


AN ABSTRACT OF THE THESIS OF

LELAND RAY SCHWEITZER for the MASTER OF SCIENCE  
(Name) (Degree)

in FARM CROPS presented on September 12, 1968  
(Major)

Title: SEED DEVELOPMENT IN MONOGERM SUGAR BEETS  
(BETA VULGARIS L.) AS INFLUENCED BY CERTAIN  
NUTRIENTS

Abstract approved:   
J. Ritchie Cowan

The influence of several fertilizer elements on the occurrence of underdeveloped seeds in monogerm sugar beets (Beta vulgaris L.) was studied. Lime ( $\text{CaCO}_3$ ), nitrogen, phosphorus and potassium fertilizer applications were made to sugar beet seed plots at two locations in the Willamette Valley, Oregon. Seed produced from each treatment was examined by radiography to determine the percentage of fruits containing underdeveloped seeds. Underdeveloped seeds include those which are completely absent from the fruit locule and those which are only partially developed.

High nitrogen fertilization negatively influenced seed development, causing an increase in the occurrence of underdeveloped seeds. A larger difference in underdeveloped seeds was noted, however, between the two experimental locations. Lime, phosphorus and

potassium applications had no apparent influence on seed development.

Experimental locations and nitrogen fertilizer levels influenced the concentrations of several nutrient elements in the sugar beet petioles. But no association was apparent between plant nutritional status and the occurrence of underdeveloped seeds.

It was concluded that inadequate or imbalanced fertilizer applications were not the primary factors impeding sugar beet seed development. Although excess nitrogen fertilization was detrimental to seed development, it accounted for only a fraction of the total underdeveloped seeds obtained.

Seed Development in Monogerm Sugar Beets  
(Beta Vulgaris L.) as Influenced by Certain Nutrients

by

Leland Ray Schweitzer

A THESIS

submitted to

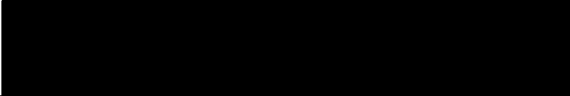
Oregon State University


in partial fulfillment of  
the requirements for the  
degree of

Master of Science

June 1969

APPROVED:

  
\_\_\_\_\_  
Professor and Head of Department of Farm Crops  
in charge of major

  
\_\_\_\_\_  
Dean of Graduate School

Date thesis is presented September 12, 1968

Typed by Donna L. Olson for Leland Ray Schweitzer

## ACKNOWLEDGEMENTS

To the following persons, I wish to express my sincere appreciation and thanks:

Mr. Ed. E. Hardin for his advice and encouragement throughout the duration of the research and helpful criticisms in the preparation of this manuscript.

Dr. J. Ritchie Cowan for his advice and guidance throughout my graduate program and preparation of this manuscript.

Drs. Rod V. Frakes, Roger K. Fendall and Thomas C. Moore for their critical reviews of this manuscript.

Drs. Thomas L. Jackson and Murray D. Dawson for their advice and counsel in the plant tissue analysis and soil fertility aspects of the research.

Mr. Sam C. Campbell and the personnel of West Coast Beet Seed Company for their extensive cooperation and assistance in providing fields, equipment and help for this research.

The Beet Sugar Development Foundation for providing the financial support for this research.

## TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
LITERATURE REVIEW	3
Analysis of the Low Germination Problem in Sugar Beets	3
Underdeveloped Seeds as a Factor in Low Germination	6
Effects of Various Nutrient Elements on Seed Quality	8
Nitrogen	9
Phosphorus	10
Potassium	11
Lime	12
MATERIALS AND METHODS	14
Experimental Design and Procedure	16
Soil and Plant Tissue Tests	20
Harvesting and Seed Processing	21
Radiographic Technique	22
Analysis of Data	23
EXPERIMENTAL RESULTS	26
Experiments I and II	26
Liming	26
Nitrogen	31
Phosphorus and Potassium	33
DISCUSSION	36
SUMMARY AND CONCLUSIONS	43
BIBLIOGRAPHY	45

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.	Schematic diagram of experimental design showing replications, lime main plots and the arrangement of NPK subplots.	17
2.	Radiograph of monogerm sugar beet fruits showing absent (A), partially developed (P) and good (G) seeds.	24
3.	Effects of liming on pH and calcium content of the soils in Experiments I and II.	30
4.	Lime x nitrogen interaction effect on the occurrence of partially developed seeds in two experiments.	34

## LIST OF TABLES

<u>Table</u>		<u>Page</u>
1.	Initial soil analysis of Experiments I and II (February, 1966).	15
2.	Nitrogen, phosphorus and potassium fertilizer levels and applications.	19
3.	Mean percentage of underdeveloped seeds from different nutrient treatments in two experiments.	27
4.	Effects of different experiments and nutrient levels on sugar beet petiole composition.	28
5.	Influence of lime applications on seed development.	29
6.	Effect of nitrogen level on the occurrence of underdeveloped seeds.	32
7.	Effects of phosphorus and potassium levels on the occurrence of underdeveloped seeds.	35



SEED DEVELOPMENT IN MONOGERM SUGAR BEETS  
(BETA VULGARIS L.) AS INFLUENCED BY  
CERTAIN NUTRIENTS

INTRODUCTION

The development and release of commercial monogerm sugar beet varieties in the late 1950's was soon followed by the observation of a stand establishment problem. The monogerm character was apparently accompanied by low germination potential. Poorly germinating 'seed'<sup>1/</sup> could not be used successfully for precision planting and the advantage of the monogerm character was largely nullified. Erratic stands in the sugar producing fields were as costly as the labor previously required for manually thinning the fields planted with multigerm 'seed'.

Poor germination was previously known in multigerm 'seed' but the problem was not critical until the introduction of the one seed per fruit character of monogerm varieties. Multigerm fruits with their two to four or more seeds per seedball had several chances to

---

<sup>1/</sup> To avoid confusion of the terms seed and fruit in reference to sugar beets the following definitions are used in this paper:

1. Fruit - ripened ovary(s), enclosing the seed(s).
2. Seed - ripened ovule, true botanical seed within the fruit.
3. 'Seed' - general agricultural term referring actually to the botanical fruit. (Association of Official Seed Analysts. Rules for testing seeds. Proceedings of the Association of Official Seed Analysts. 54:1-112. 1965.)

produce a seedling even though some of the individual seeds did not germinate. Researchers investigating the germination problem of multigerm 'seed' have suggested several factors thought to cause low germination: chemical inhibitors, physical restriction of the fruit, or environmental conditions during seed development are a few. Little information is available concerning monogerm 'seed'. Recently, however, TeKrony (61) concluded that the major factor responsible for the low germination potential of monogerm varieties is the occurrence of underdeveloped seeds. In some fruits the locule is completely empty (absent class) or contains a seed which is incompletely developed (partially developed class). The problem now becomes one of determining what agents are responsible for impeding the development of these seeds. Since reproductive development is a critical stage of plant growth that is dependent on the nutritional condition of the plant, it was thought that nutrient availability may influence seed development.

The objective of this study was to investigate the influence of several fertilizer nutrients on the occurrence of underdeveloped seeds in monogerm sugar beets. Lime, nitrogen, phosphorus and potassium fertilizer treatments were applied to sugar beet plots in two different fields. Samples of seed from each plot were radiographed and the percentages of absent, partially developed and total underdeveloped seeds were determined.

## LITERATURE REVIEW

The germination potential of sugar beet 'seed' consists of several components and is influenced by a number of factors. Insects, diseases, environmental stresses during seed development and genetic factors are all known to lower germination potential. Since the occurrence of underdeveloped seeds has only recently been identified as a major component of low germination potential, very little information is available on the possible causes of these underdeveloped seeds. The nutritional condition of plants is known to be important to reproductive growth and may significantly influence seed development of sugar beets. Several studies have been made regarding the effects of fertilizer applications and rates on the germination of sugar beet 'seed' but none have directly related the effects to seed development.

### Analysis of the Low Germination Problem in Sugar Beets

Much of the research on germination is based on work with multigerm 'seed' since monogerm 'seed' has been available for commercial use for only a decade. The assumption has been that factors which reduce germination of multigerm 'seed' are also responsible for the germination problem in monogerm 'seed'.

Several workers (50, 52, 67) have reported that germination

performance of sugar beet seed is heritable and that improvement could be obtained by selection. Sedlmayr (50) concluded that the speed of germination is largely controlled by the maternal parts (pericarp) of the fruit.

One of the more popular explanations for the germination problem is the presence of chemical germination inhibitors in the pericarp. As early as 1938 Tolman and Stout (65) reported the presence of toxic substances in the seedball which affect both germination rate and percentage. They also concluded that the inhibitory material was ammonia which was released from nitrogenous compounds of the seedball by enzymatic hydrolysis during germination. Froeschel (18) noted that chemicals from the fruits of sugar beet inhibited the germination of seeds of 28 species belonging to 14 plant families. Other workers later isolated and identified a number of compounds from the water extract of sugar beet fruits that may be inhibitory to the germination of seeds: an unsaturated yellow oil (33); water soluble oxalates (40); betaine (66); and several acids viz., caffeic, ferulic, vanillic, p-coumaric, and p-oxybenzoic (34, 37). These chemical inhibitors were found in the maternal tissue or pericarp of the sugar beet fruit (58). Removal of the corky pericarp material by seed processing or thorough washing of the fruits prior to germination significantly reduced the effect of these inhibitors in retarding germination (53, 60).

Another factor that may influence sugar beet seed germination is the tightness of seed cap attachment which may physically restrict 1) the flow of water and oxygen to the seed (56), or 2) the emergence of the seedling from the fruit even though imbibition was sufficient for germination (20). Seed cap attachment appears to be genetically controlled (46, 50). Peto (50) reported that monogerm 'seed' grown in the Vancouver, B. C., area possess thicker and tighter seed caps than the multigerm 'seed' from the same area. He attributes the lower germination of monogerm varieties to this factor. Germination of sugar beet fruits having tight seed caps can be improved greatly by seed treatment with dilute hydrochloric or sulfuric acid. This apparently dissolves the hemicellulose cementing substances of the seed cap (36, 50).

The influence of fruit and seed size on germination has not been well established. In work with multigerm sugar beets, Ingalls (30) found a definite trend of lower germination with smaller fruit size. But Hogaboam and Snyder (29) observed that in a monogerm variety they studied, the seeds in larger fruits generally germinated more slowly, apparently because of the influence of more maternal tissue.

Insects and diseases may be important agents in lowering germination potential. Extensive work by O. A. Hills (24, 25, 26) has shown that several species of lygus and stink bugs significantly

lowered the percentage of viable seeds. The greatest damage was inflicted by these insects when the developing seed was newly formed or in the soft stage (27). The mosaic disease of sugar beets has also been found to consistently lower germination potential (4).

Other research indicates that germination performance may be influenced by the environment during seed maturation (55, 57). Synder and Hogaboam (57) discovered that seed which was matured at higher temperatures germinated more rapidly than seed matured at lower temperatures. Soil fertility and the availability of plant nutrients during seed development also affect seed quality.

#### Underdeveloped Seeds as a Factor in Low Germination

TeKrony (61) and TeKrony and Hardin (62) concluded from extensive studies of Oregon-grown monogerm sugar beet 'seed' that the primary factor responsible for the low germination is the presence of underdeveloped seeds. In a study of 60 'seed' lots they found the percentage of underdeveloped seeds ranged from 4.5% to 55.5%. A survey of Arizona-grown sugar beet lots (21) reveals that the same problem with underdeveloped seeds occurs in this area of production. Hogaboam (28) observed from 2% to 35% seedless fruits in a study of one monogerm variety and others (19, 29) have also noted the presence of empty fruit cavities. Embryoless seeds are also known to occur commonly and in quite high percentages in dill, carrot, and

other species of Umbelliferae (15, 41).

Several factors may be responsible for the occurrence of these underdeveloped seeds. Namazie and Kohls (42) in attempting to induce parthenogenesis in sugar beets by treating flowers with several hormones obtained instead a number of parthenocarpic fruits containing neither embryo nor perisperm. Further evidence of parthenocarpic fruit development was obtained by Hardin, et al. (21). When male sterile plants were grown in the absence of pollen, some plants produced fruits which were normal in exterior appearances but were completely empty.

Several researchers (29, 62) reported that the size of sugar beet fruits was not related to the occurrence of underdeveloped seeds. Fulton (19), however, found in several lots of 'seed' that the smaller sized fruits contained much higher percentages of empty fruits than the larger sizes.

Insects, if not controlled, may also be significant agents in causing underdeveloped seeds. Hills (26) found that lygus bugs and stink bugs feeding on developing seeds caused the embryo to collapse resulting in hollow lightweight seedballs thus reducing germination potential. Preliminary research by Hardin et al. (21) gave additional evidence that lygus bugs can definitely increase the occurrence of underdeveloped seeds. Lygus bugs have also been reported to consistently cause embryoless seeds in dill and possibly in

carrot (16).

Ovule and seed abortion is quite common in alfalfa and may result in the development of non-functional seed-like structures in the pod (10, 11). Sato (48) concluded from a study of 11 species of Leguminosae that this seed abortion is caused by competition between the developing fertilized ovules for water and nutrients. These results create interest in the possible role of a nutrient deficiency or imbalance in the production of underdeveloped seeds in sugar beets.

#### Effects of Various Nutrient Elements on Seed Quality

The effect of nutrients on seed quality have been noted for several species. Experiments have been conducted relating the nutrient status of plants to the subsequent germination performance of seeds but most of these studies failed to analyze the effect on germination in detail. Therefore, it is not known what particular facet of germination was affected, whether the effect was due to physiological changes, seed development or other factors.

Sugar beet seed germination has been shown to be influenced by some fertilizer applications but no work could be found regarding nutrient effects on the production of underdeveloped seeds. Results of nutrient experiments often show interaction effects between two or more nutrient elements, and reports from different studies



sometimes conflict.

### Nitrogen

Hawthorn and Pollard (23) worked with several levels of nitrogen (N) fertilizer in lettuce seed production but found no effect on seed viability. These results were supported in later work by Harrington (22) who, using sand nutrient cultures, found that low levels of N did not affect the subsequent germination of lettuce, carrot, or pepper seed. Semeniuk (51), however, reported that lower levels of N resulted in higher germination percentages of seed produced by the annual common stocks (Matthioloa incana L.).

Fox and Albrecht (17) noted that N fertilization of wheat resulted in seeds with higher N content but the effect on seed performance was modified by subsequent climate. When planted in years favorable for germination, the seeds with higher N content gave better seedling emergence but in unfavorable years there was no effect or a complete reversal occurred.

Some evidence that N may influence seed development was reported by Chandler (6) who found that heavy N fertilization of sugar maple trees resulted in an increased percentage of sound or viable seed. A positive relation between the nitrate level of various plant organs and the expression of parthenocarpy in fig has also been noted (13). All organs of two parthenocarpic varieties contained

much greater quantities of nitrate than corresponding organs of nonparthenocarpic varieties. The authors did not discuss any causal relationships.

Early studies in sugar beet seed production indicated that N fertilization had no significant effect on the germination of seed produced although N was required to obtain high yields (47, 63, 64). More recent work by Snyder (54) and Pendleton (44) indicates that N may improve germination, at least under certain conditions. Pendleton's (44) field experiments show a highly significant increase in germination from N and phosphorus (P) together. These results were directly contradicted by Beresford and Jackson (1). In their sand nutrient culture work with garden beets, germination was consistently reduced by high N and P levels and by an N x P interaction.

### Phosphorus

Studies on the influence of P levels on seed quality show varying results. Some authors (22, 23) reported no response in germination performance from seed of several species grown under different levels of P. Others (17, 51) noted that seed of wheat and other plants produced at lower P levels had better emergence performance. An extreme phosphorus deficiency, however, may be critical to seed production. Iwata and Eguchi (31) found that

withholding P during the seed development stage of Chinese cabbage resulted in smaller seeds which showed slower radical elongation. Deficiencies during other growth stages had no effect on seed quality.

Beets appear to respond non-uniformly to the P nutrient level. Early trials with sugar beets in western Oregon (45) yielded no evidence of a P influence on seed germination but the later work by Pendleton (44) indicated that P along with N fertilizer could improve germination. This phenomenon may be partially explained by Tolman (63) who found that P fertilization somewhat counteracted the delayed seed maturity caused by high N treatments. As mentioned earlier, however, more recent work with garden beets (1) shows a negative germination response to P and N x P interaction.

No work was found regarding the effects of P as a nutrient on the specific problem of underdeveloped seeds in sugar beets or other crops.

### Potassium

Potassium (K) produces varying effects on seed quality and germination performance. In seed production of Chinese cabbage a K deficiency at different stages of plant growth had no effect on the germination performance of seed produced (31) but in experiments with lettuce, carrot, and pepper plants a K deficiency lowered

germination quality of the seed in some cases (22). High levels of K have also been shown to result in lower germinating seed (51).

Field experiments with sugar beet seed production (44) gave no evidence of a germination response to a K application. Higher K levels, however, significantly increased the germination percentage of garden beet seed (1).

The influence of K on the germination potential of seed may be due to specific effects on seed development. Nelson, Burkhardt, and Colwell (43) noted that K application to soils low in K markedly reduced the number of shriveled and shrunken soybean seeds produced. Several workers (2, 3, 35), on the other hand, report that higher levels of K in their experiments reduced the percentage of fruit filling in peanuts, i. e. the number of empty ovarian cavities was increased. Whether this effect may also occur in sugar beet or other crop seed development is not known.

### Lime

Liming has many direct and indirect influences on plant growth and developmental processes. Little has been reported, however, about the influence of liming or calcium (Ca) fertilization on seed quality. Harrington (22) noted that Ca deficiency lowered the germination of carrot and pepper seed produced. Calcium may play an important role in assuring seed development. Relatively large

quantities of Ca are necessary for proper peanut kernel development and the reduction of unfilled ovarian cavities (3, 7, 35): Calcium fertilizer apparently prevents ovule abortion in peanuts.

Sugar beets are also known to require considerable amounts of Ca (9) but Tolman and Stoker (64) found no response to lime ( $\text{CaCO}_3$ ) in sugar beets grown for seed in Oregon. Preliminary experiments by Hardin et al. (21), however, showed that liming may significantly reduce the occurrence of seedless fruits.

## MATERIALS AND METHODS

The influence of nitrogen (N), phosphorus (P), potassium (K) and lime fertilizers on seed development was determined on two fields in the Willamette Valley of western Oregon in the 1966-67 seed-crop year. The two experimental fields (Experiment I and Experiment II) represented different areas and soil types commonly used for sugar beet seed production. Experiment I, located north of Albany, Oregon, was of the Chehalis soil series which is a friable, well-drained, silty loam soil newly developed from recent alluvial deposits (12). Experiment II, located east of Salem and 20 miles NNE of Experiment I, was characterized by the Woodburn soil series. This soil is an older silty loam developed from old alluvial parent material and is somewhat less friable and less well drained than the Chehalis series (12). Soil tests (Table 1) indicated the soil pH for Experiment I was considerably higher than for Experiment II. Experiment I was also higher in residual fertility for the elements N, K, Ca, Mg, and B; but lower in P content than Experiment II.

The same cytoplasmic male sterile variety (USDA variety 569H3) was used for the plots in both experiments. The two pollinator varieties used were private company lines with similar bolting and maturity characteristics.

Table 1. Initial soil analysis of Experiments I and II (February, 1966).

Experimental Locations	Soil Type	Reaction (pH)	Total N (%)	P (lb/A)	K (lb/A)	Ca (me/100g)	Mg (me/100g)	Total Bases (me/100g)	CEC (me/100g)
I	Chehalis silty loam	6.2	.23	81	1096	18.7	7.4	27.48	52.5
II	Woodburn silty loam	5.5	.10	92	389	5.4	1.2	7.11	22.5

### Experimental Design and Procedure

Identical designs and procedures were used for both experiments. A factorial arrangement of treatments was used to study the following variables: 1) liming vs. no lime, 2) three levels of N, 3) two levels of P, and 4) three levels of K. A modified split plot design (Figure 1) with three replications was used with lime treatments as main plots. Randomized upon each lime plot was a factorial arrangement of all levels of N, P, and K. Three N levels x two P levels x three K levels = 18 NPK treatments. These 18 treatments x 2 lime levels x 3 replications x 2 fields = 216 total plots.

The lime application was made early in the spring (March 23, 1966) 4-1/2 months before planting and more than a full year before the seed crop actually began to develop. Ground limestone (Oswego Agricultural Lime, 95%  $\text{CaCO}_3$ ) was broadcast with an adjustable-fertilizer spreader and then worked into the topsoil. Experiment I (initial pH 6.2) received a two tons per acre application while Experiment II (initial pH 5.5) received four tons per acre. The fields were summer fallowed until the seed was planted in the fall. To minimize the possibility of soil mixing between limed and unlimed plots during summer fallow operations the lime application was made in a strip one-half the width of each experimental field across all three replications (Figure 1).



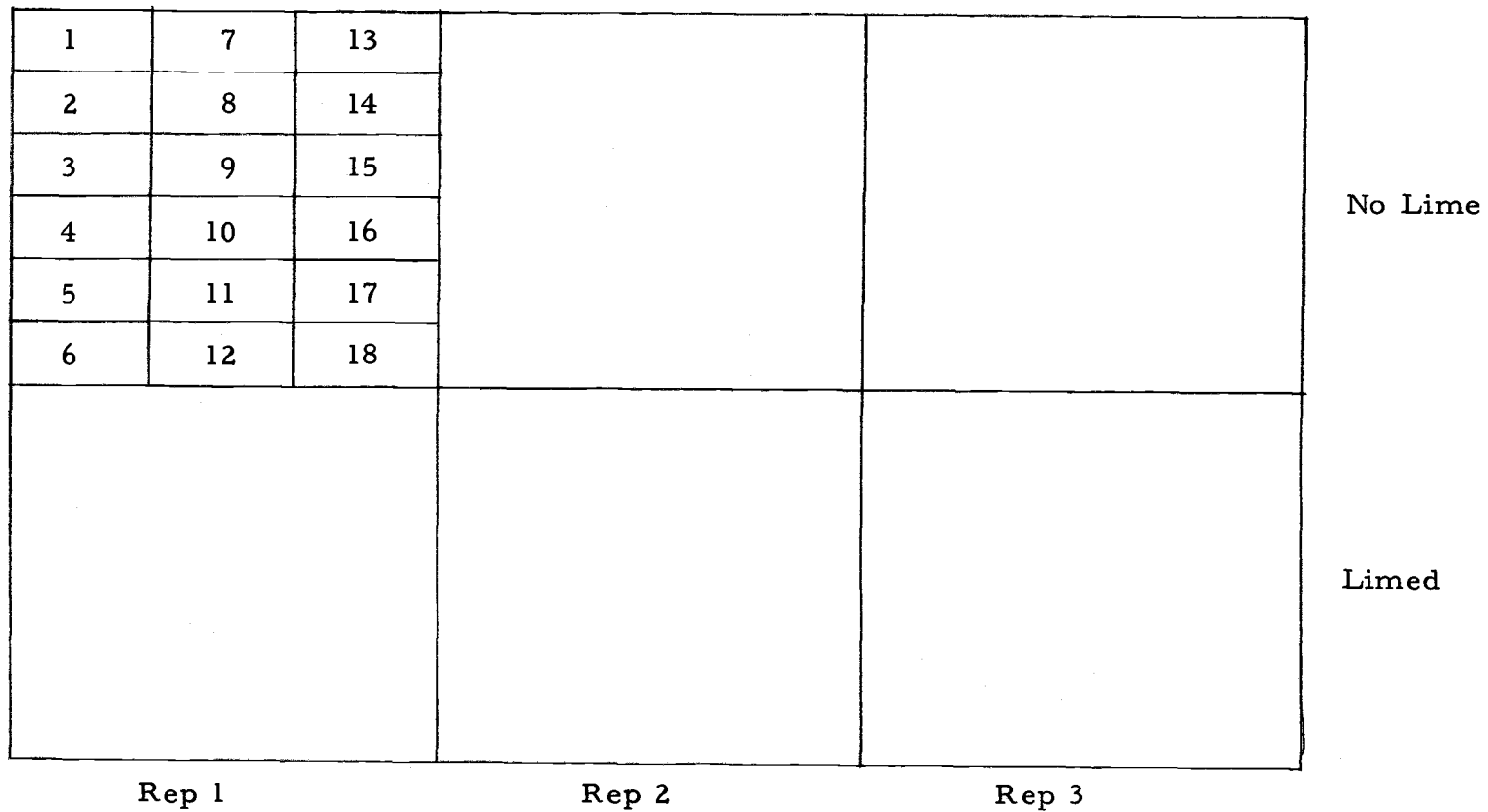


Figure 1. Schematic diagram of experimental design showing replications, lime main plots and the arrangement of NPK subplots.

A blanket application of borated gypsum (350 lb/A) was made to both fields in early July to supply the sulphur (56 lb/A) and boron (5-1/4 lb/A) requirements for sugar beet seed production on these soils. Field tillage incorporated this material and helped to prepare a seedbed for planting.

The N, P and K treatment levels and applications are shown in Table 2. The median N level (300 lb/A) was slightly higher than commercial N rates. The low P level (60 lb  $P_2O_5$ /A) and median K level (60 lb  $K_2O$ /A) also approximated representative commercial applications for these fields. High levels of N, P and K were chosen to determine if a reduction in underdeveloped seeds would be obtained by using fertilizer rates in excess of those normally used in commercial seed production. The sources of N, P and K for the experimental treatments were the commercial fertilizers ammonium nitrate (33.5% N), treble superphosphate (45%  $P_2O_5$ ) and potassium sulfate (50%  $K_2O$ ) respectively. The 216 NPK treatments for fall application were weighed out and mixed in four portions for each plot so that the exact amount could be banded with each row of the plot. The spring applications were weighed and mixed, then hand broadcast on the plots.

A heavy irrigation (eight hour set) three weeks prior to planting and a lighter irrigation (two hour set) just six days before planting brought the soil moisture to a good level for seed germination.

Table 2. Nitrogen, phosphorus and potassium fertilizer levels and applications.

Nutrient	Total Treatment (lb/A)	Applications (lb/A)		
		Banded Aug. 10-12, 1966	Broadcast April 6, 1967      May 20, 1967	
Nitrogen (N)	150	50	50	50
	300	50	125	125
	450	50	200	200
Phosphorus ( $P_2O_5$ )	60	60	-	-
	120	120	-	-
Potassium ( $K_2O$ )	0	-	-	-
	60	60	-	-
	120	60	60	-

and seedling emergence. The fields were planted August 10-12, 1967, with a four-row plot planter which had Planet Jr. type units and belt-bed fertilizer units with double disc furrow openers. Rows were spaced 24 inches apart and the fertilizer treatments were banded five inches to the side of and two inches below the seed. Each subplot measured eight feet wide (four rows) by 30 feet long.

Weed control was achieved by three cultivations and the use of herbicides. Both fields were sprayed with IPC (four lb/A) in November, 1966. Experiment II received an additional three and one-half lb/A application of Endothal February 3, 1967. Soil moisture was maintained by periodic irrigations depending on weather conditions. During the fall before winter rains began and during the following summer, irrigations were applied at about 14-day intervals up to three weeks prior to harvest. Both fields were sprayed or dusted with insecticides twice in the spring for control of lygus bugs and other insects.

#### Soil and Plant Tissue Tests

Several soil samples were taken throughout the crop year to monitor effects of the liming treatments. Sampling dates were June 30 and October 27, 1966; and April 6, 1967. One composite sample was obtained from the limed and unlimed section of each experiment and taken to the Oregon State University Soil Testing

Laboratory for analysis.

Plant tissue samples were collected and analyzed for several nutrient elements to determine the influence of NPK and lime treatments on plant composition and to relate plant composition to seed development. For these determinations, petioles from fully expanded new leaves were taken from the plots just before anthesis (May 27 and 29, 1967, for Experiment II and I, respectively). Fifteen to 20 petioles were taken from corresponding plots of the first two replications and were combined to give one composite sample per treatment for each of the two experiments. These samples were frozen, and stored for five months after which they were dried for 24 hours at 80°C and ground in a Wiley Mill using a 40 mesh screen. Only the samples from the high and low levels of NPK and lime treatments were analyzed.

#### Harvesting and Seed Processing

Experiment I matured and was ready to harvest about ten days later than Experiment II. To insure uniformity, all plots within a field were cut in one day: Experiment II was cut August 9, 1967; and Experiment I was cut August 18.

The two center rows of each plot were harvested but were shortened to 18 feet by removing a six foot border from each end of the plot. Before the plots were harvested, all plants in the pollinator

rows, and plot end and side borders were cut and stacked in separate windrows. The plots were then cut and laid in place on the stubble to cure for ten days before threshing.

Threshing was accomplished by use of a portable plot thresher after which a small M2B Clipper screening mill and an inclined draper were used to clean the seed lots. The cleaning procedures approximated the same procedures used in cleaning commercial seed lots.

A working sample ( $100 \pm 30$  grams) was obtained from each seed lot by repeated division of the bulk using a Boerner Divider. Each of these was in turn divided with a Gamet Precision Divider to obtain a small subsample of each plot to examine for underdeveloped seeds. These small samples were lightly hand-rubbed with a rubber-covered block and rubbing board to remove from the fruits the dried sepals and any remaining stem fragments that tend to obscure detail on the radiographs. Uniformly blowing each of the rubbed samples with a South Dakota Seed Blower assured uniform treatment of all samples in removing inert material and light immature fruits.

#### Radiographic Technique

The X-ray procedure used in this study was similar to that reported by TeKrony and Hardin (62). The Faxitron 804 table-top unit contained an oil immersed X-ray tube with a beryllium window. This

emitted only low voltage X-rays and allowed good contrast on low density subjects.

Two hundred fruits from the small rubbed and blown samples of each plot were placed in holders for radiographing. These in turn were laid directly on Kodak Industrial Type M film for exposure. The film and fruits were placed at 25 inches from the X-ray source and exposed for three and one-half minutes at 15 kVP voltage output setting and 3 mA current.

The developed radiographs were examined and all fruits with underdeveloped seeds were recorded. These were classified into two groups: absent or partially developed (Figure 2). The absent class consisted of those fruits which were completely empty or were entirely embryoless but may have contained the shrunken seedcoat and a slight amount of material in the perisperm area. Partially developed seeds were those which lacked the embryo or perisperm, or in which either or both were incompletely developed. Good sound seeds in the radiograph were well developed structurally and completely filled the fruit cavity.

#### Analysis of Data

The underdeveloped seed data were analyzed separately for the two experiments. An analysis of variance and F-test were performed for the percentages of absent seeds, partially developed

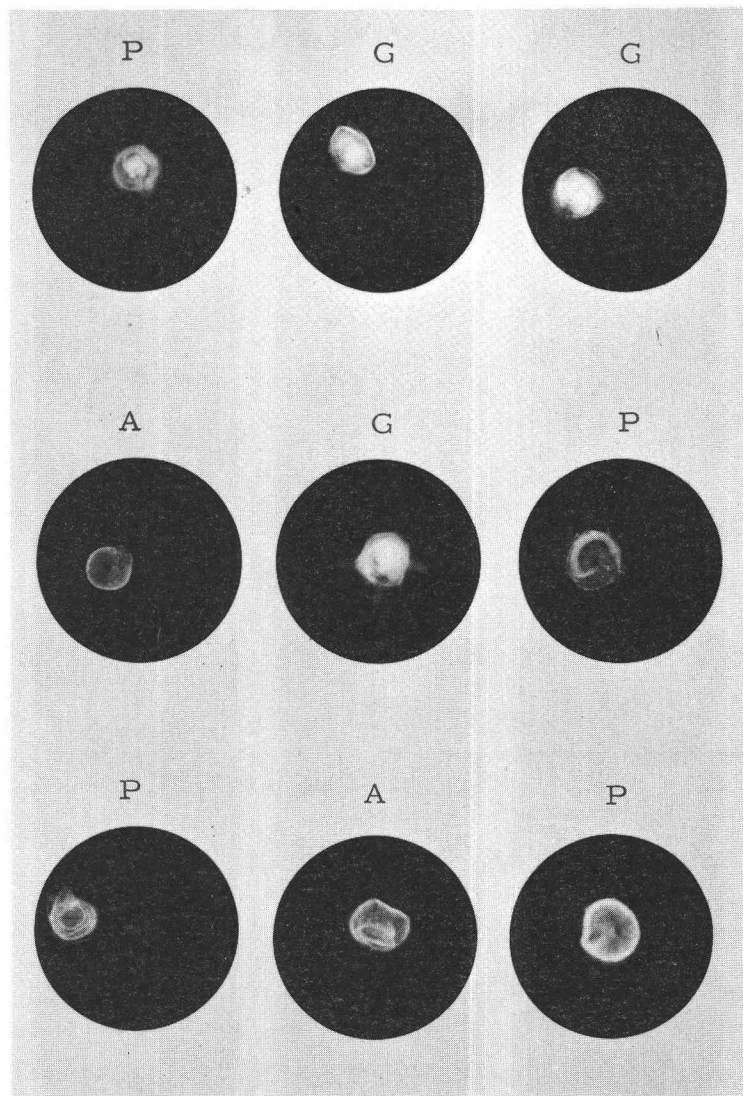


Figure 2. Radiograph of monogerm sugar beet fruits showing absent (A), partially developed (P) and good (G) seeds.



seeds, and total underdeveloped seeds. Where the F-test indicated significant differences due to treatment factors of three levels, Duncan's Multiple Range Test was used to determine which treatment levels differed significantly. The tissue analysis data were also subjected to an analysis of variance and F-test with both experiments combined.

## EXPERIMENTAL RESULTS

### Experiments I and II

The results of the underdeveloped seed determinations (Table 3) show that Experiment II had 12.93% underdeveloped seeds compared to only 4.80% for Experiment I, a 2.7-fold difference. A t-test comparing subplot means of both fields proved this difference to be highly significant.

Detailed examination and analysis of these data revealed that the response to fertilizer treatments was similar on both fields although the means of Experiment II were consistently higher than those of Experiment I. According to the petiole analyses the plants in Experiment II contained higher concentrations of every element tested (N, P, K, Ca, Mg, Na, and Mn) but only the P concentration was significantly higher than that in Experiment I (Table 4).

### Liming

The liming application in both experiments increased the occurrence of absent and partially developed seeds but the differences were not statistically significant (Table 5). The four ton/acre application in Experiment II increased the pH from an initial 5.5 to 6.7 and raised the Ca content from 5.4 to 6.3 me/100 g (Figure 3). The two ton/acre application had less effect in Experiment I which

Table 3. Mean percentage of underdeveloped seeds from different nutrient treatments in two experiments.

Fertilizer Treatment	Percent Underdeveloped Seeds <sup>1/</sup>	
	Experiment I	Experiment II
Liming (95% CaCO <sub>3</sub> )		
0 T/A	4.27	12.40
2 or 4 T/A <sup>2/</sup>	5.33	13.46
Nitrogen (N)		
150 lb/A	4.14	12.03
300 lb/A	5.04	12.42
450 lb/A	5.21*	14.34*
Phosphorus (P <sub>2</sub> O <sub>5</sub> )		
60 lb/A	4.78	12.88
120 lb/A	4.82	12.98
Potassium (K <sub>2</sub> O)		
0 lb/A	4.47	12.98
60 lb/A	4.97	12.88
120 lb/A	4.95	12.93
Total Expt. Means	4.80	12.93**

<sup>1/</sup> Means shown are averaged over all other factors.

<sup>2/</sup> Experiment I received 2 tons/acre; Experiment II received 4 tons/acre.

\*Significantly higher than the low N treatment at the 5% level (F test).

\*\*Experiment II significantly higher than Experiment I at the 1% level (t-test).

Table 4. Effects of different experiments and nutrient levels on sugar beet petiole composition.

Treatment	Percentage Means of Tissue Analysis <sup>1/</sup>							
	N	P	K	Ca	Mg	Na	ppm	Mn
Experiment:								
I	2.02	.21	3.6	.62	.22	0.51		26
II	2.17	.29*	5.1	.74	.34	1.86		53
Lime:								
None	2.10	.25	4.1	.64	.28	1.18		48
High	2.19	.25	4.6	.72	.28	1.09		31
Nitrogen:								
Low	1.96	.28**	4.6**	.59	.23	1.21		40
High	2.21	.22	4.1	.77**	.33**	1.16		39
Phosphorus:								
Low	2.09	.24	4.3	.68	.28	1.20		39
High	2.10	.26	4.4	.68	.28	1.17		40
Potassium:								
None	-	.24	4.3	.68	.29	1.21		39
High	-	.26	4.4	.68	.28	1.16		40

<sup>1/</sup> Means shown are averages over other variables of the factorial experiment. Measurements were based on tissue dry weight.

\*Significantly higher than the opposite treatment at the 5% level.

\*\*Significantly higher than the opposite treatment at the 1% level.

Table 5. Influence of lime applications on seed development.

Experiment and Treatment	Percent Underdeveloped Seeds <sup>1/</sup>		
	Absent	Partially Developed	Total Underdeveloped
Experiment I:			
No Lime	1.97	2.30	4.27
Limed (2 T/A)	2.30	3.03	5.33
Experiment II:			
No Lime	4.81	7.59	12.40
Limed (4 T/A)	5.91	7.55	13.46

<sup>1/</sup>No significant differences among treatment levels.

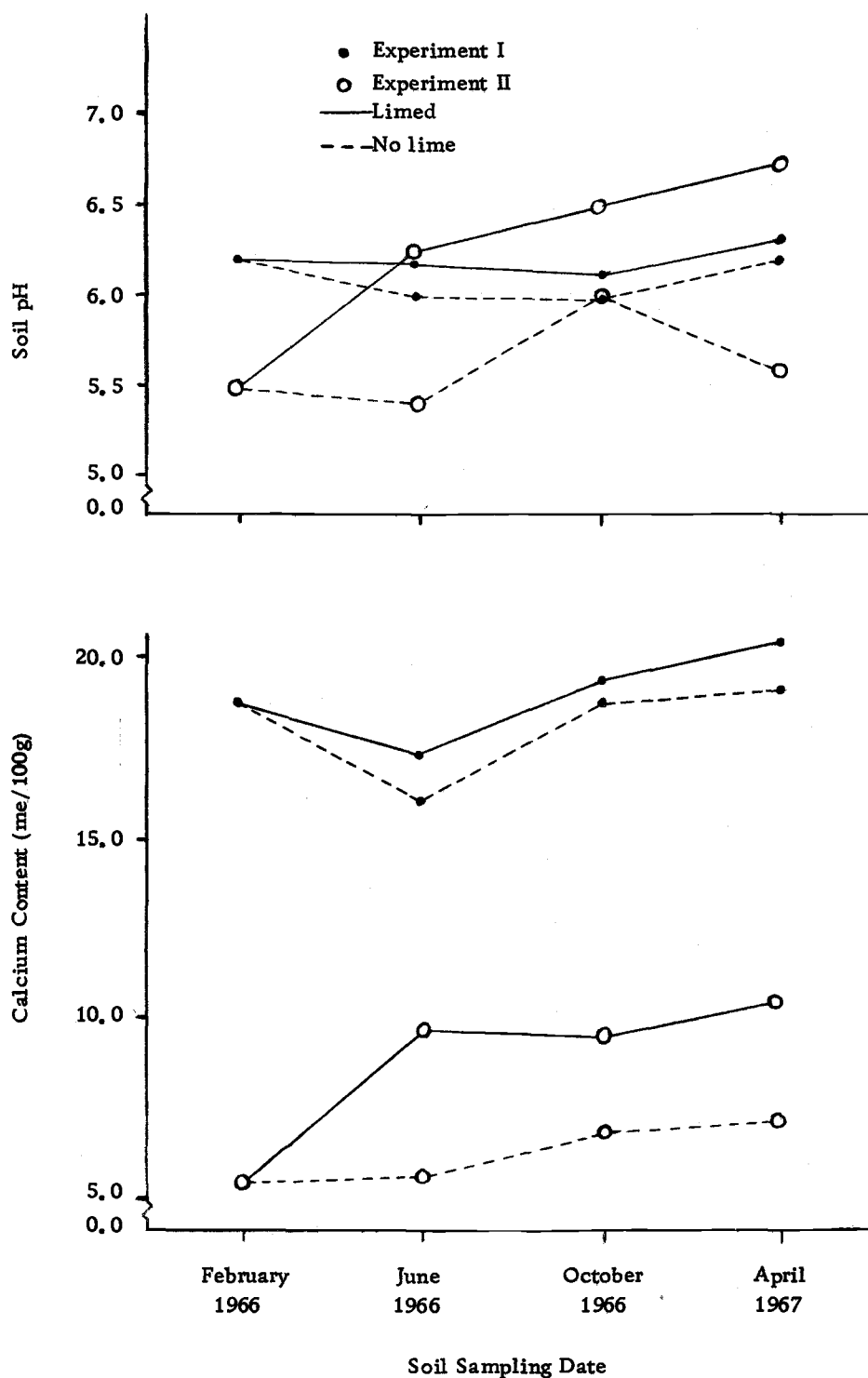


Figure 3. Effects of liming on pH and calcium content of the soils in Experiments I and II.

was initially higher in both pH and calcium (pH 6.2 to 6.3 and Ca 18.7 to 20.4 me/100 g). No trends due to liming were apparent for the other soil characters tested.

Results of the petiole analyses indicate that liming had no significant influence on the nutritional status of the plants (Table 4). Averaging the effects for both fields revealed that liming increased plant uptake or accumulation of N, K, Ca, and Mg but decreased the amount of Mn and Na in plant tissues.

#### Nitrogen

Increasing the rate of nitrogen application progressively increased the percentage of underdeveloped seeds in both experiments (Table 6). Duncan's New Multiple Range Test revealed that the high N level in both experiments resulted in significantly more underdeveloped seeds than the low N level. The mean increase in underdeveloped seeds due to the high N application was 1.07% for Experiment I and 2.31% for Experiment II.

An examination of the N effect on the components of underdeveloped seeds revealed a slightly different response from the two experiments (Table 6). In Experiment I, the high N level significantly increased the occurrence of partially developed seeds but did not influence the absent seed content. In Experiment II a significant increase in underdeveloped seeds was noted in the absent seed

Table 6. Effect of nitrogen level on the occurrence of underdeveloped seeds.

Experiment and N level	Percent Underdeveloped Seeds		
	Absent	Partially Developed	Total Underdeveloped
Experiment I:			
150 lb/A	2.01*	2.13	4.14
300 lb/A	2.21	2.83	5.04
450 lb/A	2.18	3.03	5.21
Experiment II:			
150 lb/A	4.76	7.26	12.03
300 lb/A	5.18	7.24	12.42
450 lb/A	6.13	8.22	14.34

\*Means connected by the same solid line did not differ significantly at the 5% level according to Duncan's New Multiple Range Test.



fraction but not in the partially developed class.

A significant lime x nitrogen interaction was observed in both experiments (Figure 4). The N effects on partially developed seeds were not uniform over both lime levels and the interactions differed for the two experiments. These interactions influenced the partially developed seed class and are reflected in corresponding effects on total underdeveloped seeds.

Results of the petiole tissue analyses indicated that the N level had a highly significant effect (1% level) on plant nutrient composition (Table 4). Plants from the high N plots contained markedly less P and K but more N, Ca and Mg. Little difference was noted for Mn and Na concentrations.

#### Phosphorus and Potassium

The various phosphorus and potassium levels used in the experiment had no effect on the occurrence of either absent or partially developed seeds in sugar beet (Table 7). Neither P nor K influenced plant nutritional status as shown by petiole tissue analyses (Table 4).

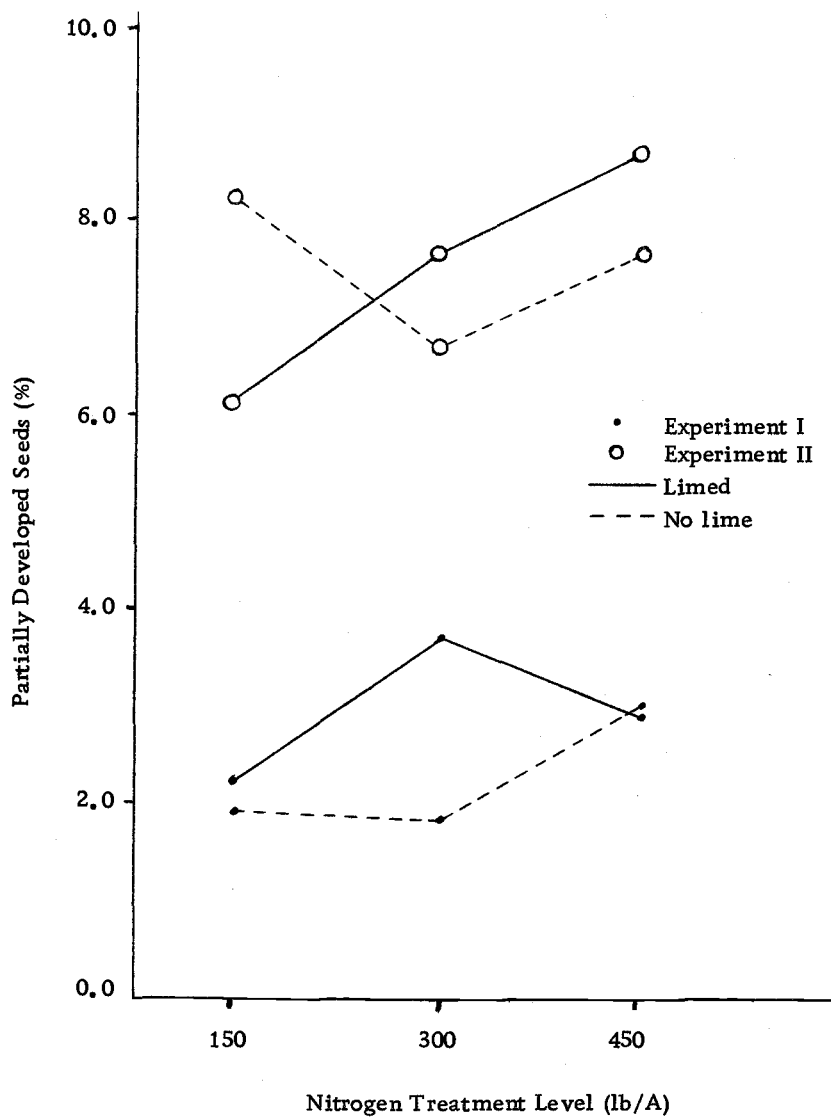


Figure 4. Lime x nitrogen interaction effect on the occurrence of partially developed seeds in two experiments.

Table 7. Effects of phosphorus and potassium levels on the occurrence of underdeveloped seeds.

Experiment and Treatment	Percent Underdeveloped Seeds <sup>1/</sup>		
	Absent	Partially Developed	Total Underdeveloped
<u>Experiment I</u>			
Phosphorus			
60 lb/A	2.06	2.72	4.78
120 lb/A	2.20	2.60	4.82
Potassium			
0 lb/A	2.01	2.46	4.47
60 lb/A	2.13	2.85	4.98
120 lb/A	2.26	2.68	4.94
<u>Experiment II</u>			
Phosphorus			
60 lb/A	5.07	7.81	12.88
120 lb/A	5.64	7.34	12.98
Potassium			
0 lb/A	5.43	7.55	12.98
60 lb/A	5.44	7.44	12.88
120 lb/A	5.19	7.74	12.93

<sup>1/</sup>No significant differences among treatment levels.

## DISCUSSION

The results of these experiments demonstrate the complexity of environmental influences on seed development. High nitrogen fertilization was found to negatively influence seed development and also to interact with lime applications. The largest difference in underdeveloped seeds, however, occurred between the two fields and not between nutrient treatments. Lime, phosphorus, and potassium applications had no effect on seed development as determined by X-ray radiography. An attempt to relate plant chemical composition to seed development showed little apparent correlation between plant nutritional status and the occurrence of underdeveloped seeds.

In the initial development of the experiment it was thought that lime would benefit sugar beet seed production, especially on fields of relatively low pH. Sugar beets have a high tolerance for alkaline soils (5) and respond well to liming on soils that are moderately acid. The calcium requirement is also high for sugar beets.

Results of this experiment, however, show that liming had no beneficial effect on seed development. In fact, the limed plots in each field averaged about 1% more underdeveloped seeds than the unlimed plots. Periodic soil testing and analysis over the course of the experiment showed that liming (four T/A) effected a marked increase in the soil pH and calcium content in Experiment II but the

lower rate of lime (two T/A) applied on Experiment I had less influence on these soil characters. A corresponding small increase in Ca content was also observed in the petioles. But in a preliminary experiment where lime was applied in the spring just prior to bolting, a significant reduction in underdeveloped seeds was observed. No analysis of tissue composition was made, however, and these data do not suggest an explanation for the disagreement of the experiments.

Neither plant nutrient composition nor seed development were influenced by the high levels of phosphorus and potassium used in the experiment (120 lb/A each,  $P_2O_5$  and  $K_2O$  respectively). These data suggest that at least for these fields the inherent amount of K and no more than 60 lbs/acre additional  $P_2O_5$  were sufficient for sugar beet seed production. Pendleton (44) also found little response in sugar beet seed quality to either P or K treatments but a combination treatment of N and P resulted in a significant improvement in germination.

High N rates (450 lbs/A) were found to significantly increase the occurrence of underdeveloped seeds, but drawing a simple conclusion is complicated by the concurrent finding of a lime x nitrogen interaction. This interaction (Figure 3), although statistically significant at the 5% level is difficult to interpret biologically. It may even raise a question about the true significance of the N main

effect. The mean percentages of partially developed seeds for both experiments progressively increased with each increase in N. But when examined in relation to the lime treatments, the N effect was not clear cut. The N effect was not consistent for the lime and no-lime treatments and the interaction was also different for the two fields, inferring additional interactions with some other field or environmental factor or factors.

That excess N may be detrimental to seed development is supported by the work of several others (1, 47, 51) who found that high N levels during seed production reduced the germination quality of sugar beets, garden beets and other species. Reports of positive N effects on sugar beet germination also have been made (44, 54). It is recognized that directly relating this study to germination experiments may be inaccurate because nutrients could have an effect on other factors of beet seed germination, such as inhibitor levels in the fruits, which would influence germination results but would have no relation to the problem of underdeveloped seeds.

The fact that high N levels increased underdeveloped seeds may be related to maturity. Excessive N increases vegetative growth and delays maturity. Both of these effects were observed in the present study. The high N plots could be easily distinguished in Experiment II by their darker color, but were not so obvious in Experiment I where even the low N plots had good color. The high

N plots also took several days longer to mature, confirming the findings of Tolman (63) who reported that high N definitely retarded sugar beet seed maturity.

Although higher N levels increased the occurrence of underdeveloped seeds the most striking feature of the results was the much larger difference between the two experiments. Averaging the N effect of the two fields shows the high N treatment increased underdeveloped seeds by 1.7% over the low N treatment. But a comparison of overall experiment means indicates that Experiment II had over 8.1% more underdeveloped seeds than Experiment I. Apparently factors other than the fertilizer nutrients used in this experiment were also responsible for impeding development of sugar beet seeds.

The beets in Experiment I appeared larger and more leafy than those in Experiment II as early as three weeks after emergence. And as noted earlier this difference in vegetative development persisted until maturity. Even though bolting was first noted at approximately the same dates on both experiments (early May), Experiment II matured about ten days before Experiment I. Relating this fact to the higher underdeveloped seed percentage of Experiment II may suggest a correlation between early maturity and increased underdeveloped seeds. This postulation, however, would directly contradict a recent report by Scott (49) that treatments which encouraged

early flowering and ripening of sugar beets seemed to produce better germinating seed. Flemion and Hendrickson (15) also found in a number of Umbelliferae species that seed produced later in the season contained higher percentages of embryoless seeds.

Another possible explanation for the location and N effects on underdeveloped seeds may lie in the physiological nutrient balance or availability within the plants. Ovule and seed abortion are common in alfalfa and other leguminous crops (10, 11, 48). Sato concluded that the abortion was caused by competition between fertilized ovules for water and nutrients. This relationship in sugar beet seed development is not known and may bear further investigation. The importance of balanced nutrition has also been pointed out by Fox and Albrecht (17) who note that high rates of major nutrients plus minor nutrients often resulted in wheat seed with low vigor.

According to the petiole analyses (Table 4) the plants in Experiment II contained higher relative amounts of all mineral nutrients tested and yet this experiment produced more underdeveloped seeds. Apparently a simple deficiency of these major nutrients is not the answer. The high N level consistently affected the concentration of several other nutrients in the petioles. These increases in N, P, and K and decreases in Ca and Mg concentrations due to N fertilizer applications are consistent with results obtained from



several other crops<sup>2/</sup> but their relation to seed development is not clear.

Parthenocarpic fruit development is known to occur in sugar beets (21, 42) and may also be influenced by the nutritional status of the plant. Meyer et al. (38) stated that in plants which produce both parthenocarpic and seeded fruits, seedless fruits are more likely to occur when the nutritional status is high. Consequently the higher nutritional status of the plants in Experiment II may have increased parthenocarpic fruit development resulting in the higher percentage of underdeveloped seeds.

Dekazoa and Crane (13) have also shown a positive relation between the nitrate level of plant organs and the expression of parthenocarpy in figs. Organs of parthenocarpic varieties contained greater quantities of nitrate than corresponding organs of nonparthenocarpic varieties, especially during fruit setting. It is not known whether a similar relationship exists in sugar beets and may explain the increased occurrence of underdeveloped seeds in the high N plots. The possibility poses an interesting problem for further study.

The results of this research show that excessive N fertilization has a negative influence on sugar beet seed quality but these

---

<sup>2/</sup>Compton, O. C. Professor, Oregon State University, Dept. of Horticulture. Personal Communication. Corvallis, Oregon. August 2, 1968.

data do not suggest the mode of action. The fact that such a large difference in underdeveloped seeds occurred between the two experiments and that no effect was obtained from lime, P, and K fertilization suggest that the problem of underdeveloped seeds cannot be solved by fertilizer management alone. It is evident that other factors or interactions that have not been identified in this study are influencing seed development. The actual cause of underdeveloped seeds will require further investigation.

## SUMMARY AND CONCLUSIONS

An investigation was made to determine the influence of several fertilizer elements on the occurrence of underdeveloped seeds in monogerm sugar beets. Applications of lime (95%  $\text{CaCO}_3$ ), nitrogen, phosphorus and potassium fertilizers were made on two separate field experiments in the Willamette Valley, Oregon, during the 1966-67 seedcrop year. Seed produced from each treatment was sampled and examined by radiography to determine the percentages of absent, partially developed and total underdeveloped seeds.

Results showed that high N fertilization negatively influenced seed development. Low, medium, and high N levels (150, 300 and 450 lb/A) produced 8.08, 8.23 and 9.78% total underdeveloped seeds, respectively (means of two experiments). A larger difference in underdeveloped seeds occurred, however, between the two experimental locations (4.80 vs. 12.93%). Lime ( $\text{CaCO}_3$ ), P and K applications had no apparent influence on seed development.

Nitrogen fertilizer levels and experimental locations both influenced the concentrations of several nutrient elements in the plant. Comparisons with seed development, however, showed no apparent association between plant nutritional status and the occurrence of underdeveloped seeds.

The major factor causing underdeveloped seeds in monogerm

sugar beets was not identified in these experiments. The conclusions of this study refute the thesis that inadequate or imbalanced fertilizer applications were impeding seed development. Deficiencies of the major nutrients, N, P, K, and Ca are not responsible for the occurrence of underdeveloped seeds. Excess N fertilization was detrimental to seed development but this factor accounted for only a fraction of the total underdeveloped seeds obtained.

## BIBLIOGRAPHY

1. Beresford, S. W. and A. A. Jackson. The nutrition of garden beets in relation to seed production. *Journal of Horticultural Science* 36:153-159. 1961.
2. Brady, N. C. and W. E. Colwell. Yield and quality of large-seeded type peanuts as affected by potassium and certain combinations of potassium, magnesium, and calcium. *Journal of the American Society of Agronomy* 37:429-442. 1945.
3. Brady, N. C., J. F. Reed and W. E. Colwell. The effect of certain mineral elements on peanut fruit filling. *Journal of the American Society of Agronomy* 40:155-167. 1948.
4. Brewbaker, H. E. Mosaic and seed production. *Proceedings of the American Society of Sugar Beet Technologists* 3:381-385. 1942.
5. Buckman, H. O. and N. C. Brady. The nature and properties of soils. 6th ed. New York, MacMillan, 1960. 567 p.
6. Chandler, R. F. The influence of nitrogenous fertilizer applications upon seed production of certain deciduous forest trees. *Journal of Forestry* 36:761-766. 1938.
7. Colwell, W. E. and N. C. Brady. The effect of calcium on certain characteristics of peanut fruit. *Journal of the American Society of Agronomy* 37:696-708. 1945.
8. \_\_\_\_\_ The effect of calcium on yield and quality of large-seeded type peanuts. *Journal of the American Society of Agronomy* 37:413-428. 1945.
9. Cook, R. L. Starvation signs, when and how. *Journal of the American Society of Sugar Beet Technologists* 8:380-385. 1954.
10. Cooper, D. C. and R. A. Brink. Partial self-incompatibility and the collapse of fertile ovules as factors affecting seed formation in alfalfa. *Journal of Agricultural Research* 60:453-472. 1940.

11. Cooper, D. C., R. A. Brink and H. R. Albrecht. Embryo mortality in relation to seed formation in alfalfa. *American Journal of Botany* 24:203-213. 1937.
12. Dawson, M. D. Professor, Oregon State University, Dept. of Soils. Class notes from Soils 210. Soil descriptions. Corvallis, 1964.
13. Dekazoa, E. D. and J. C. Crane. Fluctuations in total and nitrate nitrogen in parthenocarpic and non-parthenocarpic fig varieties. *Hilgardia* 37:155-164. 1966.
14. Field Emission Corporation. Application guide - Faxitron 804. McMinnville, Oregon. 1967. n.p.
15. Flemion, F. and E. T. Henrickson. Further studies on the occurrence of embryoless seeds and immature embryos in the Umbelliferae. *Contributions from Boyce Thompson Institute* 15:291-297. 1949.
16. Flemion, F., H. Poole and J. Olson. Relation of lygus bugs to embryoless seeds in dill. *Contributions from Boyce Thompson Institute* 15:299-310. 1949.
17. Fox, R. L. and W. A. Albrecht. Soil fertility and the quality of seeds. Columbia, 1957. 23 p. (Missouri. Agricultural Experiment Station. Research Bulletin 619)
18. Froeschel, P. Onderzoekingen over de physiologie van de Kieming. I. Remstoffen. *Natuurwetenschappelijk Tijdschrift (Antwerp)* 21:93-116. 1939. (Cited in: Evenari, M. Germination inhibitors. *The Botanical Review* 15:188. 1949)
19. Fulton, C. and H. Fulton. The use of x-ray in determining the viability and twins in monogerm sugar beet seed - Beta vulgaris. *Proceedings of the Society of Commercial Seed Technologists* 44:55-57. 1967.
20. Gemma, T. On the cause of non-germination phenomena in Beta spp. *Journal of the Society of Agriculture and Forestry in Yamagota* 11:3-5. 1957. (Cited in: Snyder, F. W. Influence of the seedball on speed of germination of sugar beet seeds. *Journal of the American Society of Sugar Beet Technologists* 10:513-520. 1959)

21. Hardin, E. E., D. M. TeKrony and L. R. Schweitzer. Sugar beet germination project - progress report. Corvallis, Oregon State University, 1968. 8 p.
22. Harrington, J. F. Germination of seeds from carrot, lettuce and pepper plants grown under severe nutrient deficiencies. *Hilgardia* 30:219-235. 1960.
23. Hawthorn, L. R. and L. H. Pollard. Production of lettuce seed as affected by soil moisture and fertility. Logan, 1956. 23 p. (Utah. Agricultural Experimental Station. Bulletin 386)
24. Hills, O. A. Isolation-cage studies of certain Hemipterous and Homopterous insects on sugar beets grown for seed. *Journal of Economic Entomology* 34:756-760. 1941.
25. \_\_\_\_\_ Comparative ability of several species of *lygus* and the Say stinkbug to damage sugar beets grown for seed. *Journal of Agricultural Research* 67:389-394. 1943.
26. \_\_\_\_\_ Insects affecting sugarbeets grown for seed. Washington, D. C., 1963. 29 p. (U. S. Dept. of Agriculture. Agricultural Handbook no. 253)
27. Hills, O. A. and E. A. Taylor. *Lygus* damage to sugar beet seed in various stages of development. *Proceedings of the American Society of Sugar Beet Technologists* 6:481-487. 1950.
28. Hogaboam, G. J. Radiography as a method for observing some seed characters in monogerm sugar beet fruits. *Journal of the American Society of Sugar Beet Technologists* 11:605-609. 1961.
29. Hogaboam, G. J. and F. W. Snyder. Influence of size of fruit and seed on germination of a monogerm sugar beet variety. *Journal of the American Society of Sugar Beet Technologists* 13:116-126. 1964.
30. Ingals, F. S. Relationship of seedball size to germination as found to be common to beet seed grown over the St. George areas. *Proceedings of the American Society of Sugar Beet Technologists* 1:97-100. 1938.

31. Iwata, M. and Y. Eguchi. Effects of phosphorus and potassium supplied for various stages of growth on the yield and quality of seeds of Chinese cabbage. *Journal of the Horticultural Association of Japan* 27:171-178. 1958.
32. Katz, R., M. R. Lee and M. Milner. X-ray inspection of wheat. *Non-Destructive Testing* 9:16-18. 1950.
33. Kock, P. C. and R. F. Hunter. Germination inhibitor from sugar beets. *Nature* 166:440-441. 1950.
34. Koves, E. and M. Varga. Comparative examination of water- and ether-soluble inhibiting substances in dry fruits. *Phyton* 12:93-99. 1959.
35. Kushman, L. J. and J. H. Beattie. Production of "pops" in Spanish and Virginia type peanuts as affected by nutritional level and balance under greenhouse conditions. *Proceedings of the American Society of Horticultural Science* 51:547-551. 1948.
36. Lackey, C. F. Chemical loosening of seed caps in relation to germination of sugar beet seed. *Proceedings of the American Society of Sugar Beet Technologists* 5:66-69. 1948.
37. Massert, L. Inhibitors of germination in the glomerules of sugar beet and other dried fruits and seeds. *Biokhimiia* 22:417-420. 1957.
38. Meyer, B. S., D. B. Anderson and R. H. Bohning. Introduction to plant physiology. Princeton, D. Van Nostrand, 1960. 541 p.
39. Milner, M., M. R. Lee and R. Katz. Application of x-ray technique to the detection of internal insect infestation of grain. *Journal of Economic Entomology* 43:933-935. 1950.
40. Miyamoto, T. The germination inhibitor in sugar beet seed-balls. *Quarterly Bulletin of the Michigan Agriculture Experiment Station* 39:518-523. 1957.
41. Munn, M. T. and C. E. Heit. Embryoless seeds of the Umbelliferae. *Association of Official Seed Analysts, News Letter* 15:10. June, 1941.



42. Namazie, J. and H. L. Kohls. Attempts to induce parthenogenesis in sugar beets. *Proceedings of the American Society of Sugar Beet Technologists* 7:377-381. 1952.
43. Nelson, W. L., L. Burkhart and W. E. Colwell. Fruit development, seed quality, chemical composition, and yield of soybeans as affected by potassium and magnesium. *Proceedings of the Soil Science Society of America* 10:224-229. 1946.
44. Pendleton, R. A. Cultural practices related to yields and germination of sugar beet seed. *Journal of the American Society of Sugar Beet Technologists* 8:157-160. 1954.
45. Pendleton, R. A., H. E. Finnel and F. C. Reimer. Sugar beet seed production in Oregon. Corvallis, 1946. 23 p. (Oregon. Agricultural Experiment Station. Station Bulletin 437)
46. Peto, F. H. Methods of loosening tight seed caps in monogerm seed to improve germination. *Journal of the American Society of Sugar Beet Technologists* 13:281-286. 1964.
47. Pultz, L. M. Relation of nitrogen to yield of sugar beet seed and accompanying changes in composition of roots. *Journal of Agricultural Research* 54:639-654. 1937.
48. Sato, H. Morphological and experimental studies on occurrence of aborted seeds in leguminous crops. *Memoirs of the Faculty of Agriculture Hokkaido University* 4:265-310. 1962.
49. Scott, R. K. Sugar beet seed production. *Agricultural Progress* 42:112-118. 1967.
50. Sedlmayr, T. E. Inheritance of speed of germination in sugar beets (*Beta vulgaris*, L.) Ph.D. thesis. East Lansing, Michigan State University. 1960. 84 numb. leaves. (Abstracted in *Dissertation Abstracts* 22:4151-4152. 1962)
51. Semeniuk, P. Effect of various levels of nitrogen, phosphorus, and potassium on seed production and germination of Matthiola incana. *Botanical Gazette* 125:62-65. 1964.
52. Smith, C. H. Heritable differences in germination of sugar beet seed at low temperatures. *Proceedings of the American Society of Sugar Beet Technologists* 7:411-414. 1952.

53. Smith, P. B. and G. E. Walters. Methods of preparation and results of field planting of various types of processed monogerm sugar beet seed. *Journal of the American Society of Sugar Beet Technologists* 12:225-232. 1962.
54. Snyder, F. W. Effect of nitrogen on yield and subsequent germinability of sugar beet seed. *Journal of the American Society of Sugar Beet Technologists* 10:439-443.
55. \_\_\_\_\_ Selection for speed of germination in sugar beet. *Journal of the American Society of Sugar Beet Technologists* 12:617-622. 1963.
56. \_\_\_\_\_ Some physico-chemical factors of the fruit influencing speed of germination of sugar beet seed. *Journal of the American Society of Sugar Beet Technologists* 12:371-377. 1963.
57. Snyder, F. W. and G. J. Hogaboam. Effect of temperature during anthesis and seed maturation on yield and germinability of sugar beet seed. *Journal of the American Society of Sugar Beet Technologists* 12:545-563. 1963.
58. Snyder, F. W., J. M. Sebeson, and J. L. Fairley. Relation of water soluble substances in fruits of sugar beet to speed of germination of sugar beet seeds. *Journal of the American Society of Sugar Beet Technologists* 13:379-388. 1964.
59. Stout, M. and B. Tolman. Factors affecting the germination of sugar-beet and other seeds, with special reference to the toxic effects of ammonia. *Journal of Agricultural Research* 63:687-713. 1941.
60. \_\_\_\_\_ Interference of ammonia, released from sugar beet seed balls, with laboratory germination tests. *Journal of the American Society of Agronomy* 33:65-69. 1941.
61. TeKrony, D. M. Germination potential in monogerm seed of Beta vulgaris L. Master's thesis. Corvallis, Oregon State University, 1967. 57 numb. leaves.
62. TeKrony, D. M. and E. E. Hardin. The use of x-ray, excision, and cutting methods as an estimate of potential germinability of Beta vulgaris L. *Proceedings of the Association of Official Seed Analysts*. Vol. 57. (In press)

63. Tolman, B. Sugar beet seed production in southern Utah, with special reference to factors affecting yield and reproductive development. Washington, D. C., 1943. 35 p. (U. S. Dept. of Agriculture. Technical Bulletin 848)
64. Tolman, B. and G. L. Stoker. Sulfur and nitrogen deficiency relationships in sugar beets grown for seed in Oregon. Journal of the American Society of Agronomy 33:1072-1079. 1941.
65. Tolman, B. and M. Stout. Some factors which influence the rate and total percentage germination of sugar beet seed. Proceedings of the American Society of Sugar Beet Technologists 1:101-102. 1938.
66. Wheeler, A. W. Betaine: A plant-growth substance from sugar beet (Beta vulgaris). Journal of Experimental Botany 14:265-271. 1963.
67. Wood, R. R. Selection for cold tolerance and low temperature germination in sugar beets. Proceedings of the American Society of Sugar Beet Technologists 7:407-410. 1952.