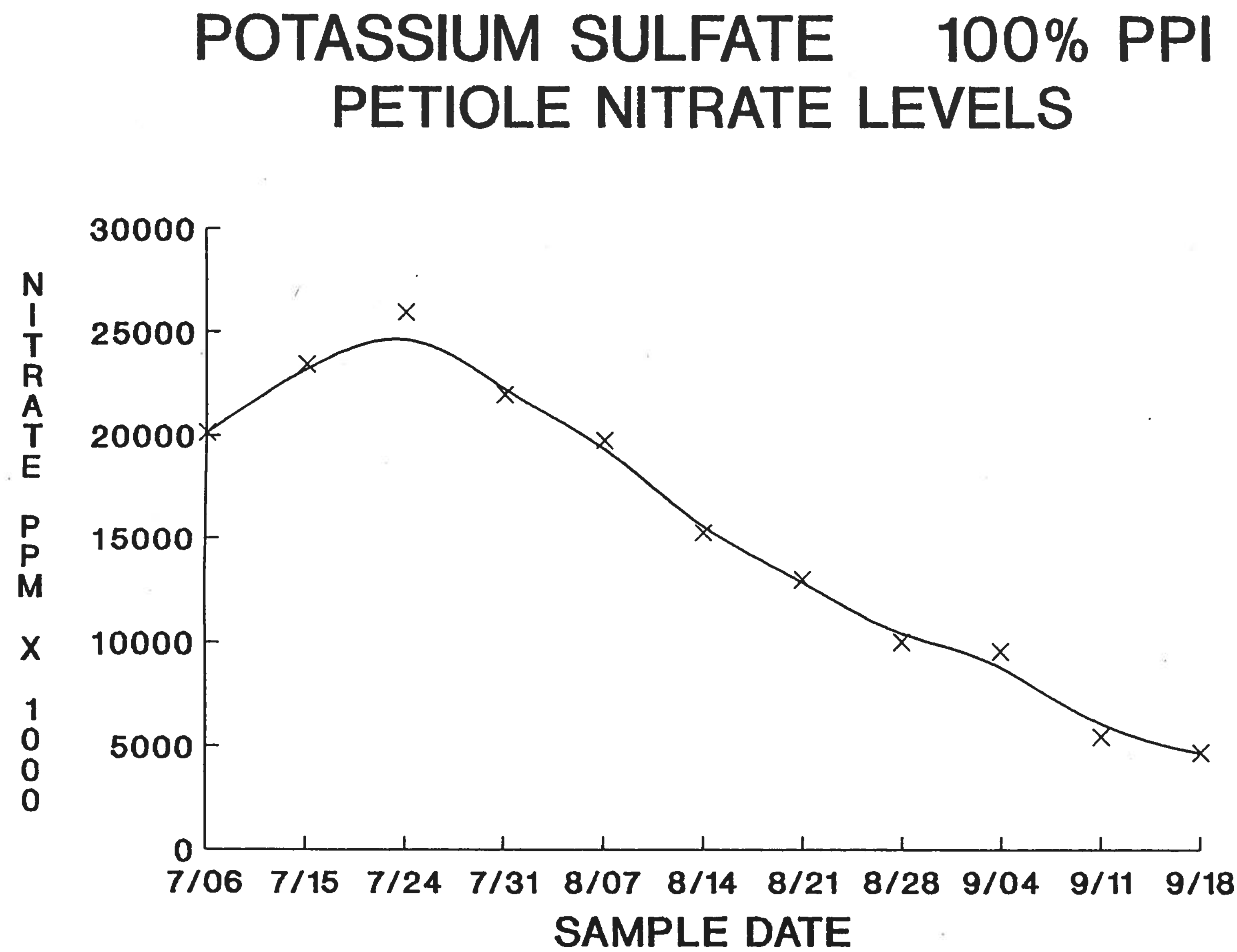

POTASSIUM SULFATE 100% PPI
PETIOLE NITRATE LEVELS
NITRATE PPM X 1000
30000
25000
20000
15000
10000
5000
0
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

Figure 6

POTASSIUM NITRATE 100% PPI
PETIOLE NITRATE LEVELS

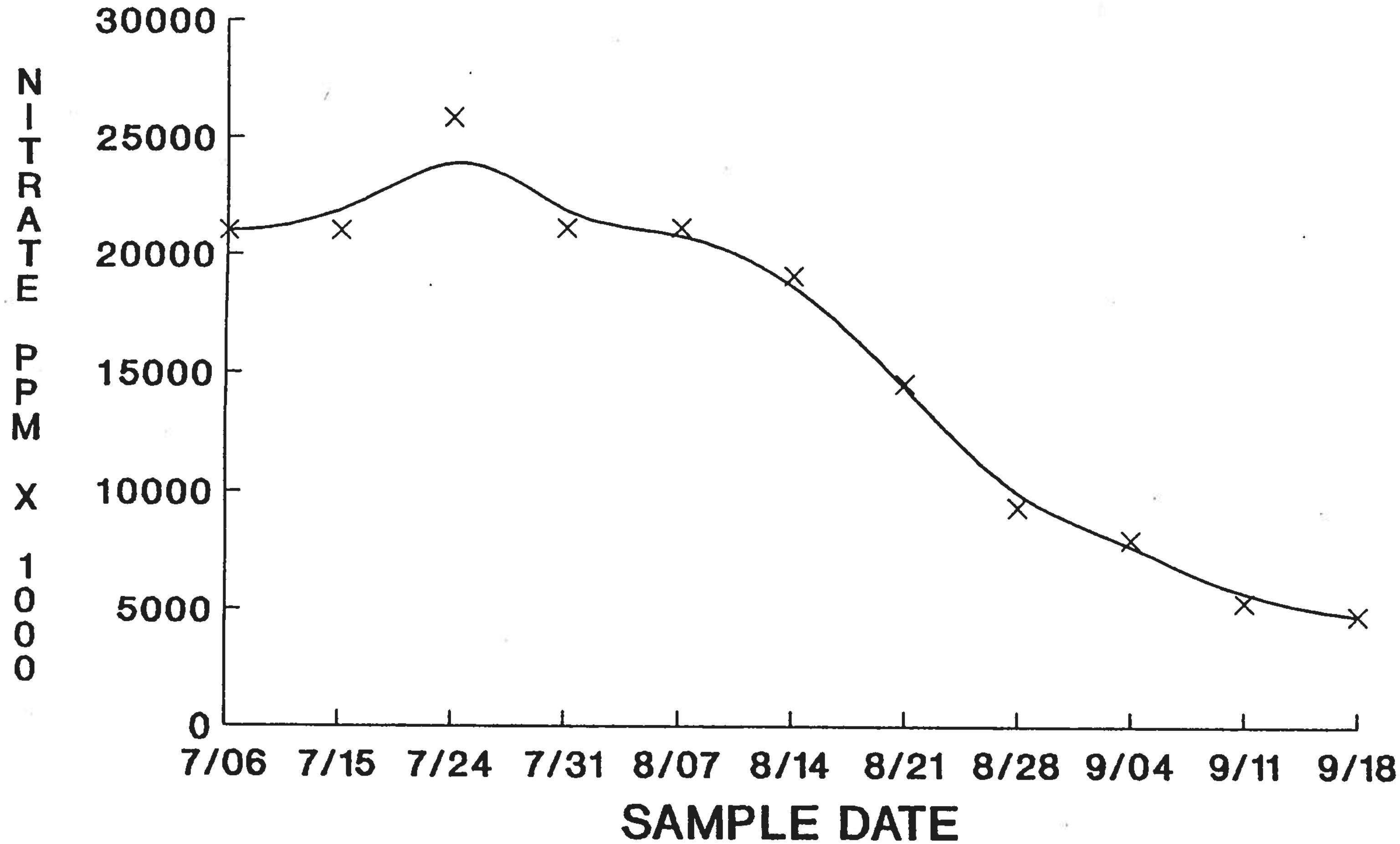


Figure 7

POTASSIUM NITRATE 50% PPI
PETIOLE NITRATE LEVELS

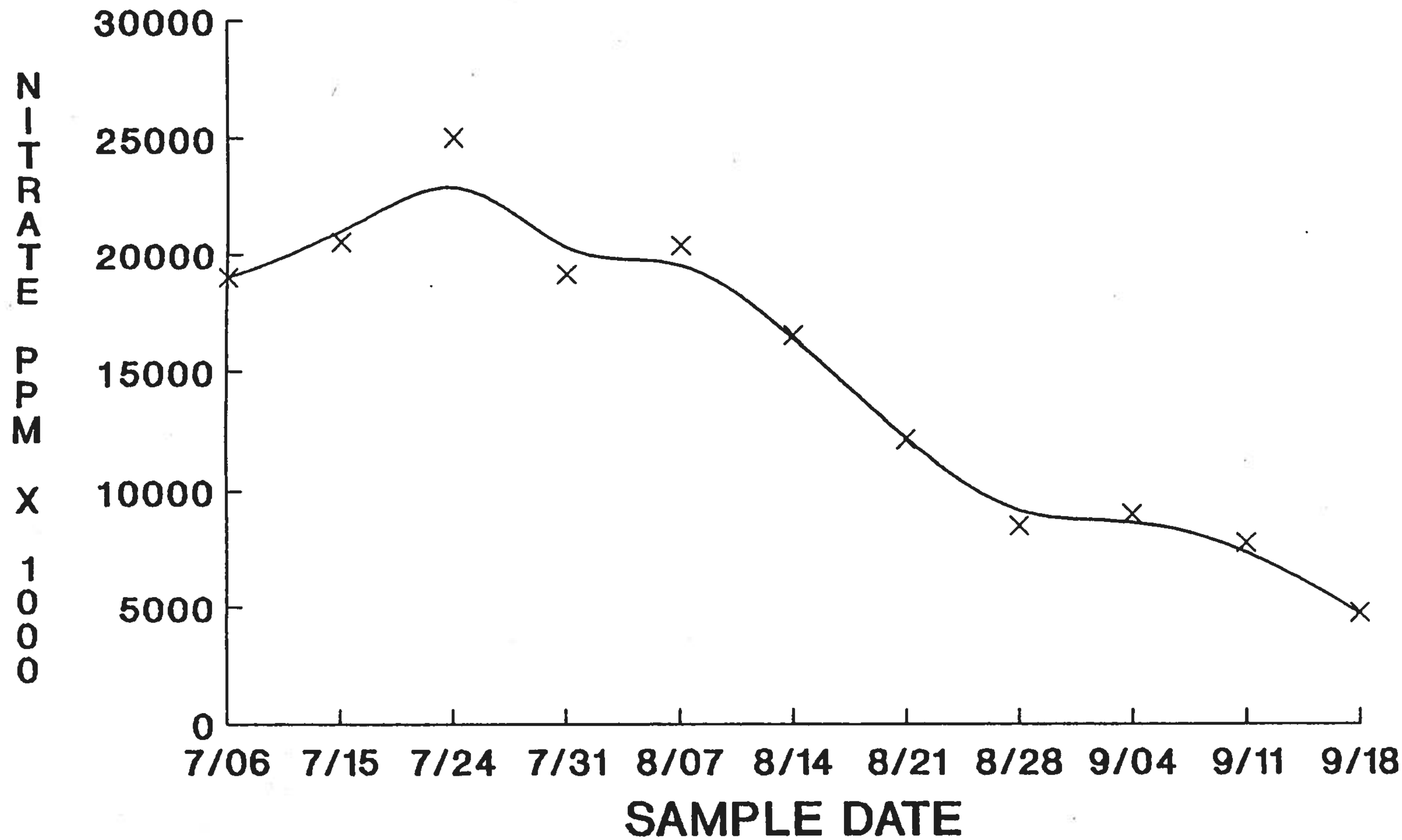


Figure 8

POTASSIUM CHLORIDE 100% PPI
PETIOLE PHOSPHORUS LEVELS

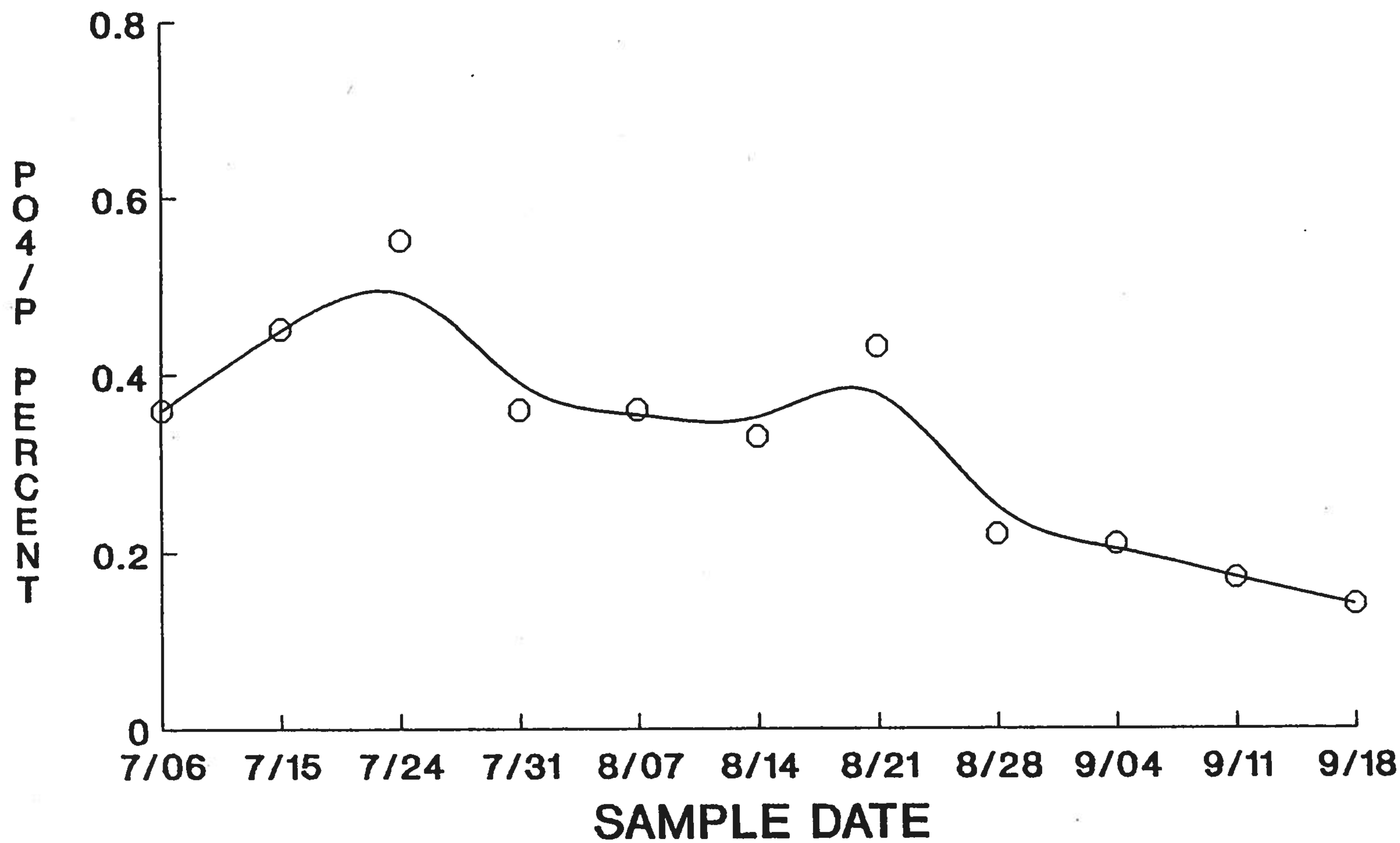


Figure 9

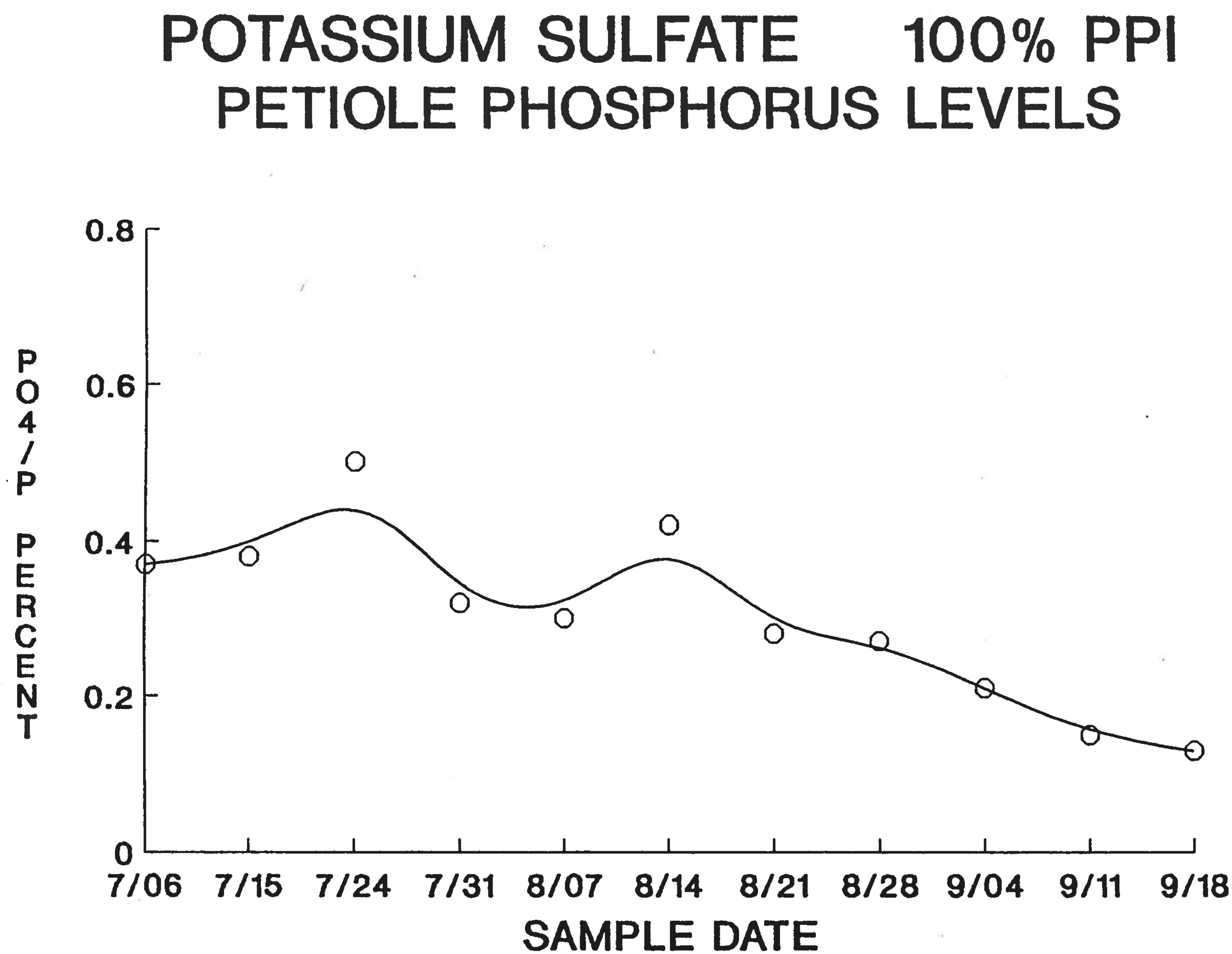
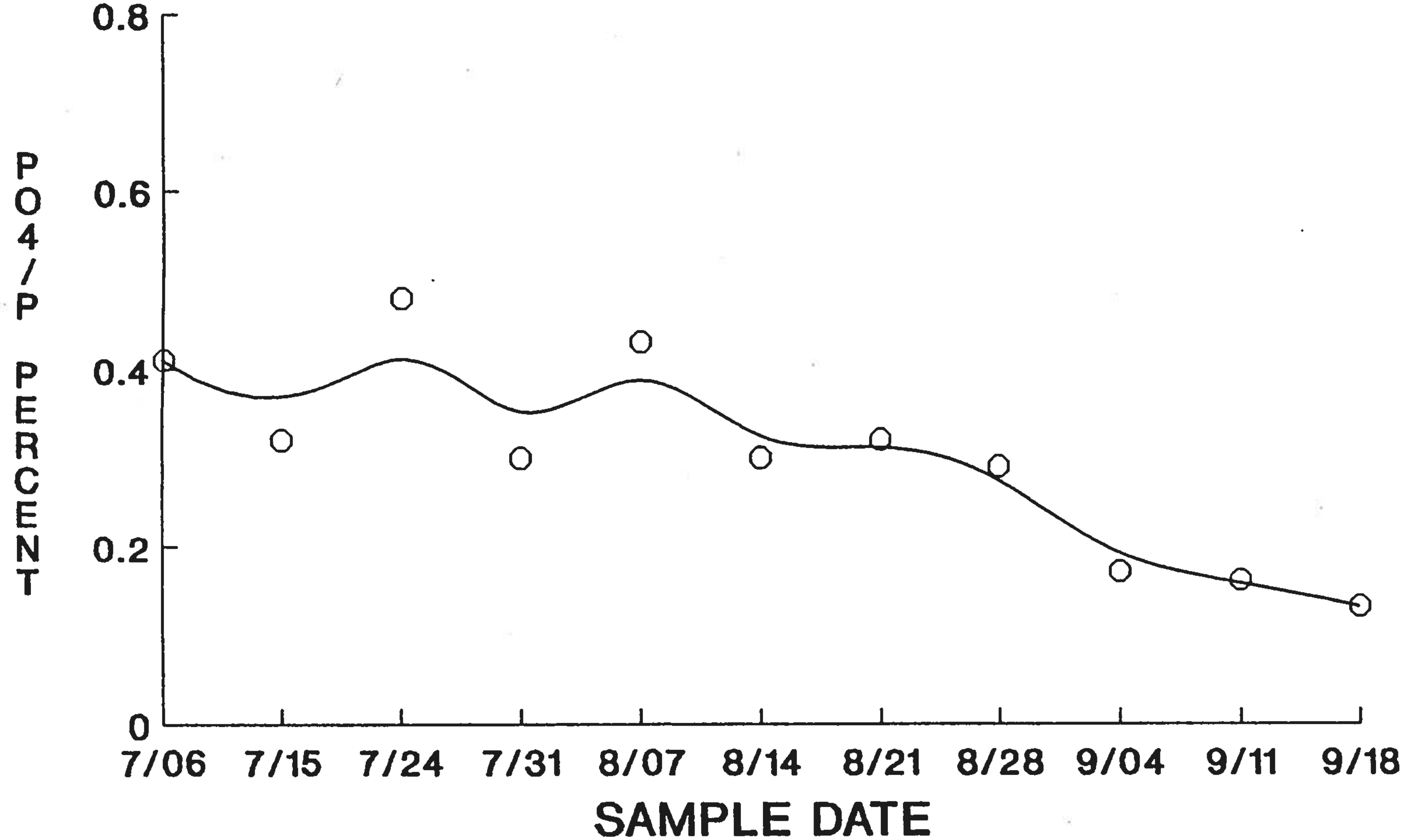
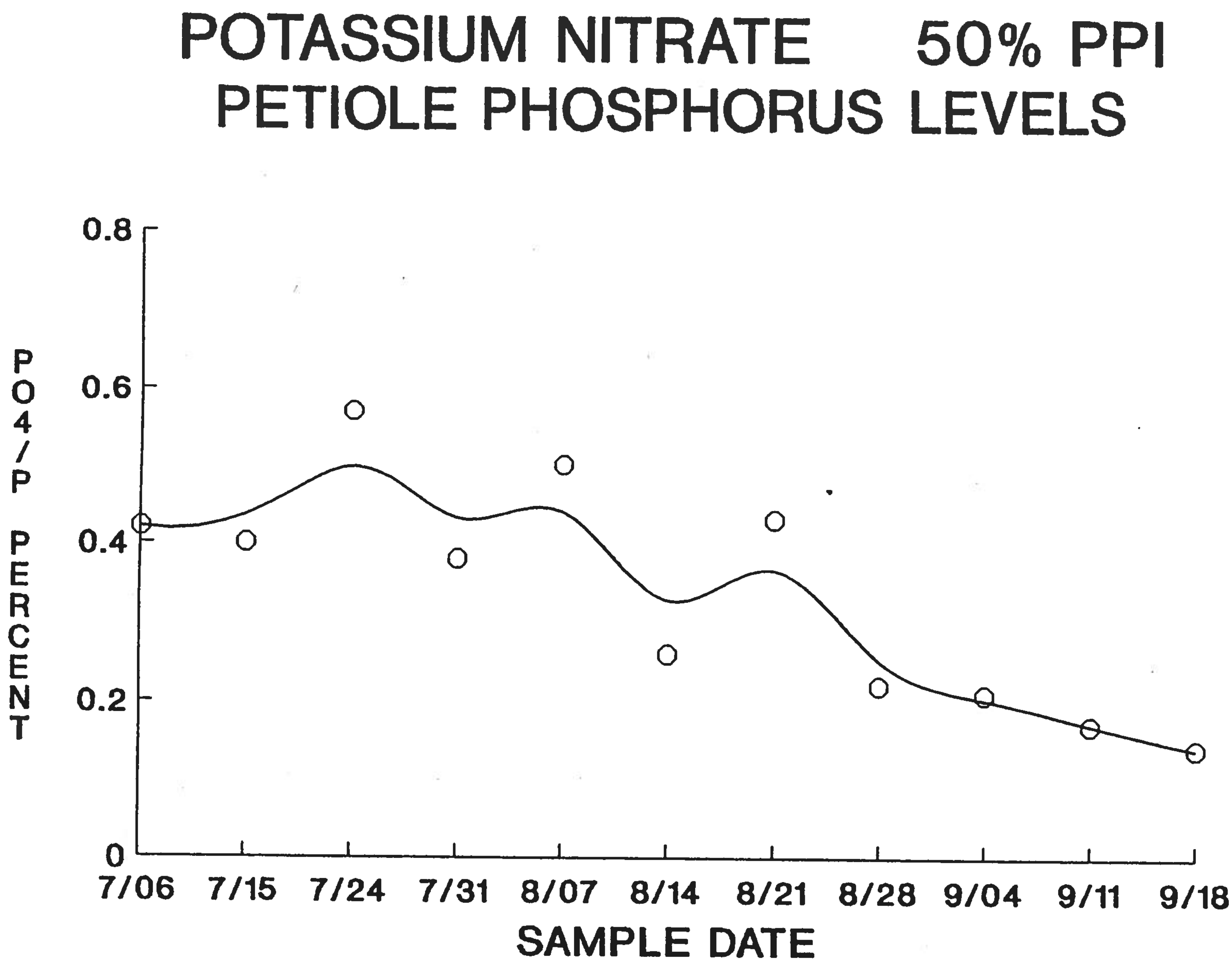

POTASSIUM SULFATE 100% PPI
PETIOLE PHOSPHORUS LEVELS
PO4/P PERCENT
0.8
0.6
0.4
0.2
0
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

Figure 10

POTASSIUM NITRATE 100% PPI
PETIOLE PHOSPHORUS LEVELS




POTASSIUM NITRATE 50% PPI
PETIOLE PHOSPHORUS LEVELS
PO4/P PERCENT
0.8
0.6
0.4
0.2
0
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

PHOSPHORUS TISSUE LEVELS (PERCENT)

DATE	KCL	K_2SO_4	KNO_3	KNO_3 Split
7/06	.36	.37	.41	.42
7/15	.45	.38	.32	.40
7/24	.55	.50	.48	.57
7/31	.36	.32	.30	.38
8/07	.36	.30	.43	.50
8/14	.33	.42	.30	.26
8/21	.43	.23	.32	.43
8/28	.22	.27	.29	.22
9/04	.21	.21	.17	.21
9/11	.17	.15	.16	.17
9/18	.14	.13	.13	.14

Table 5

POTASSIUM TISSUE LEVELS (PERCENT)

DATE	KCL	K_2SO_4	KNO_3	KNO_3 Split
7/06	10.0	9.7	9.6	9.8
7/15	11.9	10.9	10.7	10.5
7/24	12.7	12.0	12.2	12.0
7/31	11.3	11.6	11.1	10.8
8/07	10.4	10.1	10.7	12.4
8/14	10.6*	10.9	11.4	10.8
8/21	8.7	9.5	9.8	11.3
8/28	8.6	9.3*	9.6	9.6
9/04	9.3	8.9	9.1*	9.3*
9/11	8.8	8.5	8.5	8.8
9/18	7.9	8.0	7.9	7.9

*The trial in the Pacific Northwest suggests that plant senescence is initiated in Russet Burbank when K tissue levels go below 9.0 in most seasons.

Table 6

POTASSIUM CHLORIDE 100% PPI
PETIOLE POTASSIUM LEVELS

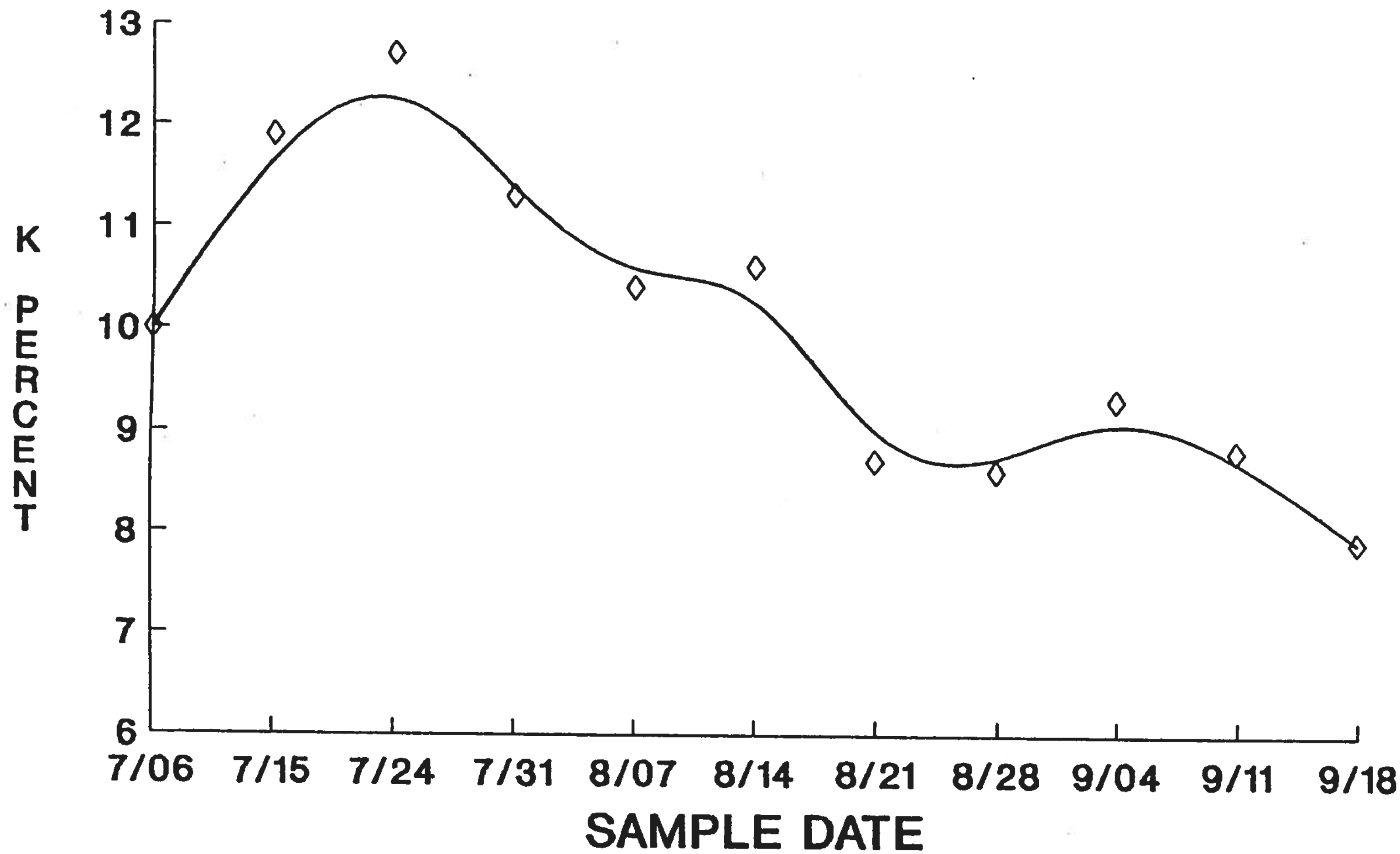
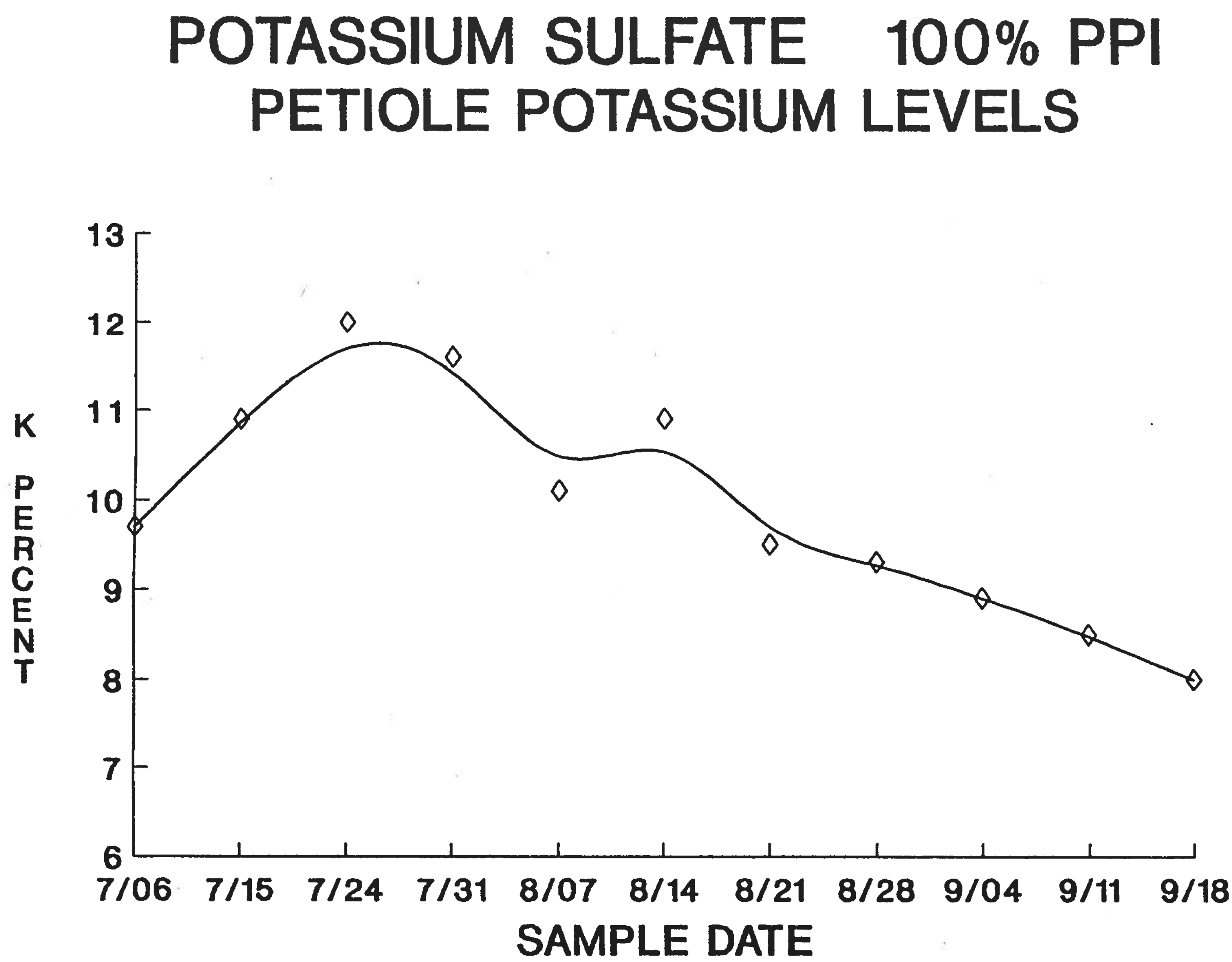


Figure 13


POTASSIUM SULFATE 100% PPI
PETIOLE POTASSIUM LEVELS
K PERCENT
13
12
11
10
9
8
7
6
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

POTASSIUM NITRATE 100% PPI
PETIOLE POTASSIUM LEVELS

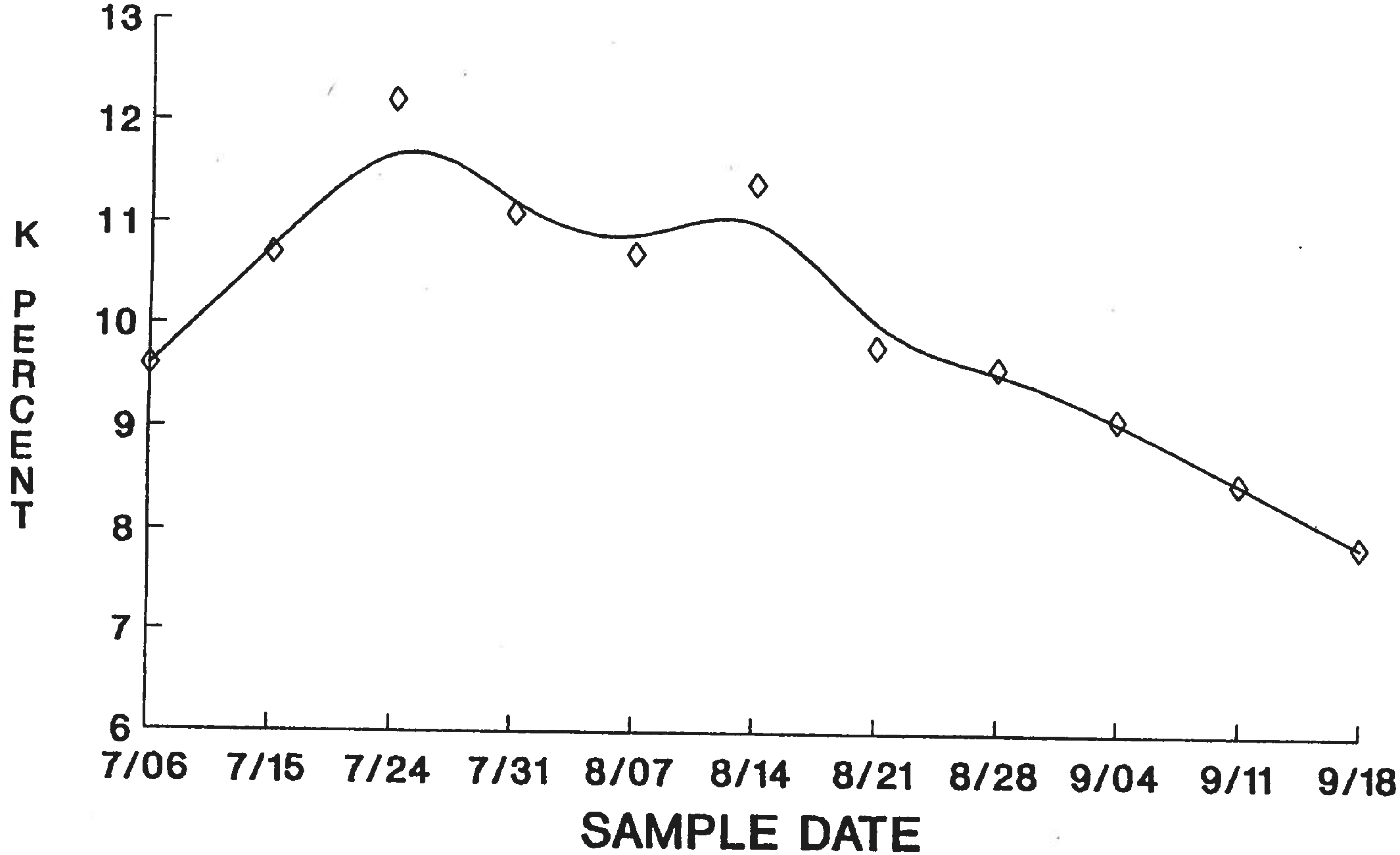
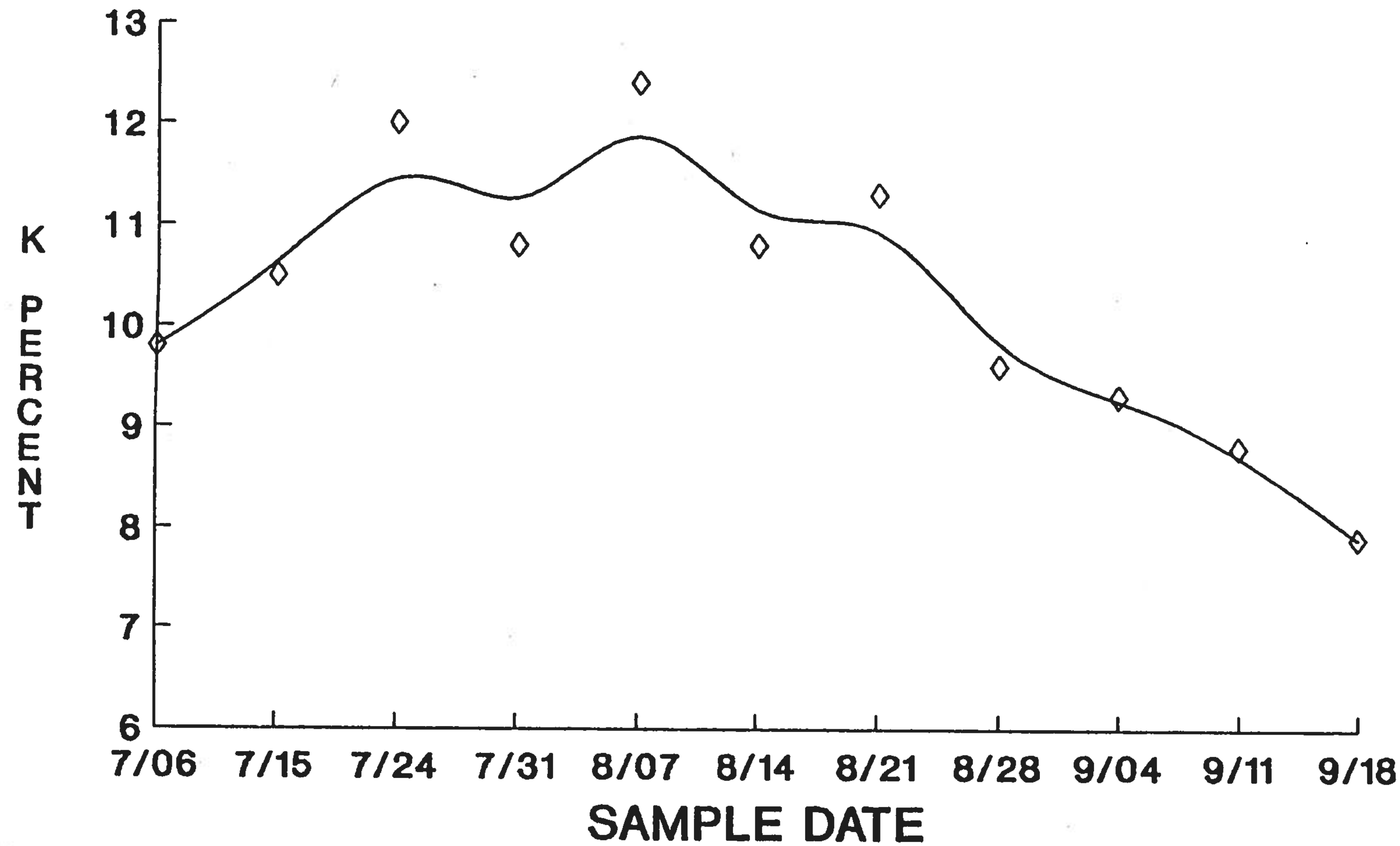


Figure 15

POTASSIUM NITRATE 50% PPI
PETIOLE POTASSIUM LEVELS



SULFUR TISSUE LEVELS (PERCENT)

DATE	KCL	K_2SO_4	KNO_3	KNO_3 Split
7/06	.21	.22	.25	.24
7/15	.26	.26	.25	.26
7/24	.30	.37	.28	.30
7/31	.27	.33	.29	.30
8/07	.29	.29	.29	.27
8/14	.32	.28	.30	.27
8/21	.31	.23	.30	.27
8/28	.21	.20	.29	.23
9/04	.22	.22	.19	.22
9/11	.25	.25	.20	.20
9/18	.19	.20	.19	.19

Table 7

POTASSIUM CHLORIDE 100% PPI
PETIOLE SULFUR LEVELS

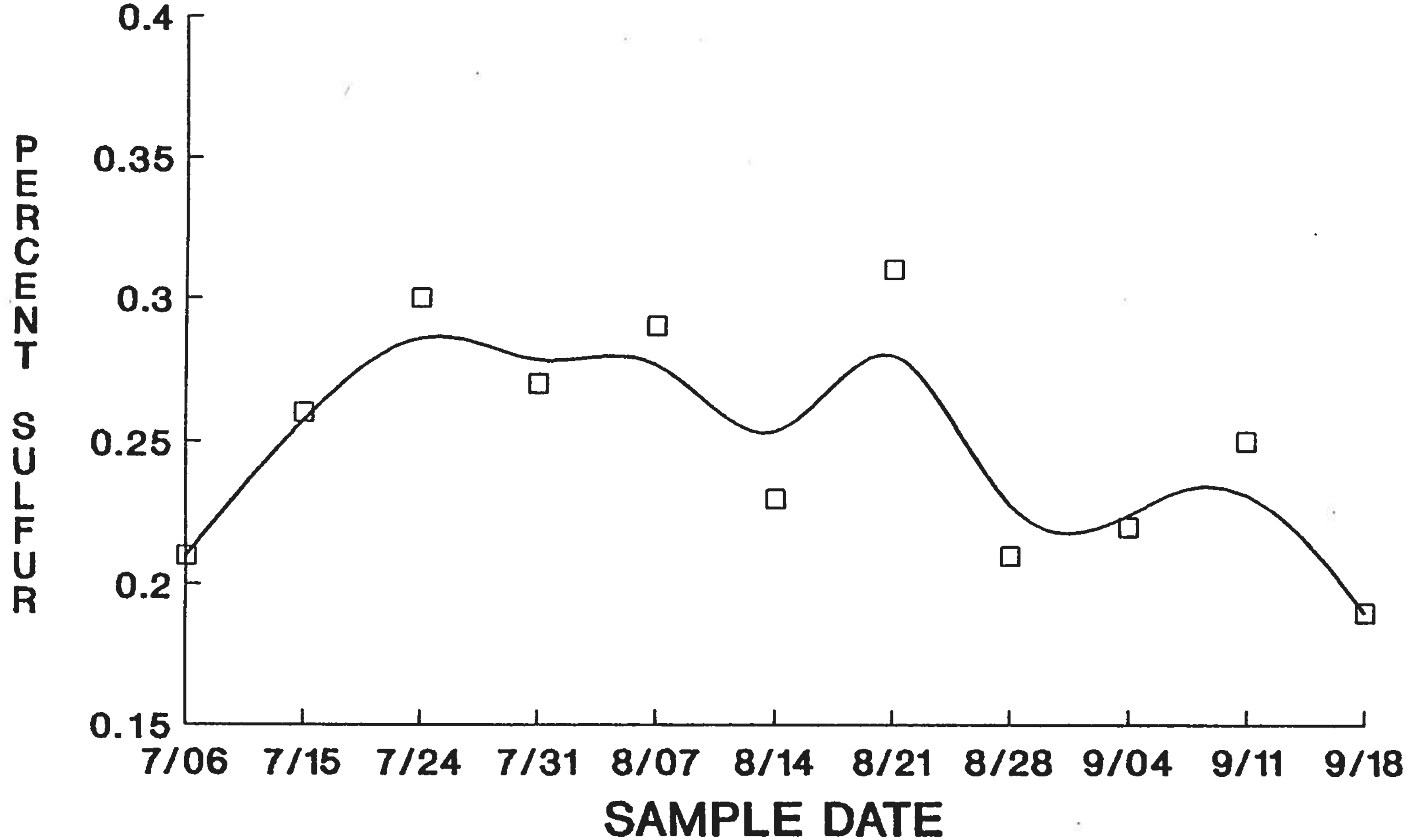


Figure 17

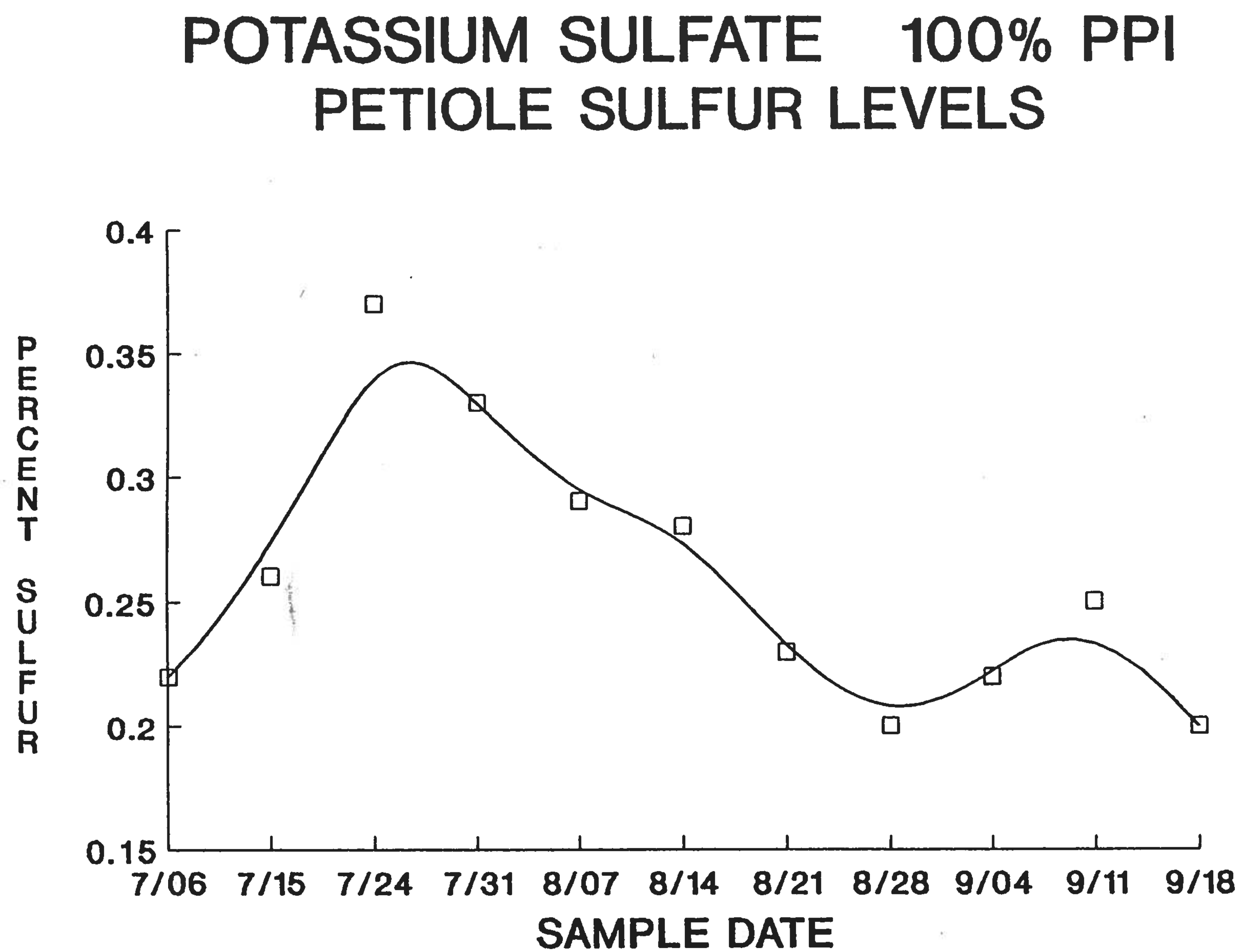

POTASSIUM SULFATE 100% PPI
PETIOLE SULFUR LEVELS
PERCENT SULFUR
0.4
0.35
0.3
0.25
0.2
0.15
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

Figure 18

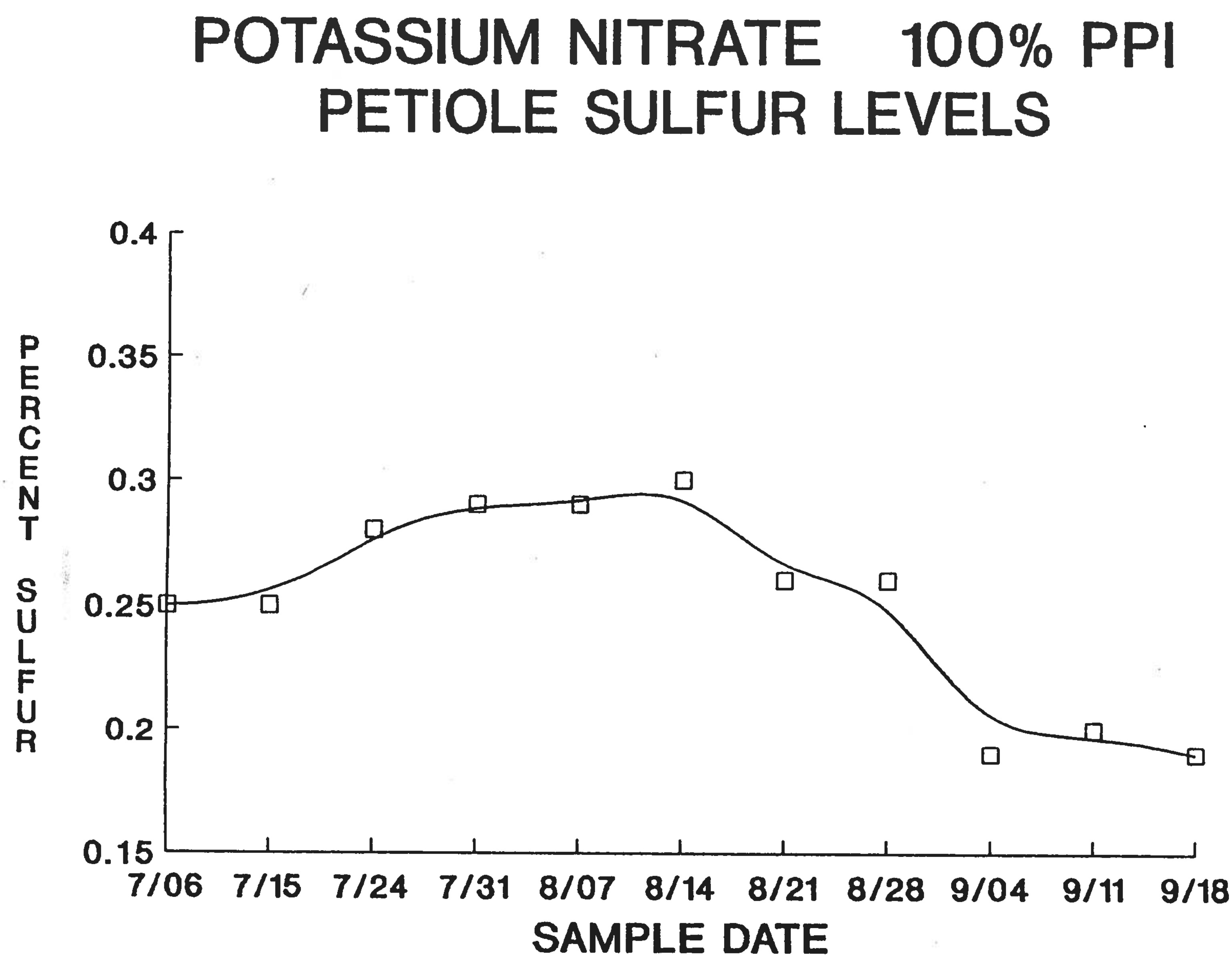

POTASSIUM NITRATE 100% PPI
PETIOLE SULFUR LEVELS
PERCENT SULFUR
0.4
0.35
0.3
0.25
0.2
0.15
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

Figure 19

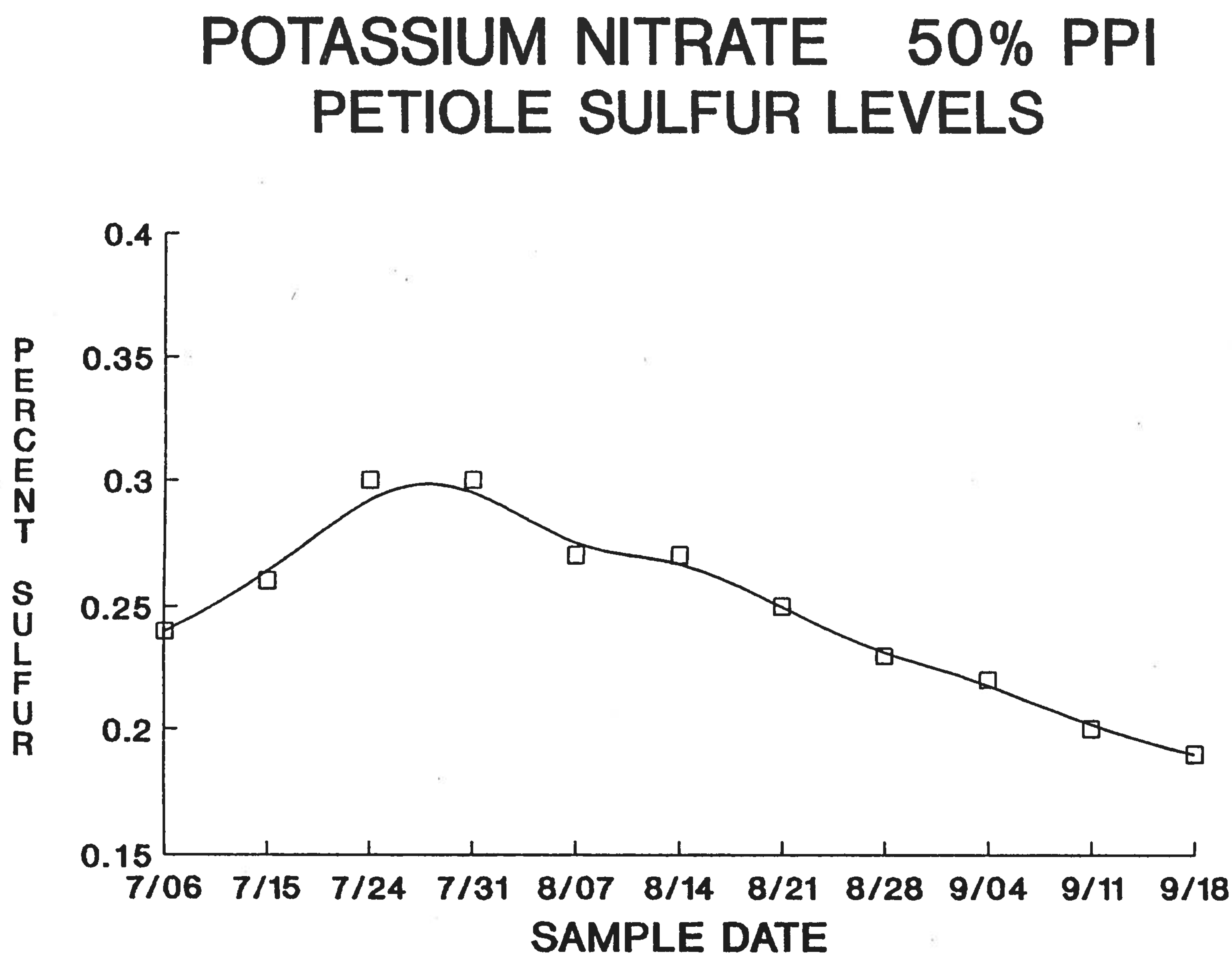

POTASSIUM NITRATE 50% PPI
PETIOLE SULFUR LEVELS
PERCENT SULFUR
0.4
0.35
0.3
0.25
0.2
0.15
7/06
7/15
7/24
7/31
8/07
8/14
8/21
8/28
9/04
9/11
9/18
SAMPLE DATE

Figure 20

YIELD DATA

TREATMENT

REP	1	2	3	4
1	227	219	199	192
2	188	202	216	183
3	236	224	247	234
4	206	258	218	210
Totals:	857	903	880	819
Average Yld:	214.25 b*	225.75 a	220 a	204.75 c
Ton/Acre:	32.96 T/A	34.73 T/A	33.85 T/A	31.5 T/A
1	29	31	20	23
2	23	25	32	21
3	24	34	2	26
4	22	31	22	27
Totals Culls:	24.5	30.25	25.75	24.5
% Culls:	11.4% a	13.4% b	11.7% a	12.0% a
1	198	188	179	169
2	165	177	184	162
3	212	190	218	208
4	184	227	196	182
Totals:	759	782	777	721
Avg Payables:	189.75	195.50	194.25	180.25
Ton/Acre:	29.19 T/A b	30.08 T/A a	29.88 T/A b	27.76 T/A c
*Crop Value/A:	$3,678.23	$3,789.69	$3,765.46	$3,490.07

Treatment 4 had the lowest yield, lowest payables and tied for lowest culls.

Treatment 2 had the highest yield, but was on 1/2% higher than treatment 3.

*Analysis at 90% level of significance.

*Payable yield X grower return ($126/ton) = crop value per acre.

TABLE 8

TOTAL YIELD

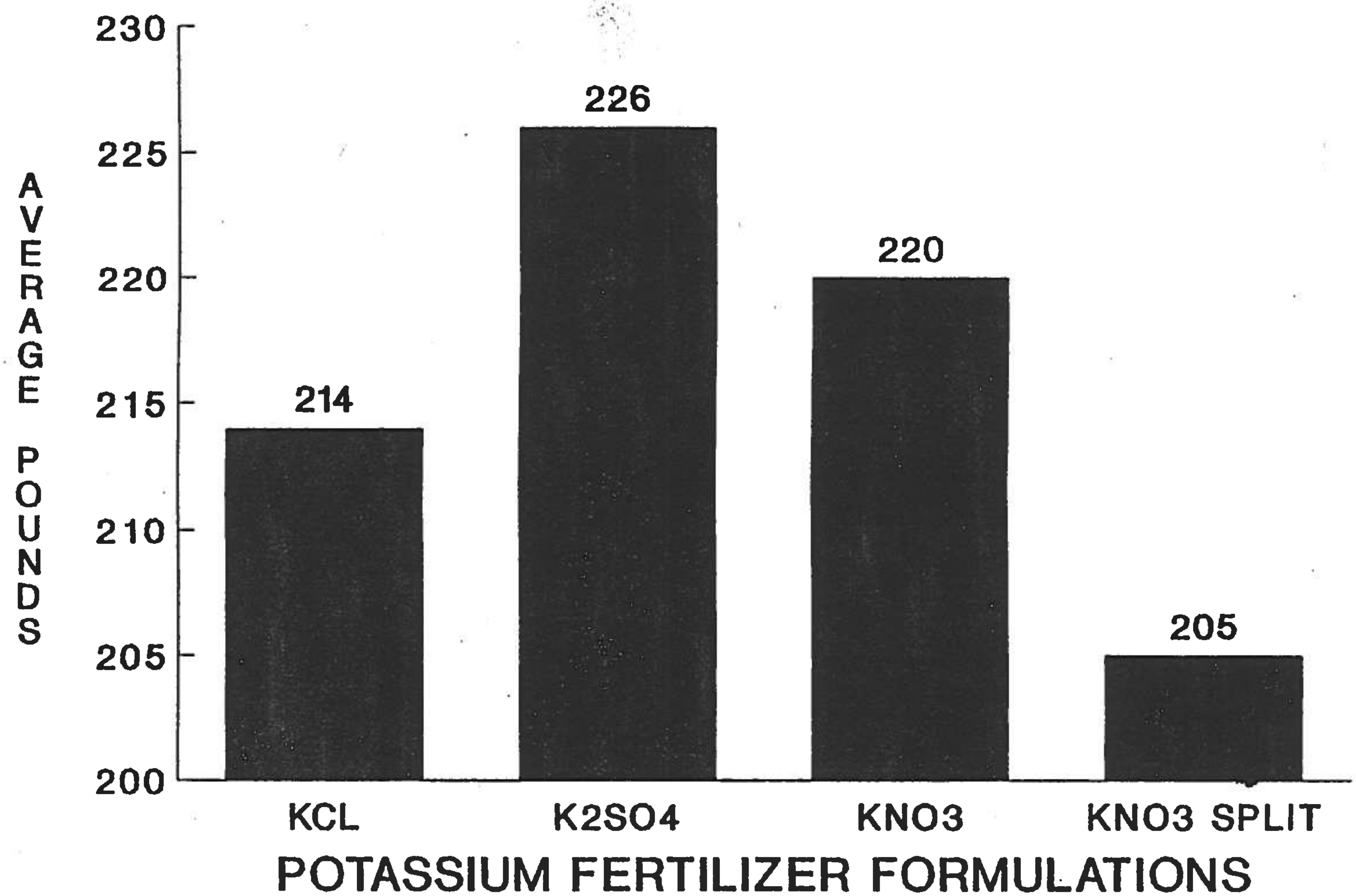


Figure 21

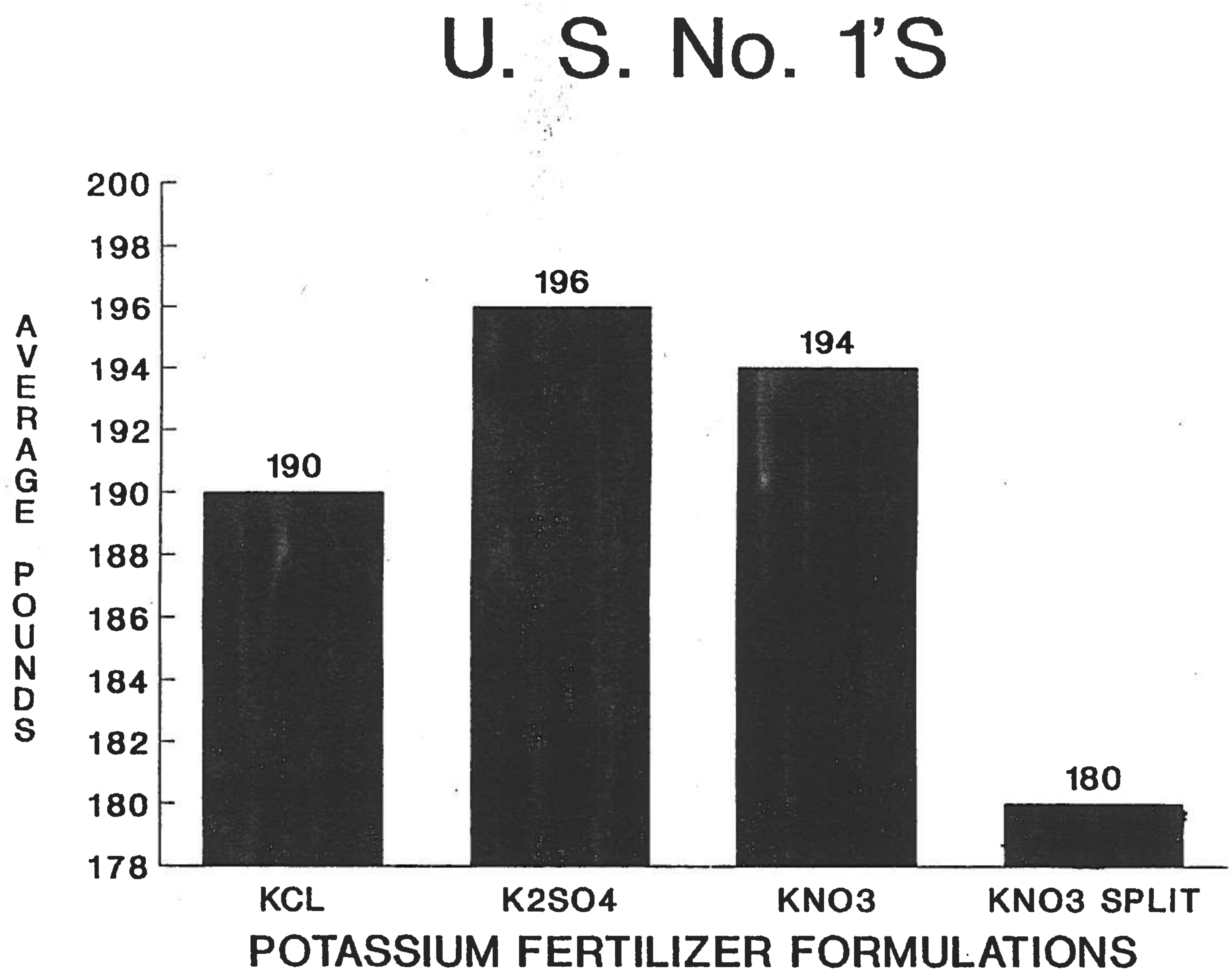

U. S. No. 1'S
AVERAGE POUNDS
200
198
196
194
192
190
188
186
184
182
180
178
190
196
194
180
KCL
K2SO4
KNO3
KNO3 SPLIT
POTASSIUM FERTILIZER FORMULATIONS

Figure 22

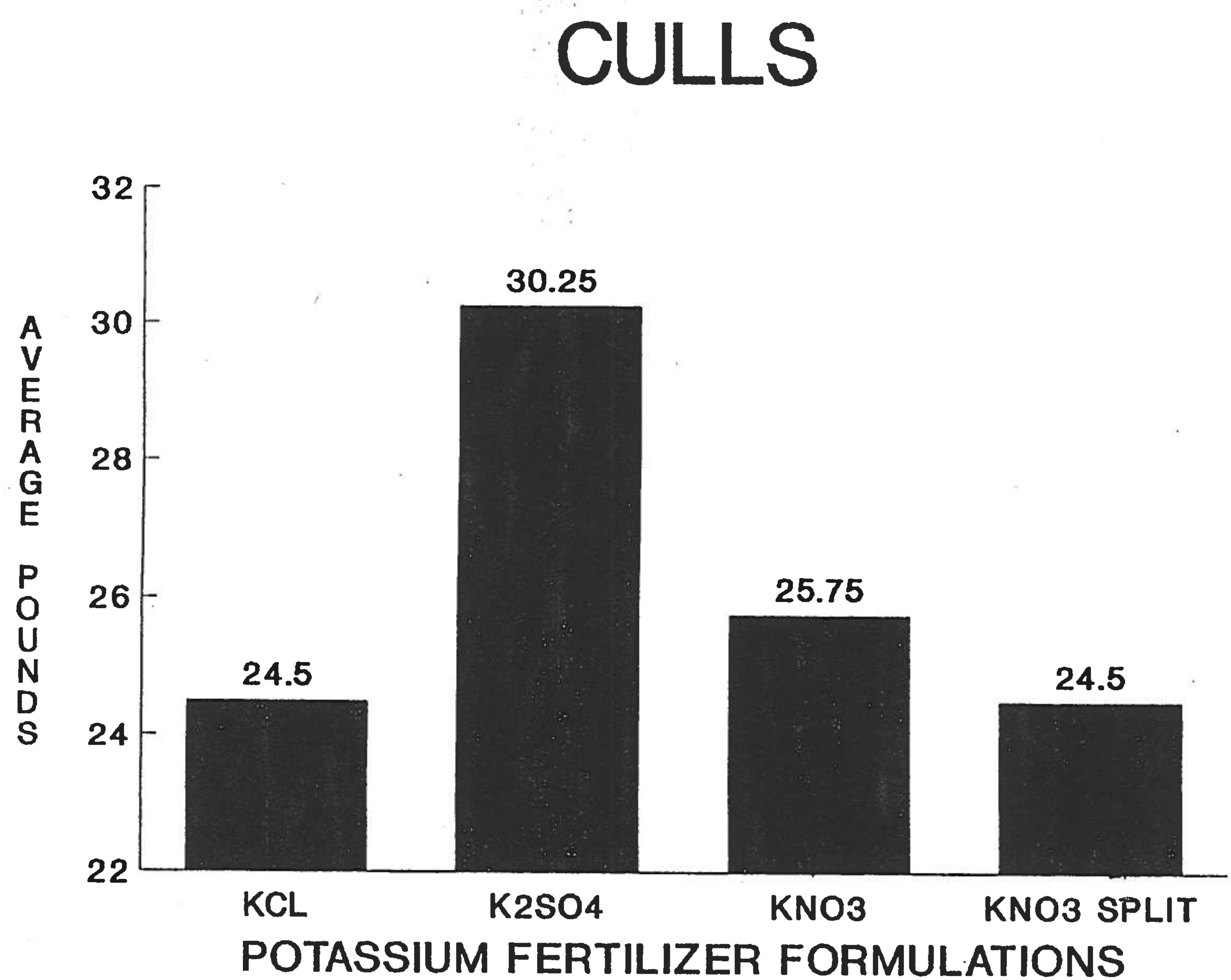

CULLS
AVERAGE POUNDS
32
30
28
26
24
22
30.25
24.5
25.75
24.5
KCL
K2SO4
KNO3
KNO3 SPLIT
POTASSIUM FERTILIZER FORMULATIONS

Figure 23

INTERNAL DEFECTS

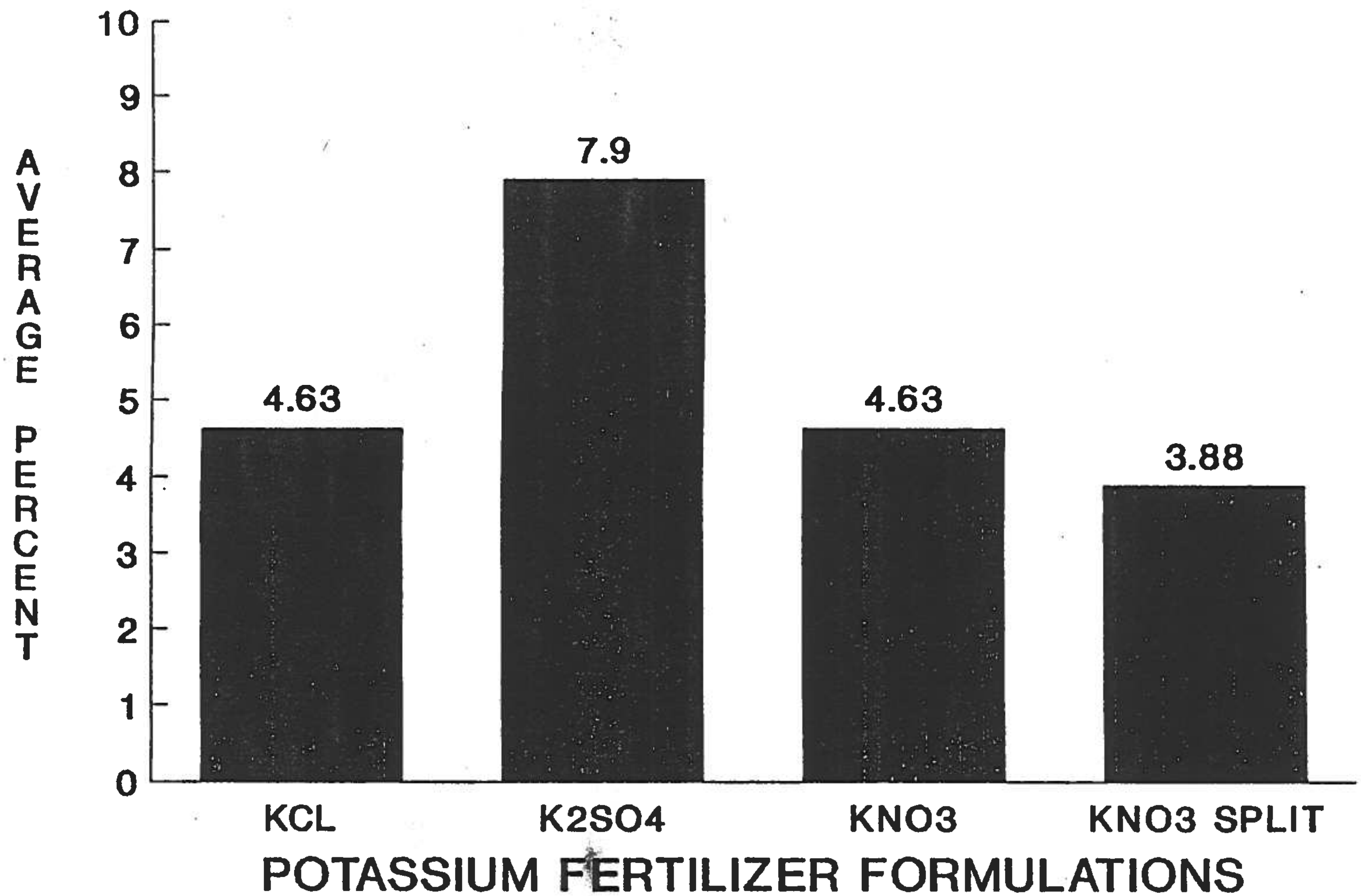


Figure 24

POTATO SIZE DISTRIBUTIONS

TREATMENT	REP	TUBER WEIGHT CATAGORIES 4-6 OZ	6-10 OZ	10-14 OZ	>14 OZ
(1)	1	67	80	30	21
	2	33	60	42	30
	3	53	82	35	42
	4	41	82	35	26
	Totals:	194	304	142	119
	Average:	48.5	76	35.5	29.75
		25.6% a*	40.0% a	18.7% a	15.7% a
(2)	1	53	78	29	27
	2	45	60	35	37
	3	48	63	48	31
	4	60	84	41	42
	Totals:	206	285	153	137
	Average:	51.5	71.25	38.25	34.25
		26.4% a	36.5% a	19.6% a	17.5% a
(3)	1	49	76	36	18
	2	48	69	45	22
	3	56	84	41	37
	4	50	88	27	36
	Totals:	203	317	149	113
	Average:	50.75	79.25	37.25	28.25
		26.0% a	40.5% a	19.1% a	14.4% a
(4)	1	35	63	37	34
	2	28	48	44	42
	3	50	75	47	36
	4	49	86	30	17
	Totals:	162	272	158	129
	Average:	40.5	68	39.5	32.25
		22.5% a	37.7% a	21.9% a	17.9% a

*Analysis at 95% level of significance.

TABLE 9

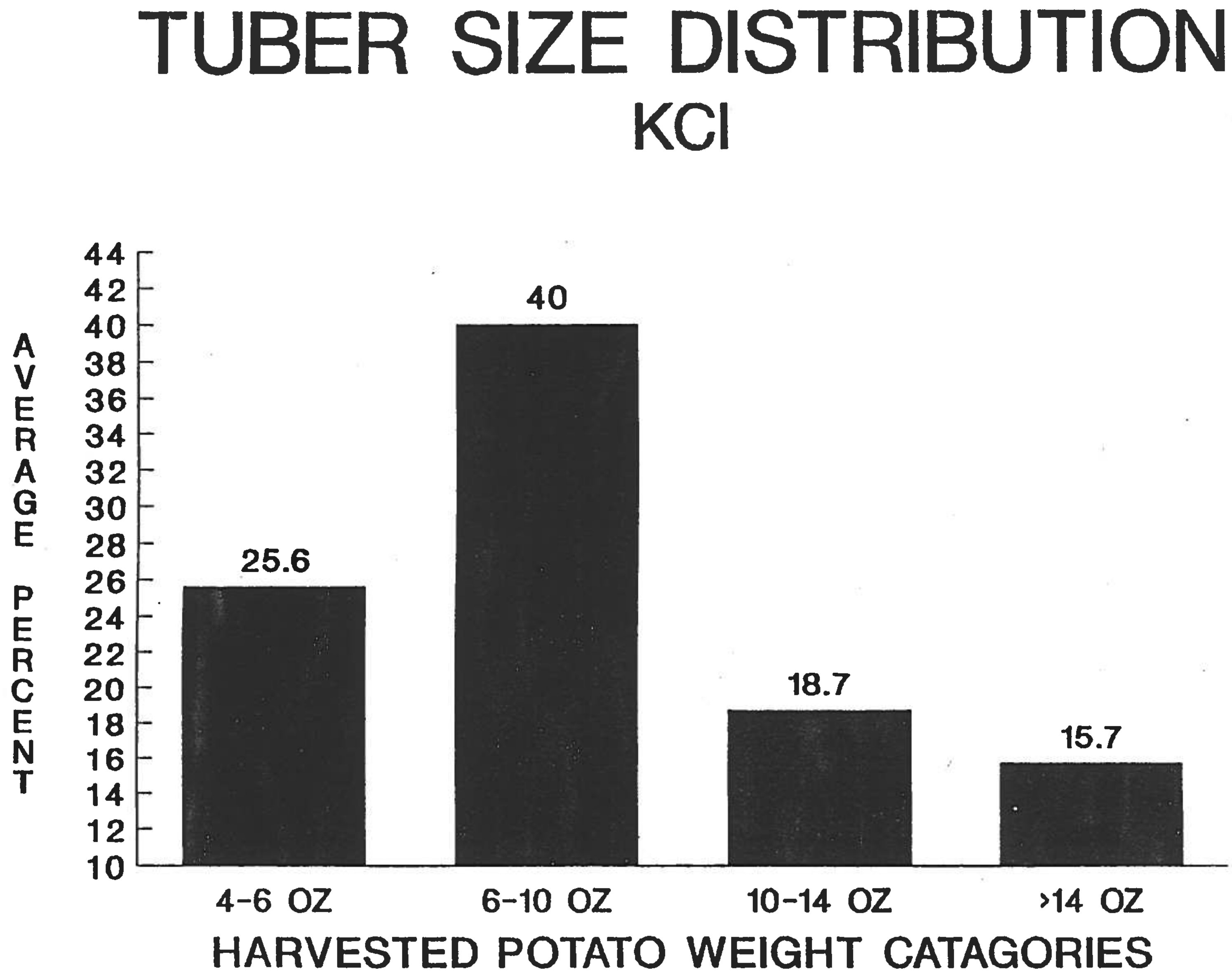

TUBER SIZE DISTRIBUTION
KCl
AVERAGE PERCENT
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
25.6
40
18.7
15.7
4-6 OZ
6-10 OZ
10-14 OZ
>14 OZ
HARVESTED POTATO WEIGHT CATAGORIES

Figure 25

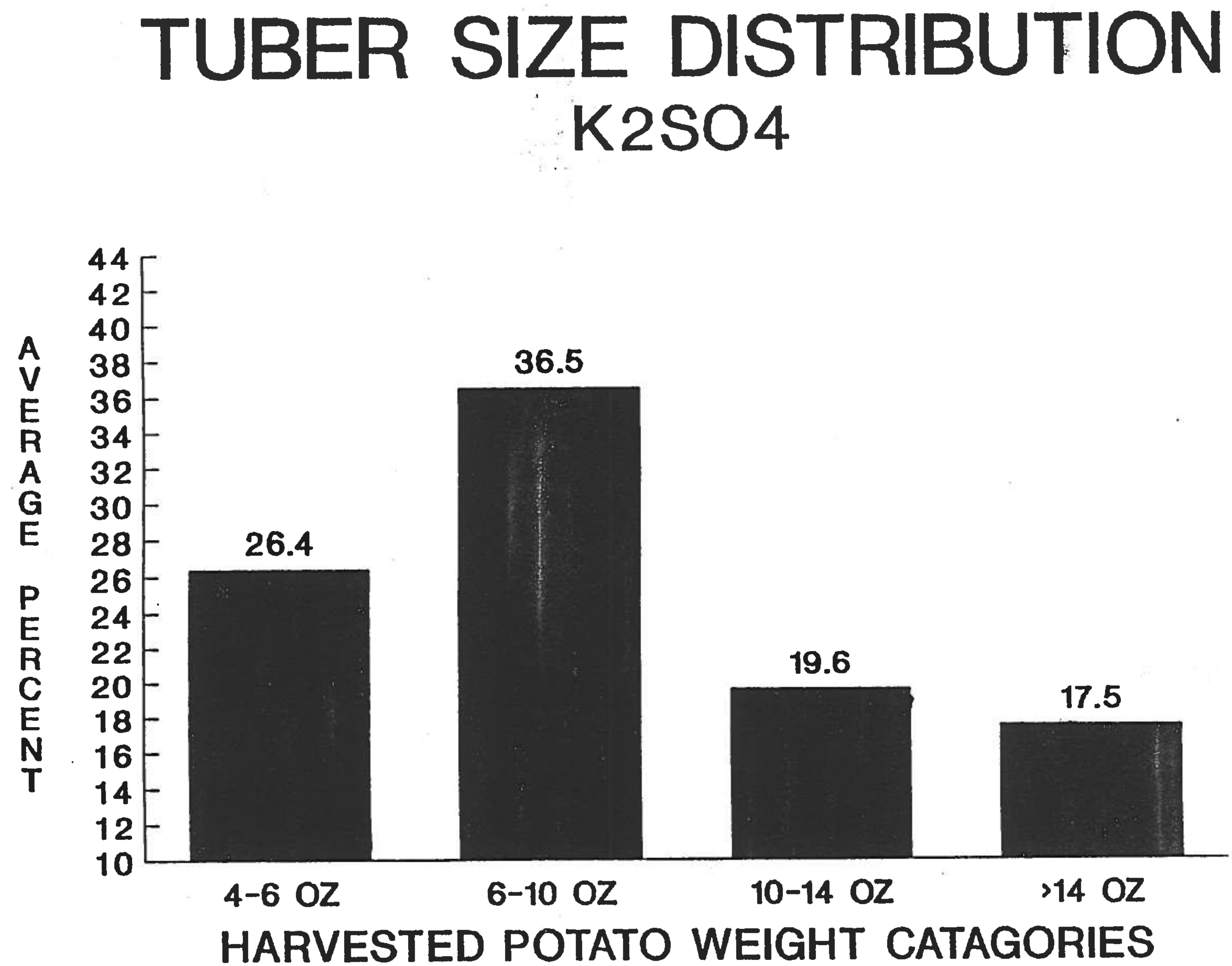
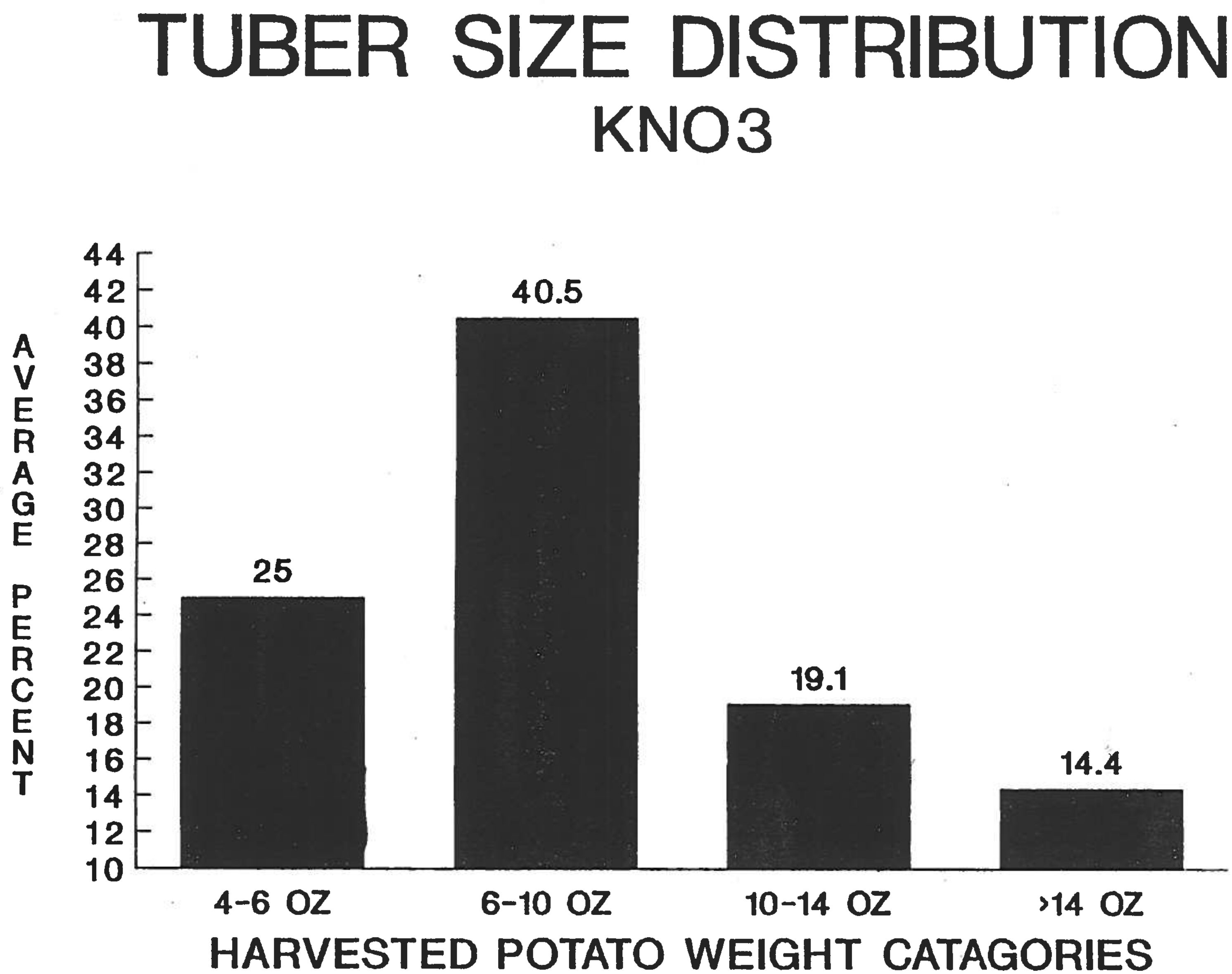

TUBER SIZE DISTRIBUTION
K2SO4
AVERAGE PERCENT
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
26.4
36.5
19.6
17.5
4-6 OZ
6-10 OZ
10-14 OZ
>14 OZ
HARVESTED POTATO WEIGHT CATAGORIES

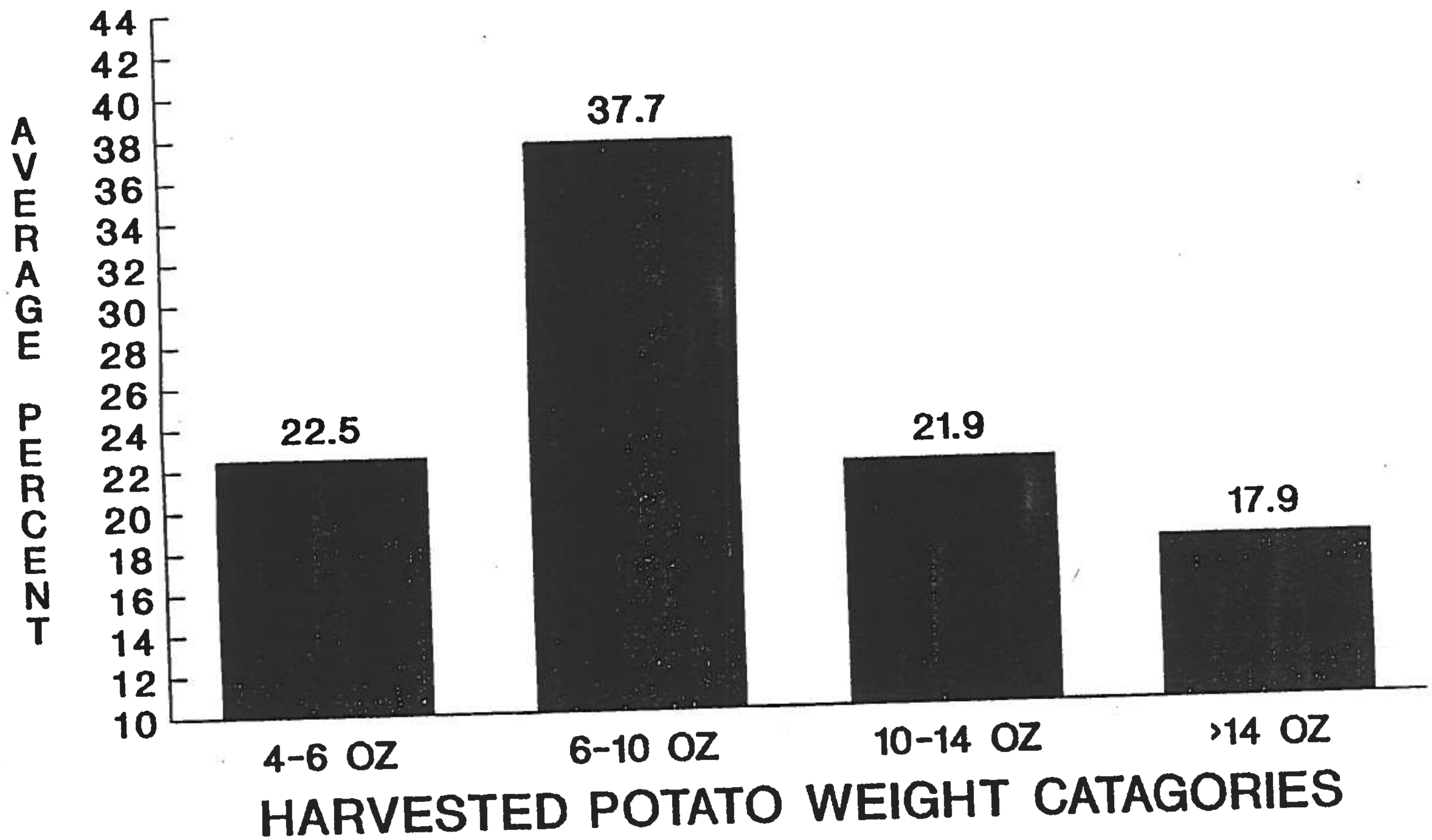
Figure 26



TUBER SIZE DISTRIBUTION
KNO3
AVERAGE PERCENT
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
25
40.5
19.1
14.4
4-6 OZ
6-10 OZ
10-14 OZ
>14 OZ
HARVESTED POTATO WEIGHT CATAGORIES

Figure 27

TUBER SIZE DISTRIBUTION
KNO3 SPLIT



SPECIFIC GRAVITIES

TREATMENT	REP	2-4 OZ	4-6 OZ	6-10 OZ	10-14 OZ	OVERALL AVERAGE
	1	1.0790	1.0849	1.0857	1.0849	1.0830
(1)	2	1.0746	1.0800	1.0840	1.0851	1.0808
	3	1.0807	1.0837	1.0840	1.0860	1.0834
	4	1.0781	1.0820	1.0829	1.0808	1.0811
	Average:	1.0781 c*	1.0827 b	1.0842 c	1.0842 d	1.0821 c
	1	1.0815	1.0866	1.0866	1.0897	1.0856
(2)	2	1.0808	1.0835	1.0821	1.0855	1.0829
	3	1.0753	1.0799	1.0823	1.0850	1.0801
	4	1.0825	1.0835	1.0845	1.0847	1.0836
	Average:	1.0800 b	1.0834 a	1.0839 d	1.0862 b	1.0831 a
	1	1.0793	1.0853	1.0854	1.0869	1.0838
(3)	2	1.0810	1.0797	1.0838	1.0831	1.0814
	3	1.0769	1.0811	1.0853	1.0833	1.0811
	4	1.0817	1.0816	1.0878	1.0889	1.0837
	Average:	1.0797 a	1.0819 c	1.0856 b	1.0856 c	1.0825 b
	1	1.0792	1.0844	1.0841	1.0817	1.0827
(4)	2	1.0811	1.0863	1.0892	1.0866	1.0849
	3	1.0773	1.0825	1.0842	1.0871	1.0824
	4	1.0789	1.0819	1.0893	1.0924	1.0833
	Average:	1.0791 b	1.0838 a	1.0867 a	1.0870 a	1.0833 a

Treatment 4 had the highest gravities overall and for each category above 4 oz tuber weight. *LSD 10% by size category and 5% for overall.

Treatment 1 had the lowest gravities overall and for the 2-4 oz and 10-14 oz size categories and was only slightly better than the lowest levels in the 4-6 oz and 6-10 oz size groups.

TABLE 10

FRY COLOR (SUGARS) DATA

TREATMENT	REP	4-6 OZ	6-10 OZ	10-14 OZ	>14 OZ	
	1	00	00	00	00	
(1)	2	00	00	01	00	a
	3	00	00	00	00	
	4	00	00	00	00	
	Totals:	00	00	01	00	
	1	00	00	00	00	
(2)	2	00	00	00	00	a
	3	01	00	00	00	
	4	00	00	00	00	
	Totals:	01	00	00	00	
	1	00	00	00	00	
(3)	2	00	00	00	02	a
	3	00	00	00	00	
	4	00	00	00	00	
	Totals:	00	00	00	02	
	1	00	00	00	00	
(4)	2	00	00	01	01	b
	3	00	02	00	00	
	4	00	00	00	00	
	Totals:	00	02	01	01	

Although sugar accumulation is normally very low at harvest, treatment 4 had more sugar and symptoms than any of the others by a factor of 2X. Sugar ends are generally associated with stress conditions during the growth of the plant. It has not been directly linked in this researchers experience to lower potassium tissue levels. This connection merits further investigation because such a relationship would be very important to understand and may be a grower controlled variable.

TABLE 11

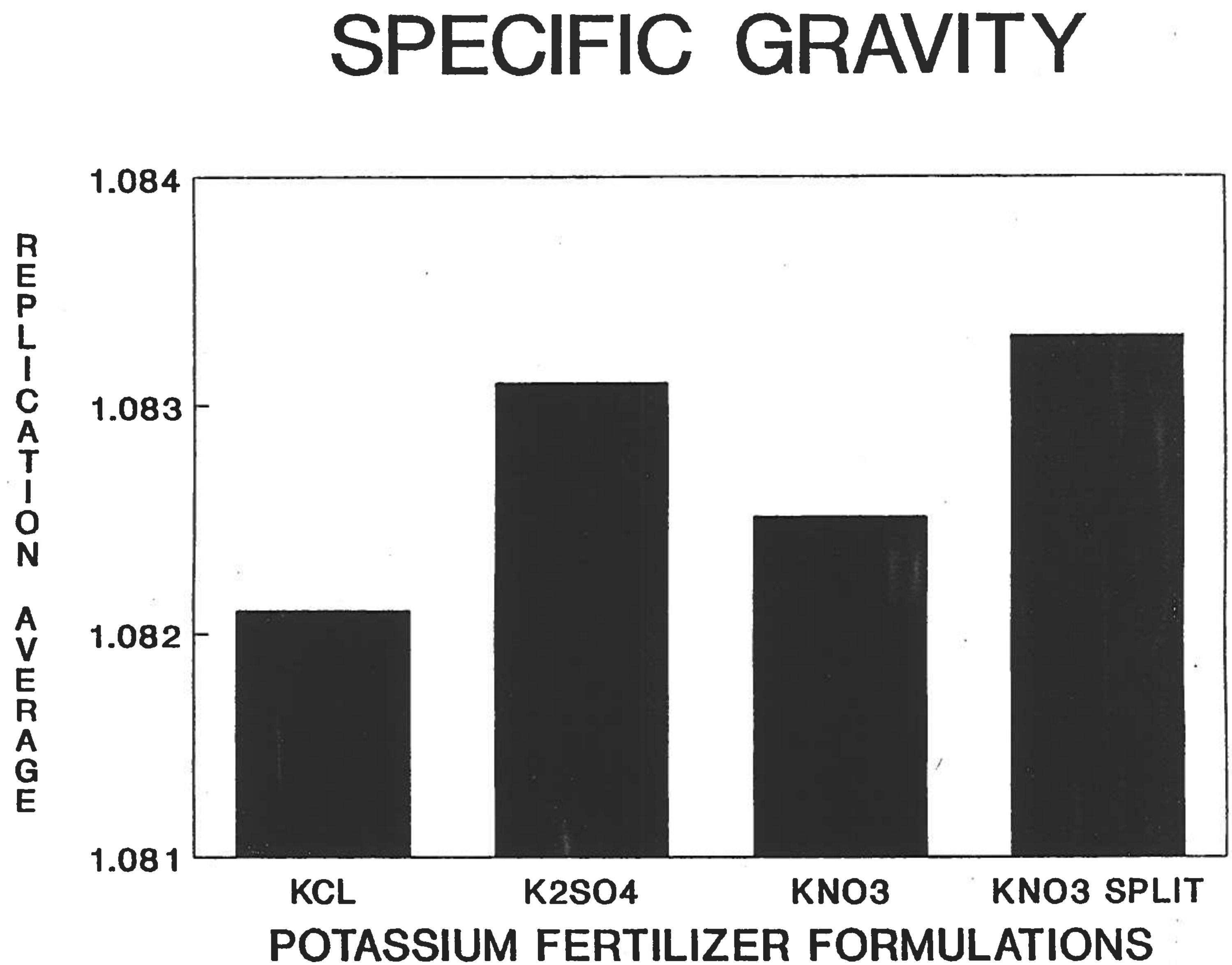

SPECIFIC GRAVITY
REPLICATION AVERAGE
1.084
1.083
1.082
1.081
KCL
K2SO4
KNO3
KNO3 SPLIT
POTASSIUM FERTILIZER FORMULATIONS

Figure 29

UNDERSTANDING THE ROLE OF THE NUTRIENT POTASSIUM

Steve Holland

There are growing numbers of potato producers who would argue that growing a crop which one can be proud of is an increasingly complex undertaking. Each season they re-examine countless variables while contemplating the important choices to be made. Some of their decisions will involve parameters we don't control while others are reasonably manageable. It makes a lot more sense to focus our attention on those things which we can improve, if we make the right choices, than to dwell on the aspects we can't change. Growers recognize crop fertility as an aspect of potato production that can be effectively managed. It is nevertheless only a small part of the overall decision making process that needs to be re-addressed annually. Almost everyone appreciates the importance of the fertility program, yet, surprisingly few understand all that they should about the rather intricate role each nutrient plays in soil and plant systems.

This discussion will review some of the more important properties of potassium as a plant nutrient. Each of the sixteen elements recognized as having nutrient properties are considered *ESSENTIAL* to the growth and vigor of plants. Accept, if you will, that "*essential*" means nothing more or less than **ABSOLUTELY NECESSARY**. Each nutrient has at least one and generally many very specific functions. In fact, most nutrients are involved in a number of complex activities and interactions both in the soil and inside the plant. Potassium is one of the three *major* nutrients along with nitrogen and phosphorus. *Major* simply means it is required by plants in much larger quantities than are any of the *micro* and *minor* nutrient elements. It is however no more or less "*essential*" than any of the other fifteen nutrients. Typically almost as much potassium is removed from the soil by the potato plant as are all the rest of the nutrients combined. Somewhere between .5 and .6 lb is contained in each hundred weight harvested. This does not correlate well with application rates since nutrient uptake efficiencies vary widely with soil type, texture, structure, organic content, pH, temperature, and moisture, etc etc. Potassium is unique among the fertilizer elements in that it does not chemically react with anything in the plant. It remains a free ion and performs its function in that form alone throughout the entire season. Potassium is perhaps best known for its' role in balancing water relations within the plant. A number of the other functions of potassium in the plant are less widely understood. Potassium appears to be necessary for (1) synthesis of simple sugars and starch, (2) the translocation of carbohydrates, (3) chemical reduction of nitrates, (4) synthesis of proteins (particularly in meristems), (5) normal cell division, (6) opening and closing of the stomata, (7) maintaining permeability of cytoplasmic membranes, (8) hydration of protoplasm and (9) promoting foliage and tuber maturity. The bulk of the potassium normally absorbed by the plant is taken in through the root hairs during the early stages of growth. Since potassium remains in an inorganic and ionic form it is readily transported from one plant part to another throughout the life of the plant. Older leaves and organs frequently lose potassium to new growing regions. Potassium is almost always the most abundant univalent cation in plant cells. Potassium is absorbed from the soil in quantities far in excess of the amounts necessary for the plants physiological processes. Potassium's importance to water relations within plants especially in high temperature and low humidity climates cannot be over emphasized. Since potassium is not chemically combined to any extent into organic compounds within the plant, it remains in ionic form in the vacuole of cells and this property alone permits it to remain osmotically active. This activity enables the plant roots to extract water from the soil and to resist transpiration loses through the leaves. The symptoms of potassium deficiency commonly observed are also those commonly associated with water deficits and include such symptoms as low turgor pressure, reduced cell division, limited stomatal opening, dark green foliage color, tissue necrosis, leaf margin scorch, shedding of lower leaves, reduced yield, high dry matter, immaturity and highly black spot susceptible tubers.

In the soil, potassium exists in three forms: exchangeable K, solution K, and mineral K, all in a dynamic equilibrium. Only the soluble form which represents 1%-2% of the total soil K is available to plants and it like all other disolved nutrient ions must be osmotically absorbed by the plant root hairs. This is especially important to the plant since without adequate water, cell turgor is lacking and without cell turgor there is no cell division. Thus, at the risk of over-simplification, potassium functions as a nutrient as well as a water regulator. A high concentration of potassium ions within the cell can by virtue of an associated high osmotic pressure, prevent or delay water movement out of cells and the loss of plant turgor, i.e., wilting. Thus, high levels of potassium within a plant or tuber will have a buffering effect against water loss and reductions in turgor be it in the field or in the storage. As already noted, potassium is able to move freely to all parts of the plant during the growing stages and again this is primarily because potassium is not tied chemically to any components within, or as part of, the plant itself. The amount of potassium that ends up in the tuber is roughly equal to the amount of potassium translocated out of the vines during the tuber bulking period. Roots can not absorb potassium rapidly enough to meet the needs of the tubers during bulking and at the same time maintain the required high level in the vines. Therefore, as noted, much of the high potassium content of the vines, absorbed early in the growth season, ultimately ends up translocated to the tubers by fall. If adequate potassium is not present in the vines relatively early in the growing season there will most likely not be enough taken in during mid and late season to supplement the translocation to the tubers. In this situation, yield and quality, as they relate to hydration and tuber bulking due to translocation will suffer. For semi arid climates with high rates of evapo-transpiration, adequate potassium is particularly important since it plays its greatest role in hot weather where low humidity persists. High potassium rates play a very active role in preventing early dying and generally tend to improve quality, yield and long term storage keeping potential.

There exists an inverse interrelationship for both nitrogen and potassium with dry matter content (specific gravity) in potatoes. This decrease due to potassium results from the hydrating influence of potassium ions effectively diluting the solids within the cells. The effect of high nitrogen availability is that plants generally have more foliage with larger leaves and are more susceptible to water stress which closes stomates, reduces photosynthesis, and subsequently limits dry matter content. High nitrogen also causes the plant to continue its vegetative growth phase longer which in turn delays tuber bulking. Bruise, i.e., black spot susceptibility is in several ways directly and indirectly associated with turgor pressure in cells. Leaving the crop in the field after vine kill or natural senescence and allowing the soil to dry may have the effect of tuber dehydration thereby raising specific gravity, decreasing yield and increasing the potato tuber susceptibility to internal bruise, i.e., black spot. Specific gravity however, is not per se, uniquely related to internal bruise.

For immature potatoes, soil moisture should be at or just slightly below 60% of field capacity in the coarser soil types at the time of vine kill. A slow vine kill and semi-dry fields can improve solids whereas, fast vine kill on wet fields generally reduce solids because the roots don't die as quickly as the foliage. They continue to take in soil moisture and much of it ends up going into the tubers. This may boast yields without cost, which may be good as long as it doesn't reduce dry matter below acceptable levels.

Low relatively humidity (below 90% relative humidity) in storage may contribute a reduced ability of the potato to properly wound heal and suberize damaged tissue. It may also contribute to excessive tuber dehydration and ultimately pressure bruise. These problems are always more severe in tubers which are low in potassium. Sunken areas on tubers that have been stored in undesirably low relative humidity situations, which we call pressure bruises, are extremely fragile. The normal impacts associated with unloading and delivering a stored crop is usually enough to cause high levels of black spot bruise to the tissue within the pressure bruise sites. This same response will also occur in highly dehydrated or physiologically old tubers and for the same reasons.

Tuber temperature is also effects bruise susceptibility. Cold potatoes are most susceptible to internal bruise, therefore, it is desirable to avoid harvesting and handling activities when potato pulp temperatures are below 45° F. Immature and low specific gravity potatoes will usually bruise more easily than mature, high gravity potatoes regardless of the harvest time and temperatures. Immature potatoes also accumulate reducing sugars faster, are more prone to skinning, and do not suberize as well. They also accumulate more frying oils, take longer to cook, and have lower recovery rates,. There can also be too much of a good thing. Overly mature potatoes do not suberize well, have more shrink in storage, will sprout sooner, and are more susceptible to internal black spot bruise. It is generally believed that long season, slightly immature potatoes are more desirable for long term storage followed by processing into French fries. For fresh pack utilization, a slightly more mature (vine killed) potato with a firmly set skin is preferred since the appearance factor is most critical.

Stresses on the plant during the growing season resulting from nutrient deficiencies, insects pressures, disease incidence and cultural mismanagement all tend to increase tubers susceptibility to internal bruise. By way of review, high levels of potassium in the soil are not only needed for a top production but they have significant beneficial secondary effects as well. The effects of potassium in reducing tuber black spot have been well documented. The potassium relationship to water content in the tubers as measured by specific gravity are also well established. The effect of proper soil moisture at harvest in reducing black spot is most effective if the plant contains adequate amounts of potassium. If potassium is deficient, adequate soil moisture will not control black spot. Stresses in the storage environment including improper humidity, inadequate (CO_2 build-up) or excessive ventilation (dehydration) and undesirable temperature regimes can contribute further to the potatoes susceptibility to internal disorders. Thus, it is safe to say that potato yield, quality, maturity, black spot susceptibility, specific gravity, and long term storage potential are all closely related to potassium nutrition. Recognize at least that potassium is the only major nutrient that can consistently reduce the severity of black spot bruise in potato tubers.