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Title: FACTORS AFFECTING UNDERDEVELOPED AND EMPTY FRUITS OF MONOGERM SUGARBEETS (BETA VULGARIS L.)

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Don F. Grabe

The occurrence of empty and underdeveloped fruit was evaluated by X-radiography on harvested sugarbeet seed from plants subjected to separate bolting, maturity, clipping, lodging, and chemical treatments. Several monogerm male sterile lines were studied. Fruits were usually evaluated for yield, weight and size. The contribution of various plant parts and fruit size components to the amount and quality of the seed lot was also determined.

Fruit immaturity, whether caused by delayed planting, bolting variability, or premature swathing, was found to be the primary cause of empty and underdeveloped fruits. Sugarbeets planted increasingly later than August 10 produced fruits that were increasingly abnormal. When uniformly selected, aged plants that later varied significantly in bolting habit were allowed to mature completely in the protected environs of a greenhouse, they produced insignificant levels of abnormal fruit.

Seed size was of fundamental importance to seed quality. Small fruits were predominately empty and underdeveloped. Since small fruits constitute a minor portion of most lots, they should be removed and discarded during processing. Combine-run seed should first be sized and examined by X-ray to foretell economic processing.

Although the indeterminate growth habit of sugarbeets contributed significantly to the occurrence of empty and underdeveloped fruit, it accounted for only half of these abnormal fruit in the seed lot. Also, high levels of abnormal fruits were produced in lygus-free cages. Severe clipping increased the level of abnormal fruit, but lodging plants manually at anthesis or 30 days later had no effect on fruit quality. Yield was seriously reduced by lodging.

Prematurely harvested plants normally produced fruits with filled ovarian cavities when first windrowed but later developed high amounts of shrunken or empty fruits. These data suggest that the stored reserves in immature fruit are either respired or resorbed.

Several pesticides and growth regulators (DDT, Endothal, IPC, 2, 4-D, and GA_3 all at 10^{-3}, 10^{-6}, and 10^{-9} M; Alar-85 and Ethrel at 500, 1000, and 1500 ppm; TIBA at 500 and 1000 ppm; and MH-30 at 2000, 4000, and 6000 ppm) were applied once to sugarbeet plants from early bolting to post anthesis. Except for one unlikely case, no chemical at the rates used significantly reduced the level of abnormal fruit.

Several chemicals applied at early flowering were detrimental to fruit quality, particularly DDT at the lower rates, 2, 4-D at the higher rates, in some cases GA_3, and most rates tested of Ethrel and MH-30. Alar-85 and TIBA showed some promise of improving fruit quality. The empty fruit produced were considered parthenocarpic, although microscopic examinations were not made.

Factors Affecting Underdeveloped and Empty Fruits of Monogerm Sugarbeets (*Beta vulgaris* L.)

by

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INTRODUCTION

Poor germination and emergence are the two most important roadblocks to the wide scale introduction of precision planting of monogerm sugarbeet (Beta vulgaris L.) seed.[1] These leading problems continue to plague the sugarbeet industry (169), despite the discovery of five monogerm plants in Oregon during 1948 (33, 174).

Underdeveloped and empty fruits are the primary cause of low germination of Oregon-grown sugarbeet seed (211, 212, 214). In one study at the Oregon State University Seed Laboratory (212), fruit abnormalities varied from 4.5 to 55.5% in 60 lots of seed examined,

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[1] For the purpose of this dissertation, the following definitions are used in reference to sugarbeet seeds and fruits:

a. Fruit: Ripened ovary(s), enclosing the true seed(s).
b. True seed: Ripened ovule or the true botanical seed within the fruit.
c. Seed: The general agricultural and seed technology term referring to the botanical fruit.
d. Seedball: The fruit cluster of multigerm sugarbeets.
e. Empty fruits: Fruits containing empty ovarian cavities; these are frequently referred to as seedless fruits.
f. Underdeveloped fruits: Fruits containing 1) shriveled, shrunken, or underdeveloped embryo and perisperm, 2) fully developed embryo but no perisperm, and 3) fully developed perisperm but no embryo.
g. Abnormal fruits: Fruits that are abnormal in any manner, as detected by viewing X-ray radiographs (negatives). This specifically includes both empty and underdeveloped fruits mentioned above.

with many lots in the 20% range. When over 100 lots were examined annually over a four-year period, abnormal fruits averaged about 18% (76).

Abnormal sugarbeet fruits are of worldwide occurrence, according to reports on seed produced in Arizona (214), England (182), South Africa (168), and in red beets in Russia (66).

Oregon produces nearly 60% of the monogerm sugarbeet seed planted in the United States. During 1970 alone, Western Oregon produced nearly nine million pounds of sugarbeet seed on approximately 3,500 acres (162). Some of the seed was grown and processed under contract for shipment to European markets (40).

Previous research at Oregon State University has basically eliminated the effects of macro- and micronutrients, the location of fruit on the plant, fruit size, pollen concentration, and sprinkler irrigation during flowering as important causes of abnormal fruit (76). Although lygus bug (Lygus elisus Van Duzee) infestations can contribute to the problem, abnormal fruit are still produced in the absence of lygus.

TeKrony (210) found that the percentage of abnormal fruit increases rapidly the earlier that maturing plants are windrowed. However, no attention was given to the fact that sugarbeets are extremely variable in bolting habit so that the maturity of individual plants in any given field may vary from late July to late August.

Sugarbeets are notorious for lodging severely when laden with

fruit. Due to their indeterminate growth habit, lodged plants quickly lose their already weak apical dominance and much late growth occurs.

There have been increasingly frequent reports on the presence of pesticides in the environment. More attention is being given to possible secondary or indirect effects of pesticides on the growth of nontarget plants (139). Therefore, it is suspected that pesticides in the microenvironment of the sugarbeet seed field might contribute to the occurrence of abnormal fruit.

Audus (11) pointed out that few people interested in plant growth are unaware of the tremendous advances in, and utilization of, plant growth regulating compounds. Therefore, it is equally important to investigate the effects of these compounds on the occurrence of abnormal fruit.

The two key objectives of this research were to investigate several possible causes of underdeveloped and empty fruits in monogerm sugarbeets and to evaluate metabolic promoters and inhibitors as a means of stimulating fruit development or of halting late growth.

The main efforts were in determining the effects of: 1) bolting variability on individual plant and fruit maturity, 2) lodging and clipping, 3) fruit size, 4) low rates of pesticides applied to the flowering plant, and 5) growth regulators to control the occurrence of abnormal fruit.

The effects of planting date, lygus-free environment, the location

of abnormal fruit on the plant, and the time of abnormal fruit development were also investigated. Measurements were made on yield, fruit weight and size, and the percentage of empty and underdeveloped fruit as determined by radiographs.

LITERATURE REVIEW

Remarkably little progress has been made in the past 20 years toward improving the germination potential of monogerm sugarbeet (Beta vulgaris L.) seed. "Growers who were expected to benefit the most from the development of monogerm seed have benefited the least [as] thinning costs on a per care basis have increased steadily since the introduction of monogerm seed!" noted Rush (169, p. 6).

Economics alone demand solutions to the problem. Early mechanization of spring operations in sugar production is essential. This will hinge on precision planting of viable seed, prompt seedling emergence, and control of weeds and diseases (92).

Becker (15) reported that yield for sugar production is mainly dependent on stand. Yet, it is common for growers to plant two to four times as much seed as needed, merely to hedge against 1) germination and emergence failures, 2) hazards of soil crusting, pest and pesticide injury, and 3) excessive losses from wide spacings after mechanical thinning. Expensive row skips of 15 to 40 inches are not uncommon after thinning.

The single most important factor lowering the germination potential of Oregon-grown sugarbeet seed is the occurrence of abnormal fruit, as recognized by TeKrony and Hardin in 1964 (210, 211, 212, 213, 214). In 1940, however, Artschwager (8), and his contemporary H. E. Brewbaker, first recognized the significance of

abnormal fruit in lowering viability and reported that, "low quality seed is characterized by a failure of embryo development" (8, p. 133). Other factors which play less important roles in lowering the germination potential are chemical inhibitors (109, 213), physical restrictions by the fruit (185, 196, 197, 210), and the environment (75, 109, 181).

The key interests of this review are the possible causes of abnormal fruit. This includes factors of maturity, reproductive development of the flower and fruit, lodging, clipping and lygus control, seed size, and chemical control of abnormal fruit.

Cultural and Maturity Factors

TeKrony (210) recently reviewed the literature on general plant maturity as it affects seed quality. He also discussed reproductive development and seed germination problems of sugarbeets. A few of his more pertinent references are repeated here, but many additional facts have come to light during this investigation.

Cultural Methods

The sugarbeet plant is a long-day, indeterminate biennial with a cold requirement, normally needing two years to produce seed (156). In mild climates, sugarbeets for seed are grown as a winter annual. Fall-planted sugarbeets vernalize during the long, cool fall,

overwinter successfully, and bolt seedstalks during the spring. In Oregon, plants flower by early July and then produce an abundant seed crop by mid-August.

Overwintering Method. Elcock and Overpeck (50) reported that the first attempts with the overwintering method of producing sugarbeet seed began in 1922. Overpeck (144) noted that sugarbeet seed growers in New Mexico were forced into late plantings largely to avoid the curly top virus infestations associated with spring or summer sowings. He found that about half of the November and December plantings survived the winter and produced seed the following summer. Such late-planted sugarbeets frequently winterkilled and failed to produce a seed crop. Even so, large scale use of the overwintering method became established in the Southwestern United States about 1934 (50).

Exploratory investigations of sugarbeet seed growing in Oregon by the overwintering method began in the fall of 1936 (204), and Western Oregon has since become the major production center for hard bolting lines. With the advent of cytoplasmic and Mendelian male sterile monogerm sugarbeets, two basic types of plantings are used for seed production. These include 1) planting the male sterile line and the male pollinator in alternate strips, or 2) planting the male sterile and male pollinator lines in solid stand mixtures (25, 164). With the alternate strip method, about three-fourths of the field is

planted to the male sterile parent.

Planting Date. Date of planting has long been an important facet of sugarbeet seed production. Raleigh (160) pointed out in 1936 that early planted multigerm mother beets flower in the spring and early summer when temperatures are cool. Overpeck (144), however, was quick to recognize the value of late planting with the overwintering method as a means of being able to harvest a seed stock increase and then plant it again during the same fall.

Pendleton (149) found that about one-third of a thick September planting of multigerm sugarbeets in Oregon failed to bolt the following spring. Where stands were thinned manually, bolting was satisfactory. Early August or even July or June plantings gave more uniform and complete reproduction than September plantings.

Pendleton (148) had previously pointed out that early planted sugarbeets produce large roots and frequently suffer severe damage from freezing during the winter. However, contrary to expectations, the frozen beets recover well during the spring, produce normal seed-stalks, and give better than average seed yields.

In 1948, Pendleton (147) concluded that hard bolting varieties bolt better if planted in June or July than in late August or September. Early-planted beets reach their maximum growth early in the following spring before bolting. Late-planted beets, by contrast, continue root growth late into the spring.

Hardin, TeKrony and Schweitzer (76) found no significant differences in the level of abnormal fruits produced between early (July 26) and late (September 6) plantings in Oregon. But in a second year, September 8 plantings failed to establish a satisfactory stand.

Plant Spacing. Pendleton (149) found no significant differences in sugarbeet seed yield or germination in Oregon due to plant spacings in an early fall sowing. Multigerm germination averaged 93%. However, Hardin, TeKrony and Schweitzer (76) reported that wide spacings (6 and 12-inch) in the row usually reduces yield and increases the percentage of abnormal fruits produced over those in narrow spacings (3-inch) or solid stands.

Sugarbeet crops grown in narrow, 10-inch rows lodge less and generally produce more but smaller seeds than those planted in wide, 20-inch rows, according to Scott (182). Row width has little effect on germination. Spacing farther apart in narrow rows increases seed size. In wide rows, plants spaced a foot apart in the row often lodge, make secondary growth and produce small, late-maturing clusters with poor germination.

Hull and Scott (96) concluded that steckling plants grown at wide spacings often lodge, produce secondary growth that matures late, and give smaller yields with poorer germination than close spacings. Closer spacings ripen earlier, produce lighter seed with better germination, but yield slightly less on the average. Hull (94) also

reported that closely spaced plants produce fruits with slightly better germination than widely spaced plants.

European Work. Important British work during much of the past decade bears directly on the problem of planting date and seed germination. Work by Scott (182), Hull and Scott (96), and reports by Hull (94, 95) revealed that summer plantings of sugarbeets for seed production are superior to fall plantings in yield, seed size, and germination.

Scott (182) compared the effects of cultural practices on the yield and quality of sugarbeets for seed in 16 field experiments. He found that July plantings give earlier flowering and ripening than August plantings. This usually increases seed yield, cluster size and germination. Late plantings emerge slowly and plants are small at the onset of winter. Weeds and diseases often infest late plantings, whereas early plantings quickly cover the ground which retards winter freezing. The large, early plants grow rapidly and bolt during the early spring. Flowering was somewhat similar in all years studied, with initial anthesis during mid-June for early plantings and early July for late plantings.

Hull (94, 95) reported on subsequent work in 1968 and 1969 which supported Scott's earlier findings. Hull noted that planting date has no effect on multigerm yield if harvest is delayed, and delaying the harvest increases germination. The best germination in 1968 was

obtained from an early planting (mid-July) coupled with a late harvest (mid-September). In 1969, yields were decreased significantly if harvest was delayed until mid-September. Results of monogerm seed were similar. The proportion of small seeds increases with later harvests, however, which is attributed to natural shattering of some of the large, ripe seeds.

Scott (182) claimed that early maturity of early plantings was a distinct feature in all experiments. Late plantings always looked pale and undernourished, producing small clusters with poor germination. One cool, wet season cut seed germination of an early (mid-August) harvest to only 6%. Yields increased as the crop changed color from green to yellow and germination increased as plants matured. Yields of all plantings increased during August and remained stable or fell slightly during September, due to natural shedding and bird damage. Cluster size and germination continued to increase while yields decreased.

Hull and Scott (96) concluded that, in England, July plantings give better yields and germination than August plantings, provided that the sugarbeet crop can be kept free of disease.

Other Crops. Klebesadel (111) recently found that, under stress conditions of the subarctic, two winterhardy bromegrasses[1]

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[1]The scientific names of all crops or plants referred to by common name in this thesis are presented in Table A. 1 (Appendix).

produce their highest seed yield the following year when planted by mid-May. Seed yields decline precipitously with planting dates between May and early August, and plants fail to produce seed heads with later plantings. With a timothy, seed yields the following year are unchanged with plantings prior to early July, but later plantings into September result in progressively less heading and lower seed yields.

Requirements of Flowering

Long-day biennials produce healthy fruits only after they undergo adequate periods of environmental perception, induction, stalk initiation, floral development, and fertilization. Inappropriate exposure at any age can result in partial or complete failure of plants to complete the reproductive cycle.

In Hillman's review (85) of photoperiodism and vernalization, he pointed out that if flowering and fruiting occupies a few months (as in sugarbeets), plants for some reason (even late germination) may fail to attain sufficient size, to initiate flowering properly, and to produce viable fruits early in the season.

Some plant species, treated with a single day of proper photoperiodic induction, may eventually flower. But more extensive induction will induce rapid, vigorous flowering. For example, a large number of inductive cycles causes cocklebur plants to flower

profusely and fruit within weeks. With a single inductive cycle, flowers develop slowly and fruiting may take most of a year.

Plant Age and Vernalization. Certain plants must attain a minimum age before they are sensitive to photoperiodic induction. Working with darnel, Evans (52) found that two-week old plants require six times as many long photoinductive cycles to flower profusely as do six-week old plants. Fewer cycles result in progressively less flowering. Conversely, increasing the number of inductive cycles increases the length of the flowering stem.

McGowan and Peterson (129) drew similar conclusions on plant age before cold induction of perennial ryegrass. When four-week old plants were given cold treatments, they flowered completely and increasingly sooner with up to four weeks of cold induction. Seedlings immediately given cold treatment never flowered completely, even with 20 weeks of cold induction, and heading was much delayed.

Much of the early work on plant age before induction was done by Wellensiek. He and Hakkaart (228) found that dollar plant, a typical cold-requiring biennial, will not respond to cold treatment (6 to 8 C) until the plants are about seven weeks old, after which all plants flower completely.

In other words, the older a plant is before induction, the more likely it is to flower and to flower rapidly. Very young plants must first pass through a juvenile phase before they are ready for induction

(225). The effect of seed vernalization does not promote flowering, but it can help. The size requirement for vernalization in biennials is interpreted as a need for the plant to first produce and store energy substrates (85).

In Wellensiek's review of the work on Sweet William silene (227), a long-day plant that bolts, he pointed out that increasing the age of the plant up to 12 weeks before inductive treatment hastens flower budding by nearly a month. Biennial henbane must reach a certain size before cold treatments essential for flowering are effective (85). Brussel sprouts also have a minimum age for flowering, but then they show a gradual increase in responsiveness in the number of plants that flower (121).

Realization to Flower. Wellensiek and Hakkaart (228) noted that red garden beets do not have a juvenile phase and respond to cold at any age, including seed vernalization. However, there is a gradual increase in responsiveness or "realization" to flower as plants age in the preinduction phase. Less than 20% of the beets flower if given no preinduction growth and some beets do not flower even after ten weeks of growth before cold treatment.

The principal highlight of one of Gaskill's studies with sugar-beets (60) was the important relationship between seed yield and quality with plant age before induction. Bolting, yield per plant, and percent germination of the seed all increase with an increase in plant

age before induction, particularly when induction treatments are borderline. Also, there is a tendency for older seedlings to bolt and flower more promptly than younger seedlings.

The generally accepted site of vernalization is the growing point of the plant and particularly the apical meristem. However, Wellensiek (226) has shown that vernalization is dependent on dividing (mitotic) cells, whether they be in germinating seeds, apical meristems, and leaf or root cuttings.

Loss of Induction. Devernalization can occur in winter annuals, biennials, and even perennials. Relatively high post-induction temperatures are usually responsible, but inappropriate light, darkness, or photoperiodism may play roles (85).

Neither germinating seeds nor seedlings of garden stocks can be induced to flower by low temperature, according to Kohl (112). Plants with at least ten leaves require only three weeks at 10 to 16 C to initiate flowering. But, if the temperature rises above 18 C for as little as six hours per day, flowering is completely inhibited. The plants must remain at favorably low temperatures until the floral primordia are fully differentiated. Once this happens, flower development continues readily at high temperatures.

Stout (205) found that storage temperatures for sugarbeet root stecklings above 10 C tend to reverse the induction process. Roots of a nonbolting sugarbeet stored for 36 days at 9. 1 C bolted 98%, whereas

those stored at 10.6 or 13.2 C bolted only 79.5 and 23.5%, respectively, when grown at 15 to 30 C under continuous illumination for 43 days during the post-induction period.

Bolting Variability. Munerati (136) wrote a major historical review of the bolting tendency of beets. He found that it is not uncommon for seeds from a single multigerm fruit cluster to produce plants of totally different bolting behavior. Individual sugarbeet plants of a given line, grown for roots or fruits, are often extremely variable. This is particularly true of open-pollinated cultivars (217).

Owen, Carsner and Stout (145) elucidated that sugarbeets require a minimum amount of photothermal induction to flower. This consists of up to 100 days of cumulative low-temperature thermal induction, followed or accompanied by long photoperiods. Plants which fail to receive the minimum critical exposure, or are subjected to short days or high temperature during seedstalk development, frequently bolt extremely irregularly or revert to the vegetative condition.

These workers found that shading lowers soil temperatures sufficiently to provide the low-temperature induction needed to increase bolting under California conditions. Shading during the preinduction phase, however, does not increase bolting and may be detrimental. Leaf shading of soil may be one of the chief benefits of early planting.

Although partially germinated sugarbeet seeds can be vernalized, late plantings fail to germinate regularly under cool fall temperatures. Late-sprouting seeds fail to accumulate sufficient low-temperature induction which, in turn, retards or prevents bolting during the following spring. Post-induction temperatures above 16 C will also cause reversal, but even higher temperatures will not if plants receive continuous light. Reversals result in no seedstalk, two to six-inch seedstalks followed by reversion to the vegetative condition or even complete bolting without flowering.

Greenhouse Requirements. Gaskill (62) has shown that a long preinduction of up to seven weeks plus continuous incandescent lighting during post-induction have major beneficial effects on the percentage of sugarbeet plants that bolt and flower. Such conditions are more important for hard bolting than easy bolting varieties.

For preinduction conditions, Gaskill (59, 62) used continuous incandescent illumination at night with a day/night temperature of 25/16 C on an eight-hour day. Photothermal induction conditions consisted of continuous light and temperatures of 8 C for 9 or 14 weeks for easy or hard bolting cultivars, respectively. Supplemental light counteracts any induction reversal action of high temperatures during the post-induction period. Gaskill concluded that supplemental light is more important for small plants that receive only brief preinduction growth, particularly for the hard bolting cultivars.

Gaskill (63) later found that while low temperature (7 C) is essential during the induction period, the type of lighting is unimportant and is needed only to provide energy used in photosynthesis and growth. However, during the post-induction period, lights with a high level of far-red light (as found in incandescent lamps) are essential to flower development. Lamps with no or low far-red light during the post-induction period are totally ineffective in promoting flowering. [1]

Undesirable Bolting. Although bolting is essential for sugarbeet seed production, the tendency to bolt or "annuality" has been a problem since sugarbeets were first grown for industrial purposes (136, 146). This trait is considered as a return to the primitive type.

Nelson and Deming (140) found that early bolters that set seed yield only half as much sugar as nonbolting plants. Late or leafy bolters without seed have root yields comparable to those of normal plants. Johnson and Kidman (102) recently noted that a small percentage of bolters make the field look extremely ragged, and these plants can be removed economically.

To prevent this problem in sugar production fields, hard bolting lines are used. But Johnson (103) noticed a continual deterioration in

[1] The effect of light on plants must be considered in three facets: a) intensity (measured in foot-candles or lux and used as energy for photosynthesis and growth), b) quality (measured in wavelengths which influence specific pigments in photomorphogenesis), and c) duration (measured in time which influences photoperiodism) (54).

the nonbolting quality of hard bolting lines produced by the over-wintering method. To prevent this, he recommended that breeders rogue early bolters from early-generation seed fields. The strongest nonbolters are usually the poorest seed producers and are often dropped from breeding programs (145). Optimum and uniform conditions for induction are assumed to be essential for the best results in developing nonbolting types.

Maturity and Abnormal Fruit Development

The stage of maturity at which seeds are harvested has a fundamental effect on their viability and usefulness in producing new plants. Harlan and Pope (77) harvested immature seeds of seven barley varieties and found that most seeds germinate in only six days after anthesis. However, as seeds are allowed to mature before harvest, germination and emergence vigor continues to increase.

Seed Maturity. These workers subsequently found that if the immature barley kernels are kept moist on the culm, the seeds will continue to grow, both in endosperm and embryo, for at least eight days after harvest (78). Harlan and Pope therefore concluded that immature barley kernels almost certainly abstract food material from the culm after windrowing.

In early work by Arny and Sun (6), cutting wheat and oats prematurely resulted in reduction in yield, test weight, and kernel

weight. Their evidence indicated that food materials are not translocated into grain windrowed prematurely, although some of the green color disappears from immature kernels.

Aldrich (3) reported that plant appearance in corn is not a reliable index of relative or actual maturity. Even so, ear appearance is the best practical guide for farmers who do not have moisture testing equipment. Corn yield continues to increase until grain matures, as moisture drops to about 35%. Translocation into individual kernels, however, ceases above 35% moisture.

Aldrich found no record in the literature that translocation into the grain occurs after corn is cut and shocked. Yet, he assumed from his preliminary studies that appreciable grain development takes place in corn cut prematurely. He felt that additional research was needed to verify his conclusion.

The Hermanns (82) found that crested wheatgrass seeds have high viability when harvested in the early dough stage but do not produce vigorous plants until the hard dough stage. Even at this stage, chill stressing such seeds for a week during germination revealed that they are less vigorous than more mature seeds.

McAlister (128) tested eight western grasses and found that seeds harvested in the pre-milk and milk stages are inferior in viability and longevity to seeds harvested either in the dough or mature stages. In field tests, immature seeds were much inferior in

seedling emergence compared with mature seeds. However, McAlister concluded that, if a seedling emerges under favorable conditions, its chances for survival and development are about equal from immature or mature grass seeds.

Birdsfoot trefoil seeds are morphologically mature within 27 days after full bloom, according to Anderson (4). Seeds from light green, light brown, dark brown, and black pods are of high quality and germinate well. Seeds from dark green pods are low in viability and seed weight.

Grabe (68) found that some smooth bromegrass seeds are capable of slow germination only five days after flowering. Maximum germination, dry weight and seedling vigor are not attained until 17 or 18 days after anthesis. Moisture content decreases slowly from over 60 to about 47% by the time of functional maturity, and then moisture decreases rapidly.

Sorghum seed harvested only 12 to 15 days after pollination germinate well but emerge poorly (107). Nine-day old seeds fail to germinate. Light, immature seeds are slower to emerge than heavy, mature seeds. Dry weight of seedlings (vigor indicator) is closely related to seed weight ($r = 0.98$).

Sugarbeet Maturity. TeKrony (210) used an easy bolting and a hard bolting line over a three-year period to study the importance of maturity on sugarbeet fruit development. He noted that due to the

indeterminate habit of sugarbeets, flowering continues for about 30 days after initial anthesis. But 75% of the flowers open during the first 7 to 14 days of anthesis and this is considered the peak of anthesis. TeKrony found that maturity, based on maximum germination and dry fruit weight, is reached approximately 45 days after peak anthesis.

TeKrony collected fruits at various intervals after anthesis. He found that a few seeds (20 to 30%) can germinate only 20 days after anthesis, but the bulk of the fruits are underdeveloped[1] at this stage (i. e., 70 to 80%). Abnormal fruits decrease to 5 to 10% of the lot by maturity but remain at that level, according to radiographs (see section on X-rays). He concluded that sugarbeets cut prematurely continue true seed development on the drying windrowed plants. However, such seeds germinate slower than those harvested directly from standing plants, due to the formation of inhibitors and seedcap cementing agents in the fruits.

Plants and fruits of hard bolting lines remain green and seldom

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[1] TeKrony and Hardin (214) previously defined underdeveloped sugarbeet seeds as those fruits having either completely empty (seedless) ovarian cavities or partially developed shrunken seeds, which cannot be externally differentiated from completely filled fruits. Partially developed fruits exhibit three types of development: a) shriveled, shrunken or underdeveloped embryo and perisperm, b) a fully developed embryo but no perisperm, and c) a fully developed perisperm but no embryo. (This definition has been clarified slightly into two basic categories of empty and underdeveloped fruits, which, when combined, are called abnormal fruits, per my footnote on p. 1.)

shatter throughout the maturation period, but easy bolting plants reach senescence and shatter. For this reason, TeKrony considered plant appearance a poor indicator of maturity for hard bolting lines, but conceded that appearance might be useful for easy bolting lines. He then stated that plant appearance and percent fruit moisture are unreliable indicators of sugarbeet seed maturity. TeKrony concluded that germination, dry fruit weight, heat unit accumulation, and days after peak anthesis can all be used to advantage in estimating the optimum time of harvest and thereby reduce the level of abnormal fruit and inhibitors.

Abnormal Fruit Development. In contrast to TeKrony's findings, Kim (109) found a slight increase in empty fruits with late harvests. He suggested poor pollination or abnormal pollen tube growth due to rainy conditions during late anthesis as possible causes, but lygus may have been a factor. In a second, more normal year, Kim's results still differed from TeKrony's in that empty fruits first increased before, and then decreased after, maturity. The English workers (94, 182) suggested that large fruits tend to shatter with late harvests and thereby increase the proportion of small fruits in the lot.

Earlier, Hogaboam (91) found that the seed of 19 monogerm plants radiographed all contained some empty (seedless) fruits, ranging from 2 to 35%. Some fruits contained sound embryos but underdeveloped perisperms and visa versa. Of nearly 7,000

monogerm fruits examined Hogaboam and Snyder (92), 10.2% contained no true seeds and another 0.5% were incompletely developed.

Hull and Scott (96) referred to Scott's earlier work in England which revealed that sugarbeet seed germination percentages increase greatly as the crop ripens. They concluded that premature harvest is probably the most frequent cause of poor germination.

Work by their colleagues with desiccants on beet seed crops tends to bear out the conclusion that plants windrowed prematurely are prevented from complete fruit development. Austin and Longden (12) found that germination is not affected when the seed parents are sprayed with diquat or SMA. However, field emergence is adversely affected when seed parents are sprayed with high rates of the chemicals. They assumed that such emergence difficulties are due to the premature arrest of growth of the true seeds on the desiccated plants.

Abnormal Fruit Location. TeKrony and Hardin (214) examined two monogerm sugarbeet cultivars to determine the location of abnormal fruit on the plant. In the first test, they radiographed fruits on the primary axil, five descending whole laterals, and those on the secondary and tertiary laterals. They found that abnormal fruits occur at all locations on a plant, with at least 5% occurring at each location. There is a consistent increase in abnormal fruits only on the tertiary laterals, which was expected due to the late development of these branches and the indeterminate flowering habit of the species.

In a second test, 200 lateral branches from 12 plants in each of two cultivars were each segmented into ten equal sections. The percentage of abnormal fruit increases rapidly toward the outer tip of the branch, but such fruits occur at not less than 4% in all sections. These workers contended that the late-developing, immature fruits would be eliminated during normal harvesting operations.

Reproductive Development and Embryo Nutrition

There are 12 basic steps in the reproductive growth of angiosperms, according to Meyer, Anderson and Böhning (133). Briefly, these include flower initiation, maturation of floral parts, development of pollen grains within anthers and the embryo sac within each ovule of the ovary, pollination, sperm formation and pollen tube growth, fertilization, endosperm and embryo development, followed by seed and fruit development.

These authors pointed out that the five principal causes of seed development failures are: 1) the pollen fails to germinate, 2) pollen tubes may grow too slowly to accomplish fertilization, 3) fertilization fails to occur, 4) fertilization occurs but abortion follows, and 5) fertilization occurs and embryo growth proceeds but is arrested in later stages of development. The first four conditions can lead to the development of empty fruit, and the last one usually results in underdeveloped seed.

Fruit Development

In the late 1920's, Artschwager (7) made a detailed study of the development of sugarbeet flowers and true seeds. He found that a single vascular trace nourishes the three-carpellary ovary. These three fused carpels contain a single campylotropous ovule that is attached laterally by a short funiculus to the ovary wall. Fused and unfused strands of the surrounding cortical bundles supply each carpel. These strands (usually three) end blindly in the parenchyma cells of the carpel tissue. The ovule finally twists about its own funiculus and lies horizontally in the ovarian cavity.

After fertilization, the ovule grows rapidly and reaches nearly full size before the tiny embryo develops. By free nuclear division, the endosperm quickly fills the entire cavity of the horseshoe-shaped embryo sac, but the growing embryo dissolves and absorbs the endosperm. Only a single layer of endosperm cells remains, which surrounds the radicle. The perisperm, which is directly connected to the funiculus through the reserve-poor chalaza region, soon becomes packed with large starch grains to complete the true seed.

Later, Artschwager and Starrett (10) studied the time required for fertilization and embryo development in the sugarbeet. They found that most stigma lobes open within 24 hours after anthesis. Many pollen tubes grow down the micropyle and usually more than one reaches the embryo sac.

Fertilization usually occurs within a day after pollen germination. The primary endosperm nuclei divide rapidly, but the zygote undergoes a rest period of 24 to 36 hours. Early embryo growth and differentiation is extremely slow, with the eight-celled embryo appearing within three days after anthesis. Growth continues slowly up to nine days, after which rapid growth matures the embryo by 12 to 14 days after anthesis. As mentioned before, TeKrony's work (210) indicated that only 20 to 30% of the seeds are capable of germination by 20 days after anthesis, however.

Pollen Viability and Incompatibility

There have been many hints that poor pollen viability is one of the primary causes of abnormal fruit development. These suggestions stem from research reports by plant breeders and morphologists who have observed such problems in other species. For example, Sayers and Murphy (178) and Rao (161) pointed out that poor pollen germination on the stigma, slow pollen tube growth, failure of pollen tubes to effect fertilization, and post-fertilization ovule abortion are important causes of low seed set during self-pollination or in breeding work on various species.

Sugarbeet breeders are well aware of these potential problems and procedures have been worked out to quickly check pollen viability (81). Although self-sterility, or self-incompatibility, may be a

factor, most workers who have studied the problem doubt that pollen concentration or viability is a major cause of abnormal fruit development in sugarbeets.

Pollen Concentrations. Comprehensive studies on daily and seasonal sugarbeet pollen concentrations by Scott (183) revealed that rain during the morning washes pollen out of the air and damages developing anthers. Rain in the late afternoon, followed by a sunny morning, does not affect pollen load. Rain at night may cause an immediate, temporary increase in pollen concentration, which is followed by normal pollen release if the weather turns sunny during the day. Total pollen catch was 83, 31, and 100% during 1965, 1966, and 1967, respectively. However, the seed harvested in each of these three years germinated similarly.

Similar studies by Scott and Longden (184) on multigerm sugarbeets revealed that tetraploids produce only two-thirds as much pollen as diploids. Tetraploid pollen grains are larger, and their anthers require drier air to release pollen than diploid pollen and anthers. Tetraploid pollen concentrations increase slowly early in the day and are low during damp days. While seed germination from male sterile plants among pollinators is consistently less with tetraploid than diploid pollinators, distance of male sterile plants from either pollinator type does not affect seed germination.

Stewart and Campbell (202) in Oregon found that sugarbeet

hybridization is higher east of a pollinator row than west of it, due to the prevailing winds. Male sterile plants up to 12 rows away from the pollinator show marked reductions in hybridization, but overall germination from hybridized and selfed seed is not significantly diminished. Pollinator-male sterile row combinations of 4-16-4 increase hybridization greatly. This basic style is in fairly wide use, although other patterns are employed.

In pollen concentration studies, including the effects of sprinkler irrigation during anthesis, Oregon State University researchers (76) found no significant trends in the amount of abnormal fruits with increasing distances from the pollen source. In some plants, up to 20% of the flowers produced abnormal fruits within four feet of the pollinator. In one preliminary pollen elimination study, however, all fruits developing in the absence of pollen were empty. This led these researchers to conclude that parthenocarpic fruit development can occur in some sugarbeet lines.

Pollen Sterility. Other factors can affect pollen viability. For example, Artschwager (9) found that when flowering sugarbeets are dusted to control insects, the sulfur used can temporarily, but severely, reduce pollen germination and viability. Some workers have used growth regulators as pollenicides (see section on selective gametocides).

Incompatibility. Helen Savitsky (173) pointed out that

self-sterility, or self-incompatibility, in sugarbeets is caused by: 1) the absence of self-fertilization because of the slow rate of pollen tube growth, or 2) the secondary degeneration of the embryo after selfing. Nonfertilized ovules appear in 10 to 12 days after the opening of the flower as small dark lumps at the base of the expanded ovarian cavity. Breeders can determine the degree of self-sterility or self-fertility in isolated plots by examining the ovules during anthesis.

Parthenocarpy and Abortion

Gustafson (73) and Luckwill (124) pointed out that the term parthenocarpy was first proposed by Noll in 1902 to cover all fruits that develop without pollination. Gustafson broadly defined parthenocarpy to include any seedless fruit, regardless of whether pollination occurs, unless it is definitely known that fertilization and abortion have taken place. This includes any seedless fruit that aborts so early that it leaves no trace of fertilization. But early abortion is not true parthenocarpy (1).

Abbott and Luckwill (1) suggested that during the course of evolution, plants have developed a mechanism to prevent fruit growth and its consequent waste of metabolites unless the fruit is likely to produce a viable seed. Occasionally, this mechanism breaks down and permits the development of seedless fruits. Such natural

parthenocarpy has never been reported in some species (plum), but it occurs occasionally in others (pear), while some plants are incapable of producing normally seeded fruits (banana).

Parthenocarpy in Sugarbeets. Apparently, parthenocarpy can occur in sugarbeets (76). From such observations and a review of the literature, TeKrony and Hardin (214) suggested that parthenocarpy may be one of the primary causes of empty fruits. For example, Downs and Lavis (46) found some rudimentary seedballs in isolation studies with sugarbeets. Many other seedballs appeared normal but failed to germinate. Internal examination revealed that the fruit cluster developed normally without producing true seeds. Down and Lavis suggested that pollination had stimulated the fruit to develop, but fertilization had failed to occur.

In attempts to induce parthenogenesis in sugarbeets, Namazie and Kohls (137) applied chalk, flour, soapstone, and maize pollen to receptive stigmas, but flowers failed to produce fruits. However, when flowers were treated with a hormonal sodium nucleate dust or solution, over 600 seedballs produced normal-appearing but empty, parthenocarpic fruits.

Parthenocarpy in Other Species. Crocker and Barton (41) reported that it is not unusual to find seeds which are entirely devoid of contents or contain aborted or shriveled material. In the carrot family, for example, embryoless seed runs from 8 to 34%. In

seedless peppers with viable pollen, ovules are elongated while those in normal fruits are nearly round. This trait is said to be controlled by a single Mendelian recessive character. In the 'Thompson Seedless' grape, the embryo sac degenerates early so fertilization cannot occur, but pollination is necessary to induce fruit growth (1).

With induced parthenocarpy, pollination without fertilization as above--even by foreign or dead pollen, or the application of various growth substances, regulators and chemicals--can stimulate fruit growth (1, 72, 73). In other instances, some of these materials enhance true seed formation (41).

Natural Parthenocarpy. One of the key results of pollination is an increase in auxin content of the ovary (11). Gustafson (73) cited his own work which indicated that naturally parthenocarpic cultivars have higher auxin content in the ovaries than those of normally seeded cultivars.

Abbott and Luckwill (1) suggested that one of the effects of growth regulators such as auxin is that they mobilize nutrients, or stimulate vascular development, and thereby induce parthenocarpic fruit. They pointed out that high nutritional status of the plant, frost, high temperature, or aphids which inject auxins into the tissues as they feed, all can induce parthenocarpy.

Leopold (121) noted that natural parthenocarpy is a biological accident of widespread occurrence of which the physiological basis

remains obscure. Special environmental conditions are frequently associated with parthenocarpy. These include 1) rapid and extensive vegetative growth, 2) low temperature plus high light intensities so that pollination is poor, 3) frost which may induce embryo abortion, and 4) inadequate nutrition for the available fruits.

The slow growth of rosette plants is associated with high levels of IAA oxidase activity, according to Leopold. When plants bolt, the auxin content rises dramatically. GA treatments tend to cause a large increase in auxin content. Also, citrus and grapes that are commonly seedless have appreciably higher auxin contents than seeded cultivars. Leopold cited Luckwill who suggested that parthenocarpy may be a state of auxin autotrophy in the ovaries.

Induced Parthenocarpy. Crane (37) pointed out that some fruits respond parthenocarpically to auxins (several), GA (several), combinations of both (cherry), or neither (plum).[1] All attempts to induce parthenocarpy in plum have failed with auxin, GA, or cytokinin, either alone or in combination. In others (zephyr lily), GA induces parthenocarpic fruits with seeds void of embryos, while IAA induces parthenocarpic fruits without true seeds.

Crane (38) and his colleagues used several individual auxins, a gibberellin, and a cytokinin to induce parthenocarpy in Calimyrna fig.

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[1] The chemical names of all growth regulators and pesticides referred to by common name or abbreviation are presented in Table A. 2.

Carne proposed from this work that fruit growth is not controlled by hormones emanating from the true seeds, as had long been believed, but by the capacity of these hormones to attract metabolites from other regions of the plant. The fruit tissues surrounding the seeds then tap the metabolite supply and act as storage organs. He cited the well-known hormone mobilization of metabolites in barley seed germination, apical dominance, senescence, abscission, and fruit growth to support his case.

Bonde (20) found that GA caused the formation of inflated, seedless pods, deformed flower petals, and elongated penduncles in 'Dwarf Telphone' pea. The GA is most effective when it is applied to the first true leaves of young seedlings and it becomes progressively less effective as plants age. Ray (163) obtained parthanocarpic fruit set in cotton with GA. Later, Crane and Hicks (39) induced parthenocarpy in cherries with sprays of 2, 4-DM plus GA, as well as with other auxin moiety-GA combinations. Neither growth regulator used alone will induce parthenocarpy in cherries.

No further attempt was made to review the literature now accumulating in horticultural science on induced parthenocarpy.

Abortion. Although there are a few scattered reports on fruit abortion (see pollen viability and embryo nutrition sections), no specific reports were found in the literature concerning the physiological or biochemical causes of abortion in plants. Woodworth (234),

working with soybeans, found that seed abortiveness ranged from 9.4 to 22.2% and that certain varieties have significantly more abortion than others. He also noted that seed abortion is most common near the top of the plant, and more frequent at the base than at the tip of the pod.

Fruit and Embryo Nutrition

The primary purpose of this section is to address the question of food transport into--and out of--the developing fruit and embryo between the time of fertilization and maturation. A special curiosity exists in what happens to the accumulated reserves of the seed in the event of late embryo abortion or arrested development.

Food Accumulation. In the previous section on maturity, conflicting views were presented on whether or not seeds continue to abstract food from harvested plants. Conclusions varied from the positive when barley culms are kept moist (78), to the probable when corn is cut early and shocked (3), to the negative when cereals are windrowed prematurely (6). TeKrony (210) concluded that when sugarbeets are windrowed prior to maturity, the true seeds continue to develop on the drying plants.

On intact plants, maximum dry weight accumulation of seeds at maturity ranges from a high of 47% moisture for bromegrass (68) to a low of 23% for sorghum (107). Most figures range from 35 to 45%

moisture (3, 6, 210). In sugarbeets, TeKrony (210) found that the high moisture content was a poor indicator of maturity. Fruit moisture content changed slowly and ranged from over 80% nearly 15 days before, to 70% at maturity, to 60% about 20 days after maturity.

Transport Mechanisms. Since little specific literature is available about the transport of solutes and assimilates to and from the embryo (see later), it is first important to recognize transport patterns of intact plants. Crafts (34) reviewed the now historical literature before 1960 on translocation in plants. He contended that food in plants moves from the site of synthesis to the site of utilization by mass flow. He suggested that there is a correlated flow of assimilates, hormones, growth regulators and viruses from source to sink (shoot and root tips, flowers, fruits, etc.).

Crafts (35) later used labeled herbicides to follow the simultaneous bidirectional movement of assimilates in the phloem, which he considered possible only by mass flow. He found that herbicides move with the assimilates, bypassing mature exporting leaves, and accumulate at very high levels in the sinks.

Bidirectional Transport. As pointed out by Artschwager (7), a single vascular trace nourishes each sugarbeet fruit. Hogaboam (91) noted striking differences between sugarbeet plants in the size of the vascular trace scars of the fruits. Therefore, the question of simultaneous phloem transport is pertinent to the discussion of food

movement into and out of developing fruits.

Swanson's early review (209) pointed out that organic solutes move via the phloem in opposite directions in the same stem. This could even occur in a single sieve-tube element, just as water can flow in two directions from the "T-joint" of a pipe.

Biddulph and Cory (17, 18) were the first to show that bidirectional movement occurs in the phloem. Using two labeled compounds, they found that substrates can move simultaneously upward and downward in bean stems in separate but adjacent old phloem bundles. Assimilates can also move in two directions in the same young phloem bundle, but probably not in the same sieve tube.

Inorganic and Organic Transport. On the translocation of inorganic solutes, Biddulph (16) pointed out that certain elements (phosphorus) are rapidly mobilized and readily circulated throughout the plant. Other elements (calcium) are seldom moved once deposited. Nutrients first used in initial leaves are later withdrawn as the leaves senesce and then are metabolically reutilized by young, nutritionally related leaves. This process is repeated until the nutrients are lost (via exudate or organ abscission) or utilized in the inflorescence.

Zimmerman (241) noted that the primary translocated assimilate in most higher plants is sucrose (plus a few other sugars). During senescence of leaves and flowers, some nitrogen- and phosphorus-containing materials are broken down into amino acids, amides and

other substances and translocated back into the plant before an organ abscisses. However, calcium moves poorly in the phloem as it is rapidly deposited in adjacent cells as oxalate crystals.

Sugars enter the translocation stream of the sieve elements through parenchyma cells and are taken out again at sites of sugar consumption or storage through parenchyma cells, according to Esau (51). Materials are stored as starch in vegetative tissue or fruits and seeds. This carbohydrate changes into sugar when reserves are mobilized for transport through the phloem to sites of utilization in growth or respiration.

Water Stress. Zimmerman (241) reported that as transpiration increases and xylem tension increases, water is eventually withdrawn from the phloem, which ultimately reduces phloem transport. Yet, Zimmerman (240) found that the phloem sieve-tube system of white ash can retain its turgor for two to three weeks after the supply of photosynthetic products is interrupted by defoliation or abscission. He also cited evidence (241) for xylem water movement from fruits back into the plant. He suggested that it is conceivable that movement via the xylem is sometimes into, and at other times out of, the fruit.

Zimmerman (241) concluded that exudate studies using aphid stylet bundles on isolated branches suggest two things: 1) sieve tubes are sealed near the ends of cut branches, and 2) lowered sieve-tube turgor results in a mobilization of reserve sugars. Lowered turgor

causes a net water entry into the phloem which dilutes the sugar concentration. This, in turn, triggers enzymatic net entry of sugars into the sieve tubes. Phloem transport even continues in wilting plants, which is considered as evidence of mass flow.

Crafts (36) noted that xylem and phloem systems maintain their functions even under conditions of high water stress (as with a windrowed plant). The amount and rate of transport decreases with increasing stress.

The effect of water deficits on flowering and fruiting of orchard trees has been studied intensively and was reviewed by Zahner (238). He noted that diurnal contraction and expansion of fleshy fruits, due to mid-day transpirational water stress and restoration of turgor overnight, has been measured many times. Even some highly lignified fruits (walnut) undergo diurnal dimension changes during periods of high water stress.

Embryo Nutrition. Masand and Kapil (127) reviewed the literature since 1950 on the nutrition of the embryo sac and embryo in plants. They pointed out that the funiculus is highly vascularized and densely packed with food reserves. Well developed vascular traces transport water, minerals and food substances to the ovules.

Usually the trace terminates at the base of the integuments, but in some species it enters the outer or inner integuments or both and sometimes even reaches the nucellus. The developing seeds are

nourished by the endosperm, suspensor haustoria, perisperm, chalazosperm or the pseudo-embryo sac in various species. In most plants, the zygote divides only after the endosperm begins to develop [as in the sugarbeet (7)]. If the endosperm fails to develop, the embryo aborts.

In a major review on the morphogenesis of plant embryos, Raghavan (159) cited earlier work that has traditionally revealed the function of the endosperm in nourishing the zygote and then the embryo. In many hybrids, however, the embryo soon aborts after fertilization but before cotyledons form. Embryo abortion is usually preceded by endosperm disintegration, which deprives the embryo of nutrition and contributes to its final collapse.

Ovular Tumors. Raghavan reported that abnormal ovular tumors often prevent embryo formation in certain incompatible crosses. Evidence suggests that the tumors not only contribute to endosperm disintegration but also to the release of embryonic growth inhibitors. Hence, embryo abortion is probably due to some limited metabolic factors during embryogenesis.

In compatible crosses of datura, the endothelium degenerates during embryo maturation. In incompatible crosses, endothelium cells multiply rapidly and form ovular tumors that grow inward and absorb the contents of the embryo sac (171).

In Russia, Savchenko (172) studied ovule abnormalities in

several angiosperms. In abnormal florets of sunflower, he found that the integumentary tapetum has eight or nine cell layers which separate into groups of 10 to 20 cells each around the embryo sac. This aberrant development occurs after the embryo sac is formed.

Savchenko suggested that food entering the ovule is not used by the embryo sac and accumulates in the tapetum instead, causing it to grow. The growth blocks further food transport into the embryo sac. A similar problem occurs with nucellar growth in other species, including certain ones in the goosefoot family (Chenopodiaceae) of which the sugarbeet is a member. In these cases, nucellar growth may even protrude through the micropyle and result in peculiar abnormalities of the embryo sac. In some species, this nucellar overgrowth serves as a pollen receptor.

Embryo Absorption. Masand and Kapil (127) concluded that although the structures involved in the absorption of food by the embryo are well known, the precise chemical nature and form in which these substances are absorbed are unknown. They suggested that radioactive isotopes and histochemical methods should prove useful in identifying them. They also suggested that tissue cultures could shed light on the normal (and abnormal) differentiation of the embryo.

For example, Coe (32) studied the ovary and developing ovules of a certain zephyr lily by using radioactive carbon. Coe concluded that most of the nutrient material accumulates in the nucellus instead

of passing directly into the embryo sac. New substances are synthesized in the nucellus. During endosperm and embryo development, the embryo sac derives much of its nourishment by the constant growth and constant breakdown of the nucellar tissues around it.

Coe found a concentration of ^{14}C in the nucellus and surrounding embryo sac. But the hypostase at the chalazal end of the embryo sac never contained any ^{14}C. Although the hypostase lies directly in the main stream of nutrients passing from the vascular supply to the embryo sac, the structure must compel food and water to pass around it through the nucellus.

Embryo Respiration. Forman and Jensen (56) pointed out that virtually nothing is known about the metabolism associated with embryogenesis in higher plants, not even the oxidative pathways involved in respiration. This is in sharp contrast to the vast amount of information concerning animal embryology.

In studies on the early embryo stages of cotton, they found that oxygen uptake increases as embryo size increases, due to an increase in cell number. On a per cell basis, however, oxygen uptake decreases with embryo age. These workers concluded that the tricarboxylic acid cycle is the only oxidative pathway involved in early embryo development.

No evidence was found in this review to indicate what actually happens to accumulated embryo reserves in the event of embryo

abortion, or arrested development due to premature harvest. Although embryo mortality and resorption have been observed repeatedly in the animal kingdom for half a century, references to like reutilization or metabolic respiration of the aborted embryo in the plant kingdom were not found.

In swine (Sus domesticus), for example, regular embryonic losses of 25 to 30% and late fetal deaths of 5 to 10% are probably the greatest unsolved problems affecting litter size (28). They are thought to be due to physical and/or physiological incapacities of the uterus, but nutritional deficiencies are unlikely causes in animals fed well-balanced rations.

Other Factors That May Affect Abnormal Fruit Development

Numerous other factors have been suggested as possible causes of abnormal fruit development in sugarbeets. Usually, they are all associated with various levels of stress on the plant. These factors include those caused by the natural environment, soil fertility levels, lodging, plant injury and insect infestations.

Environmental Factors

"There is mounting evidence that the environmental conditions under which seeds mature may influence seed germination and the

growth and vigor of the developing seedling," according to Khan and Laude (108, p. 55).

Kohls (113) recognized that the inherent variability of sugarbeet seedstalk development and yield of individual plants are affected by the environment. He suggested that temperature, precipitation and relative humidity influence the variability of seed production.

In a study on the effects of soil aggregate size on sugarbeet seed germination, Hammerton (75) concluded that emergence difficulties are due to physiological and genetic factors rather than physical differences between seeds. He claimed that emergence hinges on the number of viable seeds per cluster which he assumed to be genetically controlled but open to modifications by the environment under which the seed set and matured.

Effect on Pollen. Artschwager (8) found major differences between the ability of individual sugarbeet plants to produce good pollen. He saw little correlation between environmental anomalies and pollen germination behavior, however. He felt that poor pollination and poor seed setting could be associated only if unfavorable weather were to continue for several days.

Poor seed set is often traceable to injury of the female part of the flower, especially to the stigma, which is sensitive to hot, windy weather. Good pollen germination throughout the season usually indicates a good seed crop, noted Artschwager. As pointed out by

Scott (183--see pollen concentration section) rain can seriously reduce the pollen load, but his work indicated that it did not affect seed germination during three years of study.

Effect of Drought. Working with a winter annual [Teesdalia nudicaulis (L.) R. Br.] at Aberystwyth, Wales, Newman (142) concluded that drought hastens rosette senescence and reduces fruit and seed set. Brief periods of drought do not reduce the total number of flowers produced. Newman found no evidence that soil moisture conditions directly influence flowers, fruits or true seeds once they start to develop, apart from delaying flowering. All other effects of stress seem to be exerted on the vegetative, not the reproductive, tissue.

Goiko (66), as cited by TeKrony (210, p. 36), concluded that the seedless fruits produced by a red beet variety in the southern Ukraine of Russia was due to the environment. He reported that drought, high air temperatures and dry winds during the flowering period were chiefly responsible.

Effect of Temperature. Khan and Laude (108) found that heat stress on maturing barley seeds is much more detrimental to subsequent seedling emergence if the stress occurs shortly after the awns emerge. Heat stress later in the season is not as harmful and some heat is beneficial to speed seed maturation.

In garden stocks, Semeniuk (186) found that seed yield decreases with increasing temperatures above 18 C during anthesis and

maturation. Plants maintained at temperatures near 29 C are usually entirely sterile due to various abnormalities. For example, at high temperatures, 91% of the pollen grains were empty and the anthers failed to dehise. However, below 18 C, plants do poorly and set fewer seeds per plant.

Temperatures in the seed producing area obviously play a major role in the development and quality of sugarbeet fruits. This includes temperatures during establishment, preinduction, induction, winter freezing injury, bolting, flowering, fruit maturation, and even during the post-harvest period.

Snyder and Hogaboam (199) found that, with a monogerm and a multigerm line, high temperatures (24 C with daily highs of 27 to 35 C) cut fruit yield in half but usually produces faster germinating seeds than low temperatures (18 C with daily highs below 27 C).

Low temperatures result in shoots with greater fresh weights, fruits that are larger, heavier, and greater in number, but usually with tighter seedcaps than plants and fruits matured at high temperatures. Plants grown at low temperatures are more efficient than those at high temperatures. But high temperatures after anthesis hasten maturity by about two weeks (71 days for low vs. 57 days for high temperature maturation). High temperatures are generally detrimental to fruit development, but the adverse effect usually occurs during anthesis.

Using a single plant, Kim (109) found that low curing temperatures after harvest significantly reduce sugarbeet seed germination.

Work by the Savitskys (176) revealed that the fruit and true seed weights of sugarbeets vary with the environment (both in years and location), genetics, and ploidy level of the chromosome. The percentage of small and large fruits also varies with the environment.[1]

Soil Fertility Factors

Although the literature on nutrition and flowering is extensive, there is no good evidence for close association between any major element and flower initiation in most plants if nutrients are adequate for plant growth, according to Hillman (84). There is some indication that certain elements are involved, including iron, magnesium and boron, if they are deficient.

Boron Required. Stoker and Tolman (204) established that boron additions are essential for the production of sugarbeet seed in Western Oregon. Boron reduces overwintering frost damage and is essential for seedstalk development (prevents "heart rot"). Boron is regularly

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[1] Although of minor importance, polyembroyony complicates the relationship between fruit and true seed weight because an increased number of true seeds per fruit does not result in a corresponding increase in fruit size. For example, non-identical twinning, caused by abnormal flower development, results from a) two ovaries per flower with one ovule in each, b) two ovules in a single ovarian cavity, and c) one ovule with two embryo sacs. Identical twinning, due to cleavage of the proembryo or zygote, is rare (176).

included in the fertility program for producing sugarbeet seed.

Pendleton (150) obtained improved multigerm seed yield, germination, and less lodging with adequate applications of nitrogen, phosphorus and potassium in balanced amounts.

There were no marked differences in speed or percentage germination of seed from sugarbeet plants supplied with low or high levels of nitrogen fertilizer, according to Snyder (195). He concluded that nitrogen on seed crops should be added in amounts adequate for the variety grown and in balance with other nutrients. Snyder (193) had previously noted that since sugarbeets have a very limited reserve in the germinating seed, rapid and greater emergence occurs when mineral nutrient solutions are added to the seedbed.

Hardin, TeKrony and Schweitzer (76) found that sprays of magnesium, manganese and zinc, alone or in combination, failed to reduce the percentage of abnormal fruits, when applied to sugarbeets at seedstalk initiation. The field had previously received blanket applications of N, P, K, S and B.

Later, Schweitzer (181) reported an increase in the occurrence of abnormal fruits with excess nitrogen fertilization. He noted a large difference in the level of abnormal fruits at different locations, however, and concluded that although heavy nitrogen fertilization is detrimental to true seed development, it accounts for only a fraction of the total abnormal fruit.

Schweitzer also found liming had no beneficial effect on the prevention of abnormal fruit development and increased the occurrence of such fruits slightly but not significantly. Kim (109) used seed from the same experiment and obtained slightly lower germination of seed from sugarbeet plants grown on limed than unlimed soils.

Balanced Fertility. Scott (182) reported that fertilizers in England had no consistent effect on cluster size or germination. The only experiment in 16 where fertilizers affected germination was on a poorly-drained site. The crop grew slowly in the early spring and matured late. Otherwise, there is no evidence, even at the earliest harvests, that seed germination is depressed by nitrogen.

In fertility trials subsequently reported by Hull (94), phosphorus and potassium applied before planting, plus nitrogen applied during the spring, increased germination of the harvested multigerm seed. In a trial on monogerm sugarbeets, only one treatment improved yield. Yet, none of the treatments affected germination, monogermity, or the size distribution of the fruits.

The effect of fertilizers and manure on the yield, germination and size distribution of sugarbeet seed was reviewed by Longden (122). He noted that good seed crops can be produced in England with 70 pounds of N, 43.6 pounds of P (100 of P_2O_5), and up to 166 pounds of K (200 of K_2O) per acre applied during the first year, plus 140 pounds of N applied during the following spring. Chemical composition of the

seed is changed by manure applications, but manures seldom affect germination, seedling emergence or seedling weight.

Lodging Problems

Lodging has been a problem since man first gathered plants for food. Its importance has been recognized since the beginning of scientific agriculture. For example, Glynne (65) summarized the 1843 to 1967 lodging and disease history of wheat on the Broadbalk Farm of the Rothamsted Experiment Station. She quoted Lawes and Gilbert's 1864 report that "the heaviest plots would have yielded considerably more had they not been laid so flat. . . ." (p. 126).

In Tysdal's classic work on alfalfa (216), he found that upright plants produce more forage than lodged plants under both low and high moisture conditions. More importantly, upright plants yield two to five times more seed than lodged plants. Lodged plants produce much new growth and have about 15% more shriveled seed than upright plants.

Anderson and Metcalfe (5) prevented lodging in birdsfoot trefoil seed fields by growing the crop in association with adapted grasses.

In sugarbeets, plant spacing has an important effect on lodging (see earlier section on plant spacing). In general, narrow row, closely spaced or solid stands lodge less than wide row, loosely spaced sugarbeet plants or stecklings (94, 96, 182). Widely spaced plants often make secondary growth when they lodge and produce small

late-maturing fruits with poor germination.

Artificial Lodging. Incidental observation of lodging in agronomic research is a standard practice. More recently, specific artificial lodging trials have been conducted on crops to assess the actual losses.

The work on winter wheat by Weibel and Pendleton (224) is a good example of such research. These workers found that lodging results in great decreases in yield, test weight and kernel weight. The harmful effects of lodging are more severe when lodging is imposed at the heading stage than later. Lodging at heading, milk, soft-dough, and hard-dough stages cuts yields below the unlodged check by 31, 25, 20, and 12%, respectively. Lodged plants, however, have higher grain protein than erect plants.

Working with staked and unstaked soybeans, Weber and Fehr (223) attributed only a 1.3% yield loss at combining to lodging. They found that combine yield losses due to cutterbar height are four to ten times greater than lodging losses. However, preventing any lodging will further increase yields up to 15%, increase plant height, delay maturity and decrease seed size slightly.

Later work by Johnston and Pendleton (104) supported such yield increases in soybeans. These workers found that upright plants yield about 10% more than naturally lodged plants.

Physiological Causes. Phillips (155) pointed out that apical

dominance is manifest in three basic ways: 1) complete or almost complete growth inhibition of lateral buds, 2) growth inhibition of one shoot by another more dominant shoot, and 3) control, orientation and development of lateral organs such as branches, leaves, rhizomes and stolons. The degree of apical dominance is genetically and environmentally determined and is greatly influenced by the physiological age of the plant.

Some work by Phillips indicated that exogenous gibberellins promote lateral shoot growth. But usually such treatments result in main stem elongation with inhibition of lateral growth.

Ample nitrogen supplies will stimulate the growth of lateral buds. Less evidence is available on the effects of other nutrients on apical dominance, however. Recent studies have shown that the synthetic growth retardants such as Cycocel, Amo-1618, Phosfon-D and Alar reduce apical dominance. Also, Johnson (101) reported less lodging in soybeans with a certain herbicide combination.

Clipping Effects

Sugarbeet seed growers occasionally cross-cultivate or clip plants in the early spring to control weeds, thin the stand or even achieve more uniform bolting. Such practices may have mixed value. It is also suspected that clipping may influence the occurrence of abnormal fruit.

Legume Crops. Clipping legumes for hay and then saving the second growth for seed has long been a standard practice in some areas. The effectiveness of such practices varies with the crop, the cultivar, the season, and the presence of pollinator insects.

Some of the early work indicated that double-cut medium red clover that is clipped during early June for hay produces the highest seed yield. This work by Megee, Frakes and Larson (131) revealed that clipping does not increase the yield of mammoth red clover, however, and it seriously decreases seed yields of alsike clover.

Dade (42) found that red clover which is not clipped, or that clipped in early May, outyields clover clipped in late May or early June. This Washington work revealed that reductions in seed yield, percent flowering and head number are greater for single-cut than double-cut varieties. Dade found that late blooming due to late clipping treatments results in fewer florets per head, seeds per head and lower seed weight than early blooming of unclipped or early clipped material.

Spring and early summer clipping of birdsfoot trefoil greatly reduces seed yields compared with unclipped stands, according to Anderson and Metcalfe (5). Johnston and Pendleton (104) removed the leaves from the upper, middle, and lower thirds of soybean plants. This reduced seed yield by 17, 22, and 4%, respectively, compared with whole plant yields.

Sugarbeet Clipping. Raleigh (160) cut back sugarbeet branches and obtained larger seedballs than those of nearly identical branches that were not clipped. Pendleton (150) found that clipping of multigerm plants increasingly later in the spring is increasingly detrimental to seed yield and germination.

Hull (95) reported that defoliation by scissors at flowering halved the yield of clean seed. Within a treatment, however, seed yield per plant ranged from 2.5 to 49 g. Hull concluded that individual sugarbeet plants should respond dramatically to selection for increased seed yields.

Insect Injury

Insect damage has been suggested as a possible cause of abnormal fruits in sugarbeets (210). Seed damage by insects is known to occur in other crops.

Carlson (27) found several types of bud damage in alfalfa due to lygus bugs. Mechanical punctures and lacerations made by the lygus mouth parts are clearly evident, although indirect pathological effects usually occur within 48 hours after controlled infestations. Carlson attributed any bud abortion to physiological factors other than those due to lygus, however.

Hills (86) reported that sugarbeet seed plants are attacked by 1) foliage feeders, chewing insects and sucking insects, 2) insects that

feed directly on developing seeds, and 3) vectors of various virus diseases.

Seed-feeding insects such as lygus bugs (Lygus spp.) and Say stinkbugs (Chlorochroa sayi Stal) infest sugarbeet seed fields during the spring, according to Hills and Romney (88). These insects reduce seed viability and even yield when they are numerous.

Hills (86) and Hills and Taylor (89) found that the primary damage by lygus is to the soft, newly-formed fruits. Little damage occurs at the prebud, bud or full-bloom stages, but maximum damage occurs at the late-bloom and early seed stages. The young nymphs do most of the damage by causing young embryos to collapse, but adult lygus will also damage seed. Sugarbeet plants so infested produce light-weight seedballs with empty or hollow ovarian cavities.

Hills recommended that sugarbeets for seed be treated with an insecticide first during early bloom. He noted that rarely will one application of insecticide produce satisfactory results.

Hills and Brubaker (87) studied the effects of fall and spring infestations of curly-top-infective beet leafhoppers [Circulifer tenellus (Baker)] on sugarbeets grown for seed. Using artificial infestations, they found that fall and spring infections can reduce seed yield and sometimes reduce germination by nearly half when infestations occur during early bloom. However, germination in the uninfested check plots was consistently lower than 70%.

Aphids [Aphis fabae (Scop), Myzus persicae (Sulz), and Macrosiphum euphorbiae (Thos.)] are most likely to colonize sparse, weak stands rather than uniform ones, according to Heathcote (80). A complete early cover of the ground by foliage limits aphid colonization in sugarbeets grown for sugar production. Early spring plantings are usually less infested by potential virus vectors than late-sown crops. Also, nitrogen fertilizers and irrigation make plants tall and likely candidates for aphid colonization.

In lygus caging studies at Oregon State University (76), increasing the level of lygus infestation increased the percentage of abnormal fruits in all and particularly in the small fruits. Several hundred flowers were closely examined, but no visible evidence of lygus damage could be found. An average of 11.6% abnormal fruits were still produced in the total absence of lygus.

When six commercial seed fields were sprayed at weekly intervals with DDT to control lygus during the month of sugarbeet anthesis, no significant reductions occurred in the level of abnormal fruits. The Oregon researchers concluded that lygus can contribute to, but are not the only cause of, the abnormal fruit problem.

Seed Size and Processing

The importance of seed size has long been considered, disputed and refuted, only to become the continuing center of attention in much

agronomic and seed technological research. For example, in 1908, Zavitz (239, p. 104) reported that results from his 14 years of work gave convincing evidence that "large seeds will give a greater yield than an equal number of small seeds, in the case of at least 12 different classes of farm crops."

Montgomery (134) soon pointed out in a discussion on seed size research in cereals that studies on the problem had been underway since 1860. In 1933, Elcock and Overpeck (50) reported that sugarbeet seed was screened to 7/64 inch to eliminate the immature seeds. In fact, sugarbeet seed processors have long been aware of the empty or hollow seedball problem and have attempted to determine its level by the often misleading "crack" test (214).

Other Crops

Grabe (68) reviewed some of the literature on seed size. Although reports were conflicting, small, immature seeds generally germinate as well as large, mature seeds in the laboratory, but usually more mature, large seeds are essential for maximum seedling emergence and vigor.

Seed size, coleoptile length, emergence and seedling height vary widely in intermediate wheatgrass, but all are positively correlated, according to Hunt and Miller (98).

Harper and Obeid (79) reported that seed size has an important

effect on flax. They found that both seedling leaf area and dry weight are closely related to seed size. Seedlings from small seeds emerge faster from shallow sowings (1 cm) and those from large seeds from deep sowings (6 cm). Seed size advantage generally is not maintained through maturity, however, although large seeds produce significantly taller flax plants than small seeds.

Germination generally increases as seed size increases in wheat, according to a study by Kittock and Law (110). Emergence, vigor, individual shoot weight, shoot weight per plot and seed weight were positively correlated for five seed size classes in their study. Smaller seeds produced lower values in all cases, but this might have been due to greenhouse temperatures.

Fruit Size in Sugarbeets

Seed size was one of the early standards used in the sugarbeet trade in Europe, according to Price and Carsner (157), who reviewed the early history on seed sizing. Large seedballs were recognized as giving higher germination than medium and small seedballs.

In this country, interest in seed size arose among the directors of the West Coast Beet Seed Company in 1938. In field tests, small seed emerged poorly and gave poor stands. But interest in the question of seed size then lagged.

When segmented seed began to be used by the industry, seedsmen

found that small seeds usually produce single seedlings so they were saved and, without segmenting, were planted alone or in combination with segmented seed. Small seed (passing through a 2.5 mm screen) amounted to about 3.5% of most lots and germinated between 50 and 75%. Therefore, small seeds from high-germination lots were saved and, instead of being discarded, were blended back into the lot as long as they did not lower the contract germination standard below 75%.

In their own laboratory, greenhouse and field studies, Price and Carsner found that large seeds germinate faster and better and give more vigorous seedlings and higher yields than small seeds. At this early date (1946), these workers concluded that harvested seed should be first sized, the small seed discarded, and only the medium and large seed saved for processing and planting.

The importance of these findings apparently fell out of favor or lay in a state of dormancy. With the exception of some work by Savitsky and researchers at Michigan State University, little attention was again given to seed size until the late 1960's.

Fruit-True Seed Relationships. Savitsky (175) found that the weight of true seeds increase in proportion to the size of monogerm fruits. These two characteristics are highly correlated ($r = 0.95$). In multigerm sugarbeets, however, the weight of true seeds decreases as the number of fruits in a seedball increases.

Savitsky et al. (177) observed no differences in final germination

of filled monogerm fruits (italics mine) between small, medium and large fruits. Small filled fruits germinate slightly earlier, but fruit size does not influence the root yield or quality factors when seed is planted for sugar production.

Hogaboam and Snyder (92) found that fruit size, whether measured by diameter, thickness, or volume, is a poor indicator of the ovarian cavity contents. But fruit size significantly influences the time required for germination. Generally, the true seeds in large fruits germinate slowly and are regulated mainly by the maternal tissues of the fruit. Fruit volume is highly correlated with true seed diameter, but when the effects of fruit volume are statistically removed, true seed diameter has little effect on the germination rate.

Effect on Abnormal Fruits. Hardin, TeKrony and Schweitzer (76) concluded that abnormal fruits are not directly associated with fruit size, because some large fruits are empty. They recognized that, due to the indeterminate flowering habit of sugarbeets, small fruits (6-7/64 inch) are usually more abnormal than large fruits (10/64 inch).

Hull (94) reported that fruit size differences per harvest have no effect on seedling weight of open-pollinated sugarbeets, but seedling weight is less from early-harvested fruits. For cross-pollinated cultivars, large fruits produce heavier seedlings than small fruits. Generally, seedlings from early-harvested fruits weigh less than those

from late-harvested fruits.

Hull (95) later reported that fruits from three harvest dates (increasingly later per year) over three years were sorted into sizes of 7-8, 8-9, 9-10, 10-11, and 11-12/64th inch diameter and sown in England on April 13, 1969. Final emergence for the five size classes was 33, 51, 63, 72, and 90%, respectively. Mean emergence from early, middle, or late harvest was 59, 66, and 68% respectively. Although not affected by year or harvest date, seedling dry weight at eight weeks generally increased with increases in fruit size.

For a given monogerm seed lot, more large fruits germinate than small fruits, according to work by Snyder and Filban (198). Seeds of large fruits produce hypocotyls that are larger and heavier than those from viable small fruits.

As planting depth increases, a smaller percentage of seedlings emerge from both large and small fruits, but proportionally fewer seedlings emerge from the small than the large fruits. Snyder and Filban concluded, from both laboratory and field studies, that true seeds in large fruits have a greater emergence force and emergence potential than true seeds in small fruits.

Breeding Potential. The Savitskys (176) pointed out that sizing fruit in breeding and seed production programs have been used for different purposes in the United States and Europe. In this country, small fruits are saved for planting from mixed monogerm-multigerm

populations (i. e., male sterile-male pollinator mixtures). In Europe, large fruits frequently are screened to increase the percent of triploids for sugar production.

Doxtator and Helmerick (48) found that large-fruited sugarbeet parents produce progenies with large fruits and small-fruited sugarbeet parents produce small-fruited progenies. In addition, the fruit size of large stecklings is significantly larger than that of small stecklings.

Several nonofficial seed testing laboratories in Western Europe use a "screening analysis" on sugarbeet seed to determine the count and weight of fruits in as many as seven size classes (19). Procedures on screening methods have been proposed by the "Institut International des Recherches Betteravières." Specific modifications have been under consideration by the International Seed Testing Association.

Processing Sugarbeet Seed

Peto (153) of the British Columbia Sugar Company concluded that proper processing could eliminate the need for more than one size class of monogerm seed for planting. He first polishes seed to pass through a 10/64-inch round hole, then discards the dust and small seed passing through a 7/64-inch round hole screen. Seed longer than 10/64 inch in any dimension is removed with an indent cylinder for further polishing. All seed is then processed by size and thickness.

Fruit weight by size varies little after such processing.

Peto found that germination increases with increasing fruit thickness, but the large fruits are primarily multigerm in nature. Therefore, he further eliminates thin monogerms and thick multigerms with a ribbed cylinder.

Smith and Walter (192) of the Great Western Sugar Company pointed out that one cannot realize the potentiality of monogerm seed simply by sizing the unpolished seed. These authors make a strong case for polishing (decorticating) monogerm seed, sizing it carefully to 1/64-inch size ranges, and planting the seed with the proper drill seed plate.

Thin seeds (less than 4/64 inch) can be removed by careful operation of an Oliver Steele gravity table and this helps to insure maximum germination. Multiple- or double-seeded fruits are then removed with a Carter drum separator. Decortication removes inhibitors and fruit restrictions, increasing the emergence potential.

TeKrony and Hardin (214) noted that the removal of underdeveloped fruits by processing has been suggested as a means of improving sugarbeet seed germination. Certain companies with certain lots of decorticated seed have done this effectively, but the processes are not uniformly successful. Some lots are not effectively cleaned, even when sized into a range of 8-10/64 inch.

These researchers used a laboratory pneumatic seed blower on

several lots with known levels of abnormal fruit. By using increasing air speeds, the first fruits removed are primarily empty ones. However, complete separation of empty fruits in unsized seed is seldom achieved at any air speed setting. Some empty fruit always remain in the heavy portion, even when well-filled fruits are blown into the light portion. TeKrony and Hardin concluded that abnormal fruits could not all be removed by processing.

Air flotation research on sugarbeet fruits indicates that pneumatic separation of empty fruits from normal fruits may not be possible, even if the fruits are first sized. Kunze, Hall and Snyder (115) hand processed, sized and weighed sugarbeet fruits. They found that although fruit weight increases sharply for each size class, only minute (insignificant) increases in air velocities are needed to move fruits as fruit size increases.

Heavy, dense fruits often lodge in the moving air stream, but fast-moving light fruits frequently collide with them and help move the heavy fruits along. Fruits of the same size have a two to three-fold weight variation, according to these Michigan State University researchers, but unsized fruits vary in weight by over seven fold.

Use of X-Radiography on Seeds

Kamra (105) reviewed the literature on the use of X-rays in seed testing. He pointed out that A. N. Lundström of Sweden was the first

to use X-rays to investigate seeds nearly 70 years ago. Most of the early work was in relation to the presence of insects within the seed. During the 1950's, however, some workers began to use this technique to determine seed quality.

Grimm (71), as cited by Hogaboam (91, p. 605) and TeKrony (210, p. 35), used X-rays to examine the internal contents of sugarbeet fruits. He was able to rather accurately predict the subsequent germination of whole and segmented multigerm fruits. Hogaboam (91) used the same method and concluded that the roentgen levels required had no perceptibly deleterious effect on subsequent seed germination.

Using these leads, TeKrony and Hardin (212) compared the X-ray, excision and cutting methods for determining the potential germination of sugarbeet seed. They concluded that both the X-ray technique and the cutting method are effective and accurate means for determining empty and underdeveloped fruits. [1]

The X-ray method does not permit detection of all seedling abnormalities or the inhibitors that may be present in the sugarbeet fruit. Even so, TeKrony and Hardin suggested that an X-ray unit be incorporated into sugarbeet seed processing and cleaning operations

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[1] The cutting test consists of the hand sectioning of all ungerminated seeds at the final count of the standard germination test. It gives an accurate estimate of abnormal fruits and firm ungerminated seeds in determining the germination potential of a lot. The excision method is an adequate but slow method, and it is not as effective, or are results as high, as those of the other two methods (212).

to give immediate information of true seed development. This suggestion seems particularly pertinent with the availability of Polaroid X-ray film.

California agronomists (219) are using X-rays for rapid and accurate identification of abnormal seed cotton. These workers classified seed as damaged (cracked or broken) and underdeveloped (empty or partially filled).

X-ray photography has been used to identify fertile and sterile florets in seed of indiangrass (13). X-radiography is also used extensively to examine seed traits of a large number of species in the special testing section of the Oregon State University Seed Laboratory.

Chemical Factors Affecting Abnormal Fruit Development

The occurrence of abnormal fruit in sugarbeets is of worldwide occurrence and appears to be associated with factors of mechanical, environmental and physiological stress. But the presence of desirable and undesirable chemicals in the environment, be they natural or applied, could conceivably be a cause of abnormal fruit development.

The 120-mile Willamette Valley lies in a north-south direction, nestled between the Coast Range and the Cascade Mountains. There are four high population centers spaced along the Willamette River, with considerable industrial and adjacent agricultural activity. By nature of this geography, and the lack of strong prevailing winds to

sweep the valley, the area is a natural pocket for the frequent buildup of pollutants in both the macro- and microenvironment.

No attempt was made to monitor the occurrence of chemicals in the environment at this stage of the research. The crux of the question dealt with here was: "Can certain chemicals influence the occurrence of abnormal fruit when they are applied to the sugarbeet plant during anthesis ?"

In addition, the increasing availability and applicability of growth regulating compounds offer promise for the eventual control of plant growth. Their use in preventing the development of abnormal fruit offers intriguing possibilities.

Air Pollutants

The threat of air pollutants in the environment heightens the concern of the ecologist and the ire of the manufacturer and agriculturalist. Yet, many pollutants are known to injure plants. Certain compounds can induce cell division in tobacco pith at astonishingly low concentrations of one part per billion, when auxin is also present (57).

Recent research (220) suggests that all United States areas east of the Mississippi may have enough photochemical pollution alone to injure sensitive plants at certain times during their development. This suggestion was based on work with tobacco plants distributed 5 to 75 miles from a metropolitan center. Plant damage was noted almost

daily, but the level of injury varied from site to site, depending on the meteorological conditions and phytotoxic potential.

Current research (90) also reveals that air pollutants at concentrations below one part per million can inflict plant injury. For example, ozone at 0.3 ppm caused 75 to 90% leaf injury in certain tobacco cultivars. A combination treatment of ozone at only 0.03 ppm and sulfur dioxide at 0.45 ppm caused 5 to 15% leaf injury.

Phytological Effects of Pesticides

A subcommittee of the National Research Council (139) reviewed the literature on the effects of pesticides on fruit and vegetable physiology. The authors pointed out that while references to indirect or secondary effects of pesticides abound in the literature with great profusion, few studies have been undertaken for the specific purpose of determining such effects.

Certain studies revealed that when bluegrass, cotton and mangos are treated with physiologically active compounds, such as 2,4-D, both stimulatory (reduced dormancy) and inhibitory effects (poor germination, malformed seedlings, etc.) are found. One worker who treated a beet seed crop with insecticidal mixtures of DDT and disulfoton obtained low seed viability from the crop. Other workers obtained increased seed germination of carrots following seed crop treatment with DDT or dieldrin, but the increase in germination was

attributed to the control of insects attacking the seed.

The subcommittee also pointed out the fundamental importance of timing, rates and stage of plant growth when applying any chemical.

Pesticides applied during the critical fruit-setting stage of growth may impair set by reducing pollen viability, deforming pollen tubes, reducing the receptivity of the stigma, or otherwise interfering with the fertilization process. Several chemicals will increase natural fruit set or induce parthenocarpy. For example, under conditions of poor pollination, GA induces seedless, early-maturing grapes. Yet, there is a paucity of studies designed specifically to elucidate the effects of pesticides on the maturation and post-harvest physiology of plants.

Effects of Insecticides. In 1948, Chapman and Allen (29) pointed out that certain cucurbits show chlorosis and stunting while potatoes have greener, more vigorous vines and produce higher yields when treated with DDT. In an insect-free greenhouse, they obtained plant injury, stunting, deformity and necrosis with high rates of DDT.

Plants in order of increasing susceptibility were corn, peas, potatoes, carrots, beans, tomatoes, cucumbers and squash. The first four plants are extremely resistant to DDT. However, at reduced concentrations of DDT, specific for each type of plant, growth is stimulated and flowering occurs. Chapman and Allen concluded that some of the effects of DDT resemble the actions of some plant

hormones.

Roark, Pfrimmer and Merkl (167) found no obvious effects on cotton plant metabolism from treatment with DDT, toxaphene, or DDT + toxaphene combinations. They did report that multiple applications of methyl parathion during early plant growth delay floral branch initiation and therefore floral bud production. These authors reviewed the literature on the problem of insecticides affecting plant metabolism.

According to a report by Briggle (22), certain wheat species are resistant to the effects of DDT while others are not. He found that such resistance in durum is recessive and is controlled by a single major gene.

Hills and Romney (88) found an insecticide (a pyrethrum-in-oil spray) that controls lygus but also injures the sugarbeet seed produced. In studies reported by Hardin, TeKrony and Schweitzer (76), six commercial sugarbeet seed fields were sprayed weekly for a month with DDT to control lygus during anthesis. They found no significant reductions in the level of abnormal fruits.

Recent research by Nash (138) revealed that ^{14}C-labeled soil insecticides or their metabolites are absorbed and translocated into the shoots of wheat seedlings and soybean plants. The insecticidal residues in plants increase as the soil application rate increases. Wheat seedlings absorbed about 18% of the dieldrin and 3 to 10% of the

DDT or their metabolites. Soybeans absorbed and translocated labeled endrin into the forage and seed (0.12 ppm).

Effects of Herbicides. Texas workers (130) applied 2,4-D to flowering cotton to study the translocation of the stimulus into the embryos. They found that all seeds from bolls set prior to application and those set within eight weeks after application produce seedlings which exhibit symptoms of 2,4-D injury. Early, low-rate applications to seedlings or plants in the floral primordia stages show no significant transmission of 2,4-D into the seed.

Wort (235) obtained a 44% sugarbeet root production increase with a dust containing 0.1% 2,4-D and a complex of micronutrients. The dust is applied when the sugarbeet (Beta saccharifera) seedlings are one month old. Using the same dust on 14-day old beans, he found increases in plant growth, pod yield and seed production (16 to 20%).

Wiedman (230) studied the effects of sub-lethal concentrations of herbicides on seedling oats. He found that 12 herbicides stimulate root growth and four stimulate shoot growth, while only three others produce no effect at the low dosages tested. He used at least one herbicide from each major chemical class of herbicides.

Plant Growth Substances and Regulators

From the early theories of Sachs, to the work on auxins by Went,

to the discovery and use of 2, 4-D, there has been an ever-broadening realization among plant scientists that some day it may be possible to control many aspects of plant growth by applying specific growth regulating substances (11).

The literature on flower physiology, however, has grown beyond comprehension without the process being thoroughly understood. In 1963, Salisbury (170) cited eight books and 30 review articles on the subject. In Crane's 1964 review (37) on growth substances in fruit set and development from the time of anthesis to maturity, he cited nine major reviews and four books that had appeared in the preceding five years.

Books edited by Evans (227) and Wilkins have appeared since. The Wilkins book includes chapters on auxins by Thimann (215), the gibberellins by Cleland (30), the cytokinins by Fox (57), and the transport of regulators by Goldsmith (67). Kolli's review (114) pointed out that a number of compounds, including auxins, gibberellins, purines, pyrimidines and steroids, have been used in the chemical control of flowering.

Little specific literature on the effects of growth substances on sugarbeet fruits was found, however. Therefore, it is tempting to give an oversimplified account of the complexities of the control of fruit and true seed growth. For example, Abbott and Luckwill (1) pointed out that cytokinins are essentially cell division hormones which

seem to be required for early fruit growth. Gibberellins and auxins promote growth by both cell division and cell expansion, probably in conjunction with one another. Auxins also inhibit abscission and are necessary for the retention of the fruit on the plant.

It was once thought that true seeds were essential to supply these hormones to the developing fruits. However, Crane (37) pointed out that evidence continues to accumulate indicating that hormones function by stimulating mobilization of assimilates into the fruit. In the final analysis, fruits contain a variety of growth substances and inhibitors which may differ in physical and chemical properties from fruit to fruit.

Application of exogenous growth regulators to fruits may induce the same source to sink movement of assimilates as do hormones in seeds, but not necessarily through the same pathways. For example, 2, 4-D and cytokinins move with rather different velocities than IAA. If applied growth regulators penetrate the leaf surface and reach the vascular tissue, they are distributed to regions of active growth at rapid velocities of 50 mm h^{-1} (67).

Auxins and Gibberellins. Cleland (30) reviewed several important effects of auxins and gibberellins on plant growth, including the production of parthenocarpic fruit (Table 1). The action of gibberellins on plants may simply be to activate the subapical meristem. The relationship of applied gibberellins and internal auxin holds

Table 1. Comparison of some of the biological effects of auxins and gibberellins. (From Cleland, R. E. 1969. p. 72. In M. B. Wilkins, ed. The Physiology of Plant Growth and Development. McGraw-Hill, New York.)

Response	Effect of	
	Auxin	Gibberellin
Dwarf pea stem growth, sections	promotes	no effect
Dwarf pea stem growth, intact	no effect	promotes
Cucumber hypocotyl growth, intact	promotes	promotes
Root growth	inhibits	no effect
Parthenocarpic fruit growth, tomato	promotes	promotes
Cell division, tobacco pith	promotes	no effect
Root initiation	promotes	no effect
Flower initiation, long-day plants	no effect	promotes
Seed germination, Grand Rapids lettuce	no effect	promotes
Sex expression promoted, cucumbers	femaleness	maleness

true for shoots of several plants and in parthenocarpic fruits of certain plants.

Cleland noted that the possible mode of action is that gibberellins may act at the gene level to cause de-repression of specific genes. The activated genes would, in turn, produce enzymes which initiate morphogenetic changes. But more evidence is needed.

Promoters and Inhibitors. Certain growth retardants can reduce endogenous gibberellin levels, according to Cleland. The best known examples are Cycocel, Phosfon D and Amo-1618 (and sometimes Alar). These chemicals are often but unfortunately called "anti-gibberellins." Many plants fail to respond to these retardants because they may fail to penetrate into the plant, may be detoxified after entry, or fail to interfere with gibberellin synthesis once inside

of the plant. Minute differences in the chemicals, combinations, rates, timing, methods of application and cultivar can cause entirely different responses in a crop (11).

Ferry and Ward (54) noted that plant growth regulators can both promote or inhibit auxin synthesis and action. Promoters include TIBA, chelidonic acid and phthalamic acid. Inhibitors or the so-called "anti-auxins" include phenylbutyric acid, trans-cinnamic acid, 2, 4, 6-trichorophenoxyacetic acid and 2, 4-dichoroanisole. Other chemicals inhibit growth in the presence of increasing auxin concentrations and apparently affect growth processes by other than the auxin-receptor complex. These inhibitors include maleic hydrazide, coumarin and other unsaturated lactones.

Plant growth regulators used to induce seedless fruits include naphthaleneacetic acid, para-chlorophenoxyacetic acid, 2, 4, 5-T, beta-naphthoxyacetic acid and gibberellins. Certain chemicals can inhibit preharvest fruit drop, including 2, 4-D, 2, 4, 5-T and other auxin-like compounds. In general, most plant growth regulators inhibit flowering. Only a few promote flowering, such as naphthaleneacetic acid when used on pineapples.

IAA itself, 2, 4-D and other substituted phenoxyacetic acids, TIBA and other substituted benzoic acids, and NPA all inhibit the basipetal movement of IAA (67). Some growth retardants such as Cycocel and Alar not only reduce insect pests such as aphids, but they

also increase plant resistance to fungal, viral and bacterial diseases (11).

Endogenous and Exogenous Gibberellins. There is a strong correlation in normal fruits between the gibberellin content at various stages and the growth rate of fruit between anthesis and maturity, according to work by Jackson and Coombe on apricots (100). Following fertilization, synthesis of gibberellin-like substances occurs in the endosperm and embryo. This gibberellin is required for fruit growth to proceed. The correlation between fruit growth and gibberellin content is better than that between fruit growth and auxins.

Stoddart (203) analyzed perennial ryegrass and timothy florets for gibberellin content from early inflorescence to seed harvest. He found that gibberellin is high at floret emergence but declines during anther formation. After anthesis, gibberellin content increases until the final stages of seed maturation when it falls steadily to a stable plateau before harvest. The immature seeds are rich in gibberellins.

Israeli workers (74) found that GA treatments increase the dry matter mobilization out of the cotyledons and into the growing hypocotyl of cucumber. GA applications also increase water absorption and therefore increase the water level in leaves. In addition, GA always increases the upward translocation of ^{14}C and decreases its downward movement in bean stems.

Applications of GA_3 and sucrose after an inductive dark period

promotes flowering in cocklebur, according to Mukherjee (135). The promotive effects of the two compounds are independent but additive. Sucrose alone, either before or after induction, speeds flowering. This is probably due to an increase in translocation of the flowering stimulus, while GA_3 increases synthesis and translocation of the flowering hormone.

Yeh and Bingham (237) reported that simple- and multi-foliate-leaved alfalfa clones are affected both positively and negatively by treatments of IAA, GA and TIBA at low rates. A standard trifoliate-leaved clone does not respond. These workers suggested that GA may be useful in enhancing growth and seed production of specific alfalfa clones for breeding work.

Cycocel and GA treatments on young sugarbeets affect leaf production, leaf number, petiole length and total dry matter of plants, according to Humphries and French (97). However, neither chemical influences net assimilation rates or root weights. When treated plants are overwintered, they continue to increase in total dry weight. Cycocel alone does not affect the number of flowering stems, but GA increases them. Cycocel alone increases stem height, and GA, alone or in combination, doubles stem height. Unfortunately, the plants tested were harvested before fruit set had occurred.

Bolting of Biennials. Marth, Audia and Mitchell (126) were among the first in the United States to evaluate the effects of GA.

They tested its efficacy on 49 genera and species of plants. In red beets, seedstalk elongation was stimulated by 100 ppm of GA. But there was no good evidence to indicate that GA could induce plants to initiate flower primordia or cause fruit development.

Since the early work by Lang (116), there have been many successful and unsuccessful attempts to initiate flowering in many species with GA applications. Lang found that GA induces flower formation in certain biennials requiring vernalization but not all plants also requiring long-day induction. Treated plants flower in various degrees of completeness.

Several workers (Bukovac and Wittwer, 23; Wittwer and Bukovac, 232; Gaskill, 61; Doxtator, 47; Stout, 206; Stout and Owen, 207; Snyder and Wittwer, 200, as well as Wheatley and Johnson, 229) tested GA on certain annuals, sugarbeets and other biennials to induce bolting. In general, they found that single and usually multiple applications of GA will hasten partial or complete bolting. Unless sugarbeets are given some cool temperature, however, bolting is very erratic. GA treatments are most beneficial if cold induction treatments are borderline. GA can induce bolting but not flowering, yet if plants flower they usually set seed. Continuous lighting can help, but the GA stimulus is not transferable from shoot to shoot.

According to a review by Lang and Reinhard (118), GA will substitute for both the cold and the long-day requirement in some

rosette plants, while in other similar plants, GA will substitute for only one or even neither. In the latter type, it is suspected that wrong gibberellins, combinations or inadequate treatments were responsible for the failures. GA cannot substitute for short-day photoinduction in short-day plants, however, so these authors hypothesized that gibberellins are stem-promoting, not flower-promoting, hormones.

Lang (117) later analyzed the gibberellin levels during the bolting of a biennial. He found that there is a correlated marked increase in gibberellin-like substances with bolting.

Several efforts have been made to prevent bolting with the application of growth regulators, particularly in sugarbeet fields planned for sugar production. Price, Stewart and Erickson (158) found that certain 2, 4-D sprays of 50 ppm or less effectively prevent bolting of sugarbeets. However, because of reduced sugar yield, 2, 4-D is not used on a commercial scale for this purpose.

California workers (165) later found that maleic hyrazide would reduce and delay bolting of overwintered sugarbeets used for sugar, if the material is applied before or at seedstalk appearance. Sugar percentages are increased, but root and sugar yields are not consistently or significantly changed.

Evans (53) found that once darnel is induced, a single application of abscisic acid can act as an inhibitor to reduce the flowering

response.

Selective Gametocides. Anthesis application of GA has a dual function in that it not only induces parthenocarpy but can also act as a pollenicide (37).

Skoyen (190) used FW-450 and several other selective gametocides on two sugarbeet lines. When applied two or three times beginning at early bud, increasing rates of the chemicals generally cause a decrease in seed yield and germination, and in some cases severely so. Apparently, fruits were not examined for internal contents.

Iyer and Randhawa (99) used MH, TIBA and FW-450 as pollenicides in grapes. They reported that pollen sterility depends on 1) the stage of flower development, 2) chemical concentration, 3) the number of applications, and 4) the cultivar used. Complete pollen sterility is possible with certain chemical-rate-cultivar combinations. The seeds of subsequent successful crosses all germinate normally.

Growth Regulators on Sugarbeets. Stout and Tolman (208) were the first to investigate the effects of growth regulators on sugarbeets. They concluded that there were no benefits in seedling emergence, vegetative growth, sucrose content, purity, or root yield from applications of naphthaleneacetic acid, naphthaleneacetamide, indoleacetic, indolebutyric, and levulinic acids or related compounds.

Attempts to hasten sugarbeet seed germination or affect

dormancy with GA dusts or solutions are generally unsuccessful, but results vary (47, 109, 120, 151, 194).

During the 1950's and 1960's, there were numerous attempts to improve sugar yields or reduce leaf growth with applications of MH, GA, or combinations of both, 2, 4-D, Alar and TIBA (Wittwer and Hansen, 233; Ririe, Mikkelsen and Baskett, 166; Peto, Smith and Low, 154; Shepherd and Till, 187; Schreiber and Ferguson, 179, 180; Nelson and Wood, 141; Peterson, 151, 152; Lawson, 120, and Stout, 206).

In general, efforts with 2, 4-D, Alar and TIBA were unproductive. Results with spring, summer or preharvest sprays of maleic hydrazide, although varied, offered some promise. For example, MH treatments generally inhibit respiration losses of sucrose and halt new growth in stored roots. Although such treatments frequently increase the sugar content, root yields are unchanged or reduced so that sugar per acre is unchanged. MH reduces plant growth and leaf area which reduce the spread of insects. MH also increases frost protection (46% decrease in sugar losses due to frost).

Single or multiple applications of GA, on the other hand, generally increase root yield but lower the sugar content so that sugar per acre is either unchanged or lowered. GA lowers root respiration and affects plant growth little. Since GA tends to increase bolting, Peterson (152) concluded it doubtful that GA would have a role in sugar

production.

Recently, foliar applications of MH (236), vanadyl sulfate (188) and pyrocatechol (189) have been used successfully by Singh and Wort to induce "ripening" and reduce late growth of sugarbeets grown for sugar.

Growth Regulators in Other Crops. According to the manufacturer (218), Alar causes a growth retarding effect in most dicotyledonous species but not monocotyledons. Alar treatments result in modifications of flower and fruit form, time of flowering, flower number, fruit set and numerous other morphological and physiological changes in plants.

Nittler and Kenny (143) found that Alar accentuates cultivar differences in birdsfoot trefoil. Alar treatments cause the 'Empire' cultivar to grow less and be more decumbant than 'Viking' plants.

Ethrel forms ethylene within the plant, which causes numerous morphological and physiological changes, including major shifts in sex expression. According to the manufacturer (2), Ethrel produces yield increases in cereals, soybeans, beets, potatoes, clover and peas. This compound also inhibits vegetative growth in other crops.

Ethrel applications reduce the incidence of lodging in cereals and peas. This compound inhibits terminal growth and increases lateral branching in several crops and many ornamentals. Ethrel can also increase tillering in rice, spring wheat and turf grass, as well as

inhibit tobacco sucker formation.

Slife and Earley (191) treated soybeans with increasing rates of Ethrel at six stages of plant development. These treatments reduced plant height, percentage of three- and four-seeded pods per plant, seed weight and yield. They suggested that Ethrel should be tested at lower rates as an anti-lodging agent. These workers (49) had previously found that Ethrel reduces plant height, leaf area, leaf efficiency and grain yield of corn.

The effects of maleic hydrazide on plant growth are also many and varied. Generally, it slows growth even in the presence of high auxin concentrations (54), but stimulatory effects are also reported.

Wittwer (231) reviewed the early work on the control of flowering and fruit setting by plant growth regulators. He noted that TIBA induces flower bud development in tomatoes, soybeans and other crops. MH has the opposite effect and stimulates lateral bud development. In one case with celery, MH hastened bolting of cold-induced plants. Low rates of MH on very young lettuce seedlings stimulate bolting.

TIBA and TIBA products have achieved popular success recently on soybeans. In general, this compound changes the crop canopy from an inverted "U" to a Christmas-tree like inverted "V," according to Greer and Anderson (70). This shape permits soybean plants to better utilize solar energy and results in higher yields--particularly

those planted in narrow rows. Research revealed a ten-fold increase in flower number of photo-induced soybean plants, increases in seed yield and pod set, but decreases in seed size.

Several other researchers in the Midwest have reported similar but different results on soybeans. Hicks, Pendleton and Scott (83) found that first-flower sprays of TIBA reduce leaf area (20%), plant height (33%) due to shortened internodes, and result in a triangular-shaped canopy. Increases in pod set and seeds per plant, but decreases in seeds per pod and seed size, cause total seed yield to remain unchanged. TIBA-sprayed plants do not lodge as readily as unsprayed plants.

Other workers (64) have found that foliar applications of TIBA on soybeans alter the morphology and anatomy of the stem, leaf and petiole. Wax and Pendleton (222) obtained increases in soybean yields (6.5%) only with medium row spacings (50.8 cm). Narrow row spacings increase seed yield more than TIBA treatments. Even so, TIBA reduces plant height and lodging at all row spacings, increases pod set, but decreases seed weight.

Bauer, Sherbeck and Ohlroggee (14) suggested that TIBA has potential on soybeans as a yield stimulant and anti-lodging agent. They obtained combine yield increases up to 15%, due to increases in seed number. TIBA treatments were found to inhibit apical dominance of plants treated during early flowering.

Other workers (221) have found that low concentrations of TIBA applied to flax inhibit apical dominance, break lateral bud dormancy, but decrease seed yield.

MATERIALS AND METHODS

The influence of maturity and seed size on sugarbeet fruit and true seed development was studied during 1969 and 1970 in the greenhouse, on nearby farms, in five trials at the East Experimental Farm, and on commercial seed lots from Western Oregon. The effect of pesticides sprayed on sugarbeet plants during anthesis was studied during 1969 and 1970 on nearby farms. The influence of growth regulators on flowering sugarbeets was investigated intensively during the last year in an OSU greenhouse and in a field study at the East Experimental Farm, Farm Crops Department, Oregon State University. A few other experiments were also conducted.

Several male sterile monogerm lines were used. In field studies, all sugarbeets tested were planted in 20- or 24-inch rows in solid stands. Plot size ranged from parts of an individual plant to regular field plots.

Plants were hand harvested and air dried under cover in paper bags, in burlap bags hung on outdoor drying racks, or in bundles in the field. Plants or field threshed seeds were placed in a crop dryer at 36 C for at least 24 hours and then double or single threshed, respectively, with a small Vogel thresher. The seed was passed over a 25°∠ inclined draper to remove the bulk of the trash, then cleaned with an air-screen unit containing 18/64- and 6/64-inch top and bottom round-hole screens to retain the bulk of the fruit produced.

Fruits were then weighed, in some cases sized, hand or machine counted into subsamples of 100 fruits, and examined for internal contents by means of X-ray radiography.

Evaluation of Internal Contents

The X-ray unit used was a Faxitron 804 manufactured by Field Emission of McMinnville, Oregon. Fruit exposure was for 3.5 minutes at 15 kVp at 25 inches from the X-ray tube. The Kodak Industrial X-Ray Film, Type M-2, was exposed, developed and dried under standard procedures.

The level of reading accuracy was first evaluated with a comparison of the X-ray technique and the cutting method (212). In addition, two readings, made one month apart on the same series of radiographs at the beginning of these studies, evaluated the repeatability of decisions on the internal contents.

During the first year, two 100-fruit templates were used on each X-ray film. No attention was given to fruit position. During the second year, the process was speeded immeasurably by placing 100 fruits at random in a 8.5 cm i. d. plastic petri dish. Four or five 100-fruit dishes were placed on each film for exposure.

The sugarbeet fruit images were quickly scanned with a 1.5X hand lens, and obvious characteristics were identified and marked with white ink on the black negative. Fruits were then individually

examined with the aid of a 6X hand lens to insure proper, detailed identification of the internal contents. Altogether, approximately 145,000 fruits were examined.

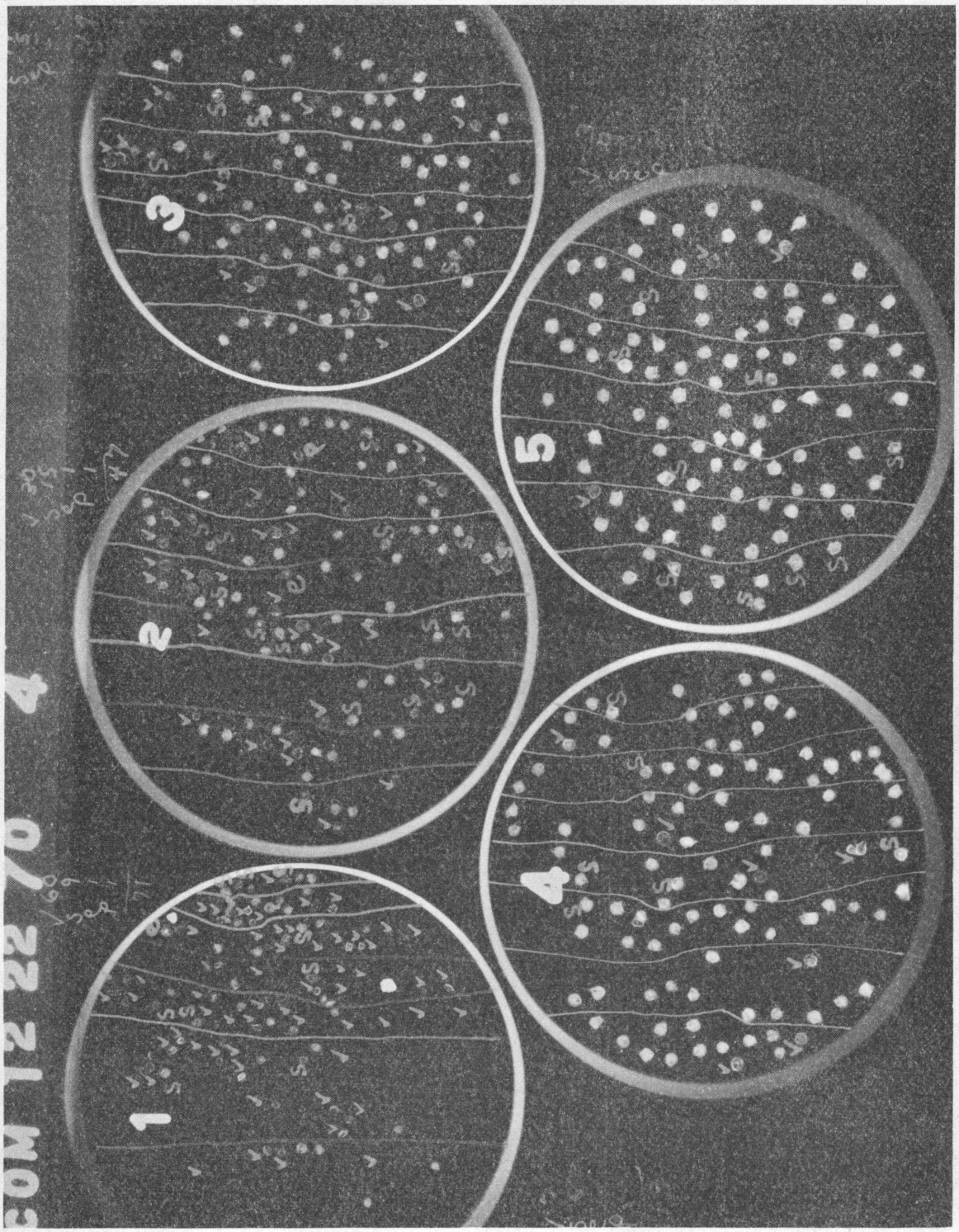
Images were marked as empty (✓), shrunken (s), no embryo but perisperm (e), and no perisperm but embryo (p) or left unmarked when the true seed was fully developed. The empty fruit and the underdeveloped fruit (shrunken, no embryo but perisperm, and no perisperm but embryo) were totaled as abnormal fruit, as shown in Figures 1 and 2.

Greenhouse Procedures

Greenhouse procedures as given by Gaskill (59, 62, 63) and Poehlman (156) were generally adhered to, except that all plants were well induced outside in pots or in the field. Single root stecklings or field transplants were potted in 10 (i. d.) x 15-inch fiber pots (manufactured by Western Pulp Products, Corvallis, Oregon), each containing approximately 20 pounds of air-dried unfertilized river bottom loam.

Plants were watered frequently. To insure adequate fertility, all pots were weekly given 800 ml of fresh, one-half strength standard Hoagland's nutrient solution (125). However, a double level of calcium nitrate [$Ca(NO_3)_2$] was used in the solution to insure high amounts of Ca and N in the soil. The iron was supplied by ferric

Figure 1. Radiograph of one sample of the commercial seed sizing study. Lead numerals identified dishes 1 through 5 which respectively identified the sugarbeet fruits held between 5-7, 7-9, 9-11, 11-13, and 13-15/64 inch round hole screens. White ink was used on the black X-ray negative to compartmentalize the 500 seeds and to record decisions on fruit quality. This positive was reduced slightly.


1
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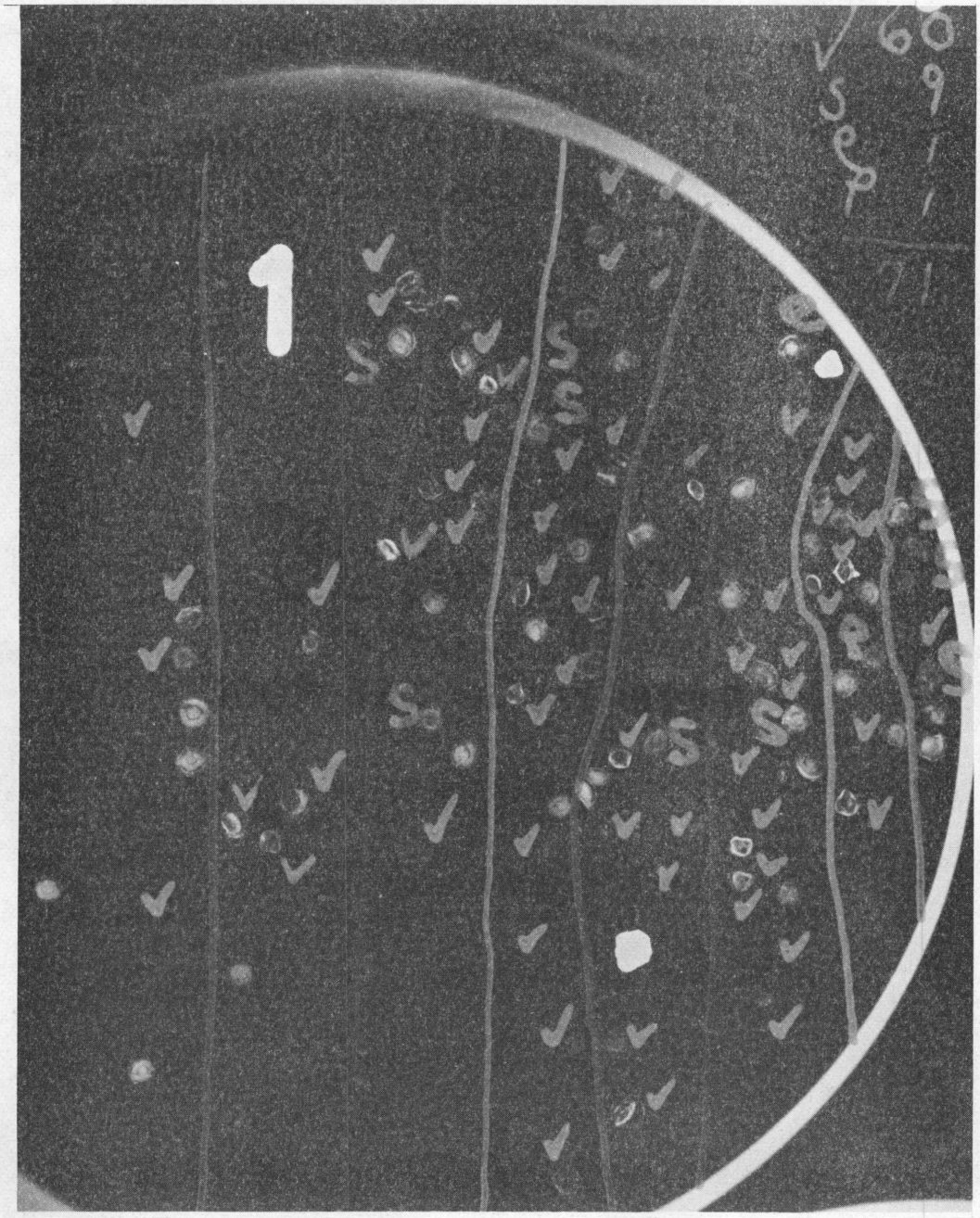

Figure 2. Radiograph of small 5-7/64 inch fruits of the commercial seed sizing study. Note that small fruits were frequently empty and underdeveloped, as indicated by white ink identification marks. This positive was enlarged about 2X.

chloride ($FeCl_3 \cdot 6H_2O$) from a stock solution mixed fresh every two to three weeks to preclude re-oxidation to the ferric form.

All stock solutions were kept in the greenhouse in tightly-capped amber glass bottles. The micronutrients were stored and used as a mixture.

Red spider mites [probably the two-spotted spider mite Tetranychus uerticae (Koch)] and aphids [probably the green peach aphid Myzus persicae (Sulzer)] were controlled with weekly or bi-weekly nicotine fumigations (14% alkaloid--marketed by Plant Products Corporation, Blue Point, New York). However, several stubborn red spider mite infestations required special dustings with malathion or TEPP.

Two banks of 100-watt, clear incandescent bulbs on an 18-hour day were hung 15 to 30 inches above the plants on each greenhouse bench and raised as necessary and possible. Light measurements, recorded in both intensity (ft-c) and wavelength (microwatts/cm^2/nm), are given in Table 2.

The temperature was set below 20 C throughout the period, although early summer temperatures over 38 C were noted on occasion during the maturation period. During these peak temperatures, the whitewashed greenhouse windows were opened, and a sprinkling system was put into operation for cooling purposes. Also, attempts were made to cool the interior of the greenhouse by frequently hosing

Table 2. Light intensity and quality measurements taken outside and inside of the greenhouse at 2 or 9 p. m. on various days during 1970. Readings were taken with the light-sensitive unit directed towards maximum light. A bank of 100-watt incandescent clear bulbs were used above the greenhouse bench.[1]

Condition and Date	Distance from light, ft.	Illumination foot candles	Microwatts/cm^2/nanometer		
			blue	red	far-red
Clear day (October 12)					
Outdoors above gravel		12,000	57	111	119
Greenhouse + lights	1	5,200	17	40	30
	2	5,000	17	40	30
	3	5,000	17	40	30
	4	5,000	17	40	30
Greenhouse - lights	1	5,200	17	40	30
	2	4,800	17	40	30
	3	5,000	17	40	30
	4	4,800	17	40	30
Overcast day (October 20)					
Outdoors above gravel		2,000	11	7	5
Greenhouse + lights	1	840	5.5	7.5	6.5
	2	820	5.3	7.0	6.0
	3	800	5.0	6.5	5.5
	4	800	5.0	6.0	5.0
Greenhouse - lights	1	800	5.0	6.0	4.0
	2	800	5.0	6.0	4.0
	3	800	5.0	6.0	4.0
	4	800	5.0	6.0	4.0
Dark night (October 24)					
Outdoors above gravel		0	<0.5	<0.5	<0.5
Greenhouse + lights	1	120	<0.5	2.5	3.0
	2	88	<0.5	2.0	2.5
	3	68	<0.5	1.5	2.0
	4	52	<0.5	1.3	1.6
Greenhouse - lights	1	0	<0.5	<0.5	<0.5
	2	0	<0.5	<0.5	<0.5
	3	0	<0.5	<0.5	<0.5
	4	0	<0.5	<0.5	<0.5

[1] Blue, red, and far-red light in ranges of 400-500, 600-700, and 700-800 nm, respectively.

the floors and benches with tap water.

Red marker male pollinator plants (see later) were intermixed at regular intervals with the male sterile plants in the growth regulator trials. During anthesis, plants were shaken manually and a 20-inch fan was used on occasion to encourage pollen dispersal. Male pollinators were not used with the cytoplasmic male sterile line in the bolting experiment.

Plant-Fruit Measurements and Calculations, and Fruit Size Class Distribution

Plant height measurements were usually taken. Lodging ratings ranged from one (no lodging) to nine (complete lodging) and were taken on certain experiments. Plant color ratings were made on the field growth regulator study. They ranged from one to seven as dark green, green, light green, light yellow, yellow, very yellow, and extremely yellow or chlorotic. A 21-day growth rate reading was made on five short, medium and tall plants per plot (15 per plot) for those plants treated with growth regulators at the early bolting stage.

The air-dried fruit yield of each plant or plot was determined after cleaning. Samples of several experiments were sized into five classes of 5-7, 7-9, 9-11, 11-13, and 13-15/64th inch. This was done by placing 200 ml of seed (about 50 g) onto the laboratory 7-7/8 square i. d. round hole screens. The nest of screens with seed were vibrated for one minute at a setting of 3.5 on a Syntrone paper jogger

and given an occasional, hard horizontal thumping. An entire plot or up to 1000 ml of seed were used per sizing. The weights or their percentages of the sized fruits formed a profile (frequency distribution) of the lot for seed size.

Depending on the experiment, one, two, four or five 100-fruit subsamples for each plot were counted by hand. An attempt was made to speed the counting process with the aid of a 100-hole vacuum counter plate, and the results are reported for the lodging and the Gilmour chemical spray studies.

Fruit counts per 5 or 10 g of seed were made by first placing the hand-drawn subsample (100 ml equal to about 25 g) from each plot onto a 5/64-inch round hole screen to remove all small loose particles. The screen was then vibrated for 15 seconds at a setting of 3.5 on a Syntron paper jogger, before weighing the desired amount on a two-place Mettler scale. These fruits were then counted in entirety with an electronic seed counter manufactured by Agricultural Specialty Company, Hyattsville, Maryland.

Most of the 100-fruit samples were weighed on a four-place Mettler balance after a 24-hour equilibration in the laboratory. Fruits were then X-rayed and the radiographs examined for the internal fruit contents.

Where evaluated, fruit moisture content was determined on a wet weight basis by oven drying about 8 g of air-dried fruits at 105 C

for 24 hours. Several measurements and calculations were made on various samples, as shown in Table 3.

Statistical Procedures

Standard statistical procedures as presented by Steel and Torrie (201) were used to evaluate the data by analysis of variance, including a split-block design referred to as a systematic arrangement by Cochran and Cox (31). Data of the five maturity studies were combined by the procedures outlined in Chapter 14 of Cochran and Cox. Simple correlation coefficients were determined among several variables.

The stand uniformity trials on the field growth regulator study were analyzed using both a nonrandomized systematic arrangement and a randomized arrangement of plots (55, 69, 123, 132).

The Duncan's new multiple range test (.05 level) for main effects and the least significant difference (.01 level) for interactions were calculated for all differences exceeding the .10 level of F.

Bolting Variability and Sugarbeet Maturity

The standard evaluation procedures in this section were to air-dry the harvested plants indoors in open paper bags, double thresh and clean the seed, take weight measurements, and then evaluate the fruits by radiography.

Table 3. Measurements, definitions and calculations made on sugarbeet plants and fruits in the various experiments.

Measurement	Definition and method of calculation
Yield	Reported in g/plant part, g/plant, g/plot or lb/A
Dry matter, %	Windrowed plants on a wet weight basis: $\frac{\text{Air-dried weight of plants}}{\text{Fresh weight of plants}} \times 100$
Moisture, %	Oven-dried fruits on a wet weight basis: $\frac{\text{Weight of water lost}}{\text{Initial weight of air-dried fruits}} \times 100$
100 Fruit weight, g	Hand counted fruit as an average of the subsample, sample, or size class distribution
Empty fruits, %	Empty ovarian cavities per 100 fruits
Abnormal fruits, %	Empty + underdeveloped fruits per 100 fruits
Size class, g	Frequency distribution of fruits in grams for each of five size categories in a sample or lot
Size class, %	Frequency distribution of fruits in percent for each of five size categories in a sample or lot. Each frequency was based on the percent by weight from each size as shown below. All five size classes totaled to 100%. $\frac{\text{Fruit weight in a size class}}{\text{Total fruit weight in all sizes}} \times 100$
Empty in lot, %	Frequency distribution of the percentage of empty fruit in a lot, based on: $\frac{\text{\% empty fruits in a size} \times \text{\% of size class}}{100}$
Abnormal in lot, %	Frequency distribution of the percentage of abnormal fruit in a lot, based on: $\frac{\text{\% abnormal fruit in a size} \times \text{\% of size class}}{100}$
Total empty, %	Sum of % empty in the lot for all sizes
Total abnormal, %	Sum of % abnormal in the lot for all sizes
X-ray germination, %	100% minus % total abnormal; the total filled fruits in all size classes with sound ovarian cavity contents.

Preliminary Investigations

During the summer of 1969, two replications of nine individual but adjacent plants in the DeFord field (see later) were harvested a week early on August 1 and ranked visually for maturity. Fruits were then evaluated for yield per plant and the occurrence of empty and abnormal fruits.

Plant and Fruit Maturity Studies

Plants from five nearby farm fields of sugarbeets were evaluated for individual maturity during 1969 and 1970. Ten adjacent plants in a row, from five predetermined locations (replications), were harvested from each field and immediately ranked visually on the basis of plant maturity. The rankings ranged from 1 (immature) to 10 (mature). Cleaned seeds from each of the 250 plots in all five studies were placed in petri dishes and ranked visually from 1 to 10 by replicate per study on the basis of fruit maturity. Yield per plant, 100 fruit weight, percent empty and abnormal fruits were determined.

The data were analyzed as a randomized complete block. The data were further summarized by combined analyses, using the results from either four or five studies on both plant and fruit maturity, after which simple correlations for all four variables were determined.

The commercial fields from which the plants were obtained

were grown in strips (164) under standard farm practices which included sprinkler irrigation. All fields received a preplant fall fertilizer mixture that provided approximately 75, 43.6 (100), 33.3 (40), 50, 5 and 5 pounds of N, P (P_2O_5), K (K_2O), S, Mg, and B per acre. Four pounds per acre active ingredients of Ro-Neet or three pounds of Eptam were added with the fertilizer mixture to control weeds (119).

March and April split applications of fertilizer provided an average of 165 and 90 pounds per acre of N and S, respectively, and 1-1/4 pounds per acre active Diazinon were applied in early June for lygus bug control. Additional information about the fields is given in Table 4.

Table 4. Commercial fields of sugarbeets, male sterile and pollinator lines, and the dates of planting and harvesting for the five maturity studies during 1969 and 1970.

Year, Number and Field	Male sterile	Pollinator	Planted	Harvested
1969				
1. DeFord	SL(100363 x 12163)	SP 6322-0	9/21/68	8/ 8/69
2. Millhouser	GW 916	GW 916	9/ 6/68	8/11/69
1970				
3. Gilmour	SL(100363 x 12163)	SP 6322-0	8/25/69	8/ 5/70
4. Millhouser	70 MSH5	AI-75-70R	9/ 5/69	8/11/70
5. Millhouser	AI-75	AI-75-70R	9/ 5/69	8/11/70

Bolting Variability Studies

Greenhouse Bolting Study. Plants of the male sterile line FC504 that were planted in the fall of 1968, but reverted as stecklings in the spring of 1969, were placed outside to vernalize naturally during the fall. On December 31, 1969, 24 plants were returned to the greenhouse under proper, specific conditions of temperature and light (see section on greenhouse procedures).

Plants began to bolt within 40 days (February 6, 1970) and were grouped into three replications of eight plants each on the basis of earliest to latest bolting in a randomized complete block design. Plant height measurements were made during eight weeks of bolting, until the plants passed peak anthesis by the first week of April. No male pollinator line was provided for these cytoplasmic male sterile plants.

The 20-month-old plants were allowed to flower to determine if they would develop naturally parthenocarpic fruit as there was no other sugarbeet pollen in the environment during March and April. Examination of a few fruits indicated that selfing must have occurred under these conditions. The plants were watered and given nutrient solutions regularly for an extended period of 90 days after anthesis to insure maximum maturity for all plants before they were harvested on July 17, 1970. Little or no shattering occurred under these protected conditions.

Besides plant height measurements, data were taken on yield per

plant, 100 fruit weight, percent empty and abnormal fruits. The data were summarized by the analysis of variance.

Field Bolting Study. Border rows of the nine check plots of the field growth regulator study (see later) were used to determine bolting variability of the male sterile monogerm line F68-546H3. Beginning on June 1, 1970, and continuing at five day intervals until June 30, five plants per plot per date were tagged in the initial bolting stage of 10 to 15 inches tall.

Plants were harvested on August 15, 1970, which was considered as maximum maturity of 50 to 55 days after peak anthesis for the line. Those tagged on June 30 failed to set fruit and were discarded. Data were taken on yield per plot, 100 fruit weight, percent empty and abnormal fruits. Calculations were made on the percent of the lot by weight per bolting date, as well as percent empty and abnormal in the lot.

The six bolting dates and nine replications were summarized by the analysis of variance, using a randomized complete block design. Simple correlations were also determined for all variables.

Location of Abnormal Fruit Development

Six monogerm sugarbeet lines, planted at the East Experimental Farm on September 8, 1969, were used to determine the contribution of lateral tips and late developing branches to the abnormal fruit

problem. Cultural methods were the same as those used in the field growth regulator study.

The six male sterile lines were: 1) F68-546H3, 2) F66-562HO, 3) F66-569H3, 4) F67-569H3, 5) SL(100363 x 12163) and 6) SL(11866 x 12166). They were pollinated with the red tester line. Five plants from each of the six male sterile lines in four replications were harvested on August 16 and 17, 1970, Each plant was immediately segmented into four sections as follows: 1) primary axis down to the first main lateral branch, 2) the lower three-fourths of all lateral branches, 3) the upper one-fourth of all lateral branches, and 4) all lateral spurs consisting of the secondary and tertiary lateral branches.

Data were taken on yield per plant part, 100 fruit weight, percent empty and abnormal fruits. Calculations were made on the percent of the lot by weight for each plant part, percent empty and abnormal in the lot, as well as percent total empty and total abnormal. The data were summarized by the analysis of variance, using a split-block design.

Time of Empty Fruit Development

The purpose of this experiment was to determine if immature fruits contained filled ovarian cavities when plants were first windrowed and then later developed shrunken or empty fruits.

Three replications of individual plants for the same six

monogerm lines were harvested prematurely on July 28, 1970, to determine the time of empty fruit development. Beginning at the apical tip, and continuing to the tips of the first and subsequent lateral branches, 100 odd-numbered fruits on each plant were immediately sectioned with a razor blade and the number and position on the plant of abnormal fruits determined.

Plants were then stored indoors to dry in open paper bags. Subsequently, the 100 even-numbered fruits were removed in the same pattern, placed in templates, and evaluated by radiography. Unfortunately, replications one and two were mutilated during storage and could not be X-rayed accurately. Data were taken on the basis of percent abnormal fruit when cut fresh and when X-rayed dried.

Lygus-Free Caging Study

Four mesh screen cages were placed over lygus-free male sterile plants of lines 1, 2, 3 and 5 on June 15, 1970. The 1.5 x 3 x 5-foot cages were inspected regularly to insure the absence of lygus and aphids during the summer. Other than the two regular sprayings with Diazinon, no special chemical treatments were necessary.

Plants in the lygus-free cages, and plants from an equal length of the exposed rows, were harvested late on August 31, 1970. Plots were bundled separately and left to dry in the field. The cleaned fruits were weighed for yield per plot and sized into five classes.

Data were taken on 100 fruit weight, percent empty and abnormal fruit, and size class distribution weights. Calculations were made on size classes in percent, percent empty and abnormal in the lot, as well as percent total empty and total abnormal. The data were summarized by the analysis of variance as a 2x4x5 or a 2x4 factorial. Simple correlation coefficients were determined for most variables.

Lodging and Clipping Studies

Clipping Study

Three replications of four plants each were selected for uniformity in the DeFord field on June 17, 1969. The following single plant treatments were applied: 1) clipped the tips of all laterals, 2) tipped the primary axis, 3) an untreated check, and 4) removed the top one-half of the plant.

Plants were harvested on August 1, 1969, and stored in the laboratory to dry. Data were taken on yield per plant, 100 fruit weight, and percent empty and abnormal fruits. The data were summarized by the analysis of variance, as a randomized complete block design.

Lodging-Clipping Study

A 4x5 randomized complete block design was superimposed on a portion of the 1970 Gilmour field, using 100 square foot plots (four 20-inch rows x 15 feet long). The following treatments were applied:

1) an untreated check, 2) tipped primary axes, 3) area staked and plants tied upright on June 18, 4) plants tied upright on June 18 then manually lodged later (approximately 30 days) on July 15, and 5) plants manually lodged early on June 18.

The four-row plots were windrowed on August 6 and left to dry in the field. Cleaned seed was weighed and sized into five classes. Data were recorded on yield per acre, fruit count per 10 grams, size class distribution weights, 100 fruit weight, percent empty and abnormal fruits on the basis of vacuum counted samples (four 100-fruit subsamples of unsized seed), and hand counted samples (one 100-fruit subsample for each of the five sizes).

Calculations were made on the size classes in percent, percent empty and abnormal in the lot, as well as percent total empty and total abnormal. The data were summarized by the analysis of variance, and simple correlation coefficients were determined on most variables.

Seed Sizing and Agronomic Practices

The importance of seed size on the occurrence of empty and underdeveloped fruit in sugarbeets was investigated on the assumption that small fruit may be less mature than large fruit. Fruit quality was also compared with agronomic practices used by growers, particularly dates of planting, lygus control and harvesting.

Crocker Seed Sizing Study

Four 500-g samples were taken by the grower on November 4, 1970, from a 22,000-pound commercially processed problem lot of Solorave B7-0-53S that germinated less than 70%. Each of the four samples (replications) was sized into five classes (treatments).

The seed came from a nearby field planted on September 9 and 10, 1969, following a preplant fertilizer application providing approximately 55, 52.3 (120), 40.8 (50), 25, and 5 pounds per acre of N, P (P_2O_5), K (K_2O), S, and B, according to the grower (40). Approximately 160 and 85 pounds per acre of N and S, respectively, were added during the early spring, and 1-1/4 pounds per acre of active Diazinon were applied during early June to control lygus.

The crop was windrowed beginning September 2, 1970. The combine-run seed was first scalped (15/64 inch) and processed over a 7/64 inch round hole screen, then run over an 11/64 inch triangular hole screen, to remove the large and the small seed before shipment.

Data were recorded on size class weights, 100 fruit weight, percent empty and abnormal fruit. Calculations were made on size classes in percentage, percent empty and abnormal in the lot, total empty and total abnormal, as well as X-ray germination. Data were summarized by the analysis of variance, as a randomized complete block.

Commercial Seed Sizing Study

With the discovery from this research that seed size is of primary importance to the occurrence of abnormal fruit, ten samples of commercially processed seed were obtained on December 9, 1970, from the West Coast Beet Seed Company of Salem, Oregon. The samples from the following growers were arranged in order of increasingly abnormal fruit: 1) Dun, 2) Bohnert, 3) Bright, 4) Aman, 5) Chambers, 6) Hultman, 7) Edwards, 8) Schnider, 9) Groah, and 10) Kuenzi.

All of these monogerm male sterile lines were grown in the Willamette Valley, except Nos. 1 and 2 which were grown in the Medford, Oregon area. Standard cultural practices were used, including a single application of Diazinon in the valley, but two applications of Meta-Systox near Medford, to control lygus during June (119).

Data were recorded on weights of size classes, 100 fruit weight, percent empty and abnormal fruits, as well as germination and dates of planting, spraying and swathing. Calculations were made on size classes in percent, percent empty and abnormal of the lot, percent total empty and total abnormal, and X-ray germination. Where possible, the data were summarized by the analysis of variance as a randomized complete block. Simple correlations were computed on fruit vs. lot attributes, as well as lot attributes vs. agronomic practices.

Effect of Pesticides and Growth Regulators

Experiments were conducted to evaluate the effects of several chemicals on the occurrence of empty and underdeveloped sugarbeet fruits. These chemicals included several pesticides and metabolic promoting and inhibiting growth regulators.

DeFord Chemical Spray

During the summer of 1969, a chemical spray study was superimposed on a portion of the DeFord field, which was planted in strips to SL(100363 x 12163) x SP 6322-0 (see plant and fruit maturity section). Four uniform, healthy male sterile plants per plot were tied upright in three replications of a randomized complete block design. The 16 treatments consisted of an untreated check, an insecticide (DDT), two herbicides used for controlling weeds in sugarbeets (Endothal and IPC), and two growth regulators (2, 4-D and GA_3). Each aqueous solution of chemical was sprayed on plants at 10^{-3}, 10^{-6} and 10^{-9} molar concentrations during peak anthesis on June 20 and 21.

The GA_3 was solubilized with 2 ml of 2% Na_2CO_3, although not all of the material may have gone into complete solution at the high rate. Increasing concentrations of each chemical were applied with a CO_2-charged sprayer under 20 psi of pressure. The hand-held sprayer with a single 9503-E Tee Jet nozzle delivered 100 ml of

solution in 5 seconds and was completely emptied in an additional 10 seconds. Three washings with water and one rinse with acetone were assumed to have removed the residues between chemicals.

Cloudy to sunny weather prevailed with occasional light breezes. To retain any drift, plants were sprayed under a 7-foot polyethylene teepee that was left in place for 5 minutes.

The plants were windrowed on August 4, 1969, weighed for dry matter determinations and hung in burlap bags on outdoor drying racks. Data were recorded for yield per plot, 100 fruit weight, percent empty and abnormal fruit, and summarized by the analysis of variance. Simple correlations were determined on all variables.

Gilmour Chemical Spray

During 1970, the same 3x16 randomized complete block chemical spray study was superimposed on a portion of the Gilmour field, which was planted in strips to the same SL(100363 x 12163) line. The 16 treatments were applied on July 2 at late anthesis (delayed due to an irrigation and then rain). The same procedures were used, except that the spraying equipment (40 psi) was the same as that used in the field growth regulator study. Ideal sunny weather above 20 C with little wind permitted spraying without a polyethylene teepee.

Plants were windrowed on August 5, 1970, and hung in burlap bags on outdoor drying racks. Two 100-fruit subsamples of cleaned

seed per plot were both hand counted and vacuum counted. Data were recorded for yield per plot, 100 fruit weight, percent empty and abnormal fruit, and summarized by the analysis of variance. Simple correlations were determined on all variables.

Greenhouse Growth Regulator Studies

Two greenhouse studies were conducted during 1970 concerning the effects of five growth regulators on the occurrence of abnormal fruit in sugarbeets. Study No. 1 consisted of male sterile monogerm plants of the line F66-562HO planted at the East Experimental Farm on August 15, 1969. The male sterile plants in study No. 2 were of the line F68-546H3 planted on September 8, 1969.

Each study consisted of six treatments and four replications in a randomized complete block design on one-half of a greenhouse bench. The 24 plants in each study were transplanted from the field into large fiber pots on April 16, then moved into the greenhouse on April 24, where specific, previously mentioned procedures were followed. Seven weekly bolting records were taken, beginning on May 1.

The growth regulator treatments, consisting of Alar-85, Ethrel, MH-30, 2,4-D, TIBA and the untreated check, were applied at 1000 ppm during peak or early anthesis in the late afternoon of June 5. The plants were sprayed outdoors where the temperature was about 29 C. There was no wind. Eight plants from the two studies per

treatment were sprayed at once with 200 ml of solution which contained 1 ml of Tween 20.

Plants were harvested on August 18. Besides bolting heights, data were taken on yield per plant, 100 fruit weight, and percent empty and abnormal fruit. The data were summarized by the analysis of variance.

Field Growth Regulator Study

An experiment was conducted at the East Experimental Farm during the 1969-1970 season, using three flowering stages and 12 growth regulator treatments with three replications in a split-plot design. The 90 square-foot plots (three 24-inch rows x 15 feet long) were sown to the male sterile line F68-546H3 with a Planet, Jr. (plate hole 31). Ceresan-treated seed was planted at about 10 pounds per acre less than 1 inch deep in moist Chehalis sandy loam soil on September 8, 1969. Double rows of red tester pollinators (44, 45, 106, 156) were criss-crossed through the alleys and around the exterior of the trial.

Five weekly stand counts, beginning September 22, 1969, were made on five evenly-spaced one meter plots in each of nine replications. The data were summarized by the analysis of variance as a nonrandomized systematic arrangement and as a randomized complete block design. During late April of 1970, several plants were lifted

and transplanted throughout the field to reduce any major row skip to less than one foot. The area was hoed during late September, March and April and during mid-June.

Fertilizer treatments, including a preplant application on August 14, 1969, and a spring application on April 16, 1970, provided the standard amount of nutrients used on sugarbeet seed crops in the Willamette Valley (see plant and fruit maturity section). Three preplant sprinkler irrigations, three fall irrigations, and seven spring and summer irrigations of 2 to 4 inches each were applied. A helicopter applied 1-1/4 pounds of active Diazinon per acre on June 2 and again on July 8, 1970.

The 12 treatments consisted on Alar-85 and Ethrel at 500, 1000 and 1500 ppm each, TIBA at 500 and 1000 ppm, MH-30 at 2000, 4000 and 6000 ppm, and an untreated check. The treatments were applied only once about 20 days apart to plants in the early bolt (June 4), peak anthesis (June 23) and post anthesis (July 13) stages of flowering. Plants were small during early bolting but large and beginning to lodge at the post-anthesis stage.

Standard spraying procedures previously mentioned were employed, except that 40 psi of pressure delivered the 500 ml of solution through the 8003 Tee Jet nozzle in 20 seconds, and an additional 10 seconds voided the sprayer of all mist. Only plants, not the area, were sprayed with each solution, which included 5 ml of

Tween 20 as a surfactant.

Temperature and weather conditions were: 1) 16 to 18 C with cloudy to sunny skies and light to gusty breezes for early bolt, 2) above 20 C with partly sunny skies and a light breeze for peak anthesis, and 3) a clear day ranging from 20 to 25 C with gusty wind toward the end of spraying for the post-anthesis stage.

Plant data were taken on 21-day growth after spraying the early bolt treatments, maximum and harvest heights, as well as lodging and color ratings (July 17). The center row of each plot (1/2000th acre) was harvested on August 18, 1970, and the bundles were left to dry in the field. Clean seed data were taken on yield per acre, fruit count per 5 g, 100 fruit weight, and percent of empty and abnormal fruit.

The data were summarized by the analysis of variance, using a split-plot or a split-split plot design. Simple correlations were determined on all varaibles except the 21-day growth.

RESULTS

The occurrence of empty and underdeveloped fruit in monogerm sugarbeets was determined by X-radiography in a range of experiments. Although the level of empty fruit ranged from nearly zero to 100% in these studies, the level of underdeveloped fruit regularly ranged from 5 to 10%. Therefore, only empty fruit and abnormal fruit (empty + underdeveloped) are reported here.

Pertinent results for most of the studies are herein presented, and the means and statistical analyses are presented in entirety in Tables A.3 through A.40 (Appendix).

Validity of the X-Ray Technique

The first step in this research was to evaluate the usefulness of the X-ray technique, and the author's ability to make repeatable decisions regarding the film images of the internal contents of sugarbeet fruits.

The X-ray technique was compared with the cutting test. Results indicated that, for thirty-two 100-fruit subsamples, the X-ray method was slightly more reliable than the cutting test in permitting determinations on the percentage of abnormal fruit. The mean difference in abnormal fruit between the cutting test and the X-ray method was small: 20.8 vs. 22.1%, respectively. However, this was

significantly different at the .001 level of probability, as shown in Table A.3.

To evaluate reading repeatability, identical radiographs of the 3,200 fruits were viewed twice, one month apart. Results indicated that although the mean difference was significant at the .05 level, it was small: 22.1 vs. 22.8% for the first and second readings, respectively (Table A.4). This indicated a slight increase for the second reading in the precision of abnormal fruit detection.

Moisture Contents of Air-Dried Fruits

Fruit weight measurements were made on air-dried subsamples because of the desire to save the counted fruits for later germination and emergence tests. Therefore, percent moisture of air-dried sugarbeet fruits was determined on only three subsamples per trial in each of six studies. The fruit samples selected for moisture determinations were either those of a check or a plot of average maturity. Sugarbeet fruit moisture averaged 7.2%, as reported in Table 5.

Bolting Variability and Sugarbeet Maturity

Sugarbeet plants in the same field varied widely in maturity. This appeared to be due to variations in bolting behavior. Due to the indeterminate growth habit of this species, immature fruits on the late developing branch tips, as well as those on secondary and

Table 5. Mean moisture contents of air-dried sugarbeet fruits on a wet weight basis. A single check or an average maturity plot from each of the following studies was used as the source of fruit for oven-dried triplicate subsamples.

Study	Means, %
Maturity No. 2	7.26
Maturity No. 4	7.06
Lodging-clipping	7.23
DeFord chemical spray	7.50
Gilmour chemical spray	7.59
Field growth regulator	6.56
Grand mean moisture content	7.20

Table 6. Plant and fruit attribute means for the 1969 DeFord preliminary maturity study. Two replications of single sugarbeet plants were harvested on August 1 and ranked visually on the basis of plant maturity.

Plant maturity	Yield, g/plant	Empty fruits, %	Abnormal fruits, %
1 - Immature	17.5	64.5	72.5
2	20.5	73.5	87.5
3	21.5	16.0	26.0
4	45.0	32.0	40.0
5	23.5	15.5	18.0
6	12.5	26.0	36.5
7	14.5	15.0	21.0
8	17.0	10.5	16.5
9 - Mature	37.5	9.5	12.5
Means	23.28	29.17	36.72

tertiary branches, contributed slightly to the problem.

Preliminary Investigations

During the summer of 1969, two replications of nine adjacent plants in the DeFord field were ranked visually on the basis of plant maturity at harvest. Results on the evaluated fruits indicated that individual plant maturity could indeed be an important cause of abnormal fruits in monogerm sugarbeets (Table 6).

Plant and Fruit Maturity Studies

The results from 1969 and 1970 maturity studies indicated that sugarbeet plants immediately adjacent to each other in a row varied greatly in maturity and, as a result, varied significantly in the level of empty and underdeveloped fruits produced.

Maturity was visually determined for both plants and the harvested fruits. For extremely immature plants in some fields, results from plant maturity ratings indicated that yield per plant and 100 fruit weight occasionally varied significantly, but not usually so (Tables A.5, A.6, A.13 and A.14). When the fruit from these plants were visually rated for maturity, yield per plant and 100 fruit weight varied significantly over half of the time (Tables A.9, A.10, A.13 and A.14).

Fruit immaturity at harvest was the primary cause of empty

and abnormal fruits, however, regardless of whether it was detected by visual observations of the plants or of the harvested fruits. As shown by the results of five studies in Figures 3 and 4, comparative maturity of adjacent plants differed significantly and was consistently detected (Tables A.7, A.8, A.11, A.12, A.13 and A.14).

The only exception was study No. 3 on the 1970 Gilmour field. Most of these plants were already mature when harvested. Even so, the level of abnormal fruit was never lower than about 10% in any study, so some factor(s) other than fruit immaturity must have contributed to the occurrence of empty and underdeveloped fruits.

The results of all five or only four (removed No. 3) studies were statistically combined for both plant and fruit maturity (Tables A.13 and A.14). The five studies differed significantly at the .01 level or greater for fruit weight and quality by both rating systems. This was due chiefly to the immaturity of study No. 5 and the maturity of No. 3 (see grand means of Table A.5 through A.12).

The results of the four combined studies are illustrated in Figures 5 and 6 for plant and fruit maturity ratings, respectively. Yield per plant varied neither consistently nor significantly with either rating system, and 100 fruit weight varied significantly (.05 level) only for the fruit maturity rating system and then only for the most immature fruits, according to Duncan's new multiple range test (.05 level).

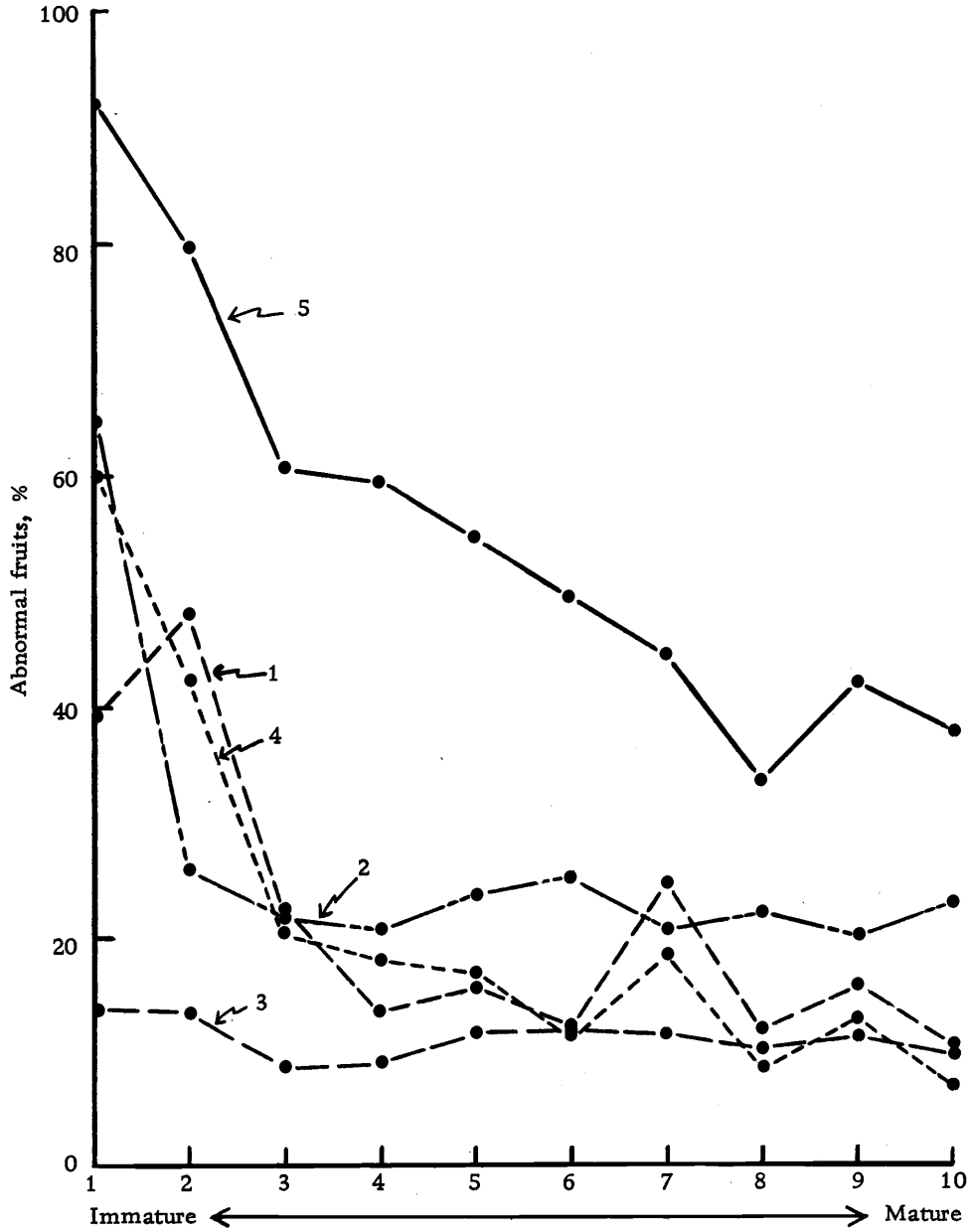

Figure 3. Abnormal fruits of adjacent plants for maturity studies 1 through 5 during 1969 and 1970, ranked on the basis of plant maturity. Although the level of maturity varied from study to study, immature plants produced fruits that were significantly more abnormal than those produced by mature plants. Each study was harvested on the same day.

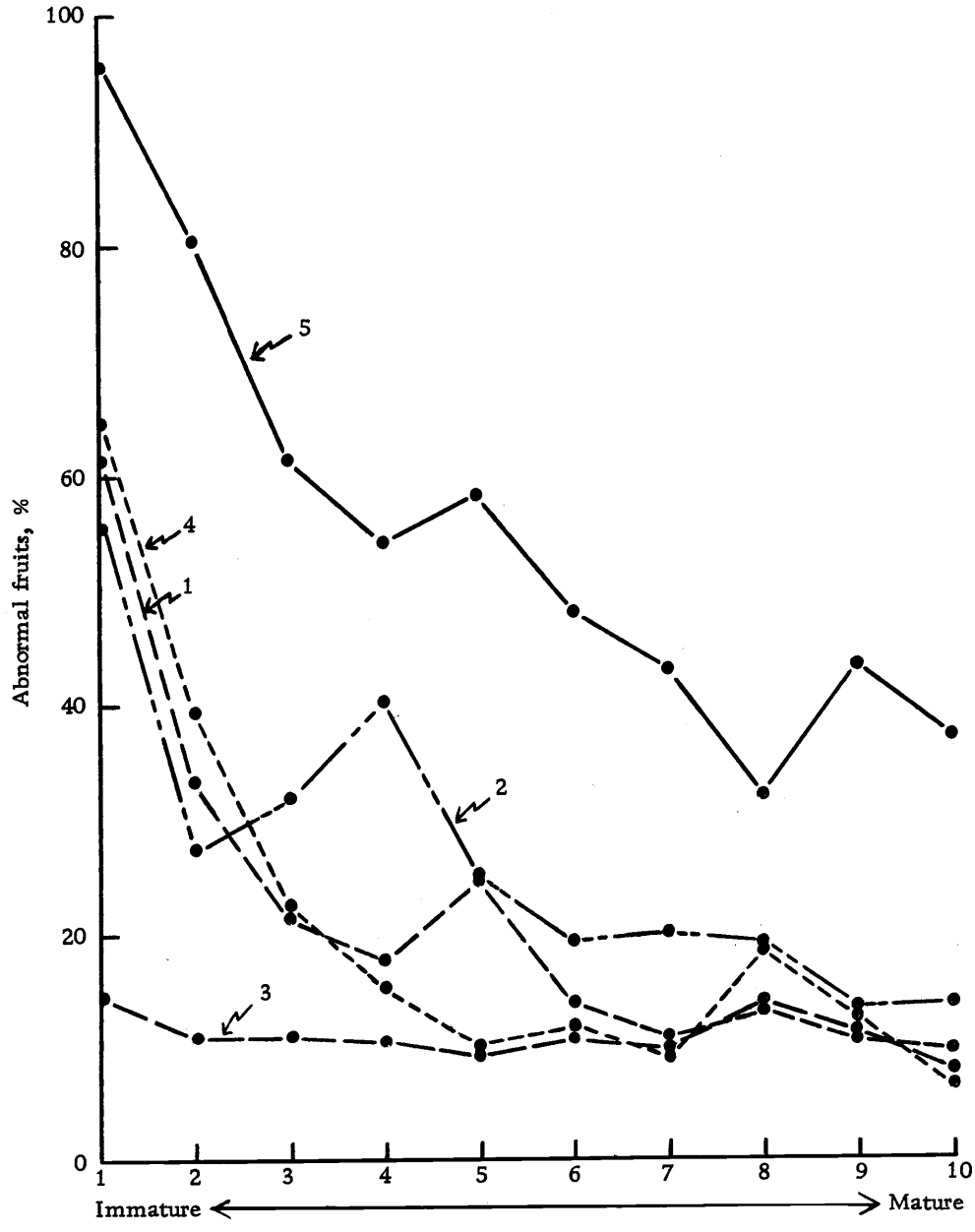

Figure 4. Abnormal fruits of adjacent plants for maturity studies 1 through 5 during 1969 and 1970, ranked on the basis of fruit maturity. Although the level of maturity varied from study to study, immature fruits were significantly more abnormal than mature fruits. Each study was harvested on the same day.

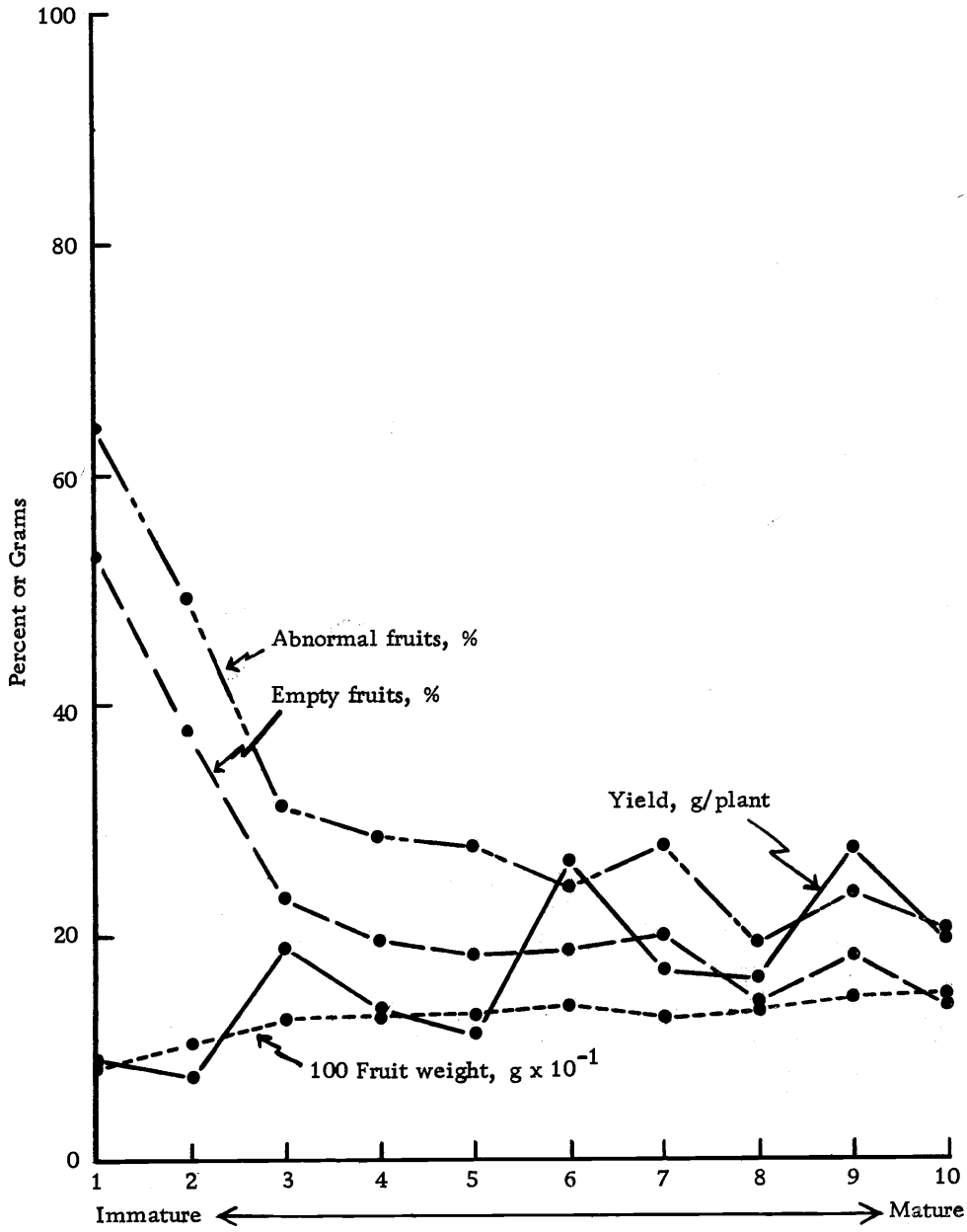

Figure 5. Combined results of adjacent plants of four (removed No. 3) maturity studies during 1969 and 1970, based on plant maturity. Yield did not vary consistently and neither yield nor fruit weight differed significantly. Both empty and abnormal fruits decreased significantly (.005 level) with increasing plant maturity. (10 g x 10^{-1} = 1 g)

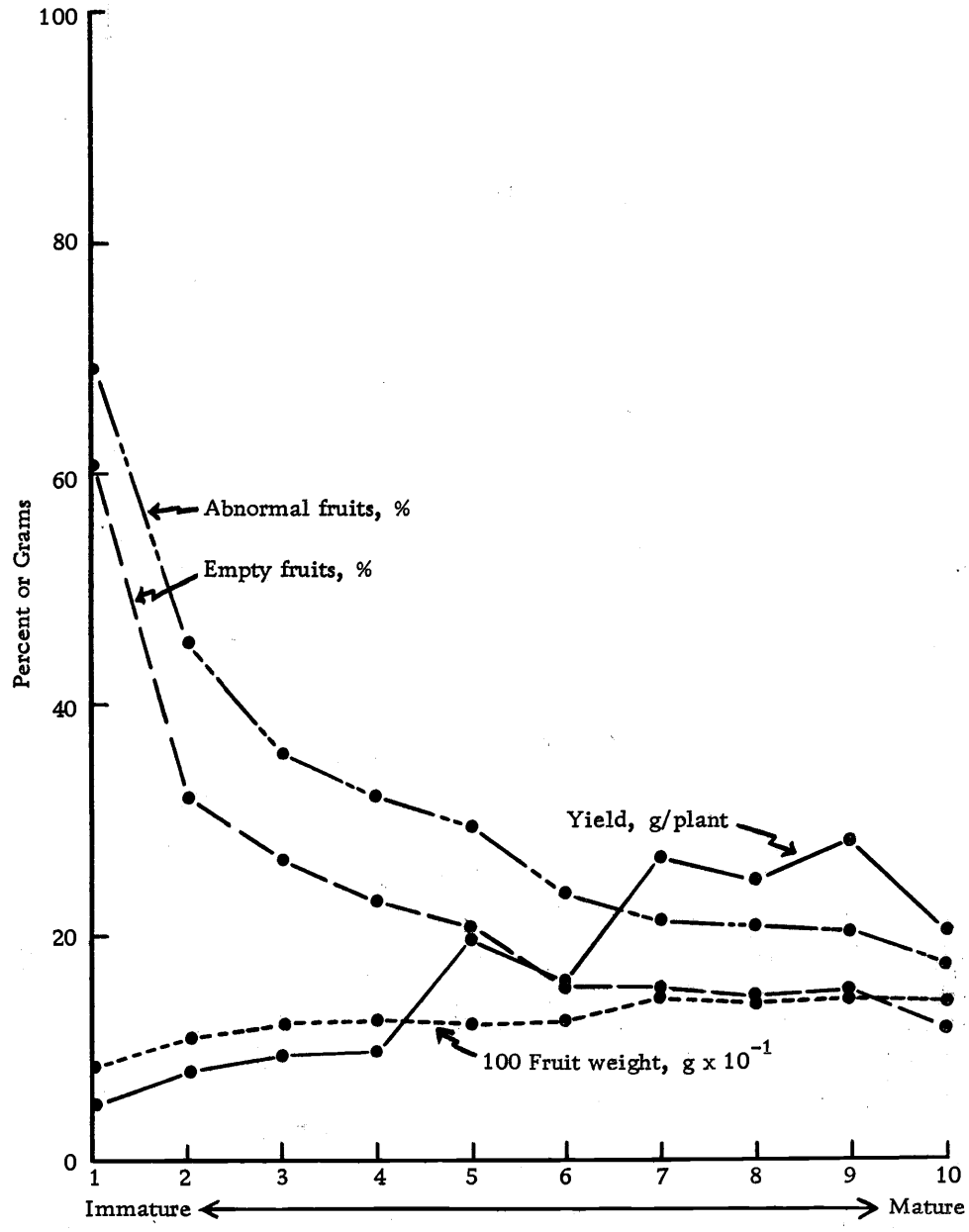

Figure 6. Combined results of fruits from adjacent plants of four (removed No. 3) maturity studies during 1969 and 1970, based on fruit maturity. Yield did not vary significantly, but fruit weight increased (.05 level) and empty and abnormal fruits decreased (.005 levels) with increasing fruit maturity. ($10\ g \times 10^{-1} = 1\ g$)

Both empty and abnormal fruit varied highly significantly (.005 level) for both plant and fruit maturity rating systems. The greater the immaturity, the greater was the level of empty and abnormal fruit.

All attributes of yield, fruit weight, and the level of empty and abnormal fruits were highly correlated (.01 level), either positively or negatively, for both plant and fruit maturity rating systems, using the combined results of all five studies (Table A.15). The direction of correlation is suggested by the graphs in Figures 5 and 6, which are the combined results of four studies.

Bolting Variability Studies

Greenhouse Study. Bolting variability appeared to be chiefly responsible for variations in plant and fruit maturity at harvest. In this greenhouse study, plants varied highly significantly (.005 level) in bolting habit. This was true for the time of stalk initiation and for stalk height throughout the entire 8-week bolting period, as shown in Figure 7 and reported in Table A.16.

However, when these protected plants were allowed to mature completely for 90 days after anthesis, there were no consistent or significant differences per bolting treatment in yield per plant, fruit weight, or percent empty or abnormal fruits (Figure 8).

Abnormal fruits were consistently less than 10% and averaged

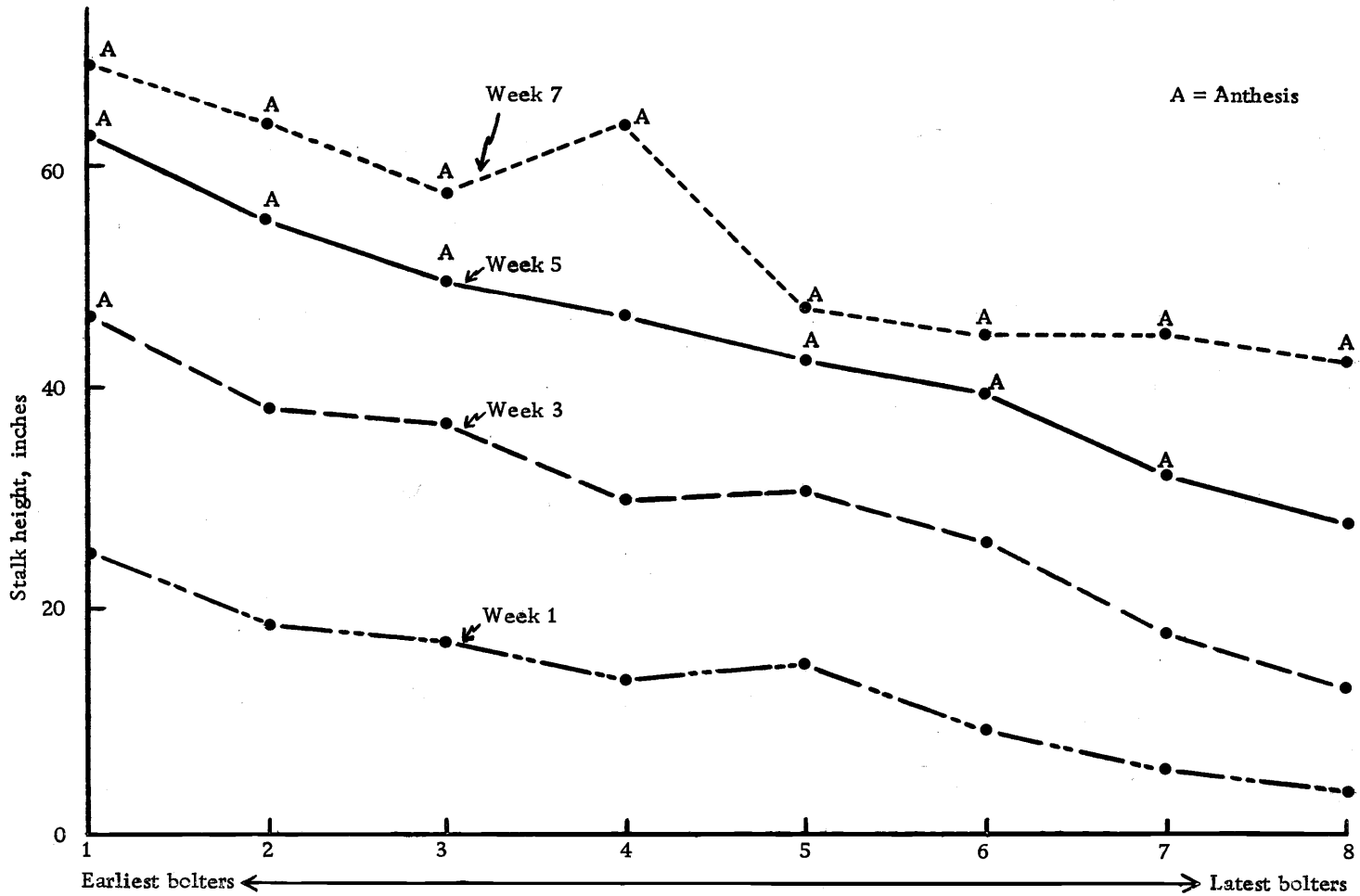

Figure 7. Stalk height measurements over seven weeks for the 1970 greenhouse bolting study. Stalk height differed significantly (.005 level) throughout the bolting period, where plants were grouped into treatments based on stalk initiation. Measurements began on February 20, 1970. Anthesis indicates that 70% or more of the plants in a given treatment were flowering.

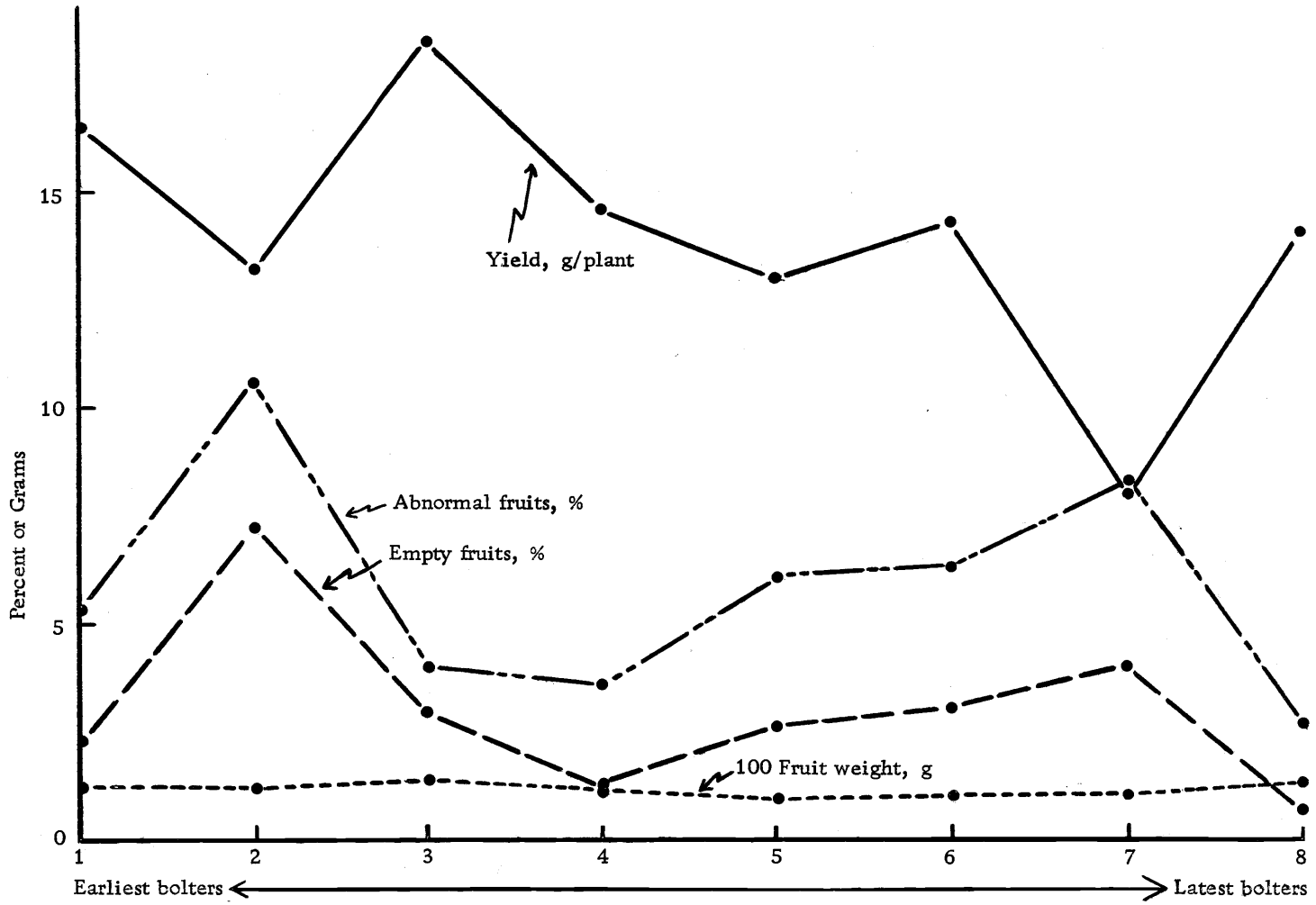

Figure 8. One lot and three fruit attribute means for the 1970 greenhouse bolting study. Extreme bolting variability had no consistent or significant effects on fruit attributes, when these protected plants were allowed to mature completely (90 days after anthesis). In fact, the latest bolter had the lowest amount of empty and abnormal fruit.

less than 6%. Empty fruits averaged only 3%, when plants were allowed to mature completely. This was despite the fact that, under these conditions, the cytoplasmic male sterile line used (FC504) self fertilized as there were no other sources of sugarbeet pollen in the environment during anthesis in March and April of 1970.

Field Bolting Study. Late bolting played a major role in determining the level of fruit maturity, when all plants were harvested on the same day 50 to 55 days after peak anthesis. The level of empty and abnormal fruits increased dramatically, and yield dropped sharply, as bolting was delayed (Figure 9). Also, fruit weight fell significantly as bolting date advanced. All of these factors were significant at the .005 level of probability (Table A.17).

The percentage of empty and abnormal fruits ranged from 2.1 and 5.1%, respectively, for the early bolting plants (June 1) to 83.3 and 87.3%, respectively, for the late bolting plants (June 25). However, because yield per bolting date fell from 45.9 to only 0.9% (i.e., 83.4 to 1.7 g) for the early and late bolting dates, respectively, neither percent empty nor percent abnormal of the lot varied significantly (.05 level) for any bolting date. Total empty and total abnormal for the entire experiment were only 6.5 and 10.8%, respectively.

By nature of their association, 1) yield per plot and percent of lot by weight, as well as 2) percent empty and percent abnormal

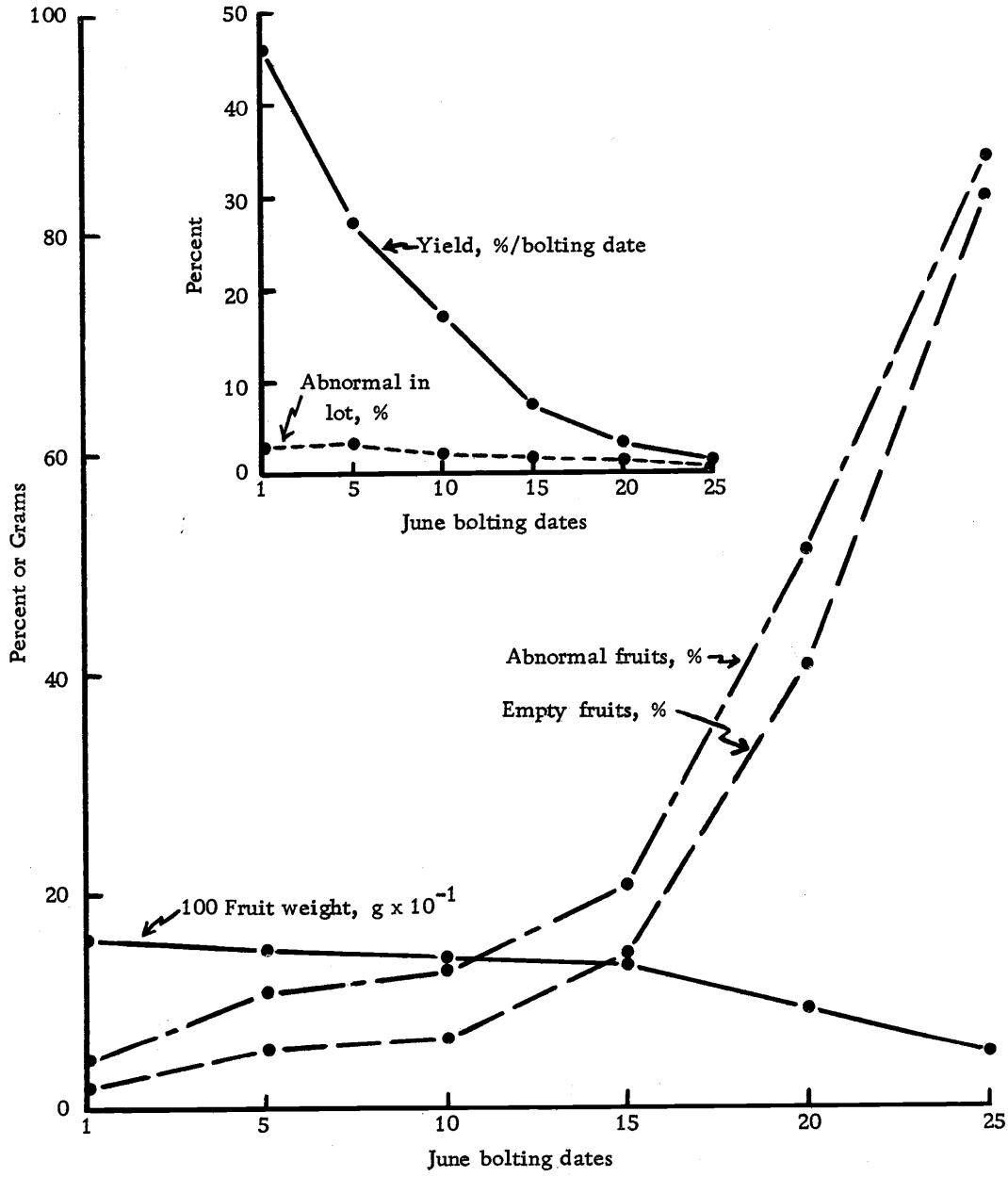

Figure 9. Three fruit and two lot attribute means for the 1970 bolting study. Empty and abnormal fruits increased dramatically, and 100 fruit weight decreased significantly, as bolting was delayed. Inset shows that yield dropped sharply with each delay in bolting, so that the percent abnormal in the lot was essentially unchanged. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

fruits, were, of course, positively correlated with each counterpart (Table A.18). Yield was positively correlated with fruit weight (r = .72**), but negatively correlated with fruit quality (r = -.61** and -.63** for percent empty and abnormal fruits, respectively). Conversely, fruit weight was negatively correlated with fruit quality (r = -.92** and -.93**, respectively).

Location of Abnormal Fruit Development

Plants of six monogerm sugarbeet lines were segmented into four basic parts at harvest. The contribution to yield by the various portions differed significantly at the .005 level of probability. In order of increasing contribution, the yields averaged over six lines were: 7.2, 14.9, 22.7, and 55.2%, respectively, for the upper primary axes, all lateral spurs, upper one-fourth of all lateral branches, and lower three-fourths of the lateral branches. (Figure 10 and Table A.19).

The primary axes produced the largest and the lateral spurs the smallest fruits. Fruits produced on the lateral tips and the late developing secondary and tertiary branches (lateral spurs) contributed slightly but significantly to the occurrence of empty (.05 level) and abnormal (.10 level) fruit. However, empty and abnormal fruits were produced at all locations, averaging 8.0 and 11.3%, respectively, for the entire plant.

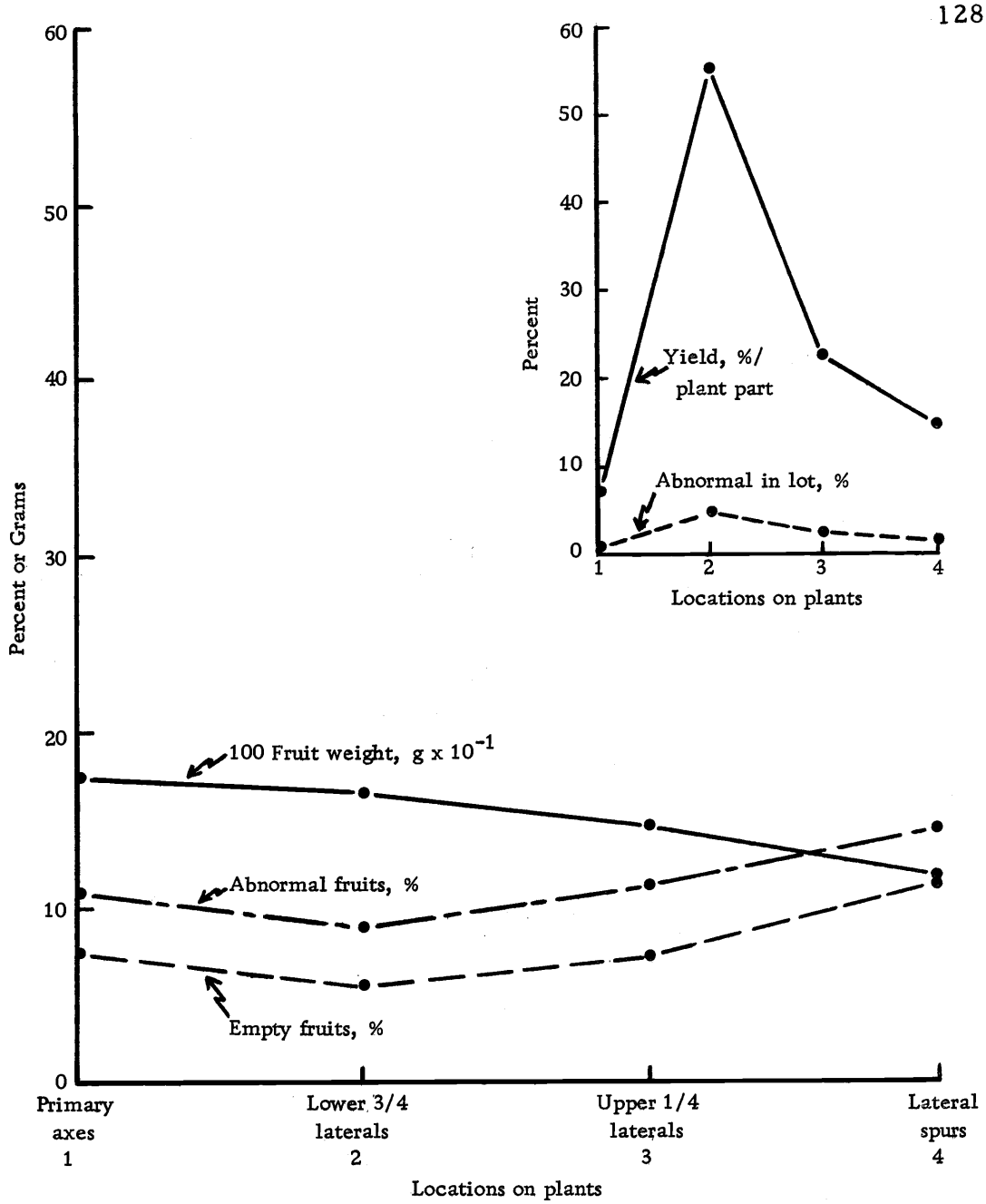

Figure 10. Three fruit and two lot attributes averaged over six lines for the 1970 empty fruit location study. All factors were highly significant (.005 level), except that empty (.05) and abnormal fruit (.10) varied less significantly and increased slightly on the tips and lateral spurs. Inset reveals that 78% of the lot was produced on the main lateral branches so that these postions contained the bulk of the abnormal fruit in the lot. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

The six lines differed significantly (.05 level) in the amount of empty and abnormal fruit produced, as well as in the percent total empty (.005 level) and total abnormal (.05). In addition, there were four significant interactions between lines x locations, including those for fruit weight (.05 level), percent empty and abnormal fruit, and percent empty in the lot (all at the .005 level, as reported in Table A.20). Some lines, especially 3 and 6, produced more empty and abnormal fruit on the lateral spurs than other lines.

Time of Empty Fruit Development

The purpose of this experiment was to determine if immature fruits from prematurely harvested plants 1) contain filled ovarian cavities when first windrowed and then 2) later develop shrunken or empty fruits. Results indicated that both premises were true.

Figure 11 shows that abnormal fruits in lines 1, 2 and 4 increased dramatically while drying naturally on the windrowed plant. Apparently, plants from lines 3, 5 and 6 were more mature. Although they did not respond as sharply, these three lines still produced an increase in abnormal fruit during the drying process.

The percentage of abnormal fruits between fresh and dried examination times differed significantly at the .05 level of t (Table A.21). These results were from single plants of six lines (replicate 3). The lines did not vary significantly in the level of abnormal fruits

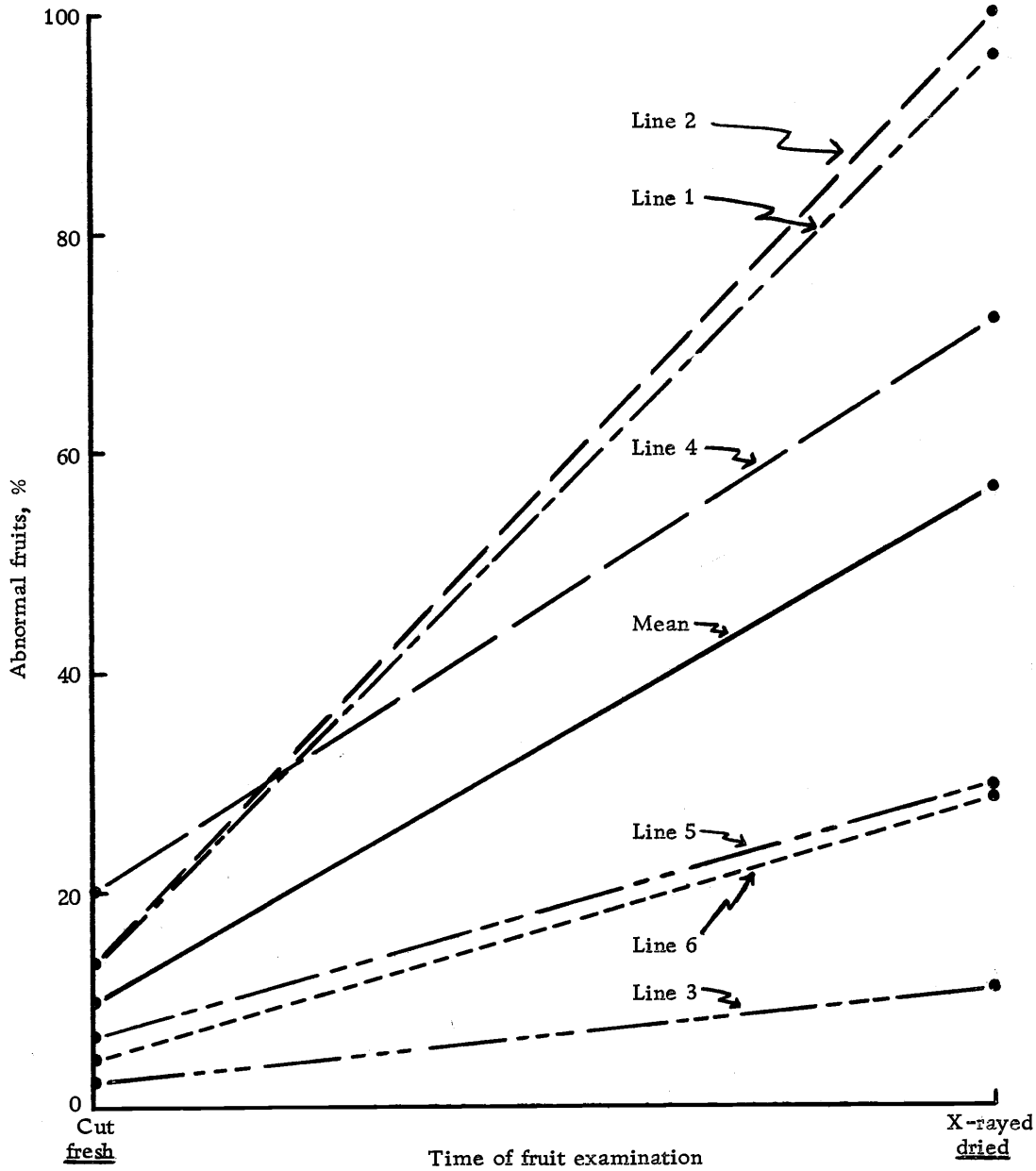

Figure 11. Abnormal fruit levels for the 1970 time of empty fruit development study. Premature harvest of sugarbeets caused empty and underdeveloped fruits to increase dramatically on single windrowed plants of certain lines. The first 100 odd-numbered fruits from the primary tip down were cut fresh from each plant and later compared with 100 even-numbered fruits (same pattern) that were dried naturally on the plant and then X-rayed. Although the fruits were X-rayed in a series from the tip down, there was no consistent pattern to the position of abnormal fruit on the plant.

present when cut fresh immediately after harvest, but did vary significantly when X-rayed dried.

Lygus-Free Caging Study

Insuring the prevention of lygus attack on sugarbeet seed by caging plants from anthesis to harvest did not prevent the occurrence of high levels of empty and abnormal fruit. In fact, while caged plants yielded significantly more (.05 level), they actually produced slightly more empty fruit (.10 level) than fruit from plants that were not caged (39.7 vs. 34.7% for caged vs. uncaged plants, respectively, as reported in Table A.22). All plants had received two regular applications of Diazinon during the growing season to control lygus.

The slight increase in empty fruit was probably due to the small size of this unreplicated experiment. For example, there were no significant differences in the percent total empty (14.7 vs. 15.3%) or the percent total abnormal (18.0 vs. 20.0%) for fruit from caged vs. uncaged plants, respectively. There were no other significant differences between caged and uncaged plants, except for the size class distribution by weight (.005 level).

The four lines of sugarbeets tested differed significantly in yield, proportion of the lot in each size class by weight, and 100 fruit weight (.05, .005, and .01 levels of probability, respectively), but not in the level of empty or abnormal fruit produced, when

averaged over caged and uncaged plants (Figure 12 and Table A.22).

Fruit size measurements resulted in highly significant differences at the .005 level of probability for all seven factors tested, including the size class distribution by weight and by percentage, fruit weight, percent empty and abnormal fruit, and percent empty and abnormal in the lot (Table A.22). As shown in Figure 13, abnormal fruit levels fell dramatically from an extreme of 94% for the small fruit size (5-7/64 inch) to a low of only 6.1% for fruit in the large size class (13-15/64 inch). There were no significant interactions. These findings led to fruit size investigations in several other experiments.

Size class distribution by weight and by percentage were, of course, highly correlated (r = .83**), and both were positively correlated with fruit weight (r = .65** and .68**, respectively). Consequently, these three factors were all negatively and identically correlated with percent empty and percent abnormal fruit (r = -.67**, -.79**, and -.90** for both, as shown in Table A.23).

Percent empty and abnormal fruits (r = .99**), and percent empty and abnormal in the lot (r = .91**), were by their nature of calculation independently and positively correlated with each counterpart. Percent empty in the lot was negatively correlated with the percent size class distribution (r = -.36*) and fruit weight (r = -.46**), but positively correlated with the percentage of abnormal

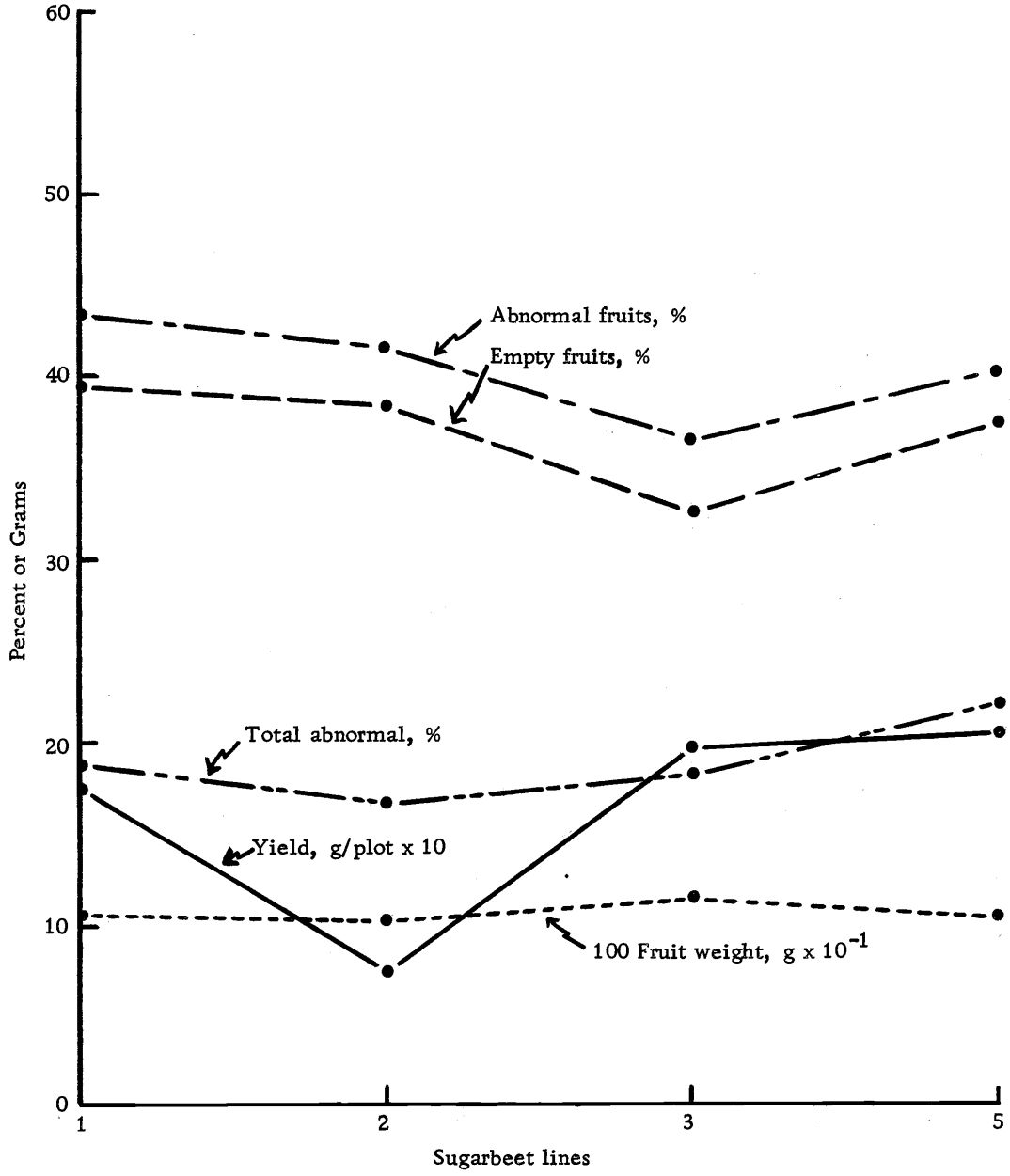

Figure 12. Three fruit and two lot attribute means for the 1970 lygus-free caging study, averaged over caged and uncaged plants for all size classes. Yield and fruit weight varied significantly between lines, but neither fruit quality nor total abnormal differed significantly in this small experiment. (10 g x 10^{-1} = 1 g)

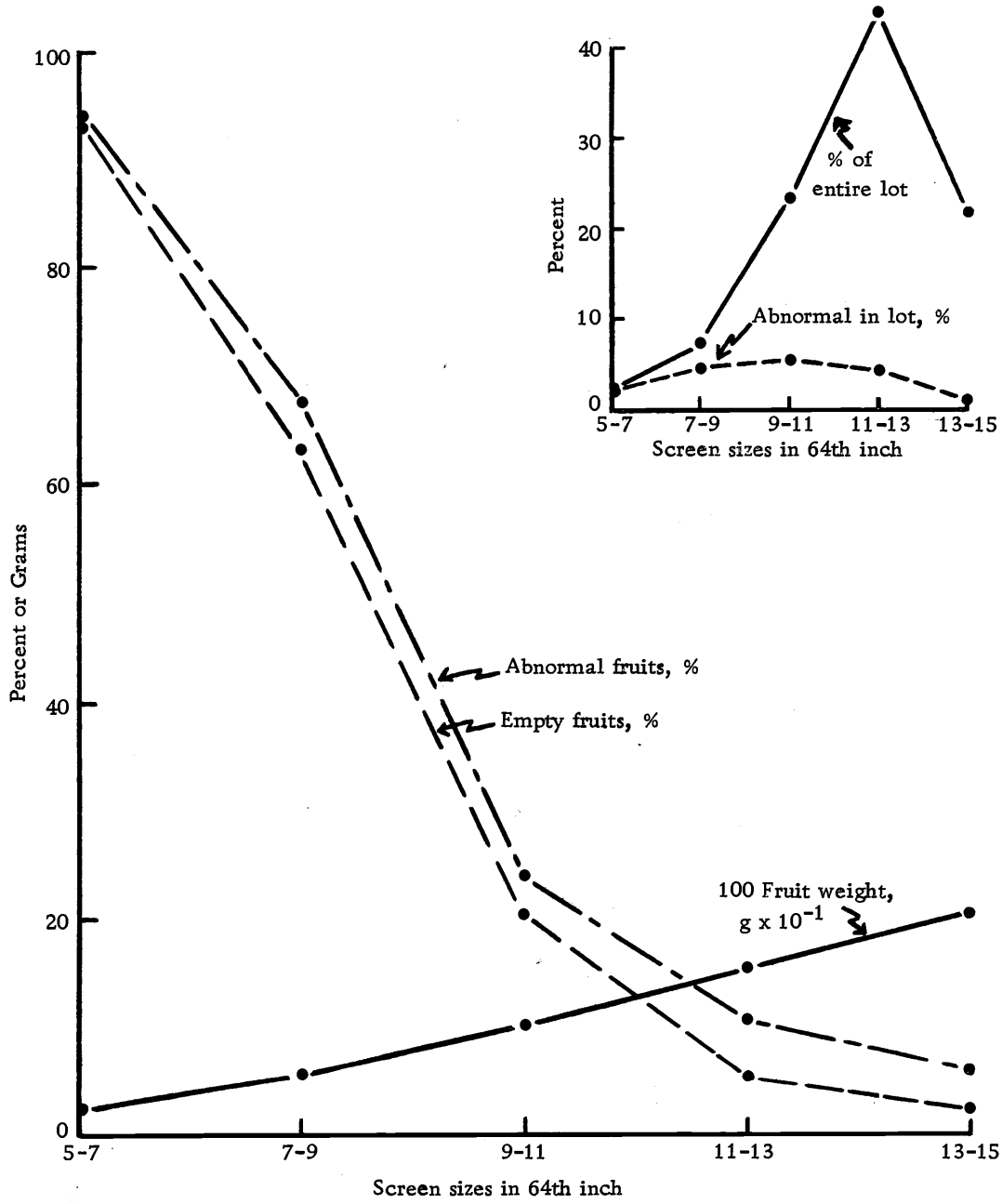

Figure 13. Three fruit and two lot attribute means for the 1970 lygus-free caging study, averaged over caged and uncaged plants for all four lines. The percentage of empty and abnormal fruits dropped sharply as fruit weight and size increased. Inset shows that although small fruits were usually abnormal they constituted only a small portion of the entire lot. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

fruits (r = .41*).

Lodging and Clipping Studies

Clipping Study

All factors investigated in this preliminary, 12-plant clipping study were significantly different at the .05 level or greater. However, according to Duncan's new multiple range test (Table A.24), yield of unclipped check plants did not differ significantly from any other treatment. This was true even though the yield from plants with the primary axes tipped was double that of the check, as shown in Figure 14. Yield of plants with the tipped primary axes was significantly greater than that from plants with clipped laterals or with the top half of the plant removed.

According to the Duncan test, only those fruits produced by plants with the top half removed differed significantly (.05 level) from other treatments in 100 fruit weight, percent empty and percent abnormal fruit. Even so, there was a distinct trend: as fruit weight decreased the percent empty and abnormal fruit increased and increased sharply where clipping was severe.

Lodging-Clipping Study

Lodging and clipping treatments produced several interesting results, but they caused no consistently significant changes in the

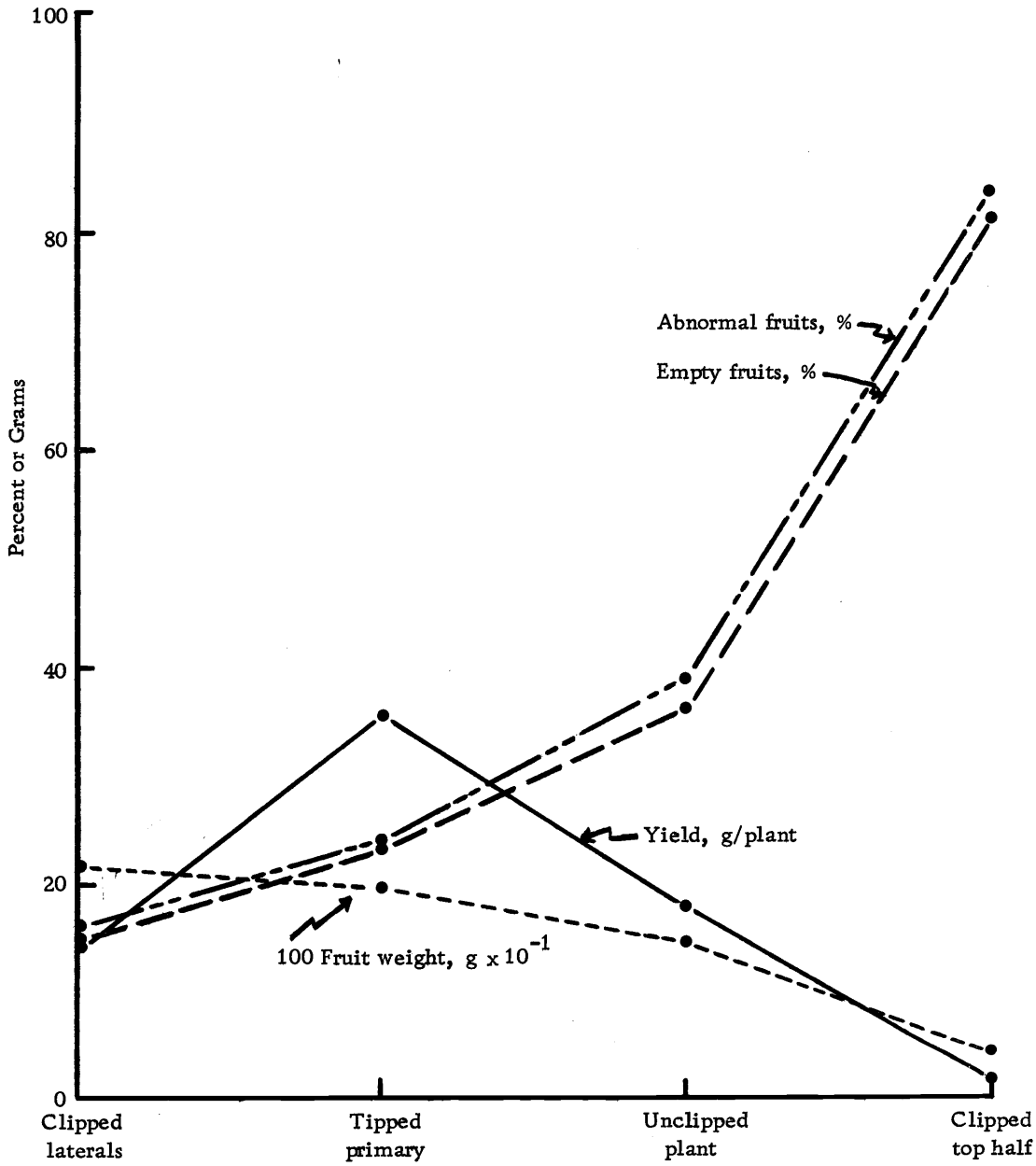

Figure 14. One lot and three fruit attribute means for the 1969 clipping study. All factors differed significantly at the .05 level or greater in this small study, but mainly because of the results obtained where the top half of the plant was removed. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

level of empty and abnormal fruits in this experiment on this sugar-beet line. For example, lodging and clipping treatments resulted in highly significant differences in yield (.005 level), with early lodged plants producing only half as much yield as plants held upright (2,136 vs. 4,359 pounds per acre, respectively). Upright plants yielded significantly more than plants in any other treatment, including the naturally lodged untreated check plants, according to Duncan's new multiple range test (Figure 15 and Table A.25).

The largest fruits were those produced by plants with tipped primary axes, but they differed significantly only from the small fruits (i.e., high count per 10 grams) produced by early and late lodged plants (Figure 15). Neither fruit weight, percent total empty, nor percent total abnormal differed significantly for any of the lodging or clipping treatments.

The method of counting fruits for examination resulted in important differences on the level of empty and abnormal fruits. For example, fruit quality levels failed to differ significantly for any treatment where 100-fruit subsamples were counted by hand from each of the five fruit size categories per treatment (Figure 16 and Table A.25). On the other hand, 400 vacuum counted unsized fruits per treatment resulted in significant differences for empty (.01 level) and abnormal (.10 level) fruits, mainly because the vacuum counter head tended to suck into the holes a disproportionate amount of small

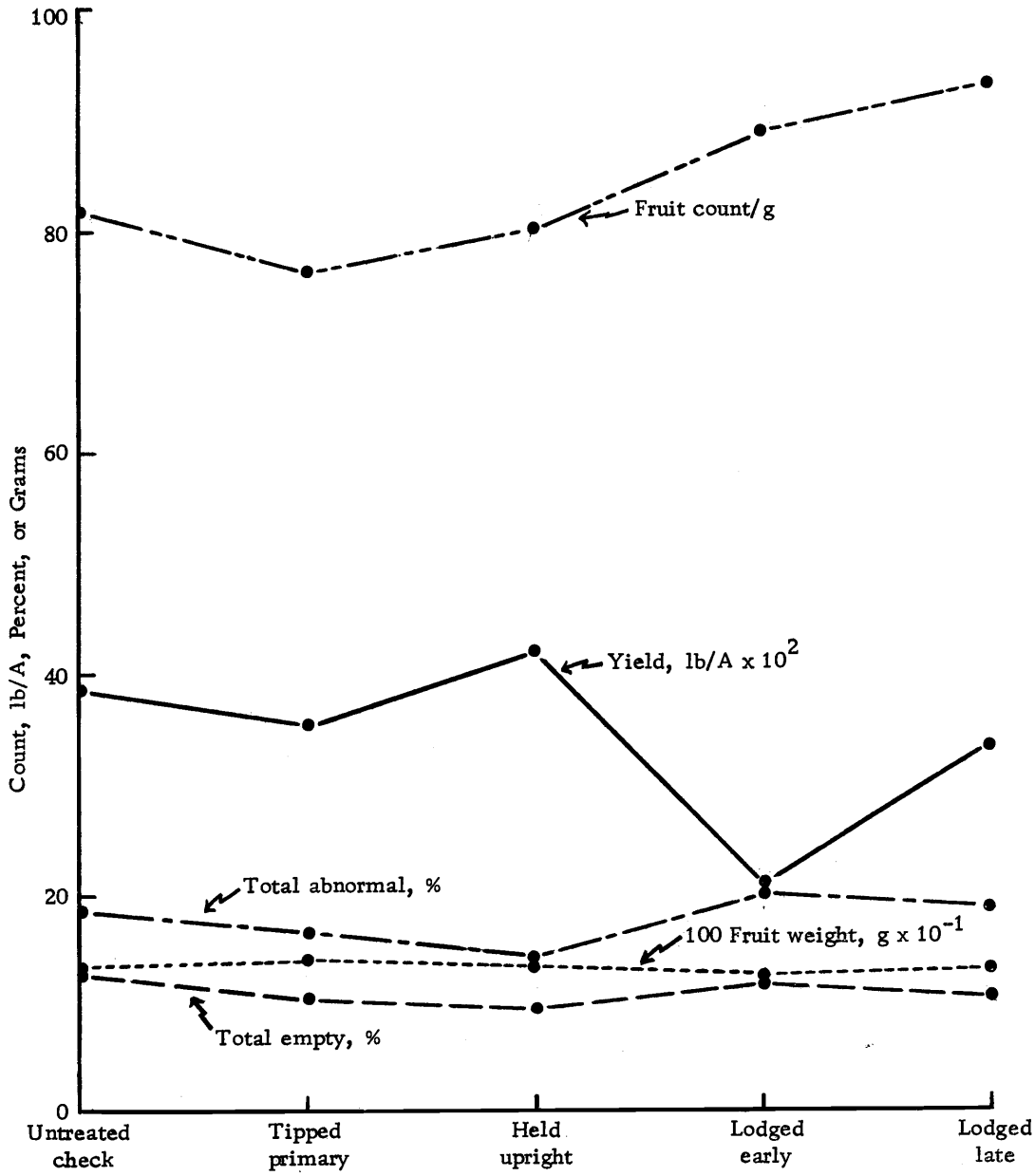

Figure 15. Three fruit and two lot attribute means for the 1970 lodging study. Only fruit count and yield differed significantly (.005 and .05 levels, respectively). Lodged plants produced significantly less yield and smaller fruits than unlodged or clipped plants. (40 lb/A x 10^2 = 4,000 lb/A)

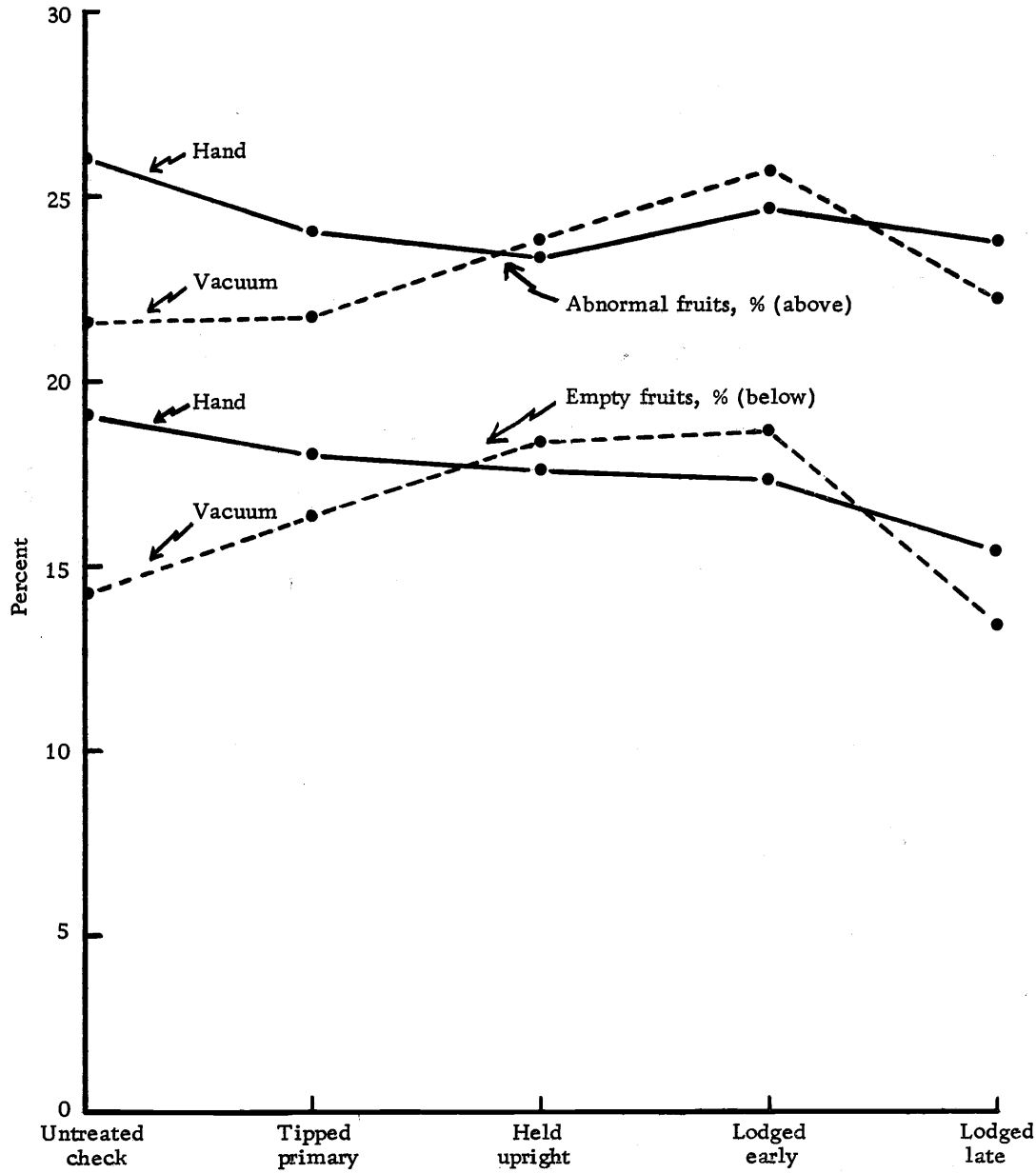

Figure 16. Occurrence of empty and abnormal fruit in the 1970 lodging study. Hand counting five 100-fruit subsamples of sized fruits resulted in no significant differences for any treatment. Vacuum counting four 100-fruit subsamples of unsized fruits resulted in significant differences for empty and abnormal fruit (.01 and .10 levels, respectively).

fruit in certain treatments.

Sizing sugarbeet fruits into five categories of 5-7, 7-9, 9-11, 11-13, and 13-15/64th inch resulted in highly significant differences (.005 level) for all factors studied. As partially shown in Figure 17 and reported in entirety in Table A.25, fruit in each size class differed significantly and dramatically for almost every factor, according to Duncan's new multiple range test. This included differences in size class distribution by weight and by percentage (percent of entire lot), 100 fruit weight, empty and abnormal fruit, and percent empty and abnormal in the lot. These results strongly support the importance of fruit size on fruit quality.

There were four, treatment x fruit size interactions that differed significantly at the .05 level of probability or greater, as reported in Table A.26. This included the five treatments for size class by weight and by percentage, fruit weight, and percent abnormal in the lot vs. the five fruit sizes mentioned in the preceding paragraph. In general, these interactions revealed that plants with tipped primary axes produced significantly more and heavier large fruits and lodged plants produced significantly more small fruits of poor quality, but the latter did not differ significantly from fruits produced by untreated check plants.

The results from this study produced few legitimate correlations (Table A.27). For example, percent empty vs. percent

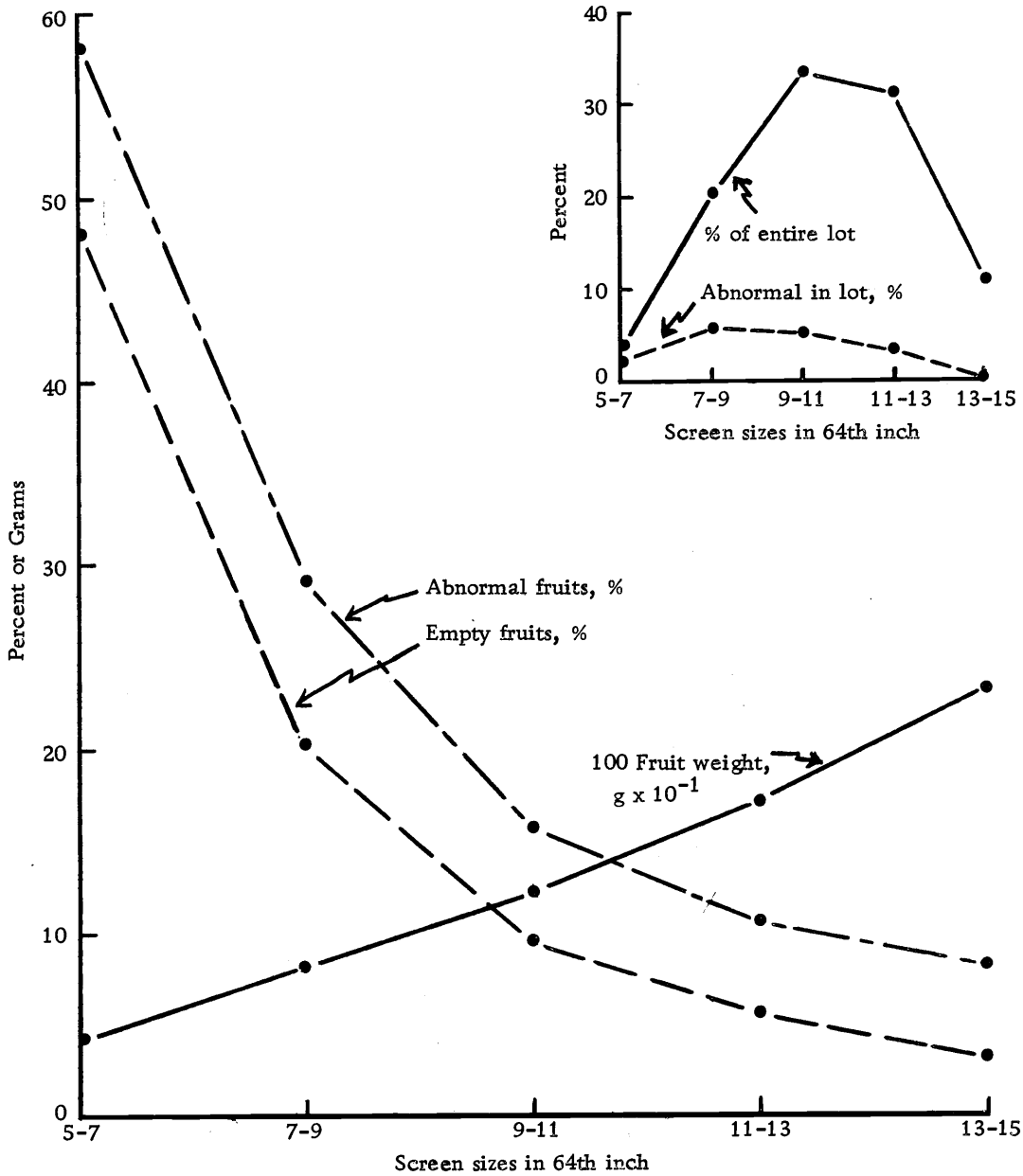

Figure 17. Three fruit and two lot attribute means averaged over five treatments for the 1970 lodging study. All factors differed significantly at the .005 level of probability. The percentage of empty and abnormal fruits dropped sharply as fruit weight and size increased. Inset shows that although small fruits were frequently abnormal, they constituted only a small portion of the entire lot. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

abnormal hand counted fruits (r = .74**), percent empty vs. percent abnormal vacuum counted fruits (r = .90**), and percent empty vs. percent abnormal in the lot (r = .80**) were, by their nature, highly correlated with each counterpart. Otherwise, only yield was negatively correlated with fruit weight (r = -.49*), percent empty hand counted fruits were positively correlated with percent empty in the lot (r = .69**), and percent abnormal hand counted fruits were positively correlated with both percent empty and percent abnormal in the lot (r = .68** and .79**, respectively).

Seed Sizing and Agronomic Practices

Results from these studies indicated that fruit size and agronomic practices such as date of planting and date of harvest play vital roles in determining the quality of sugarbeet fruits produced. Small fruits were frequently empty and abnormal, although the level varied from lot to lot.

Crocker Seed Sizing Study

When sugarbeet fruits were screened into five categories of 5-7, 7-9, 9-11, 11-13, and 13-15/64 inch sizes, highly significant differences (.005 level) were obtained for all factors studied. This included size class distribution by weight and by percentage, 100 fruit weight, percent empty and abnormal fruits, and percent empty

and abnormal in the lot (Table A.28). In addition, the level of empty fruits in the four original samples received from the grower differed significantly at the .05 level of probability.

As shown in Figure 18, fruit quality improved dramatically as empty and abnormal fruits dropped sharply from 80 and 88%, to 8.5 and 20%, respectively, with consistent increases in fruit size and weight. Fruit quality was still considered poor in the largest fruit size category, however (i.e., 20% abnormal in the 13-15/64th inch size). Small fruits constituted a proportionately minor portion of the lot. The totals revealed that 18.9 and 32.9% of the Crocker seed was empty and abnormal, respectively.

Removing fruits that passed through the 7/64 or the 9/64th inch round hole screens reduced the size of the original lot by only 0.4 and 5.5%, respectively, but this improved X-ray germination from the original 67.1 to 67.5 and 79.6%, respectively, as shown in Figure 21.

Commercial Seed Sizing Study

When samples of sugarbeet fruits from ten commercially processed lots were screened into five size classes, highly significant differences (.005 level) were obtained for every factor studied. This included size class distribution by weight and by percentage, 100 fruit weight, percent empty and abnormal fruits, and percent

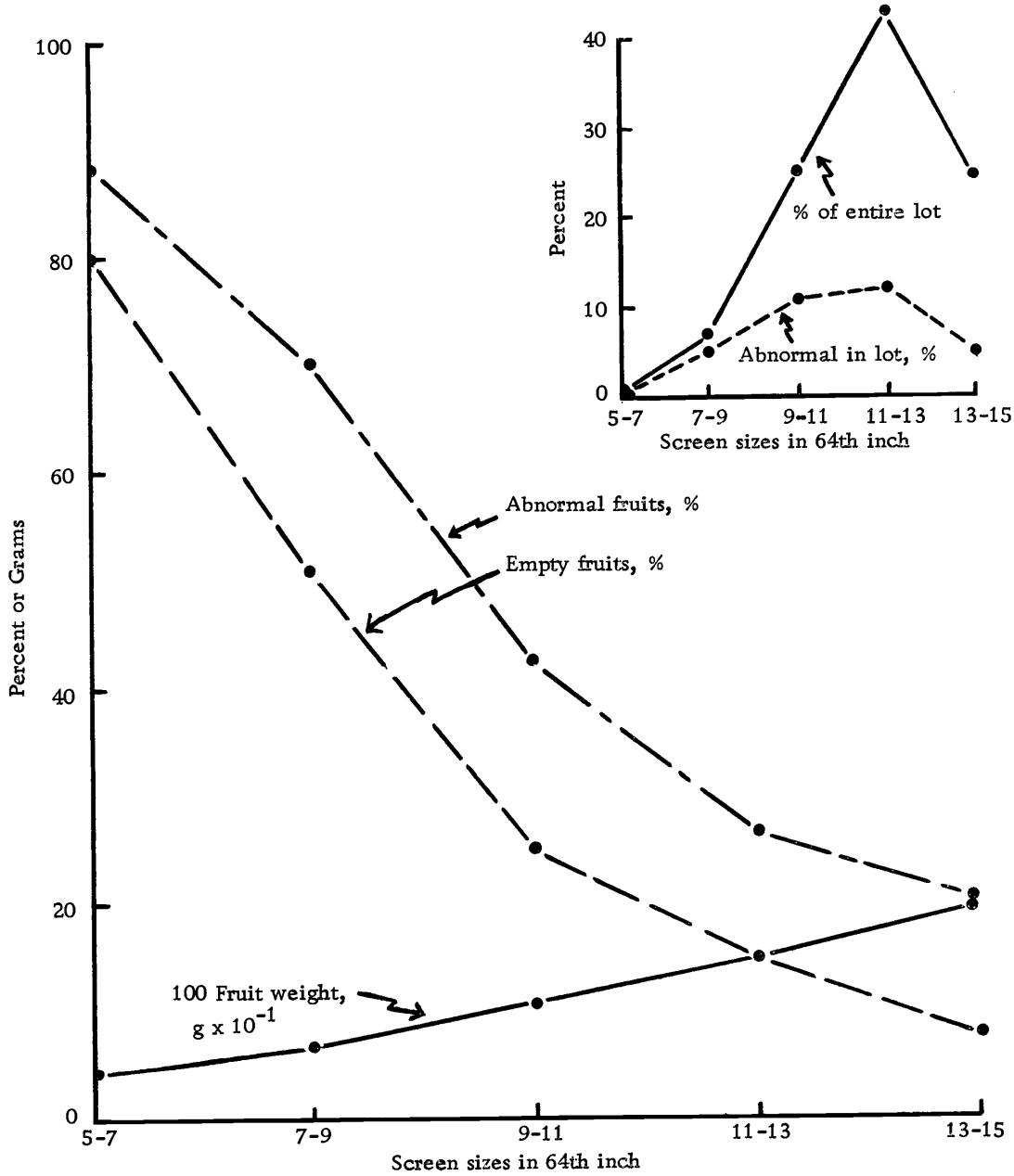

Figure 18. Three fruit and two lot attribute means for the 1970 Crocker seed sizing study. All factors differed significantly (.005 level). Empty and abnormal fruit levels fell dramatically with each increase in fruit size and weight. Inset shows that small fruits constituted a small portion of the entire lot, but percent abnormal in the lot was significantly greater in the 9 to 13/64th inch size classes than in either smaller or larger size categories. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

empty and abnormal in the lot (Table A.29). In addition, the ten commercial lots differed significantly in percent empty and abnormal fruits (.01 level), as well as the empty (.01) and abnormal (.05) in the combined lots.

As shown in Figure 19, the percentage of empty and abnormal fruit for all commercial lots dropped sharply from 57.5 and 66.8% to 2.2 and 6%, respectively, with consistent increases in fruit size and weight. Small fruits constituted only a small portion of the entire lot. In this case, however, the abnormal in all lots was significantly greater in the 7 to 11/64th inch size classes than in either the smaller or larger size categories.

As reported in Table A.30, high natural correlations included size classes by weight vs. by percentage, percent empty vs. abnormal fruits, and percent empty vs. abnormal in all lots ($r = .97^{**}$, $.99^{**}$, and $.96^{**}$, respectively). Both size classes by weight and by percentage were positively correlated with both percent empty and abnormal in the lot ($r = .48^{**}$ and $.65^{**}$ for weight plus $.50^{**}$ and $.65^{**}$ for percent, respectively). Also, the percent empty fruit was poorly but positively correlated with percent empty in the lot ($r = .29^{*}$).

The important relationships were that both size class by weight and by percentage were highly correlated with fruit weight ($r = .52^{**}$ and $.95^{**}$, respectively), and fruit weight was negatively correlated

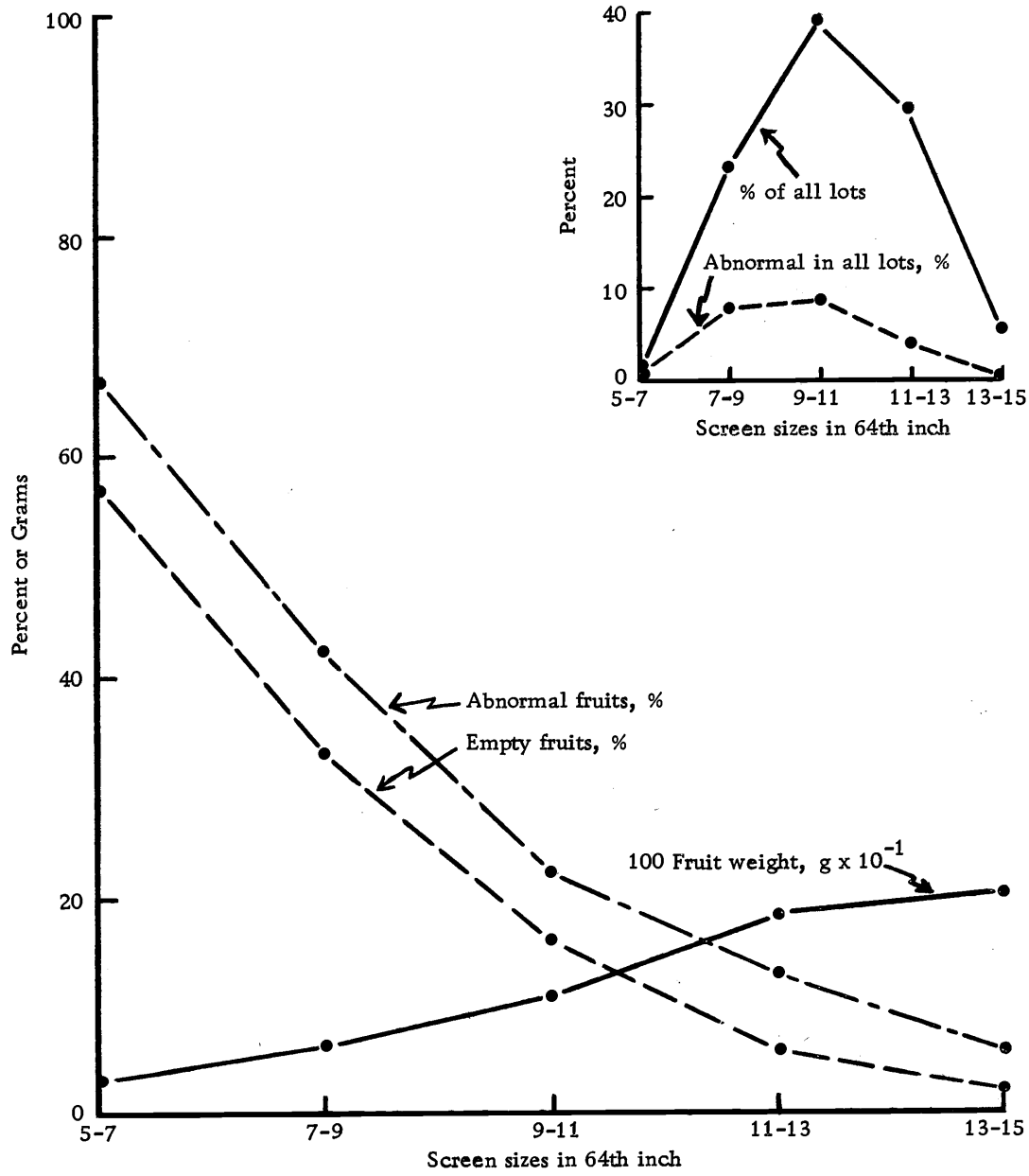

Figure 19. Three fruit and two lot attribute means averaged over ten lots for the 1970 commercial seed sizing study. All factors differed significantly (.005). Small fruits were significantly more abnormal than large fruits, despite the fact that all lots were first commercially processed for shipment to sugarbeet companies. Inset shows that small fruits constituted a small portion of all lots, so that the medium size classes were significantly more abnormal than smaller or larger classes. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

with the percent empty and abnormal fruits (r = -.62** and -.64**, respectively).

The ten commercial samples were increasingly empty and abnormal (1 to 10) and some samples differed significantly from each other in fruit quality (Table A.29). However, each lot had to be examined individually to observe the distribution pattern of the percentage of abnormal fruit. As shown in Figure 20, lots varied greatly in the level of abnormality in the different size classes, but the pattern for all lots again revealed the generally detrimental effect of small seeds on fruit quality.

The Crocker lot, the mean of the ten commercial lots, and each of the ten commercial lots were examined from the standpoint of improving the X-ray germination by discarding fruits that fell through the 7/64th or the 9/64th round hole screens. This resulted in reductions in weights (by percentage) from the original lot. This varied greatly from lot to lot, depending on the size class distribution pattern of the lot in question, as shown in Figure 21.

The fruit quality of the ten commercial lots was compared with known agronomic practices such as date of planting, date of spray for lygus control, and date of swathing, as reported in Table A.29. Simple correlations reported in Table A.31 revealed that the total empty vs. total abnormal (r = .98**), both total empty and total abnormal vs. X-ray germination (r = -.98** and -.99**,

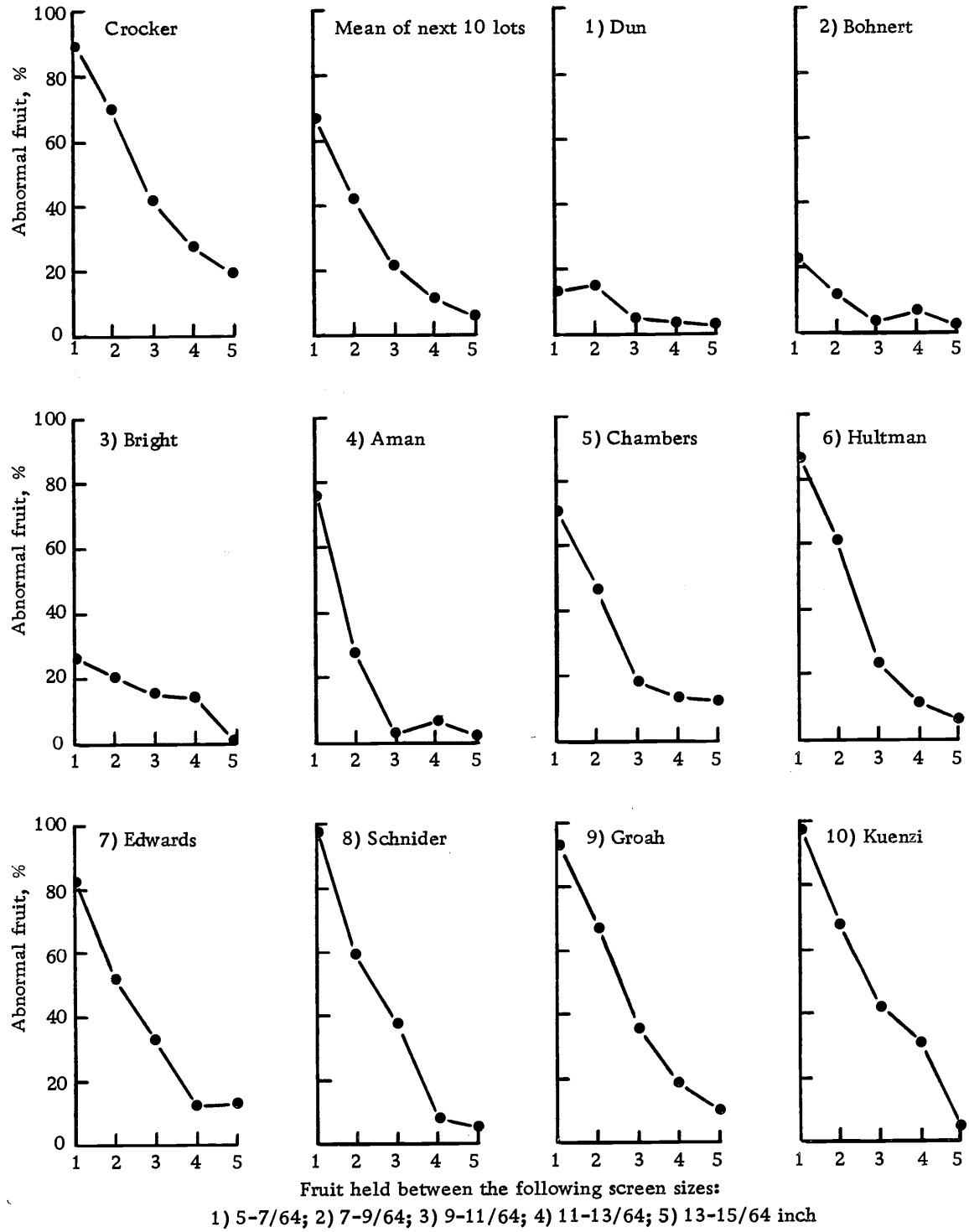

Figure 20. Profiles of abnormal fruit levels for the 1970 Crocker and commercial seed sizing studies. Small fruits were consistently and often dramatically abnormal. The ten lots differed significantly (.005 level) in the amount of abnormal fruit. Each lot must be examined individually.

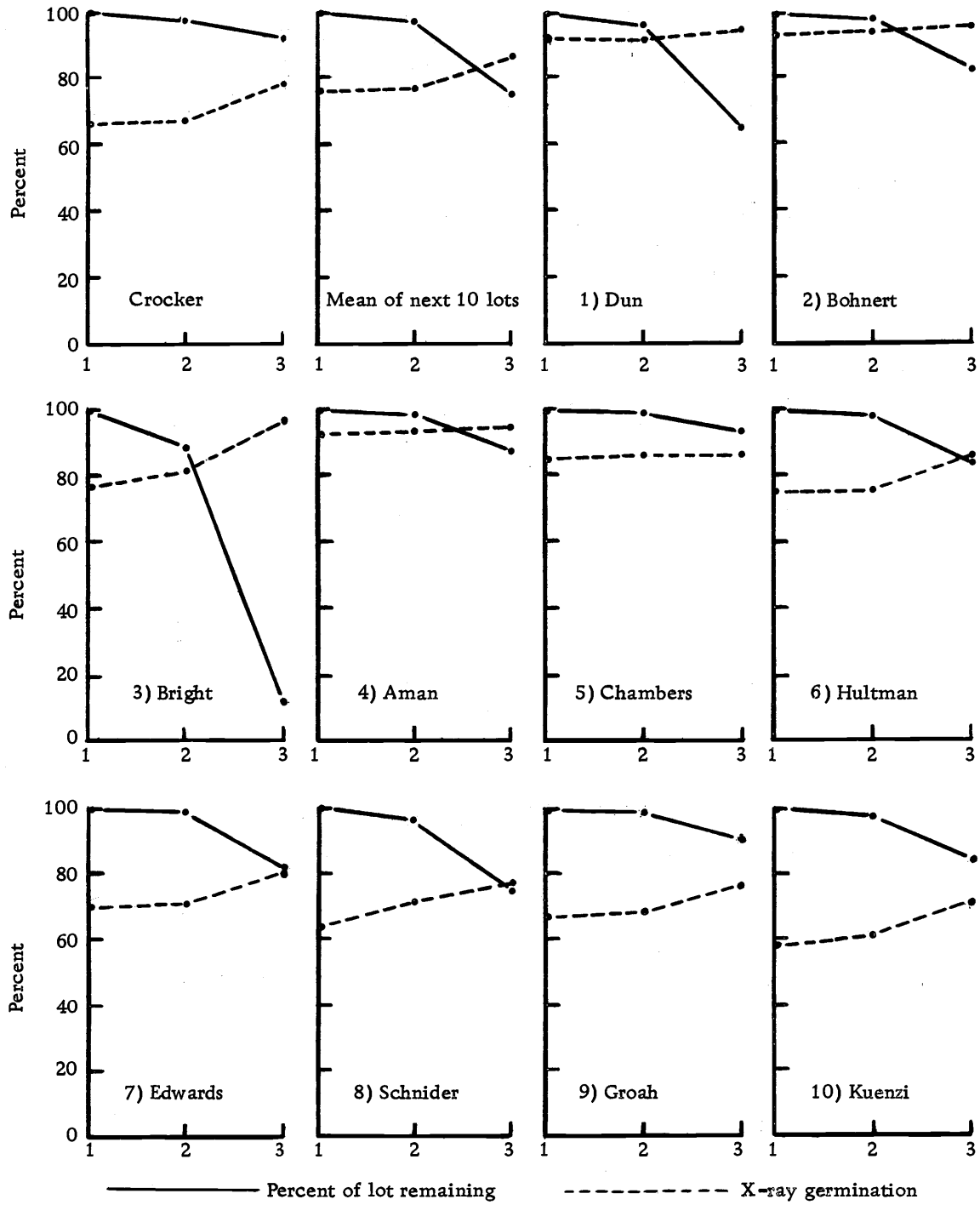

Figure 21. Lot weight decreases and germination increases for the 1970 Crocker and commercial seed sizing studies. Although X-ray germination of most lots was improved considerably by discarding small fruits passing through 7/64th or even 9/64th inch round hole screens, certain lots were seriously reduced in weight. Each lot must be considered independently.

respectively), date planted vs. date sprayed (r = -.87**), and date sprayed vs. date swathed (r = -.83**) were all significant but spurious correlations.

The important findings were that laboratory germination was highly and positively correlated with X-ray germination (r = .94**), and, conversely, negatively correlated with the percentages of the total empty and total abnormal (r = -.96** and -.94**, respectively). In addition, of the three agronomic practices investigated, only date of planting was consistently and highly correlated with fruit quality (Table A.31).

Date of planting was negatively correlated with both X-ray and laboratory germination (r = -.79** and -.70**, respectively), and positively correlated with percent total empty and total abnormal (r = .77** and .79**, respectively). In other words, as date of planting was delayed--especially when later than August 10, fruit quality decreased consistently (Figure 22).

Effect of Pesticides and Growth Regulators

All pesticides and most growth regulators at specific rates caused detrimental effects on fruit quality, when sprayed on sugarbeets at early bolt to peak anthesis. In no case did any chemical treatment reduce the level of empty and abnormal fruits below that of the check, except in one study where the abnormal fruits in the

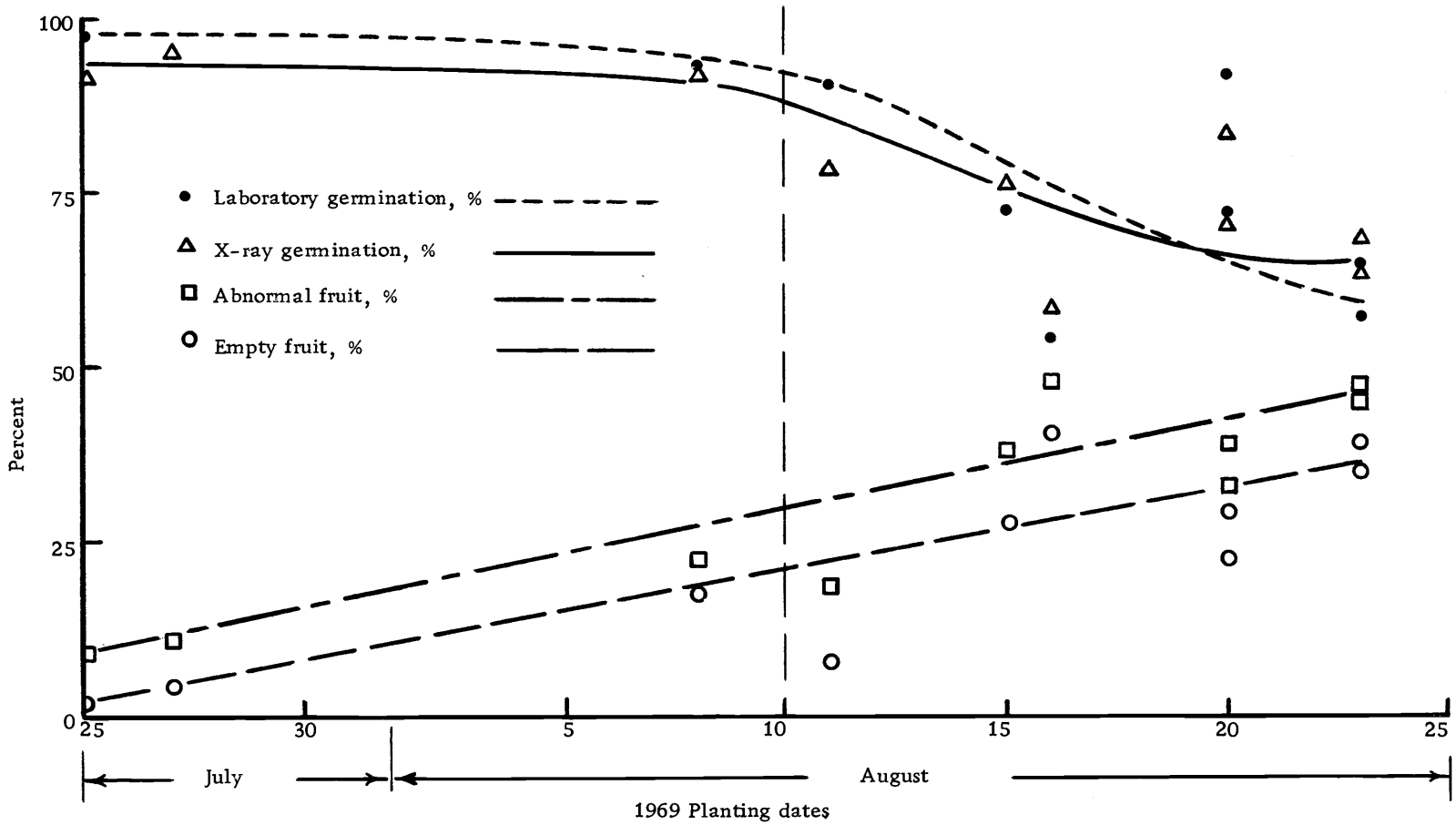

Figure 22. Fruit quality attribute means and the 1969 planting dates for the 1970 commercial seed sizing study. There was a high negative correlation between X-ray germination and planting date ($r = -.79^{**}$). Fruit quality dropped as the percent empty and abnormal fruit rose. Germination remained high as long as the crop was planted by August 10. X-ray germination for lot No. 3, planted on August 11, dipped partly because the crop was swathed at only 38 days after peak anthesis. All curves were plotted.

check were at a high 20% level. Most fruits affected were empty and were probably parthenocarpic, but microscopic examinations were not made.

Chemical Spray Studies

An insecticide (DDT), two herbicides used on sugarbeets to control weeds (Endothal and IPC), and two growth regulators (2, 4-D and GA_3) caused highly variable and inconsistent results between years, when sprayed on sugarbeet plants at peak anthesis vs. late anthesis. This was probably due to the importance of timing of the chemical application.

In the 1969 DeFord chemical spray study during the first year, neither dry matter of windrowed plants nor fruit yield varied significantly for the 16 treatments. However, 100 fruit weight, percent empty and percent abnormal fruits differed significantly at the .005 level of probability (Table A.32).

As shown in Figure 23, yield varied widely but not significantly. For 100 fruit weight, only 2, 4-D and IPC treatments at the high rate of 10^{-3} M and IPC at the medium rate of 10^{-6} M produced fruits significantly lighter than those produced by the untreated check, according to Duncan's new multiple range test. Treatment with DDT or GA_3 at 10^{-3} or GA_3 at 10^{-6} M produced fruit significantly heavier than those of the check, as shown in Figure 24 and reported in

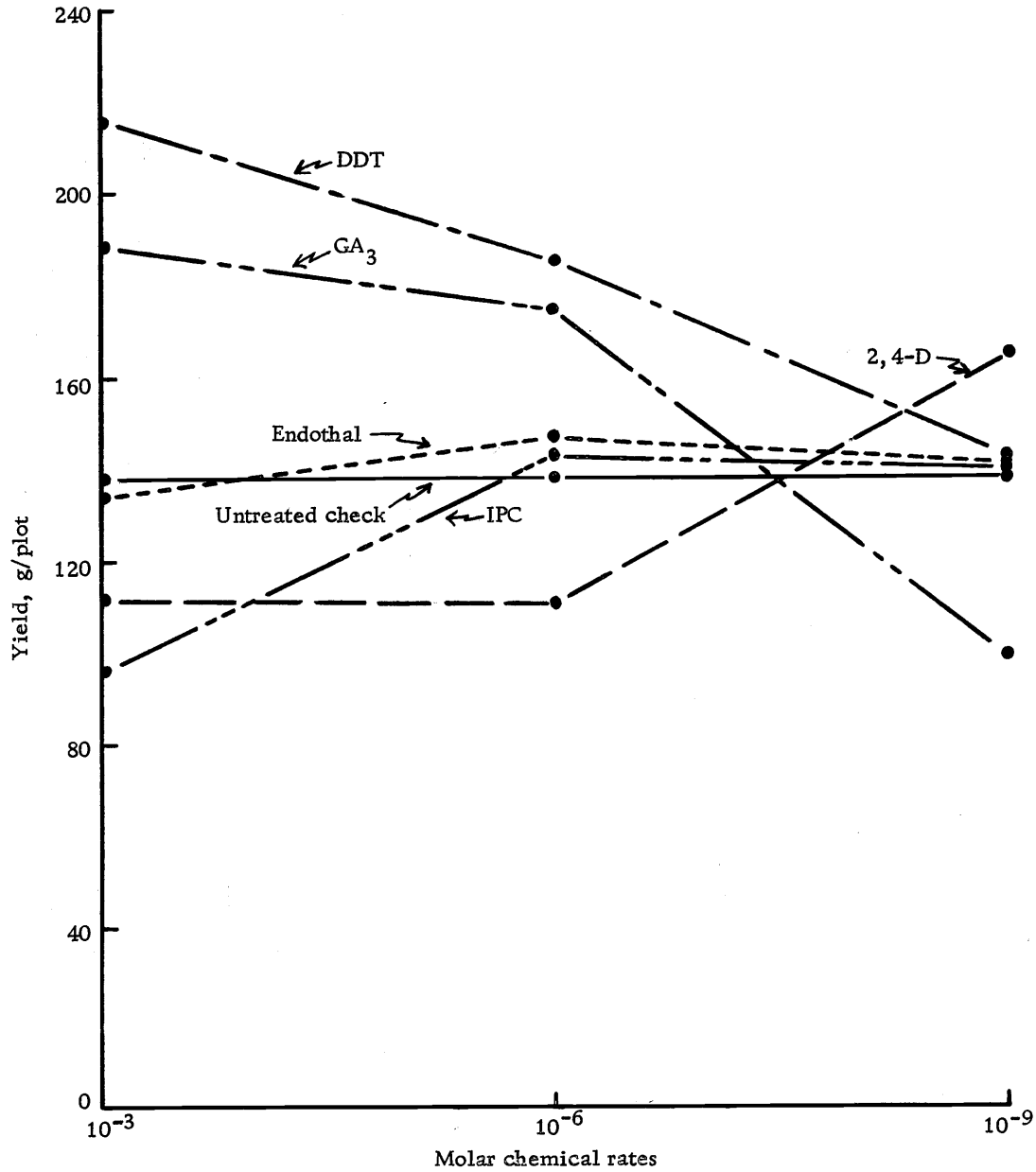

Figure 23. Fruit yield for the 1969 DeFord chemical spray study. Yield varied widely but not significantly for the 16 treatments. Each plot consisted of four healthy plants, selected visually in June on the basis of uniformity for size and maturity.

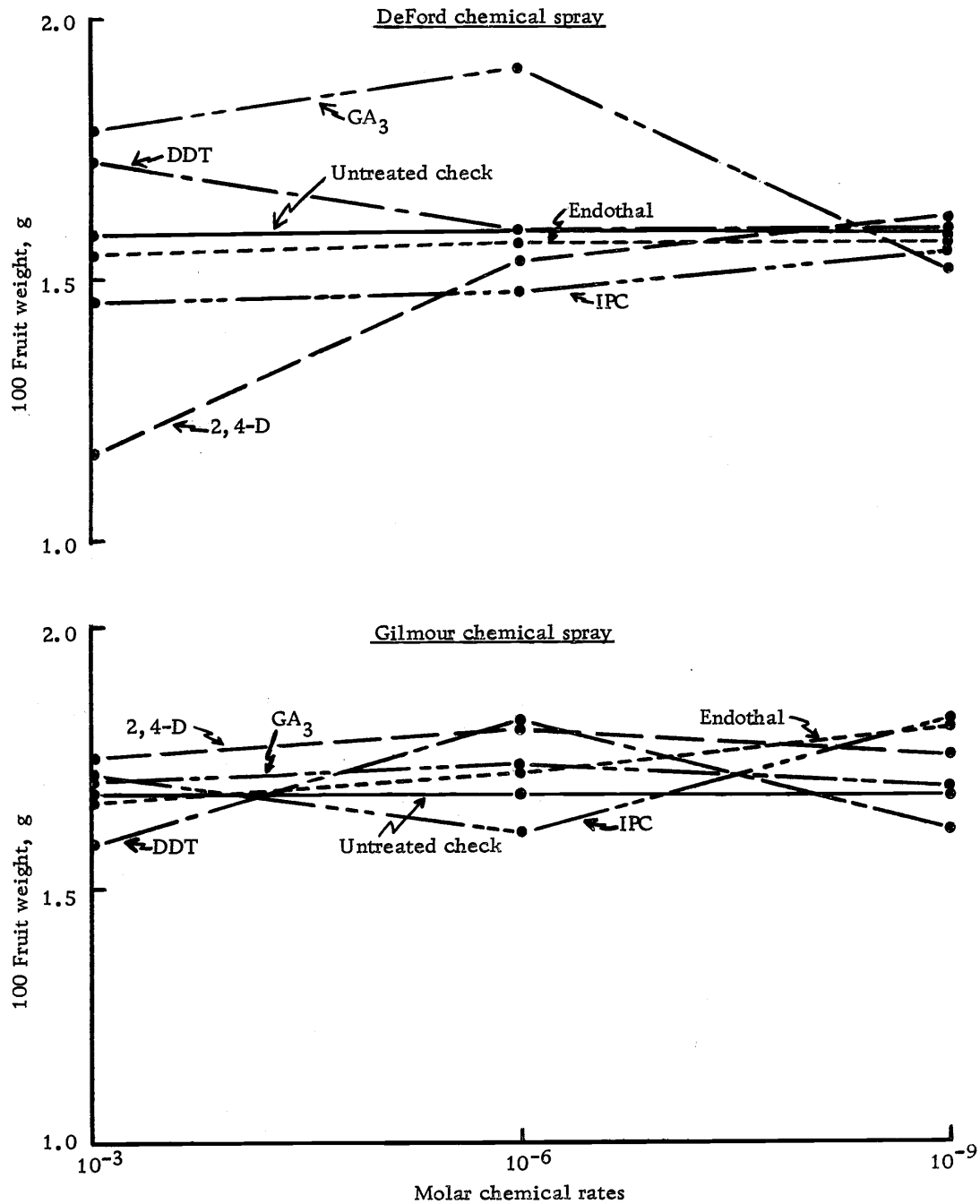

Figure 24. Fruit weight for both the 1969 DeFord and the 1970 Gilmour chemical spray studies. Although fruit weight differed significantly in both studies (.005 level), it varied widely only in the DeFord study where the six treatments (three higher, three lower) differed significantly from the check. In the Gilmour study, five treatments (four higher, one lower) differed significantly from the check.

Table A.32.

Chemical treatments produced essentially identical results in percent empty and percent abnormal fruits, so only the level of abnormal fruits are given here. As shown in Figure 25, certain chemical treatments induced serious increases in the level of abnormal fruits, when the chemicals were sprayed on plants at peak anthesis. All results above 20% abnormal fruit differed significantly from those of the check, including 2, 4-D at 10^{-3} and 10^{-6}, GA_3 at all three rates, DDT at 10^{-6} and 10^{-9}, as well as Endothal and IPC at the high 10^{-3} M rate. The high and the medium rate of 2, 4-D caused 54.2 and 42.7% abnormal fruits, respectively, which was significantly higher than all other treatments and significantly different from each other.

In the 1970 Gilmour chemical spray study during the second year, the dry matter of windrowed plants was not determined and yield again did not differ significantly. However, 100 fruit weight, as well as percent empty and percent abnormal fruits--whether counted by hand or by a vacuum, all differed significantly at the .01 level of probability or greater (Table A.33).

Although the same male sterile line was used in both years on the same farm (DeFord was a tenant during 1969), the results from the two years differed markedly, mainly because the 1970 spray applications were delayed until late anthesis due to an irrigation

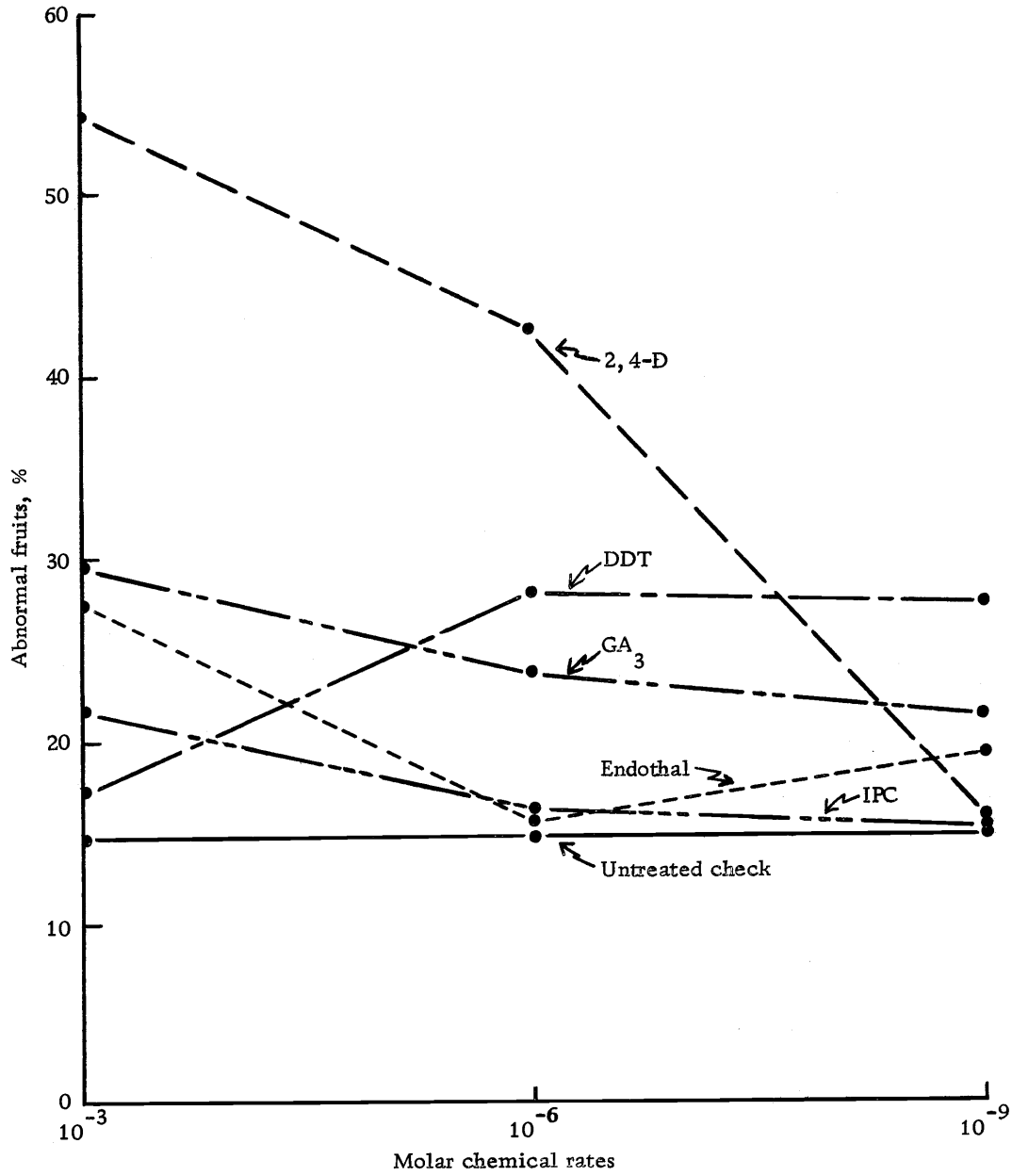

Figure 25. Abnormal fruits for the 1969 DeFord chemical spray study. All nine treatments with more than 20% abnormal fruits differed significantly from the check. The two 2, 4-D treatments produced significantly more abnormal fruits than any other treatment and also differed significantly from each other. There was no essential difference in the shape of the graph between empty fruits (not shown) and the abnormal fruits (empty + underdeveloped).

and then rain.

In the Gilmour study, only the DDT treatment at 10^{-3} M produced fruits that were significantly lighter than those produced by the check. Fruits heavier than those of the check were produced by DDT and 2, 4-D at the medium rate, and IPC and Endothal at the low chemical treatments. Even so, there were no wide differences in fruit weight in the Gilmour study, as shown in Figure 24.

In order to speed the counting process, fruits from the Gilmour study were first counted with a vacuum plate. The results for abnormal fruit are shown in Figure 26 and reported in Table A.33. It was assumed that a disproportionate number of small fruits were being drawn to the holes of the vacuum counter plate, so new fruits were hand counted and examined by X-ray in the manner similar to that used in the DeFord study.

The results from the two methods of counting gave similar major trends, except for three serious reversals including that of the check, Endothal at 10^{-6}, and IPC at 10^{-9} M. In addition, the grand mean of vacuum counted fruits was exactly twice that of hand counted fruits, indicating that many large fruits were evaluated by the hopefully unbiased hand counting method.

For vacuum counted fruits, only the 2, 4-D treatment at 10^{-3}, as well as those of 2, 4-D and DDT at 10^{-9} M produced many abnormal fruits, but only the high 2, 4-D treatment differed significantly

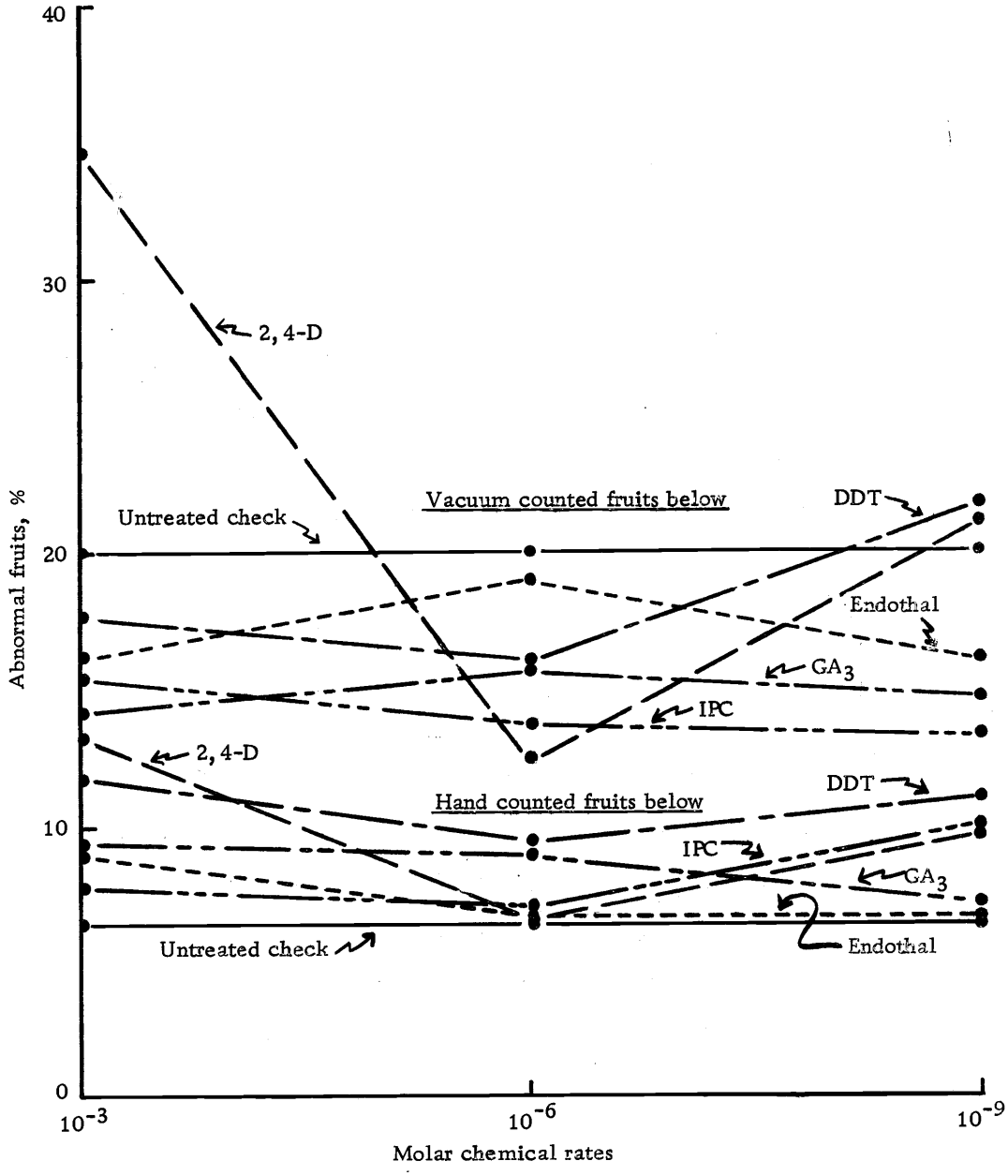

Figure 26. Abnormal fruits by both the vacuum and the hand counting methods for the 1970 Gilmour chemical spray study. For vacuum counted fruits, only 2, 4-D at the high rate produced significantly more abnormal fruits than the high check. For hand counted fruits, 2, 4-D at 10^{-3}, and DDT at 10^{-3} and 10^{-9} M differed significantly from the low check. Small fruits predominated with the vacuum counting method, while average fruits predominated with the hand counting method.

from the unusually high check. Due to the high check, treatments of GA_3 at 10^{-3}, 2, 4-D and IPC at 10^{-6}, and IPC at 10^{-9} M all produced significantly fewer abnormal fruit than the check, as shown in Figure 26.

For hand counted fruits, only 2, 4-D and DDT at 10^{-3}, as well as DDT at 10^{-9} M, produced significantly more abnormal fruits than that of the low check (Figure 26 and Table A. 33).

An examination of the simple correlations given in Table A. 34 revealed that empty fruits were, by their nature, well correlated with abnormal fruits in the DeFord study (r = .99**), and in the Gilmour study, whether fruits were counted by hand or by vacuum (r = .81** and .93**, respectively). In the Gilmour study, hand counted vs. vacuum counted fruits were well correlated for both percent empty (r = .62**) and percent abnormal (r = .50**), and even for hand counted empty fruits vs. vacuum counted abnormal fruits (r = .66**) or hand counted abnormal fruits vs. vacuum counted empty fruits (r = .38**).

Of the important relationships, yield was positively correlated with fruit weight (r = .55**) and fruit weight negatively correlated with percent empty and percent abnormal fruit (r = -.38** and -.38**) only in the DeFord study. In contrast, yield was negatively correlated with the percent empty and abnormal fruits only in the Gilmour

study and then only when the fruits were hand counted (r = -.40** and -.43**).

Greenhouse Growth Regulator Studies

In the 1970 greenhouse study No. 1 (male sterile line F66-562HO planted on August 15, 1969), stalk height of 24 uniformly selected plants varied significantly by replication throughout the seven weeks that measurements were made (Table A.35). Stalk height also varied significantly by treatment, after spraying at peak anthesis.

Although yield, 100 fruit weight, percent empty and percent abnormal fruits varied widely, only yield differed significantly and then only at the .10 level of probability, as shown in Figure 27 and reported in Table A.35.

In the 1970 greenhouse study No. 2 (male sterile line F68-546H3 planted on September 8, 1969), stalk height of 24 uniformly selected plants varied significantly by replication only during the first four weeks (.10 level). Stalk height never varied significantly by treatment during the seven weeks that measurements were made (Table A.36).

All other factors varied widely in this study, and only the percentage of empty fruits never varied significantly. Yield (.05 level), fruit weight (.10 level), and percent abnormal fruits (.10

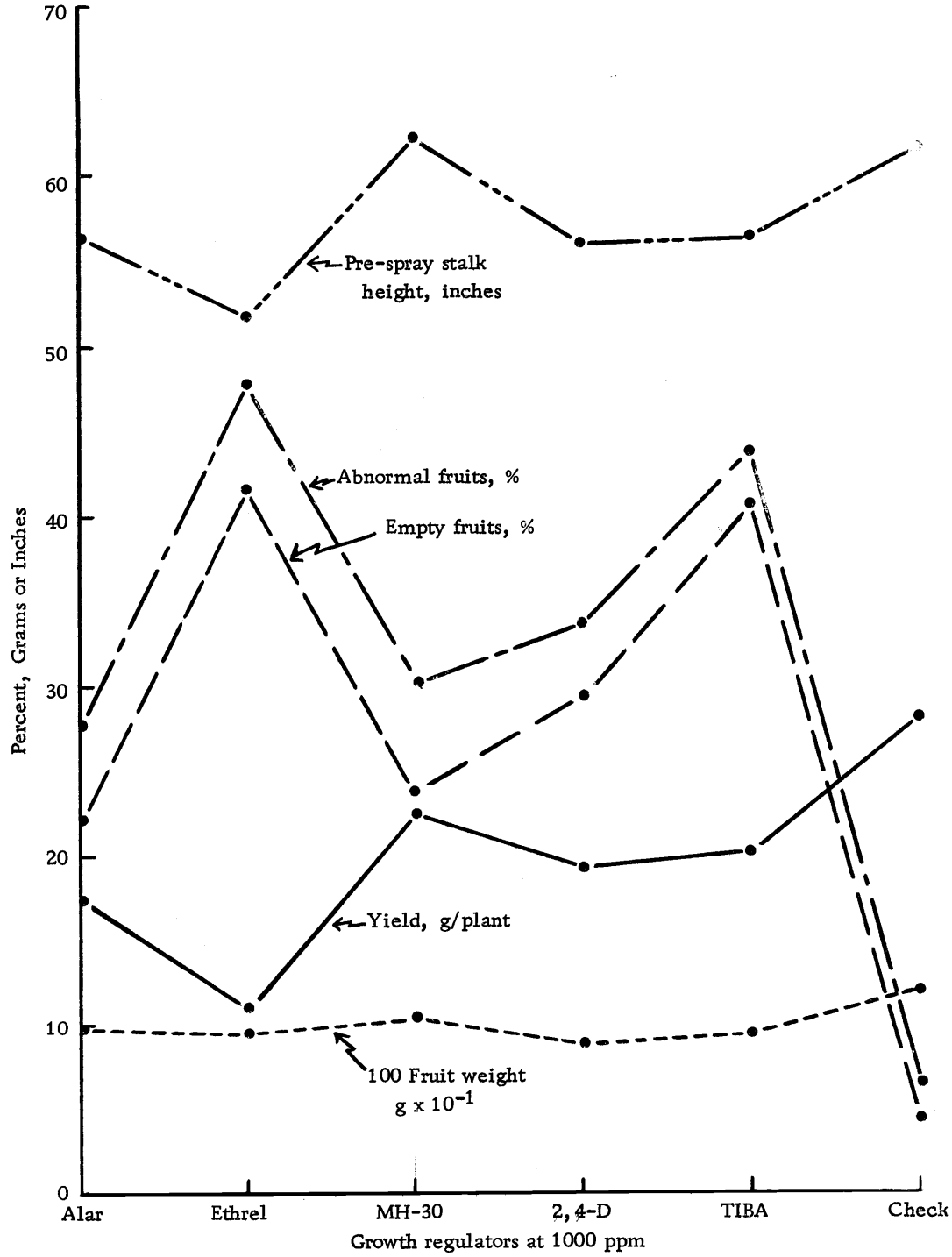

Figure 27. Plant, fruit and lot attribute means for the 1970 greenhouse growth regulator study No. 1. Only stalk height and yield differed significantly. Since these two curves followed parallel paths, yield was most likely associated with plant vigor, not the chemical treatments. Plants were sprayed at peak anthesis. (10 g x 10^{-1} = 1 g)

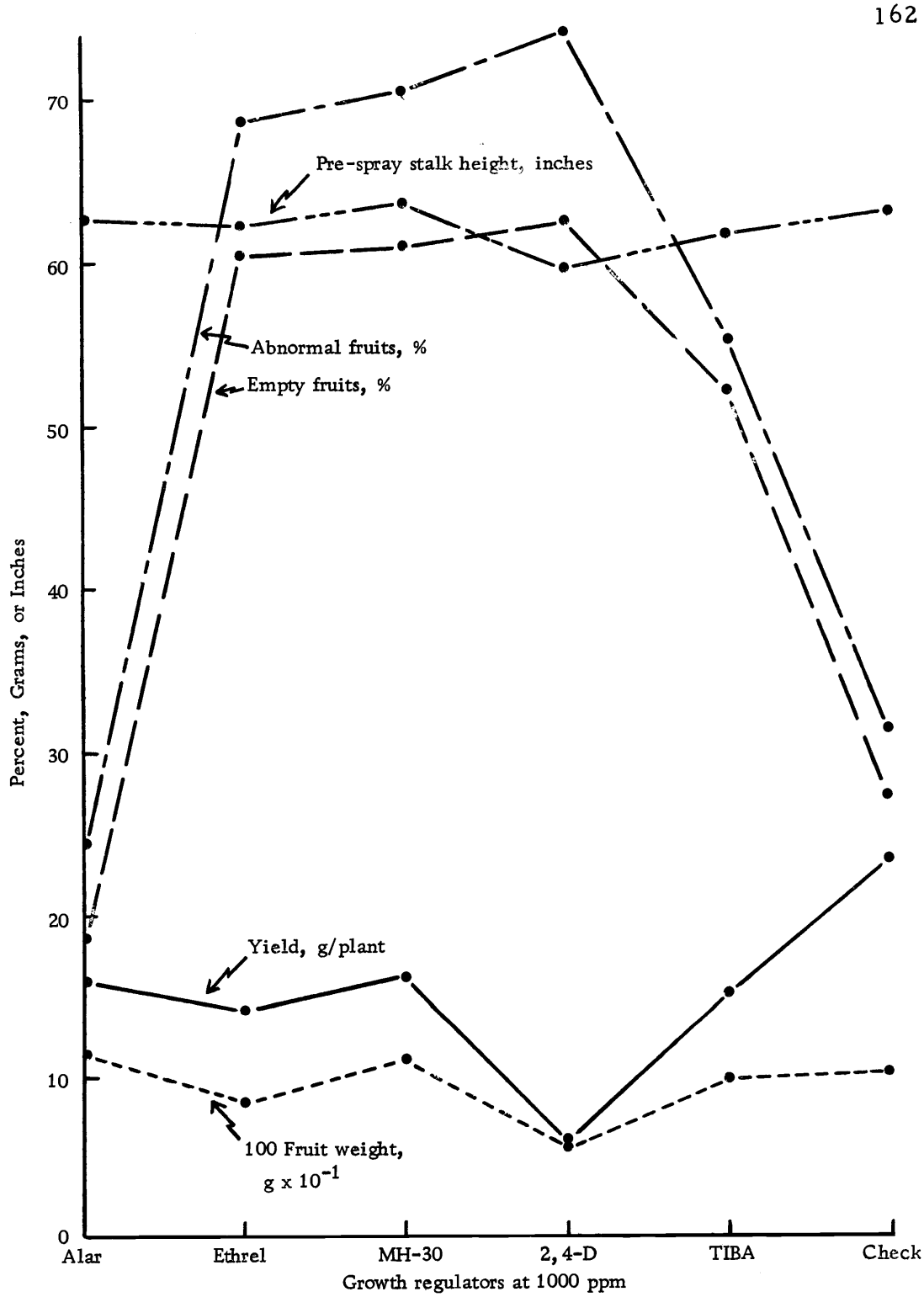

Figure 28. Plant, fruit and lot attribute means for the 1970 greenhouse growth regulator study No. 2. Only the 2, 4-D treatment differed significantly from the check, but not for stalk height or empty fruits. Plants were sprayed at early anthesis. (10 g x 10^{-1} = 1 g)

level), all varied significantly, as shown in Figure 28 and reported in Table A.36.

Field Growth Regulator Study

Five weekly fall stand counts made on the field growth regulator study indicated that there were serious, progressive declines in stand following sugarbeet emergence, particularly through the center and to one side of the trial (Figure 29). The data were evaluated by the analysis of variance, using a nonrandomized systematic arrangement of plots (Table A.37).

The stand in evenly spaced plots differed significantly (.005 level) throughout all counts. When plots were randomized, however, stand counts never varied significantly as the differences were statistically and effectively removed (Table A.37). To further insure stand uniformity, numerous transplants were made during the spring of 1970 to eliminate all major row skips of one foot or more.

When the data were summarized over all growth regulator treatments, there were highly significant differences in time of chemical application for both maximum and harvest heights, yield, fruit count, percent empty, and percent abnormal fruits (all at the .005 level). As reported in Table A.38, other significant differences included those for lodging ratings (.01 level) and fruit weight (.05 level). Only plant color ratings did not vary significantly for the

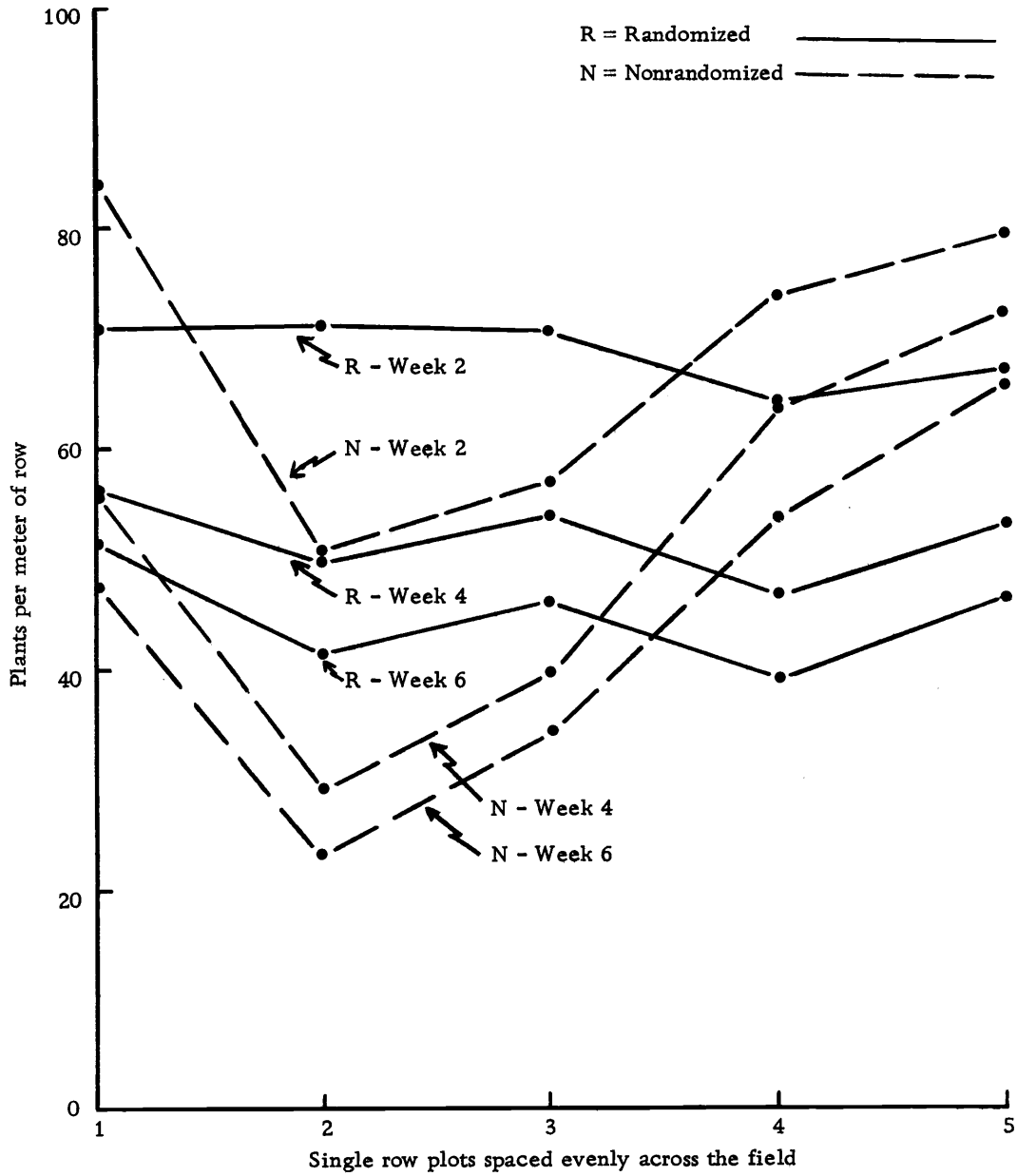

Figure 29. Fall stand counts in weeks after planting on September 8, 1969, for the 1970 field growth regulator study. There were drastic reductions in stand over time, but stand began to stabilize by the sixth week. When data were analyzed without randomization (N), there were highly significant differences between plots. When data were analyzed with randomization (R), these significant stand differences were statistically removed.

growth stage sprayed.

As shown in Figures 30 and 31, spraying at early bolt or even peak anthesis significantly reduced plant height and decreased lodging, but this also decreased yield and fruit weight, and increased the fruit count. In addition, these early sprays with growth regulators significantly increased the percent empty and abnormal fruits above that of the late spraying at post anthesis.

When the individual growth regulator treatments were examined, every one of the ten factors investigated differed significantly at the .005 level of probability, as reported in Table A.38.

As shown in Figure 32, every chemical and rate significantly reduced maximum height below that of the check, except for the three rates of Alar and the lowest rate of MH-30. The high rate of MH-30 reduced plant height significantly below that of all treatments, except the medium rate of MH-30 and the high rate of Ethrel, neither of which differed significantly from most other treatments.

Yield was seriously affected by growth regulator treatment. Increasing the rates of Ethrel and MH-30 resulted in progressive, significant yield decreases below that of the check. It should be noted that the two higher rates of Alar and the low rate of TIBA yielded slightly but not significantly more than the check.

The 21-day growth measured actual growth made by plants that were sprayed at early bolt. This factor revealed that all Ethrel

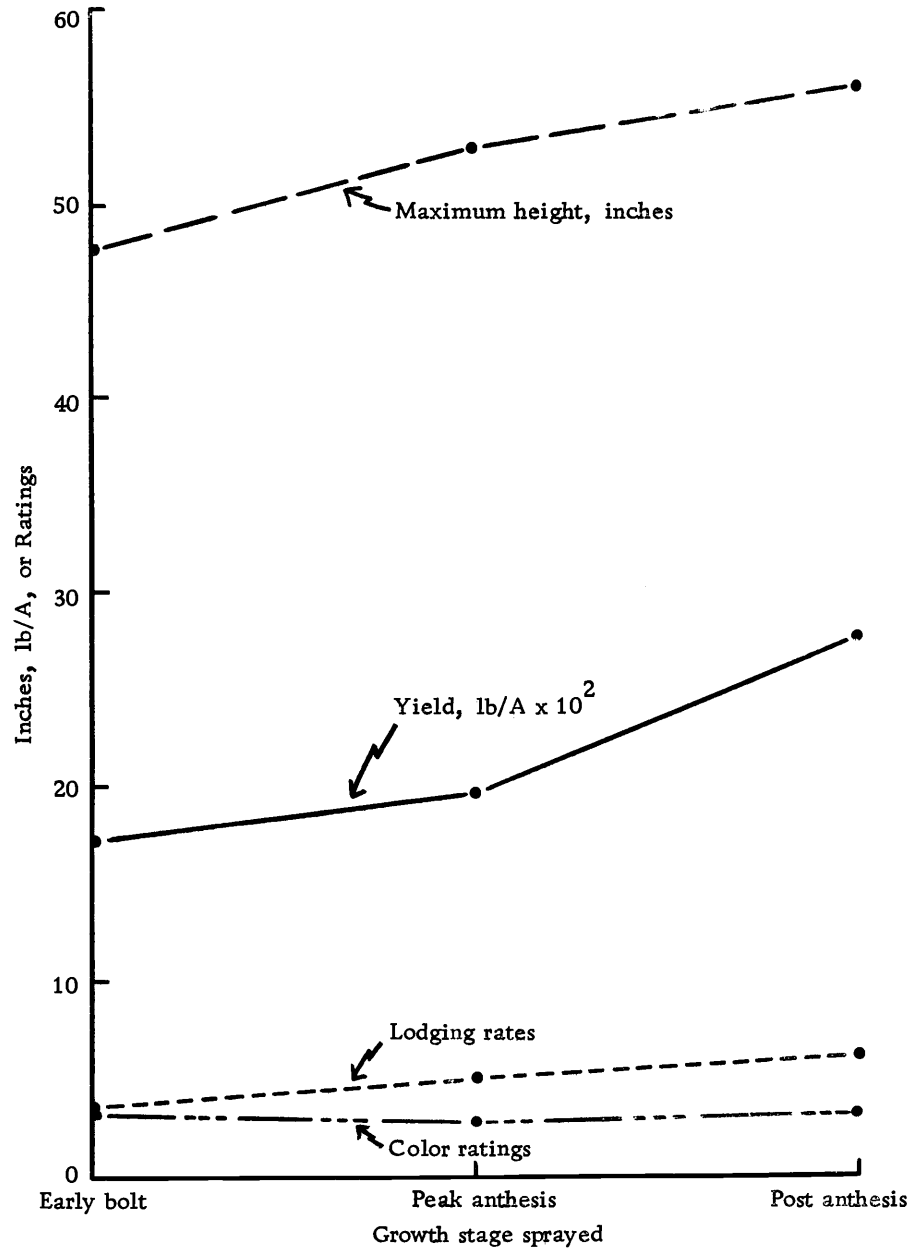

Figure 30. Four plant attribute means averaged over the 12 growth regulator treatments for the 1970 field growth regulator study. All factors except color ratings differed significantly at the .05 level of probability or greater. Lodging ratings: 1 = no lodging and 9 = complete lodging; color ratings: 1 = dark green progressing to 7 = extremely yellow and chlorotic in appearance. (20 lb/A x 10^2 = 2,000 lb/A)

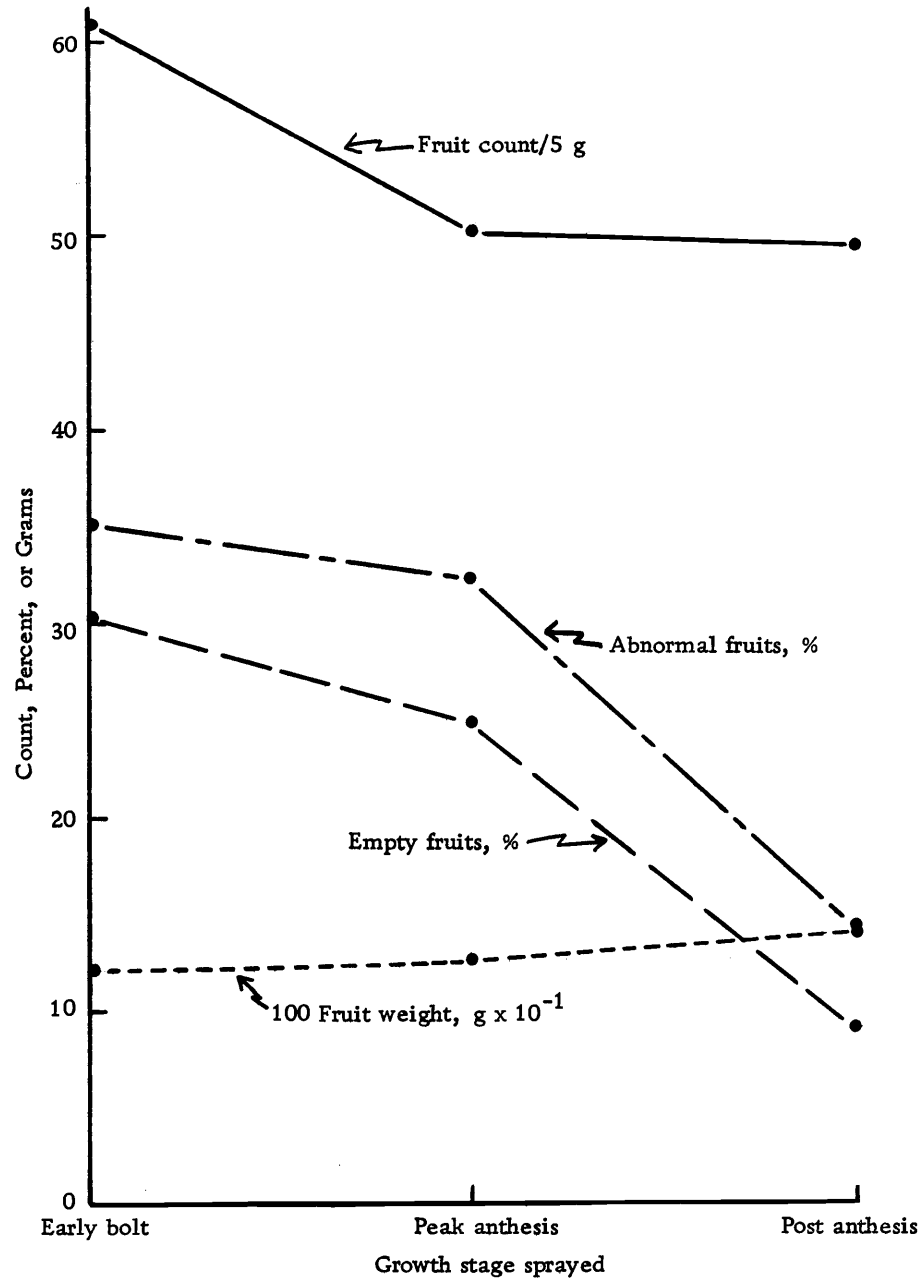

Figure 31. Four fruit attributes averaged over the 12 growth regulator treatments for the 1970 field growth regulator study. All factors differed significantly at the .05 level of probability or greater. Fruit quality was seriously affected by growth regulator treatment at early bolt and even at peak anthesis. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

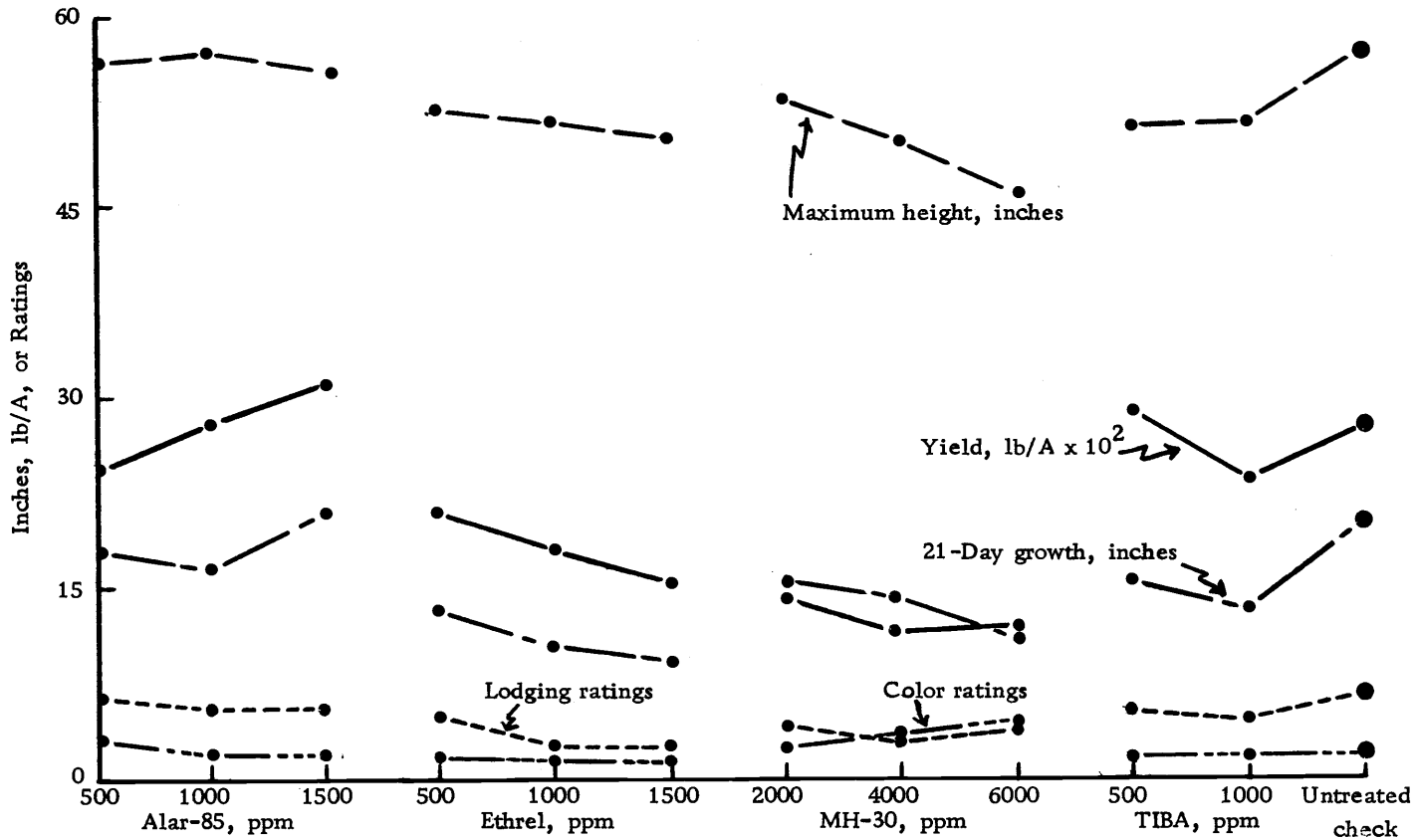

Figure 32. Five plant attributes averaged over the three growth stages sprayed for the 1970 field growth regulator study. All factors differed significantly at the .005 level of probability. The 21-day growth referred to actual growth made by plants that were sprayed once at early bolt. (30 lb/A x 10^2 = 3,000 lb/A)

and MH-30 treatments, and the high rate of TIBA, slowed growth significantly below that of the check.

The higher rates of Ethrel, and all rates of MH-30, reduced lodging significantly below that of the check. However, the two high rates of MH-30 resulted in plants that were significantly more yellow and chlorotic than the healthy, green check plants.

As shown in Figure 33, certain growth regulator treatments drastically affected fruit quality. As usual, only the high rate of Ethrel and all rates of MH-30 produced fruits that consistently and significantly differed from those of the check for fruit count, percent empty, and percent abnormal fruit. All rates of MH-30 produced fruits that were significantly lighter than those of all other treatments, including the check.

Owing to the differences caused by the timing of chemical application, there were nine significant growth stage sprayed x growth regular treatment interactions, as reported in Table A.39. These included the interactions for both maximum and harvest heights, color ratings, yield, fruit count and weight, and percent empty and abnormal fruits (all at the .005 level), as well as lodging rates (.10 level).

In general, these interactions indicated that the early sprayings with certain chemicals (usually Ethrel and MH-30) were more detrimental to plant and fruit quality than the same or other chemicals

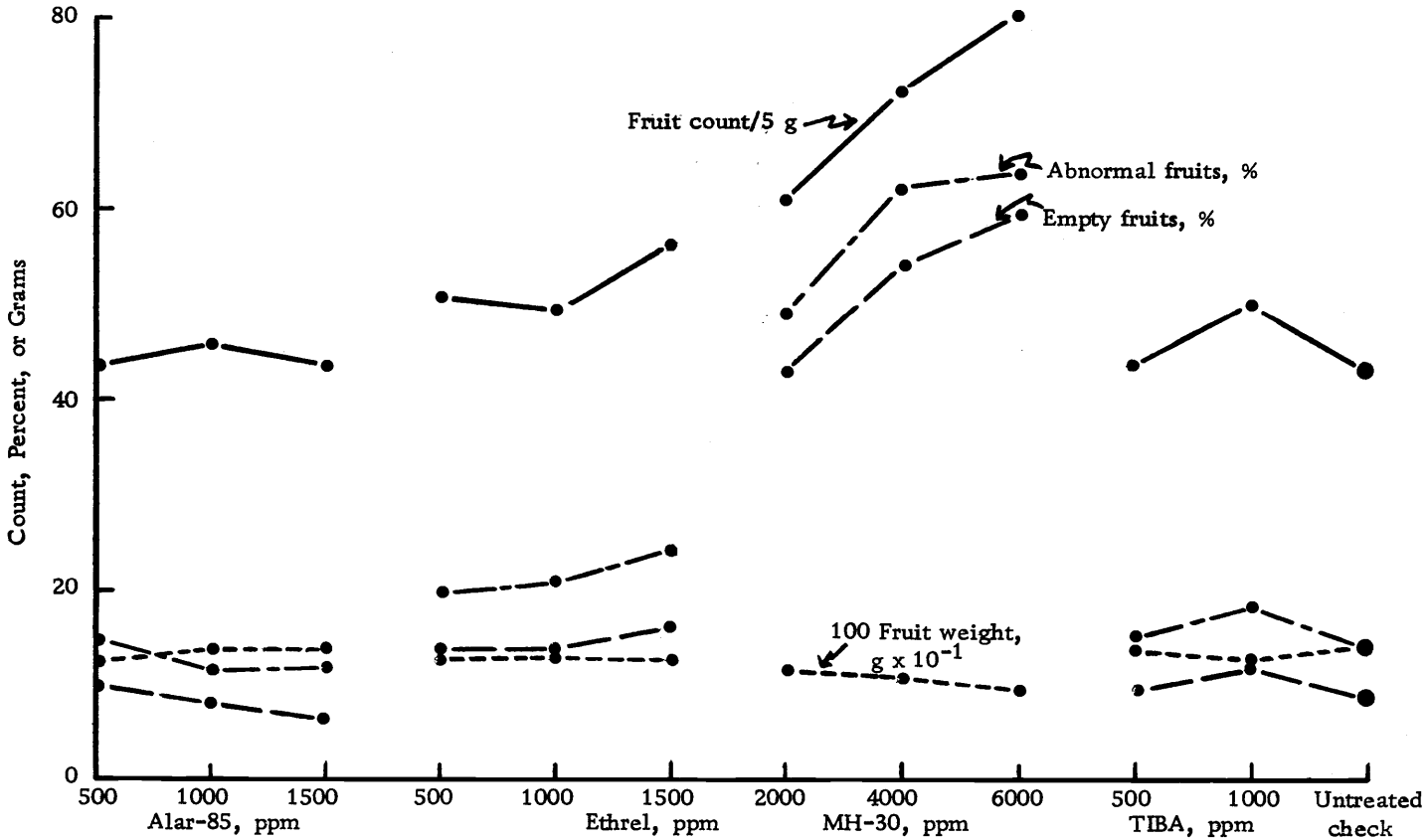

Figure 33. Four fruit attributes averaged over the three growth stages sprayed for the 1970 field growth regulator study. All factors differed significantly at the .005 level of probability. The high rate of Ethrel and all rates of MH-30 were generally detrimental to fruit quality. In no case did any growth regulator treatment significantly reduce the level of empty and abnormal fruit below that of the untreated check. ($10 \text{ g} \times 10^{-1} = 1 \text{ g}$)

and rates at the late sprayings. For example, the early bolt spraying with MH-30 at 2000, 4000, and 6000 ppm resulted in 70.8, 95.8, and 92.2% abnormal fruits vs. 15.5, 15.8, and 12.0%, respectively, for the post anthesis sprayings with MH-30. The early and late checks had 12.7 and 16.0% abnormal fruits, respectively.

Conversely, late sprays with high rates of Alar or low rates of TIBA were occasionally beneficial, but not significantly so.

With the exception of four relationships, all factors studied were highly correlated with every other factor, either positively or negatively, at the .01 level of probability. One exception was that plant color ratings were negatively correlated with yield at only the .05 level ($r = -.25^*$).

The only three factors not correlated were maximum height, harvest height, and lodging ratings, each vs. the plant color ratings, as reported in Table A. 40. The 21-day growth evaluations were not included in this summary. Although there were several natural relationships, the high regularity of significant correlations was due chiefly to the large number of data ($n = 108$). This reduced the level required for significance to only ± 0.195 and 0.254 for the .05 and .01 levels of probability, respectively.

DISCUSSION

Factors affecting the occurrence of empty and underdeveloped fruit in sugarbeets are, like the causes of a headache, many and varied. In both cases, the actual biological cause remains obscure. Yet, factors of stress are often principal ingredients.

Planting Date, Bolting Variability, and Sugarbeet Maturity

Early planting plays a fundamental role in reducing or even preventing the occurrence of abnormal fruit. Hard bolting lines especially benefit from 6 to 7 weeks of warm temperatures during preinductive growth (62). In the Willamette Valley, however, sugarbeets are planted from late July to even late September. Results of this study indicate that sugarbeets should be planted no later than August 10 in most years (Figure 22).

On the 1969 DeFord field, the late planting on September 2, 1968, resulted in a germination of 74% for the processed seed and 12% abnormal fruit for the combine-run seed. The even later September 21, 1968, planting on the same field resulted in 68 and 22% germination and abnormal fruit, respectively.

Although sugarbeets do not have a true juvenile stage (228), late plantings simply fail to permit sufficient growth and substrate storage (85) by the developing seedlings before cool inductive

conditions begin. As plants age before induction, bolting promptness, yield and germination all increase (60). In addition, large, early planted sugarbeets shade and cool the soil, reducing the hazard of warm temperature reversion during induction (145). Where bolting is hastened by early planting, anthesis usually occurs before the dry weather of July.

The current results on date of planting are well supported by Pendleton's early work (147, 148, 149) and the recent thorough investigations by English researchers (94, 95, 96, 182). These findings disagree somewhat with the conclusions reached by Hardin, TeKrony and Schweitzer (76), that abnormal fruits are not affected by planting date. However, their early September stand failed completely.

Early plantings require higher production costs including more late summer irrigations. In addition, some stand failures due to high soil temperatures at planting (93) or diseases could prove detrimental, but the potential advantages far offset these unlikely losses.

Plant age before induction probably has little to do with bolting variability, however, as shown by the results of the 20-month-old plants in the greenhouse bolting trial (Figure 7). These aged, uniformly selected plants varied significantly throughout the bolting period. Yet, bolting variability contributes to the occurrence of empty and abnormal fruit in the field because late bolting and therefore late flowering plants simply do not have time to develop mature fruits

before harvest (Figure 9).

The 1970 field bolting trial revealed a sharp increase in the level of empty and underdeveloped fruit as bolting was delayed. However, when late bolting plants were allowed to mature completely (90 days after anthesis) in the protected environs of a greenhouse, empty and abnormal fruit were reduced to a minimum (Figure 8).

The jungle of growth in heavily planted sugarbeet seed fields and inter-plant competition may contribute to bolting variability. As shown in Pendleton's work (149), thick stands of multigerm plants failed to bolt during the following spring. But, where the stands were thinned manually, bolting was satisfactory.

Bolting variability contributes directly to individual plant maturity at harvest. As shown repeatedly in these studies (Figures 3, 4, 5 and 6), plant immaturity contributes significantly to the occurrence of empty and underdeveloped fruit. Individual sugarbeet plants immediately adjacent to each other vary widely in maturity.

Visually evaluating the comparative maturity between plants or fruits is a satisfactory method for detecting these differences. However, these results in no way detract from the important findings of TeKrony's (210) that visual observations are totally inadequate for determining the relative or functional maturity of all plants in a field, particularly for hard bolting lines. The maturity guide for swathing of 45 days after peak anthesis and the more accurate heat

unit accumulation concept remain unchallenged.

The management factor most easily controlled that definitely contributes to the occurrence of empty and underdeveloped fruit is the premature swathing of plants. As shown in Figure 22, Lot 3 was planted early, yet it was swathed prematurely at only 38 days after peak anthesis (Figure 34). Although laboratory germination was a high 92%, the X-ray germination of only 79% revealed the detection of large amounts of underdeveloped fruit in the lot, some of which could probably germinate. It is suggested that while germination was high, the lot is a likely candidate for poor emergence in the field.

The grand means of the X-ray evaluations for the five maturity studies were in good basic agreement with germination results of the Oregon State University Seed Laboratory. For example, the percentage of abnormal fruit vs. the laboratory germination for the five studies were: 1) 22 vs. 74%, 2) 27 vs. 79%, 3) 11 vs. 83%, 4) 21 vs. 63%, and 5) 55 vs. 44%, respectively. This further reveals that the primary causes of poor germination in Oregon-grown sugarbeet seed are empty and underdeveloped fruit. This agrees with TeKrony's findings (210, 211, 212, 214), but disagrees with Kim's (109). Kim concluded that inhibitors were the primary problem.

Environmental conditions between swathing and combine harvesting, although not specifically investigated, could play a role in

the amounts of abnormal fruits produced. Kim (109) found that a plant cured under cool conditions had a higher level of empty fruit than one cured under warm conditions. However, an examination of the weather records for July and August of 1970 reveal that high temperatures and clear sky conditions in fact could be partly responsible for the occurrence of empty and underdeveloped fruit (Figure 34). There was no measurable precipitation during the period.

The assumptions are that under cool conditions, plant respiratory processes could be prolonged after swathing, which would permit the slow mobilization of stored food out of immature fruit to provide energy for the dying plant (see later). Conversely, as suggested by the climatological data compared with the curing dates of the poor lots 8, 9, and 10 in Figure 34, high temperatures and particularly intense sunlight permitted by clear skies could in fact speed the mobilization processes. This factor should be thoroughly investigated.

Although not deeply investigated, results of two studies indicate that sugarbeet lines differ in the level of empty and underdeveloped fruit produced (pages 129 and 131 through 136). This is thought to be due to pollen viability and compatibility (26), but the results of the time of empty fruit development study (Figure 11) indicate that it could again be a matter of maturity. For example, male sterile plants in the greenhouse without a pollinator produced insignificant

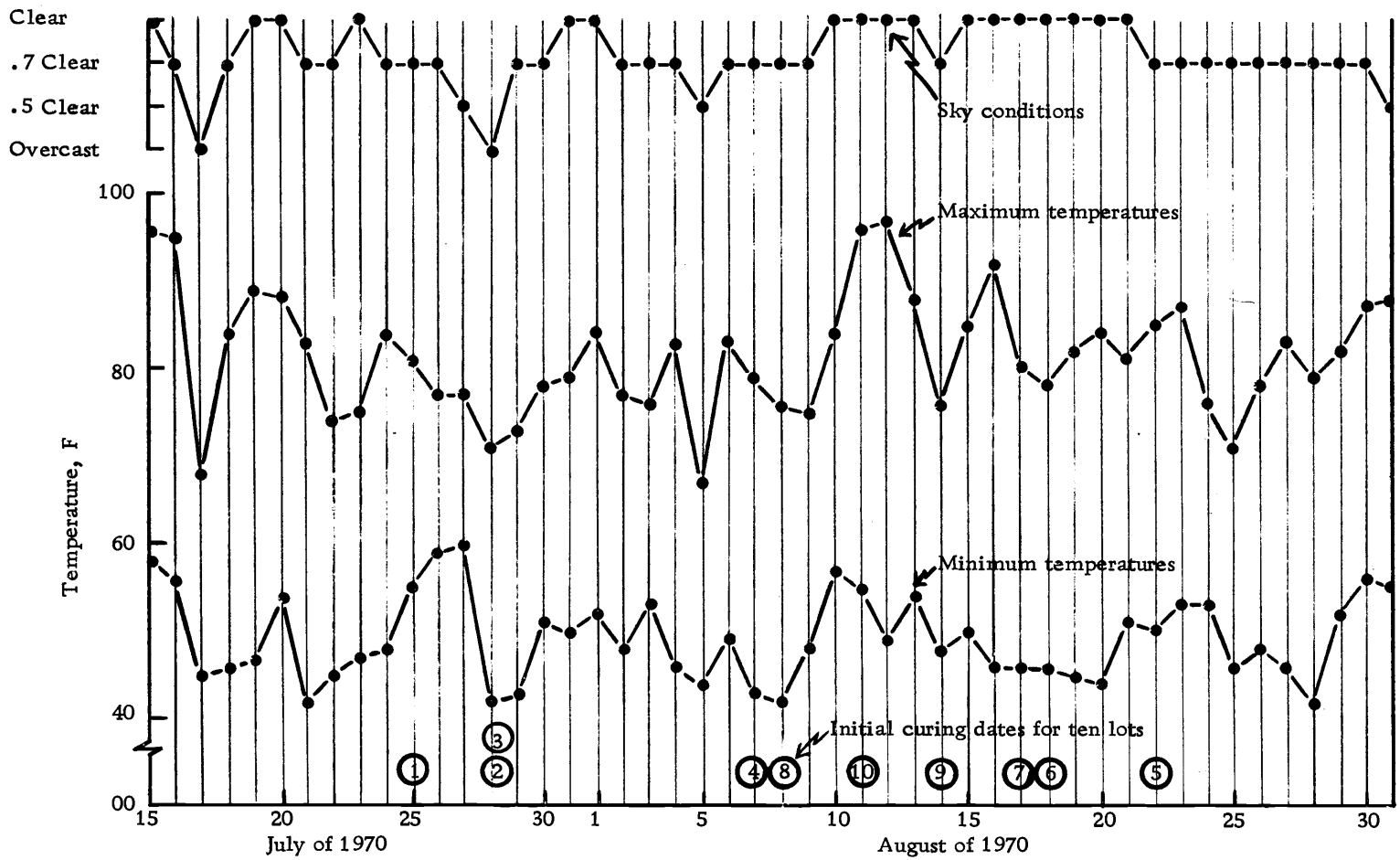

Figure 34. Sky condition, maximum, and minimum temperatures compared with the initial curing dates of the ten lots in the 1970 commercial seed sizing study. Lots 1 and 2 were from the Medford area where the season was about ten days earlier than that in the Corvallis area where these climatological data were recorded (24). High temperatures and usually clear sky conditions existed when the poor quality lots were swathed.

levels of empty and underdeveloped fruit when allowed to mature completely (Figure 8).

In addition, Scott (183) has shown that germination is not materially altered even when the seasonal pollen load is only 31% of normal. Since pollen load is affected by rain during the morning, however, serious consideration should be given by growers to restricting sprinkler irrigations to afternoons, evenings and nights during anthesis. As a safety precaution, they should never irrigate on bright, sunny mornings when pollen dispersal is greatest.

With one exception, the level of empty and abnormal fruit never fell below 10 to 15% in any study so some factor(s) other than maturity must be involved. Indeed, the grand symphony of pollination, fertilization, fruit and embryo development must function in perfect harmony or abnormalities will surely result. Therefore, it is definitely assumed that a small amount of natural parthenocarpy and late abortion do in fact occur.

A new discovery from these investigations was that prematurely harvested plants produce empty and underdeveloped fruits after swathing while drying naturally on the windrowed plant (Figure 11).

Although TeKrony (210) found up to 80% abnormal fruits when plants were windrowed prematurely, he concluded that the true seeds continue to abstract substrates from the windrowed plants. Kim (109) found that more empty fruits were produced under low curing

temperatures. Yet, neither researcher raised the question as to what must happen to the stored reserves within the true seed when fruits are empty or underdeveloped. In addition, no record was found in the literature to suggest either resorption, utilization, or respiration of these stored reserves during late embryo abortion in plants.

Since embryo resorption occurs at 25 to 35% in swine (28) and is known to occur in other animals, a similar biological axiom of energy conservation could exist in the plant kingdom as well.

Although there may be merely a loss of 90% water from immature fruit, and the small quantity of actual reserves not detected by X-radiography, the high level of underdeveloped fruit suggests an actual enzymatic breakdown of the true seed structure and the outward mobilization of components. The presence of inhibitors such as oxalates common to most sugarbeet lines (109) could be due to the out-mobilization of mobile compounds, but the retention of immobile materials such as calcium (16, 241).

These findings came from a regrettably small experiment and the concept should be tested more thoroughly. The use of daily X-rays of prematurely swathed sugarbeet plants, or even maturing fruit injections with ^{14}C or labeled calcium or strontium are suggested as potential routes of study.

A valid criticism of the current studies is that the coefficients of variability were extremely high. CV's ranged from a low of 3.2%

for 100 fruit weight to 169% for empty fruits from 24 plants in the greenhouse. These high CV's were largely due to the great variability of sugarbeets and speaks clearly of the need for large plots and multiple replication. For example, English workers (94) were faced with similar problems and recommended that 10 meter square plots be used in all sugarbeet seed yield evaluation work.

Another problem is the inherent capriciousness of the coefficient of variability, which is a relative measure affected by the size of the mean. For example, where the percentage of abnormal fruit was recorded, the grand mean of 10.5% resulted in a CV of 65% (Table A.21). Where the same identical data were recorded as filled fruits, the grand mean of 89.5% resulted in a desirable CV of only 7.6%. Therefore, it could be fortuitous that there were significant differences in any study, but more likely the differences were so great that they were significant despite the high variability.

Physical and Environmental Stresses

The biotic environment is rarely optimum in sugarbeet seed fields, and then only for fleeting moments. Therefore, the obstacles are large for the efficient production of seed.

Sugarbeets are depravated by diseases and insects, of which lygus bugs are principal villains. Extensive work by Hills and his colleagues (86, 87, 88, 89) clearly established the importance of

lygus infestations in reducing seed viability and causing hollow seedballs. However, sugarbeet seed germination in Hills and Romney's study (87) was consistently lower than 70% for the lygus-free plants.

Although mechanical punctures and lacerations made by lygus mouth parts were clearly evident in alfalfa studies (27), repeated observations with a binocular microscope by Schweitzer (76) failed to reveal any visible fruit damage in sugarbeets heavily infested with lygus. In the current study (Figure 12), mature sugarbeet plants in lygus-free cages produced nearly 40% abnormal fruit. It is suggested that stress (poor light quality and intensity within the cages) played the dominant role in raising the level of abnormal fruit. However, light was not evaluated.

Mechanical stresses due to heavy clipping (Figure 14) reduce yield and seriously increase the level of abnormal fruits. These findings are supported by those of Pendleton's (150) which revealed that clipping multigerm plants increasingly later in the spring is increasingly detrimental to seed yield and germination. Defoliation at anthesis halved yield of clean seed in European studies (95).

Conversely, tipping the primary axis of the sugarbeet plants removes apical dominance. But this increases yield and fruit size slightly, and reduces the level of empty and underdeveloped fruit in some cases (Figure 14 and 15). These results support those of Raleigh (160).

Lodging also subjects the plant to severe mechanical stresses. It has long been suspected of being a major cause of empty and underdeveloped fruit, due to the renewed vertical growth of the late developing lateral tips. Plants lodged early produced only half as much seed as upright plants in one study with one sugarbeet line. However, there was no concomitant increase in empty and underdeveloped fruit, which averaged less than 25% for all treatments (Figures 15 and 16).

Although not investigated, temperatures, both high and low, may play major roles in stressing sugarbeet seed plants (199). Temperatures should be examined as a cause of abnormal fruit. On the other hand, there is no good evidence that soil fertility levels are consistently responsible for the high occurrence of empty and underdeveloped fruit where all nutrients are normally available (76, 84, 94, 109, 122, 150, 181, 182, 195). Furthermore, well balanced fertility programs are already in use in the Willamette Valley (40, 119).

Fruit Size and Processing

Fruit size is of fundamental importance to fruit quality and the developmental level of the true seed. In every single case investigated (Figures 13, 17, 18, 19, and 21), the level of empty and abnormal fruit differed highly significantly by size (.005 level). Most small fruits were empty, but not all of them.

Fruit size is largely dependent on plant age--again a maturity factor. Although small fruits usually germinate less (95, 157) but faster (92, 177), they emerge slower than large fruits from deep plantings (157, 198). But Savitsky et al. (177) observed no differences in final germination or field root production of filled monogerm fruits between small, medium and large seeds.

An examination of Hogaboam and Snyder's data (92) strongly support the finding of the current investigations:

Fruit diameter class in 64th inch:	6	8	10	12	14	16
Percent of aborted seeds per class:	44.1	12.3	3.5	2.4	3.8	8.2

Although empty fruits (aborted seeds) were distributed throughout all size classes, there was a sharp increase of empty fruits in the small sizes. The slight increase in the largest size was distinctly different from the current studies where there was a steady decrease in empty fruit by increasing size class.

Since small fruits below 9/64 inch weigh little and usually comprise less than 10% of the lot, it is logical to recommend that all small fruits first be discarded, and only the medium and large seed saved for processing and planting. In fact, this recommendation was first put forth in 1946 by Price and Carsner (157) as a result of their emergence studies. Sugarbeet seed smaller than 7/64th inch are regularly discarded in processing. But the concept of removing all small seed (up to 9/64th inch) has never been fully accepted by the

trade.

Hardin, TeKrony and Schweitzer (76) concluded that abnormal fruits were not directly associated with fruit size, because some large fruits were empty. They contended that the small empty fruits would be eliminated in the normal processing operations anyway. As shown by the results of the Crocker and commercial seed sizing studies, however, not all small, late developing fruits are eliminated from seed ready for shipment to sugarbeet companies. Furthermore, not all small fruits are of poor quality.

When the results of the Crocker seed sizing study became known, the grower reprocessed his seed over a 9/64 inch round hole and an 11/64 inch triangular screen. The seed that dropped was then passed over the gravity table and the heavy portion returned to the lot. No X-ray examinations were made of the different fractions, but germination was improved from the original 66% to about 75%, thereby exceeding the grower's contract level of 70% germination. This entailed several 22,000-pound lots of seed (40).

Although the gravity table offers some potential in removing empty fruits from the lot, it probably removes few partially filled underdeveloped fruits. In addition, research results hold little promise for empty fruit removal by air flotation methods (115, 214).

The results of the current studies suggest a possible method of upgrading low germination seed lots: a sample of combine-run seed

should be sized and examined for weight and by X-radiography to evaluate the levels of abnormal fruit in each size class. The sizes containing high percentages of abnormal fruit should be discarded during normal processing. Processors could then decorticate, size, and run the remaining small fruit over the gravity table to further improve germination.

Chemicals--Harmful or Beneficial?

A host of chemicals can induce parthenocarpy in numerous plants. The results from these studies indicate that all pesticides and most growth regulators used induced parthenocarpic fruit in sugarbeets.

Although the actual effect may have been that chemicals stressed the plants for energy, delayed maturity in some cases, or even produced gametocidal effects on the pollen or stigma, the available evidence indicates that true parthenocarpy resulted. The most detrimental treatments were those made on the male sterile plants during early bolting before pollination occurred.

The insecticide DDT is known to have phytotoxic activity (139). Results of the chemical spray studies bear this out and reveal that extremely low rates of DDT were responsible for increased levels of empty and abnormal fruit (Figures 25 and 26). Yet, DDT was used for many years on sugarbeet seed fields in the Willamette Valley.

In one study (76), DDT was used weekly for a month during anthesis to control lygus, but the level of abnormal fruit was not reduced. Although lygus were no doubt controlled, it is probable that the DDT induced some parthenocarpic fruit.

Diazinon is the chief insecticide now used in the Willamette Valley to control lygus (119). Unfortunately, its potential phytotoxicity was not investigated in these studies. Results of the commercial seed sizing study, however, indicate that Meta-Systox, which was used twice during June to control lygus in the Medford area, had no or low phytotoxic activity on sugarbeets. The two lots from that area germinated at 97 and 94%.

Although chemical pollutants were not monitored, it is conceivable that chemicals such as 2, 4-D abound in the agricultural environment. The 10^{-3} and even the 10^{-6} molar rates of 2, 4-D consistently produced significant levels of empty and abnormal fruit (Figures 25 and 26). These rates are roughly 1/10th to 1/10, 000 of normal herbicidal levels. This auxin-like chemical was more harmful to sugarbeet fruits when applied at peak anthesis. Results with GA_3, Endothal and IPC were generally inconclusive but the rates used were frequently harmful to sugarbeet fruits.

Attempts to reduce or eliminate the occurrence of empty and underdeveloped fruit with growth regulators were not successful with these growth regulators at these rates on a single male sterile line

of sugarbeets. All chemicals were less harmful when applied at late or post anthesis (Figures 30 and 31).

Alar and TIBA were not detrimental and should be investigated further (Figures 32 and 33). In fact, Alar had a beneficial effect on yield and fruit size, when applied at post anthesis (Table A.39). Although not significant, empty and abnormal fruit were reduced 20 to 40% below that of the check. But Alar-treated plants tended to lodge more than the check.

Ethrel and MH-30 at all rates were detrimental to fruit quality. These chemicals may have promise as anti-lodging agents and could be investigated at much lower rates. However, this author is less optimistic about the possibilities of halting late growth with high rates of chemicals. Rates high enough to halt new growth are generally detrimental to the developing sugarbeet fruits.

The Potential of Artificial Lights

It must be made unmistakably clear that the following discussion is a result only of a review of the literature and observations on the growth habits of sugarbeets during the past two years. Its inclusion here is to help guide future researchers onto potentially productive paths for the improvement of sugarbeet seed quality.

The use of artificial lights (58) in seed increase fields to extend the daylength to 18 or even 24 hours during the post-induction period

from early spring to harvest holds some promise in sugarbeets. As pointed out in the review (p. 17), Gaskill (62) found that continuous incandescent lighting during post-induction has a major beneficial effect on the percentage of sugarbeet plants that bolt and flower. Supplemental light is more important for hard bolting than easy bolting lines, and particularly for those plants that receive only borderline preinductive growth.

Since our society manages to pave and light parking lots with abandon, lighting seed increase fields should be entirely feasible from the technical standpoint. Fields of only two to five acres are the rule, with not more than 100 acres devoted to all seed increases (breeder-elite-stock) in the Willamette Valley (26). This acreage produces the bulk of the stock seed needed to plant all of the commercial seed fields. Furthermore, only 5 to 7 ft-c of light up to 30 feet from the light source may be sufficient (58). But light quality and intensity must be sufficient to be of biological significance.

Lamps supplying far-red light might profitably 1) speed uniform bolting, 2) prevent reversion of hard bolting lines due to sudden high spring temperatures, and 3) speed plant development sufficiently to permit the harvest of mature fruit by early July.

Besides resulting in uniformly mature true seeds, this should have two major beneficial results: 1) increase the level of bolting resistance in a line, and 2) permit late July or early August planting

of the commercial seed fields with the stock seed produced in the same year.

The Goal--Precision Planting

The sugarbeet industry is a vitally important segment of our American agriculture. Since the costs of production continue to skyrocket, it is imperative that greater efforts be made toward precision planting of fields for sugar production.

Two of the basic objectives behind the search, discovery and development of the monogerm sugarbeet were the possibilities of precision planting and reduced thinning costs. These objectives have not been achieved, primarily because of the frequent occurrence of empty fruit in sugarbeet seed.

Precision planting is still a forseeable possibility. Some high-quality lots are now produced, particularly where the crop is planted early and the cultural and growing conditions are optimum. Processing can often do much to improve the poor germination percentage of poor lots, as shown by the results of these investigations. Therefore, it is a question of where the sugarbeet industry wants to spend its money: on seed that will approach 100% germination or on spring thinning costs in sugar production fields.

Unfortunately, seed with 75% germination has been profitable for too long. Too many seedsmen sell seed by weight, not by

germination. The practice of blending down high germination lots is all too frequently practiced.

It seems reasonable that sugarbeet seed growers should receive a basic, expense-meeting price on all seed that they produce, plus a modest return for seed germinating better than 70%. Incentive payments should be made for each incremental increase in germination, but premiums should be paid for seed that germinates over 95%. The crux of the question is this: "Is it better to buy high quality seed that could be used in precision planting or continue to pay expensive thinning costs?"

Without question, sugarbeet seed is beset with problems other than empty and underdeveloped fruit. Physical restrictions of the fruit and inhibitors contine to plague all who work with the seed, although inhibitors are less of a problem in the field. But the presence of a sound embryo and perisperm in each fruit is axiomatic for germination to occur. Results of these investigations, and those by TeKrony and his colleagues (76, 210, 211, 212, 213, 214) verify that empty and underdeveloped fruit are the chief cause of low germination in sugarbeets.

Since not all viable seed will emerge and produce vigorous plants (15), some will contend that it will still be necessary to plant twice as much seed as needed to get a stand and thinning will still be required. Therefore, the industry might want to consider a new

approach in planting sugar production fields. This approach could have value for other high-value crops as well.

For example, the sugarbeet industry has worked for 20 years on mechanical and electronic thinners, yet none has been universally successful in all types of fields. Few are in general use today (169). Lack of solid success after 20 years should warrant a change in direction. Therefore, this author proposes that instead of continuing efforts to thin heavily planted crops that attention now be given to the possibilities of "selective replanting" of precision planted fields. The technology at hand from the work with electronic thinners might quickly be inverted and adapted to this need.

Although early planted sugarbeets outyield late replanted stands for sugar production (43), this loss may be less than thinning costs and the frequent losses due to in the row skips up to 40 inches (15).

This research revealed that DDT has a harmful, phytotoxic effect on sugarbeet seed quality. Perhaps other insecticides do too. Yet, the control of lygus is essential in seed production fields. It is suspected that the strong aroma or odor of flowering sugarbeets may be the prime attractant of nearby lygus. Therefore, it seems reasonable that entomologists could biochemically isolate this odor. Then, they could put available technology to work and devise an insecticidal attractant that could be used near, rather than in, sugarbeet fields to control the lygus population before flowering. This should

eliminate the need for potentially harmful pesticidal sprays during anthesis.

X-radiography is a rapid, useful tool for the evaluation of the internal contents of sugarbeet fruits and this technique should receive wider application. This is particularly true in the sugarbeet processing industry. The current availability of Polaroid X-ray film should speed the use of this technique.

In summary, it appears that sugarbeet seed quality could be improved by using these practices in the Willamette Valley:

1) Plant no later than August 10,

2) Remove the males by July 1 to halt late pollination,

3) Swath no earlier than August 10 unless the crop is ripe, and

4) Upgrade poor seed lots by severe processing.

We still need to learn the biological causes of empty and underdeveloped fruit in sugarbeets. Although some abnormal fruits occur in all lots, their chief cause is the premature swathing of immature fruit, as these data reveal. Essentially, most of the facts for producing high quality sugarbeet seed are known. What remains is for the sugarbeet industry to put these facts together into a readily workable solution.

SUMMARY AND CONCLUSIONS

Experiments were conducted in the greenhouse, field and laboratory during 1969 and 1970 to study the occurrence of empty and underdeveloped fruit in several monogerm sugarbeet lines. Fruits were usually evaluated for yield, weight and size. The contribution of various plant parts and fruit size components to the amount and quality of the seed lot was also determined.

X-radiography provided a rapid, accurate means of evaluating the internal contents of sugarbeet fruits.

Fruit immaturity, whether caused by delayed planting, bolting variability, or premature swathing, was the primary cause of empty and underdeveloped sugarbeet fruits. Furthermore, this research supported conclusions by previous Oregon researchers that abnormal fruits are the primary cause of poor germination in Oregon-grown sugarbeet seed. The problem is of worldwide occurrence.

Sugarbeets planted increasingly later than August 10 produced fruits that were increasingly abnormal, according to the results of a study on commercial lots. On the other hand, when aged plants were allowed to mature completely (90 days after peak anthesis) in the protected environs of a greenhouse, empty and underdeveloped fruit were of insignificant consequence.

Seed size was of fundamental importance to seed quality. Small fruits were predominately empty, but were also frequently

underdeveloped. Since small fruits constitute a minor portion of most lots, they should be removed and discarded during the processing operation. However, to insure economic processing, a sample of each lot of combine-run seed should be sized and the fruit in each size class examined by X-rays before processing begins.

Due to the indeterminate growth habit of sugarbeets, late developing lateral tips, as well as secondary and tertiary branches, contributed slightly but significantly to the abnormal fruit problem. However, the poor quality fruit produced by these plant parts accounted for only half of the abnormal fruit present in the lot.

Prematurely harvested plants normally contained filled ovarian cavities when first windrowed and then later developed high amounts of shrunken or empty fruits. This suggested that the stored energy reserves of immature fruit were either respired, enzymatically degraded and utilized by the fruit, or even resorbed by the plant.

Empty and underdeveloped fruit were produced by mature sugarbeets in lygus-free cages. Therefore, factors of stress other than those imposed by lygus contributed to the occurrence of abnormal fruit.

Severely clipping sugarbeet plants reduced yield and greatly increased fruit abnormalities. Tipping the primary axes had a slightly beneficial effect on fruit size and weight. Lodging sugarbeets manually at peak anthesis, or 30 days later, reduced seed yield by half of that from upright plants. Lodging had no detrimental effect on the level of

empty and underdeveloped fruit produced by the line studied.

Several pesticides and growth regulators (DDT, Endothal, IPC, 2,4-D, GA_3, Alar-85, Ethrel, MH-30, and TIBA) were sprayed on plants from early bolting to post anthesis. A wide range of low rates were used and each chemical was applied only once. The earlier the spraying, the more detrimental was the result.

In no case did any chemical significantly reduce the level of underdeveloped and empty fruit below that of the check, except in one situation where the check had an unusually high level of these problem fruit. Conversely, high levels of empty fruit were frequently produced. These fruits were considered parthenocarpic, although microscopic examinations were not made.

Results indicated that certain chemicals, particularly 2,4-D, could detrimentally affect fruit quality, if present as an agricultural pollutant in the microenvironment of the sugarbeet field. Although DDT was used in seed fields for years in the Willamette Valley to control lygus, extremely low rates of this insecticide were responsible for increased levels of abnormal fruit.

Ethrel and MH-30 were detrimental to sugarbeet plants and fruits at the rates used. At lower rates than those tested, these two growth regulators could have potential on sugarbeets as anti-lodging agents. Alar and TIBA were not clearly detrimental to sugarbeets and warrant further investigation. Alar was somewhat beneficial to fruits when

applied to plants at post anthesis.

There is little promise of halting late growth of sugarbeets with high rates of growth regulators such as MH-30. Rates high enough to halt growth were often detrimental to the developing fruit.

Other possibilities of improving sugarbeet seed quality were discussed in light of the economic need for precision planting in sugar production fields.

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APPENDIX

Table A. 1. Common and scientific names of plants referred to in this thesis.

Common name	Scientific name
Alfalfa	Medicago sativa L.
Apricots	Prunus armeniaca L.
Ash, white	Fraxinus americana L.
Banana	Musa sp. L.
Barley	Hordeum vulgare L.
Bean	Phaseolus vulgaris L.
Beets, red	Beta vulgaris L.
Beets, sugar	Beta vulgaris L.
Bluegrass	Poa sp. L.
Bromegrass	Bromus sp. L.
Bromegrass, smooth	Bromus inermis (Leyss.)
Brussel sprouts	Brassica oleracea gemmifera L.
Carrot family	Umbelliferae
Carrot	Daucus carota L.
Celery	Apium graveolens L.
Cherry	Prunus cerasus L.
Clover	Trifolium sp. L.
Clover, alsike	Trifolium hybridum L.
Clover, red	Trifolium pratense L.
Cocklebur	Xanthium pennsylvanicum L.
Corn (maize)	Zea mays L.
Cotton	Gossypium hirsutum L.
Cucumber	Cucumis sativus L.
Cucurbit	Cucurbita sp. L.
Darnel	Lolium temulentum L.
Datura	Datura sp. L.
Dollar plant	Lunaria biennis L.
Durum	Triticum dicoccum L.
Fig, Calimyrna	Ficus carica L.
Flax	Linum usitatissimum L.
Goosefoot family	Chenopodiaceae
Grape, 'Thompson Seedless'	Vitis vinifera L.
Henbane, biennial	Hyoscyamus niger L.
Indiangrass	Sorghastrum nutans (L.) Nash
Lettuce	Lactuca sativa L.
Mango	Mangifera sp. L.
Oats	Avena sativa L.
Pea	Pisum sativum L.

(Continued on next page)

Table A. 1. (Continued)

Common name	Scientific name
Pear	Pyrus sp. L.
Pepper	Capsicum frutescens L.
Pineapple	Ananas comosus L.
Plum	Prunus sp. L.
Potato	Solanum tuberosum L.
Rice	Oryza sativa L.
Ryegrass	Lolium sp. L.
Ryegrass, perennial	Lolium perenne L.
Sorghum	Sorghum vulgare Pers.
Soybeans	Glycine max (L.) Merrill
Squash	Cucurbita maxima L.
Stocks, garden	Matthiola incana (L.) R. Br.
Sugarbeets	Beta vulgaris L.
Sunflower	Helinathus annuus L.
Sweet William silene	Silene armeria L.
Timothy	Phleum pratense L.
Tobacco	Nicotiana rustica L.
Tobacco	Nicotiana tabacum L.
Tomato	Lycopersicon esculentum L.
Trefoil, birdsfoot	Lotus corniculatus L.
Walnut	Juglans sp. L.
Wheat, common	Triticum vulgare Vill. (aestivum L.)
Wheatgrass, crested	Agropyron cristatum (L.) Gaertn.
Wheatgrass, intermediate	Agropyron intermedium (Host) Beauv.
Zephyr lily	Zephyranthes drummondii L.

Table A. 2. Definitions of certain chemicals referred to in this thesis.

Abbreviation or common name	Chemical definition
Alar (B-995, B-Nine)	N, N-dimethylamino succinamic acid
Amo-1618	2-isopropyl-4 dimethylamino-5-methyl phenyl-1-piperidine-carboxylate methyl chloride
B	Boron
C	Carbon
Ca	Calcium
Cycocel (CCC)	(2-chloroethyl)trimethyl ammonium chloride
DDT	1, 1, 1-trichloro-2, 2-bis(p-chlorophenyl)-ethane
Diazinon	O, O-diethyl O-(2-isopropyl-4-methyl-6-pyrimidinyl)phosphorothioate
2, 4-D	2, 4-dichlorophenoxyacetic acid
2, 4-DM	2, 4-dichlorophenoxyacetic methionine
Dieldrin	not less than 85% of 1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-1, 4-endo-exo-5, 8-dimethanonaphthalene
Diquat	9, 10-dihydro-8a, 10a-diazoniaphenanthrene
Endothal	7-oxabicyclo(2. 2. 1)heptane-2, 3-dicarboxylic acid
Endrin	1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-1, 4-endo-exo-5, 8-dimethanonaphthalene
Eptam	ethyl N, N-di-n-propylthiol-carbamate
Ethrel	2-chloroethylphosphonic acid
FW-450	sodium 2, 3-dichloroisobutyrate
GA_3	gibberellic acid
IAA	3-indoleacetic acid

(Continued on next page)

Table A. 2. (Continued)

Abbreviation or common name	Chemical definition
IPC	Isopropyl-N-phenylcarbamate
K	Potassium
K_2O	Potassium monoxide
Methyl parathion	O, O-dimethyl O-p-nitrophenyl phosphorothioate
MH (maleic hydrazide)	1, 2-dihydropyridiazine-3, 6-dione
Mg	Magnesium
N	Nitrogen
Na_2CO_3	Sodium carbonate
NAPA	Naphthaleneacetic acid
P	Phosphorus
P_2O_5	Phosphorus pentoxide
Phosfon	2, 4-dichlorobenzyl-tributylphosphorium chloride
Ro-Neet	S-ethyl N-ethylthiocyclohexanecarbamate
S	Sulfur
SMA	Sodium chloroacetate
TIBA	2, 3, 5-triiodobenzoic acid
Toxaphene	chlorinated camphene containing 67-69% of chlorine
2, 4, 5-T	(2, 4, 5-trichlorophenoxy)acetic acid
Tween 20	Polyoxyethylene (20) sorbitan monolaurate

Table A.3. Paired t-test comparison of abnormal sugarbeet fruits in percent between the cutting test after germination and the first reading by the X-ray method. The same fruits were first radiographed and viewed with a hand lens and then germinated. Data are from the first replicate of the DeFord chemical spray study, with two observations per treatment.

Chemical	Molar rates	Cutting test	X-ray method	Difference
Untreated check		8	10	-2
		9	9	0
DDT	10^{-3}	17	16	+1
		17	18	-1
	10^{-6}	19	20	-1
		21	22	-1
	10^{-9}	19	21	-2
		27	27	0
Endothal	10^{-3}	32	33	-1
		39	40	-1
	10^{-6}	9	10	-1
		14	13	+1
	10^{-9}	21	23	-2
		21	22	-1
IPC	10^{-3}	16	16	0
		21	21	0
	10^{-6}	11	13	-2
		21	24	-3
	10^{-9}	4	9	-5
		11	14	-3
2,4-D	10^{-3}	33	37	-4
		45	46	-1
	10^{-6}	41	45	-4
		36	37	-1
	10^{-9}	8	10	-2
		10	11	-1
GA_3	10^{-3}	25	26	-1
		26	23	+3
	10^{-6}	25	29	-4
		27	24	+3
	10^{-9}	14	15	-1
		20	23	-3
Means		20.84	22.09	-1.25
$t = \frac{\bar{d}}{s_{\bar{d}}} =$		3.898*** with 31 df		

***Statistically significant at the .001 level of probability.

Table A. 4. Paired t-test comparison of abnormal sugarbeet fruits in percent between the first and the second reading made one month later on the same X-rays. Data are from the first replicate of the DeFord chemical spray study, with two observations per treatment.

Chemical	Molar rates	First reading	Second reading	Difference
Untreated check		10	12	-2
		9	11	-2
DDT	10^{-3}	16	18	-2
		18	18	0
	10^{-6}	20	26	-6
		22	29	-7
	10^{-9}	21	20	+1
		27	26	+1
Endothal	10^{-3}	33	35	-2
		40	40	0
	10^{-6}	10	11	-1
		13	16	-3
	10^{-9}	23	23	0
		22	20	+2
IPC	10^{-3}	16	16	0
		21	20	+1
	10^{-6}	13	12	+1
		24	23	+1
	10^{-9}	9	10	-1
		14	16	-2
2, 4-D	10^{-3}	37	37	0
		46	48	-2
	10^{-6}	45	45	0
		37	37	0
	10^{-9}	10	10	0
		11	11	0
GA_3	10^{-3}	26	23	+3
		23	23	0
	10^{-6}	29	30	-1
		24	27	-3
	10^{-9}	15	15	0
		23	23	0
Means		22.09	22.84	-0.75
$t = \frac{\bar{d}}{s_{\bar{d}}} =$		2.072* with 31 df		

*Statistically significant at the .05 level of probability.

Table A.5. Mean fruit yields in grams per plant and analyses of variance for the five plant maturity studies. All 50 sugarbeets in each study were harvested on the same day and ranked visually on the basis of plant maturity.

Plant ratings		Maturity studies and Harvest dates				
		No. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		15.0	3.0	15.6	16.4	2.6a
2		9.0	6.2	15.8	8.6	6.2ab
3		28.0	10.0	11.0	30.4	6.8ab
4		18.2	9.2	19.2	15.0	10.2ab
5		12.8	7.0	16.6	16.8	8.0ab
6		42.2	12.0	14.4	36.4	13.6bc
7		21.6	4.6	20.4	27.2	14.8bc
8		22.2	10.4	14.2	14.8	21.0c
9		18.8	10.4	23.0	43.6	36.8d
10 - Mature		15.0	12.0	20.6	18.0	33.4d
Grand means		20.28	8.48	17.08	22.72	15.34
Source	DF	MS	MS	MS	MS	MS
Replicates	4	1211.07*	39.47	78.17	442.42	14.63
Treatments	9	439.43	48.59	66.36	622.85	678.40***
Error	36	359.30	35.70	119.49	439.52	48.75
Total	49					
CV, %		93.5	70.5	64.0	92.3	45.5

Values with the same letter do not differ significantly at the .05 level of probability.

*, *** Statistically significant at .05 and .005 levels of probability, respectively.

Table A. 6. Mean 100 fruit weights in grams and analyses of variance for the five plant maturity studies. All 50 sugarbeets in each study were harvested on the same day and ranked visually on the basis of plant maturity.

Plant ratings		Maturity studies and Harvest dates				
		No.. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		0.880a	1.074	1.447	1.121	0.652a
2		1.002ab	1.135	1.418	1.176	0.885ab
3		1.414b	1.236	1.433	1.477	0.928ab
4		1.302ab	1.592	1.476	1.430	1.063bc
5		1.206ab	1.315	1.518	1.617	0.905ab
6		1.477b	1.479	1.605	1.503	1.007bc
7		1.327ab	1.233	1.403	1.382	1.049bc
8		1.349ab	1.278	1.482	1.406	1.257cd
9		1.477b	1.322	1.477	1.464	1.430d
10 - Mature		1.477b	1.393	1.392	1.375	1.424d
Grand means		1.2911s	1.3056s	1.4651s	1.3949s	1.0600r
Source	DF	MS	MS	MS	MS	MS
Replicates	4	0.438*	0.326*	0.112	0.153	0.048
Treatments	9	0.213+	0.119	0.020	0.110	0.306***
Error	36	0.110	0.084	0.071	0.074	0.042
Total	49					
CV, %		25.7	22.2	18.2	19.5	19.4

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, *** Statistically significant at .10, .05, and .005 levels of probability, respectively.

Table A.7. Mean empty fruits in percent and analyses of variance for the five plant maturity studies. All 50 sugarbeets in each study were harvested on the same day and ranked visually on the basis of plant maturity.

Plant ratings		Maturity studies and Harvest dates				
		No. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		36.8ab	57.8b	10.0	38.6b	75.8c
2		45.0b	20.8a	8.4	28.4b	57.0bc
3		21.2ab	18.0a	5.2	9.4a	43.2ab
4		11.4a	18.4a	5.2	11.2a	37.4ab
5		13.8a	19.4a	8.2	9.2a	30.0a
6		10.2a	21.2a	6.6	4.4a	38.2ab
7		21.6ab	16.4a	7.0	10.4a	30.0a
8		10.4a	15.4a	7.4	4.8a	21.4a
9		15.4a	17.4a	4.8	5.8a	31.8a
10 - Mature		9.0a	17.0a	3.8	4.2a	24.6a
Grand means		19.48s	22.18s	6.66r	12.64rs	38.94t
Source	DF	MS	MS	MS	MS	MS
Replicates	4	1637.37**	257.72	55.63*	413.48+	2135.33***
Treatments	9	750.72+	800.11***	18.40	666.17***	1350.00***
Error	36	357.63	159.82	19.36	172.39	239.10
Total	49					
CV, %		97.1	57.0	66.1	103.9	39.7

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, **, *** Statistically significant at .10, .05, .01, and .005 levels of probability, respectively.

Table A.8. Mean abnormal fruits in percent and analyses of variance for the five plant maturity studies. All 50 sugarbeets in each study were harvested on the same day and ranked visually on the basis of plant maturity.

Plant ratings		Maturity studies and Harvest dates				
		No. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		39.8 b	64.4b	13.6	60.0b	92.4d
2		47.8b	26.0a	13.4	42.4b	79.6cd
3		22.4ab	22.2a	8.4	20.2a	60.4bc
4		13.8a	20.8a	8.8	17.6a	59.8bc
5		15.6a	23.2a	11.6	16.6a	54.6ab
6		12.4a	25.0a	12.2	11.4a	49.4ab
7		24.2ab	20.8a	11.4	18.2a	44.4ab
8		12.4a	22.4a	10.0	8.6a	33.4a
9		17.2a	20.0a	11.8	12.6a	42.4ab
10 - Mature		10.6a	23.0a	9.2	6.6a	37.8a
Grand means		21.62rs	26.78s	11.04r	21.42rs	55.42t
Source	DF	MS	MS	MS	MS	MS
Replicates	4	1668.17***	373.17	135.88***	724.07*	2788.57***
Treatments	9	795.31*	891.00***	17.19	1411.35***	1733.00***
Error	36	354.37	178.36	25.88	261.16	218.30
Total	49					
CV, %		87.1	49.9	46.1	75.4	26.7

Values with the same letter do not differ significantly at the .05 level of probability.

*, *** Statistically significant at .05 and .005 levels of probability, respectively.

Table A.9. Mean fruit yields in grams per plant and analyses of variance for the five fruit maturity studies. All 50 sugarbeets in each study were harvested on the same day and later ranked visually on the basis of fruit maturity.

Fruit ratings		Maturity studies and Harvest dates				
		No. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		4.8a	3.4a	15.0	10.0a	2.0a
2		5.6a	5.0ab	12.8	14.4ab	6.6a
3		11.0ab	7.6ab	14.4	9.2a	8.0a
4		18.6ab	3.6a	13.8	8.6a	7.4a
5		28.2ab	8.0ab	13.4	34.0ab	9.2a
6		19.4ab	8.6ab	17.4	23.8ab	11.2a
7		35.0b	12.2bc	17.4	34.6ab	24.8b
8		31.8b	10.4abc	20.4	31.0ab	25.4b
9		32.8b	9.2ab	18.4	43.2b	27.2b
10 - Mature		15.6ab	16.8c	27.8	18.4ab	31.6b
Grand means		20.28	8.48	17.08	22.72	15.34
Source	DF	MS	MS	MS	MS	MS
Replicates	4	1211.07*	39.47	78.17	442.42	14.63
Treatments	9	630.90+	83.34**	101.12	771.88+	567.69***
Error	36	311.44	27.01	110.80	402.26	76.43
Total	49					
CV, %		87.0	61.3	61.6	88.3	57.0

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, **, *** Statistically significant at .10, .05, .01, and .005 levels of probability, respectively.

Table A.10. Mean 100 fruit weights in grams and analyses of variance for the five fruit maturity studies. All 50 sugarbeets in each study were harvested on the same day and later ranked visually on the basis of fruit maturity.

Fruit ratings		Maturity studies and Harvest dates				
		No. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		0.702a	1.006	1.464	0.985a	0.607a
2		1.055b	1.147	1.294	1.376b	0.848ab
3		1.226bc	1.359	1.339	1.398b	0.892ab
4		1.405bc	1.160	1.392	1.355b	1.078bcde
5		1.237bc	1.365	1.429	1.394b	0.962bc
6		1.251bc	1.331	1.557	1.481b	1.014bcd
7		1.559c	1.402	1.715	1.613b	1.223cde
8		1.386bc	1.385	1.487	1.507b	1.309de
9		1.550c	1.455	1.459	1.483b	1.301de
10 - Mature		1.541c	1.446	1.515	1.355b	1.365e
Grand means		1.2911s	1.3056s	1.4651s	1.3949s	1.0600r
Source	DF	MS	MS	MS	MS	MS
Replicates	4	0.438***	0.326*	0.112	0.153+	0.048
Treatments	9	0.353***	0.111	0.070	0.137+	0.295***
Error	36	0.075	0.086	0.058	0.067	0.045
Total	49					
CV, %		21.2	22.4	16.5	18.6	20.0

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, *** Statistically significant at .10, .05, and .005 levels of probability, respectively.

Table A.11. Mean empty fruits in percent and analyses of variance for the five fruit maturity studies. All 50 sugarbeets in each study were harvested on the same day and later ranked visually on the basis of fruit maturity.

Fruit ratings		Maturity studies and Harvest dates				
		No. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		60.6c	51.2c	11.8	44.8c	83.6d
2		30.2b	21.0ab	6.4	23.4b	54.4c
3		18.6ab	27.4ab	7.2	13.6ab	45.6bc
4		14.6ab	36.0bc	6.8	10.2ab	31.2ab
5		21.6ab	20.4ab	4.6	3.6a	36.4ab
6		11.2ab	13.8a	6.0	5.6a	30.0ab
7		9.8ab	17.0a	6.2	4.2a	31.2ab
8		10.8ab	13.4a	8.6	11.0ab	20.8a
9		9.8ab	10.8a	6.6	7.4ab	32.4ab
10 - Mature		7.6a	10.8a	2.4	2.6a	23.8a
Grand means		19.48s	22.18s	6.66r	12.64rs	38.94t
Source	DF	MS	MS	MS	MS	MS
Replicates	4	1637.37***	257.72	55.63*	413.48*	2135.33***
Treatments	9	1281.83***	832.29***	29.78	827.99***	1713.96***
Error	36	224.85	151.78	16.52	131.94	148.11
Total	49					
CV, %		77.0	55.5	61.0	90.9	31.2

Values with the same letter do not differ significantly at the .05 level of probability.

*, *** Statistically significant at .05 and .005 levels of probability, respectively.

Table A.12. Mean abnormal fruits in percent and analyses of variance for the five fruit maturity studies. All 50 sugarbeets in each study were harvested on the same day and later ranked visually on the basis of fruit maturity.

Fruit ratings		Maturity studies and Harvest date				
		No. 1 8/8/69	No. 2 8/11/69	No. 3 8/5/70	No. 4 8/11/70	No. 5 8/11/70
1 - Immature		61.8c	56.6d	14.4	64.6c	95.2d
2		33.2b	27.8abc	11.2	39.8b	80.4d
3		21.8ab	33.6bc	11.2	22.6ab	61.6c
4		17.0ab	40.2cd	11.0	16.6a	54.2bc
5		24.4ab	25.0abc	8.6	10.6a	58.2c
6		14.0ab	19.6ab	11.0	12.4a	48.0abc
7		11.0ab	20.0ab	10.0	9.6a	43.2abc
8		13.0ab	19.0ab	13.6	18.8a	32.2a
9		10.8ab	12.6a	11.6	13.0a	43.8abc
10 - Mature		9.2a	13.4a	7.8	6.2a	37.4ab
Grand means		21.62rs	26.78s	11.04r	21.42rs	55.42t
Source	DF	MS	MS	MS	MS	MS
Replicates	4	1668.17***	373.17+	135.88***	724.07*	2788.57***
Treatments	9	1274.51***	921.22***	19.86	1596.95***	1920.64***
Error	36	234.57	170.80	25.21	214.76	171.39
Total	49					
CV, %		70.8	48.8	45.5	68.4	23.6

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, *** Statistically significant at .10, .05, and .005 levels of probability, respectively.

Table A.13. Combined means and analyses of variance of the five maturity studies. All 50 sugarbeets in each study were harvested on the same day and ranked visually on the basis of both plant and fruit maturity.

Maturity		Plant ratings				Fruit ratings			
		Yield, g/plant	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %	Yield g/plant	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
1 - Immature		10.5	1.035	44.0b	54.0b	7.0	0.953a	50.6c	58.6c
2		9.2	1.123	31.8b	41.8b	8.9	1.144ab	26.8b	38.4b
3		17.2	1.298	19.2a	26.4a	10.0	1.243abc	22.6ab	30.4ab
4		14.4	1.373	16.4a	24.4a	10.4	1.278abc	19.8ab	27.8ab
5		12.2	1.312	16.0a	24.6a	18.6	1.277abc	17.4ab	25.4ab
6		23.7	1.414	16.0a	21.8a	16.1	1.327bc	13.4ab	21.0a
7		17.7	1.279	17.0a	23.6a	24.8	1.502c	13.6ab	18.8a
8		16.5	1.354	11.6a	17.2a	23.8	1.415bc	13.0ab	19.4a
9		26.5	1.434	15.0a	20.8a	26.2	1.450bc	13.4ab	18.6a
10 - Mature		19.8	1.412	11.8a	17.6a	22.0	1.444bc	9.6a	14.6a
Grand means		16.78	1.3033	19.98	27.26	16.78	1.3033	19.98	27.26
Source	DF	MS	MS	MS	MS	MS	MS	MS	MS
Studies	4	296.47	0.235**	1493.27***	2790.37***	296.47	0.235***	1479.72***	2778.95***
Treatments	9	153.91	0.086	518.05***	678.82***	264.62	0.137*	711.89***	848.72***
S x T	36	54.30	0.017	52.33	71.94	41.59	0.014	56.86	75.95
Pooled error	180	200.55	0.076	189.66	207.61	185.59	0.066	134.64	163.35
Grand pooled error	216	176.18	0.066	166.77	185.00	161.59	0.057	121.68	148.78
CV, % (gpe)		79.1	19.8	64.6	49.9	75.8	18.4	55.2	44.8

Values with the same letter do not differ significantly at the .05 level of probability.

*, **, *** Statistically significant at .05, .01, and .005 levels of probability, respectively.

Pooled errors were derived from the experimental errors of the five studies and were used to test the interactions.

Grand pooled errors were derived from the interactions and pooled errors and were used to test studies and treatments.

Table A.14. Combined means and analyses of variance for four maturity studies (removed No. 3). All 50 sugarbeets in each study were harvested on the same day and ranked visually on the basis of both plant and fruit maturity.

Maturity	Plant ratings				Fruit ratings			
	Yield, g/plant	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %	Yield, g/plant	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
1 - Immature	9.2	0.932	52.5c	64.0c	5.0	0.825a	60.2c	69.8c
2	7.5	1.050	37.8bc	49.0bc	7.9	1.106ab	32.0b	45.2b
3	18.8	1.264	22.8ab	31.0ab	9.0	1.219b	26.5ab	35.2ab
4	13.2	1.347	19.2ab	28.2ab	9.6	1.250b	23.0ab	32.0ab
5	11.2	1.261	18.0ab	27.8ab	19.8	1.240b	20.5ab	29.5ab
6	26.0	1.366	18.2ab	24.2a	15.8	1.269b	15.2ab	23.5a
7	17.0	1.248	19.5ab	26.8ab	26.6	1.449b	15.5ab	21.0a
8	17.1	1,322	12.8a	19.0a	24.6	1.397b	14.0ab	20.8a
9	27.4	1.423	17.5ab	23.0a	28.1	1.447b	15.0ab	20.2a
10 - Mature	19.6	1.417	13.8a	19.8a	20.6	1.427b	11.5a	16.2a
Grand means	16.70	1.2629	23.31	31.31	16.70	1.2629	23.31	31.31
Source DF	MS	MS	MS	MS	MS	MS	MS	MS
Studies 3	394.92+	0.204*	1256.20***	2624.29***	394.92+	0.204*	1233.70***	2611.77***
Treatments 9	177.14	0.101	614.32***	812.69***	285.58	0.148*	835.29***	1030.73***
S x T 27	60.24	0.016	36.55	50.03	41.73	0.010	32.46	39.38
Pooled error 144	220.82	0.077	232.23	253.05	204.29	0.068	164.17	197.88
Grand pooled error 171	195.46	0.068	201.34	220.99	178.62	0.059	143.37	172.85
CV, % (gpe)	93.7	20.6	60.9	47.5	80.0	19.2	51.4	42.0

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, *** Statistically significant at .10, .05, and .005 levels of probability, respectively.

Pooled errors were derived from the experimental errors of the four studies and were used to test the interactions.

Grand pooled errors were derived from the interactions and pooled errors and were used to test studies and treatments.

Table A.15. Simple correlation coefficients between yield and fruit attributes of sugarbeets for the combined analyses of all five maturity studies during 1969 and 1970.[1]

Attributes	1	2	3	4
1. Yield, g/plant		.51**	-.44**	-.40**
2. 100 Fruit weight, g	.59**		-.84**	-.85**
3. Empty fruits, %	-.52**	-.91**		.97**
4. Abnormal fruits, %	-.49**	-.89**	.97**	

[1]Values of r above the diagonal are for five studies where the plants were ranked visually on the basis of maturity. Values of r below the diagonal are for the five studies where the fruits of those plants were later ranked visually on the basis of maturity. Values of r necessary for significance for both analyses where n = 50 are: .288 and .372 at .05 (*) and .01 (**) levels of probability, respectively.

Table A.16. Plant and fruit attribute means and analyses of variance for the 1970 greenhouse bolting study. Although stalk height varied significantly throughout the bolting period, there were no consistent or significant effects on the fruits due to bolting when plants were allowed to mature completely. Bolting measurements started on February 20 and sugarbeets were harvested on July 17.

Bolting habit		Stalk height, inches							
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
1 - Earliest		26.0e	39.0e	47.7e	57.0e	62.7f	66.7d	69.3b	71.3c
2		19.7de	31.3de	38.7de	47.7d	55.0e	61.0cd	64.0b	67.7bc
3		17.3cde	28.0cd	36.7d	45.7cd	49.7de	54.0bc	58.7b	59.3ab
4		14.3bcd	23.3cd	30.0cd	39.0bc	46.7d	59.0cd	64.0b	69.0bc
5		15.0bcd	24.0cd	31.0cd	38.7bc	44.0cd	46.7ab	47.7a	51.0a
6		9.0abc	19.3bc	26.3bc	34.0b	39.3bc	44.0ab	45.7a	47.3a
7		5.7ab	13.3ab	18.3ab	26.7a	32.7ab	40.0a	45.7a	47.3a
8 - Latest		3.7a	9.3a	13.0a	22.0a	28.3a	38.3a	42.3a	48.0a
Grand means		13.83	23.46	30.21	38.83	44.79	51.21	54.67	57.62
Source	DF	MS	MS	MS	MS	MS	MS	MS	MS
Replicates	2	365.17***	811.79***	1007.19***	885.79***	689.54***	383.79***	145.54*	47.62
Bolting	7	166.86***	275.80***	373.23***	389.81***	385.42***	328.85***	329.33***	329.76***
Error	14	24.50	28.27	29.41	17.22	15.92	29.74	36.07	39.72
Total	23								
CV, %		35.8	22.7	18.0	10.7	8.9	10.6	11.0	10.9

(Continued on next page)

Table A.16. (Continued)

Bolting habit		Yield, g/plant	100 Fruit weight, g	Empty fruit, %	Abnormal fruit, %
1 - Earliest		16.7	1.215	2.3	5.3
2		13.3	1.224	7.3	10.7
3		18.7	1.465	3.0	4.0
4		14.7	1.154	1.3	3.7
5		13.0	0.964	2.7	6.0
6		14.3	1.056	3.0	6.3
7		8.0	1.004	4.0	8.3
8 - Latest		14.0	1.272	0.7	2.7
Grand means		14.08	1.1691	3.04	5.88
Source	DF	MS	MS	MS	MS
Replicates	2	211.54**	0.083	30.04	59.88
Bolting	7	28.64	0.080	12.23	20.66
Error	14	27.59	0.099	26.66	29.45
Total	23				
CV, %		37.3	26.9	169.7	92.4

Values with the same letter do not differ significantly at the .05 level of probability.

*, **, *** Statistically significant at .05, .01, and .005 levels of probability, respectively.

Table A.17. Fruit and lot attribute means and analyses of variance for the 1970 field bolting study. Data are based on five sugarbeets per plot at the time of initial bolting during June. All treatments were windrowed on August 15.

Initial bolting		Yield, g/bolting date	Yield, %/bolting date	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %	Empty in lot, %	Abnormal in lot, %
June 1		83.4e	45.9e	1.659e	2.1a	5.1a	0.97	2.42ab
5		47.6d	26.3d	1.523de	6.3a	10.6a	1.70	2.74b
10		32.1c	17.0c	1.422cd	7.1a	12.9a	1.21	2.29ab
15		13.4b	7.2b	1.312c	14.2a	20.2a	1.13	1.59ab
20		5.0ab	2.7ab	0.940b	40.8b	50.9b	0.80	1.06ab
25		1.7a	0.9a	0.502a	83.3c	87.3c	0.70	0.74a
Grand means		30.54	16.67	1.2265	25.65	31.17	1.087	1.807
Source	DF	MS	MS	MS	MS	MS	MS	MS
Replicates	8	160.16	5.96	0.048	278.69	299.38	1.08	2.01
Dates	5	8764.37***	2669.52***	1.649***	8923.89***	9182.21***	1.15	5.79+
Error	40	99.21	25.35	0.033	200.89	214.44	0.99	2.72
Total	53							
CV, %		32.6	30.2	14.9	55.3	47.0	91.7	91.2

Values with the same letter do not differ significantly at the .05 level of probability.
+, *** Statistically significant at .10 and .005 levels of probability, respectively.

Table A.18. Simple correlation coefficients between fruit and lot attributes of sugarbeets for the field bolting study, comprising six bolting dates during June of 1970.[1]

Attributes	2	3	4	5	6	7
1. Yield, g/bolting date	.97**	.72**	-.61**	-.63**	.24	.47**
2. Yield, %/bolting date		.75**	-.61**	-.64**	.22	.44**
3. 100 Fruit weight, g			-.92**	-.93**	.14	.33*
4. Empty fruits, %				.99**	-.56**	-.25
5. Abnormal fruits, %					-.20	-.19
6. Empty in lot, %						.88**
7. Abnormal in lot, %						

[1]Values of r necessary for significance where n = 54 are: .273 and .354 at .05 (*) and .01 (**) levels of probability, respectively.

Table A.19. Fruit and lot attribute means and analyses of variance (split-block) for the 1970 empty fruit location study. Data are based on five healthy sugarbeets per plot at harvest on August 16 and 17. (Lateral spurs include all secondary and tertiary laterals.)

Lines and Locations		Yield, g/ plant part	Yield, %/ plant part	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
Lines						
1		17.9	25.0	1.533	6.0ab	8.4a
2		17.0	25.0	1.515	6.7ab	11.9ab
3		12.9	25.0	1.455	10.3bc	15.5b
4		22.8	25.0	1.425	3.4a	7.1a
5		14.6	25.0	1.490	8.8bc	10.1ab
6		13.7	25.0	1.670	12.6c	15.2b
Fruit locations						
Upper primary axes		4.3a	7.2a	1.762c	7.4a	10.9ab
Lower 3/4th laterals		35.2d	55.2d	1.650c	5.7a	8.7a
Upper 1/4th laterals		15.2c	22.7c	1.462b	7.2a	11.3ab
All lateral spurs		11.2b	14.9b	1.183a	11.6b	14.5b
Grand means		16.46	25.00	1.5146	7.98	11.34
Source	DF	MS	MS	MS	MS	MS
Replicates	3	218.06	0.00	0.407*	40.40	82.01
Lines	5	211.19	0.00	0.118	172.59*	195.57*
Error a	15	94.48	0.00	0.086	40.05	47.97
Locations	3	4234.08***	10635.24***	1.539*	153.49*	134.65+
Error b	9	36.71	112.72	0.036	37.55	35.98
L x L	15	38.38	36.74	0.035*	79.34***	105.44***
Error c	45	26.54	39.28	0.015	27.48	31.71
Total	95					
CV, % (a)		59.1	0.0	19.4	79.3	61.0
(b)		36.8	42.5	12.5	76.8	52.9
(c)		31.3	25.1	8.1	65.7	49.6

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Table A.19. (Continued)

Lines and Locations		Empty in lot, %	Abnormal in lot, %	Total empty, %	Total abnormal, %
Lines					
1		1.28a	1.94a	5.1a	7.8a
2		1.12a	2.29a	4.5a	9.2a
3		1.42a	2.54ab	5.7ab	10.1ab
4		0.91a	1.83a	3.6a	7.3a
5		2.16b	2.49ab	8.6bc	10.0ab
6		2.88b	3.53b	11.5c	14.1b
Fruit locations					
Upper primary axes		0.56a	0.83a		
Lower 3/4th laterals		3.14c	4.79c		
Upper 1/4th laterals		1.63b	2.57b		
All lateral spurs		1.18ab	1.56ab		
Grand means		1.629	2.436	6.52	9.75
Source	DF	MS	MS	MS	MS
Replicates	3	1.82	5.57+	7.27	22.26+
Lines	5	8.94***	5.91*	35.75***	23.66*
Error a	15	1.17	2.00	4.66	7.99
Locations	3	29.02***	71.12***		
Error b	9	1.70	2.46		
L x L	15	1.51***	1.22		
Error c	45	0.54	1.05		
Totals	23 or 95				
CV, % (a)		66.3	58.0	33.1	29.0
(b)		80.0	64.4		
(c)		45.3	42.1		

Values with the same letter do not differ significantly at the .05 level of probability.
+, *, *** Statistically significant at .10, .05, and .005 levels of probability, respectively.

Table A.20. Male sterile line x fruit location interaction means for the 1970 empty fruit location study. All interactions shown were significant in the analyses of variance at the .05 level of F or greater.

Attributes Lines	Upper primary	Lower 3/4th of laterals	Upper 1/4th of laterals	Lateral spurs
100 Fruit weight, g				
1	1.676	1.666	1.489	1.300
2	1.642	1.676	1.476	1.264
3	1.744	1.665	1.444	0.968
4	1.670	1.590	1.366	1.074
5	1.770	1.590	1.364	1.235
6	2.073	1.714	1.636	1.258
$LSD_{.01}$ = 0.3804 g for single comparisons between any two means.				
Empty fruits, %				
1	8.5	4.5	5.0	6.0
2	8.2	3.2	6.2	9.0
3	6.5	4.5	5.0	25.2
4	3.5	4.2	3.0	3.0
5	9.5	8.2	10.5	7.0
6	8.2	9.2	13.8	19.2
$LSD_{.01}$ = 11.10% for single comparisons between any two means.				
Abnormal fruits, %				
1	11.5	7.8	7.2	7.0
2	14.5	7.2	12.5	13.2
3	9.8	8.0	12.0	32.2
4	6.8	7.2	8.2	6.0
5	11.2	9.8	12.0	7.2
6	11.8	12.2	15.8	21.0
$LSD_{.01}$ = 11.86% for single comparisons between any two means.				
Empty in lot, %				
1	0.64	2.26	1.28	0.94
2	0.56	1.80	1.38	0.76
3	0.62	2.68	1.21	1.17
4	0.18	2.34	0.72	0.40
5	0.81	4.57	2.32	0.94
6	0.60	5.20	2.90	2.84
$LSD_{.01}$ = 1.811% for single comparisons between any two means.				

Table A.21. Paired t-test comparison of fruit attribute means and analysis of variance for the time of empty fruit development study. Individual sugarbeets were harvested prematurely on July 28, 1970. Beginning at the primary tip, 100 odd-numbered fruits per plant were cut and examined fresh; 100 even-numbered fruits were allowed to dry naturally on the windrowed plants. Fruits in replicate No. 3 were then X-rayed and examined.

Sugarbeet lines	Cut fresh		X-rayed dried	
	Abnormal fruits, % (3 Reps)	Abnormal fruits, % (Rep. No. 3)	Empty fruits, % (Rep. No. 3)	Abnormal fruits, % (Rep. No. 3)
1	16.3	13	58	96
2	12.0	13	72	100
3	4.3	2	7	11
4	12.7	20	24	72
5	8.3	6	8	29
6	9.3	4	2	28
Grand means	10.50	9.7	28.5	56.0

Source	DF	MS	Fresh, abnormal vs. X-rayed, empty	Fresh, abnormal vs. X-rayed, abnormal
Replicates	2	12.50		
Lines	5	51.03	$t = \frac{\bar{d}}{s_{\bar{d}}} =$ 1.762 with 5 df	3.432* with 5 df
Error	10	46.63		
Total	17			
Standard deviations			6.83	29.56	38.29
Means $\pm$ $t_{.05}s_{\bar{x}}$			7.17	31.03	40.20
CV, %			65.0	70.7	103.7	68.4

*Statistically significant at the .05 level of probability.

Table A.22. Fruit and lot attribute means and analyses of variance for the 1970 lygus-free caging study. Certain sugarbeets were caged from early anthesis on June 15 until they were windrowed on August 31.

Caging, Lines and Sizes	Yield, g/plot	Size class, g	Size class, % of entire lot	Empty fruits, %	Abnormal fruits, %
Caging					
Caged	190.0	38.0	20.0	39.7	42.4
Uncaged	132.2	26.5	20.0	34.7	38.6
Lines					
1	171.5b	34.4b	20.0	39.7	43.4
2	71.5a	14.3a	20.0	38.7	41.7
3	197.5b	39.5b	20.0	32.5	36.8
5	204.0b	40.8b	20.0	37.9	40.1
Screen sizes, 64th inch					
5-7		3.9a	2.5a	93.5d	94.0d
7-9		12.2a	7.5a	63.8c	67.8c
9-11		37.4b	23.8b	20.2b	24.0b
11-13		70.1c	44.3c	6.1a	10.6a
13-15		37.7b	22.0b	2.4a	6.1a
Grand means	161.12	32.25	20.00	37.20	40.50
Source DF	MS	MS	MS	MS	MS
Caging 1	6670*	1333**	0.00	250.00+	152.10
Lines 3	7534*	1512***	0.00	103.60	79.00
Sizes 4		5389***	2141.99***	12680.66***	11902.44***
L x S 12		229	6.44	79.75	72.85
Errors 3 or 19	628	157	43.41	65.26	76.47
Totals 7 or 39					
CV, %	15.6	38.9	32.9	21.7	21.6

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Table A.22. (Continued)

Caging, Lines, and Sizes	100 Fruit weight, g	Empty in lot, %	Abnormal in lot, %	Total empty, %	Total abnormal, %
Caging					
Caged	1.111	2.95	3.60	14.7	18.0
Uncaged	1.071	3.05	3.99	15.3	20.0
Lines					
1	1.094ab	2.80	3.77	14.0	18.8
2	1.016a	2.68	3.37	13.4	16.8
3	1.186b	2.57	3.62	12.8	18.1
5	1.066a	3.95	4.41	19.7	22.0
Screen sizes, 64th inch					
5-7	0.268a	2.33b	2.34a		
7-9	0.573b	4.68c	4.97b		
9-11	1.026c	4.81c	5.75b		
11-13	1.523d	2.74b	4.75b		
13-15	2.064e	0.45a	1.14a		
Grand means	1.0909	3.000	3.792	15.00	18.96
Source DF	MS	MS	MS	MS	MS
Caging 1	0.016	0.11	1.55	0.56	7.74
Lines 3	0.051**	4.07	1.97	20.37	9.85
Sizes 4	4.167***	26.22***	30.57***		
L x S 12	0.008	1.42	1.50		
Errors 3 or 19	0.010	1.70	3.14	26.11	51.61
Totals 7 or 39					
CV, %	9.2	43.5	46.7	34.1	37.9

Values with the same letter do not differ significantly at the .05 level of probability.
+, *, **, *** Statistically significant at .10, .05, .01, and .005 levels of probability, respectively.

Table A.23. Simple correlation coefficients between fruit and lot attributes for the 1970 lygus-free caging study, averaged over four lines of sugarbeets without replication.[1]

Attributes	2	3	4	5	6	7
1. Size class, g	.83**	.65**	-.67**	-.67**	.27	.26
2. Size class, %		.68**	-.79**	-.79**	-.36*	.27
3. 100 Fruit weight, g			-.90**	-.90**	-.46**	-.23
4. Empty fruits, %				.99**	.27	.14
5. Abnormal fruits, %					.29	.41*
6. Empty in lot, %						.91**
7. Abnormal in lot, %						

[1] Values of r necessary for significance where n = 40 are: .325 and .418 at .05 (*) and .01 (**) levels of probability, respectively.

Table A.24. Plant and fruit attribute means and analyses of variance for the 1969 clipping study. Data are based on single healthy sugarbeet plants. All factors differed significantly at the .05 level of probability or greater.

Clipping treatments		Yield, g/plant	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
Clipped laterals		14.0a	2.112b	14.3a	15.67a
Tipped primary axis		35.7b	1.951b	23.3a	24.00a
Unclipped plant		17.7ab	1.461b	36.3a	39.00a
Clipped top half		1.3a	0.452a	81.3b	83.00b
Grand means		17.17	1.4941	38.83	40.42
Source	DF	MS	MS	MS	MS
Replicates	2	30.58	0.18	121.58	108.08
Treatments	3	603.22*	1.68*	2653.00*	2697.42**
Error	6	109.14	0.24	332.92	270.75
Total	11				
CV, %		60.9	33.1	47.0	40.7

Values with the same letter do not differ significantly at the .05 level of probability.
*, ** Statistically significant at .05 and .01 levels of probability, respectively.

Table A.25. Fruit and lot attribute means and analyses of variance for the 1970 lodging study. Treatments were first applied at early anthesis on June 18. Late lodged sugarbeets were also tied upright then lodged manually 30 days later. All plots were windrowed on August 6.

Treatments and Sizes		Yield, lb/A	Size class, g	Size class, %	Fruit count/ 10 g	100 Fruit weight, g
Treatments						
Untreated check		3799b	60.1	20.0	820ab	1.293
Tipped primary		3559b	58.7	20.0	764a	1.335
Held upright		4359c	59.9	20.0	806ab	1.307
Lodged early		2136a	62.4	20.0	892bc	1.298
Lodged late		3342b	64.1	20.0	932c	1.312
Screen sizes, 64th inch						
5-7			11.2a	3.6a		0.437a
7-9			62.9c	20.4c		0.813b
9-11			103.3e	33.8e		1.235c
11-13			94.4d	31.1d		1.713d
13-15			33.2b	11.0b		2.347e
Grand means		3439.2	61.04	20.00	842.8	1.3090
Source	DF	MS $X10^3$	MS	MS	MS $X10^3$	MS
Replicates	3	487.76*	98.98	0.00	13.35+	0.011
Treatments	4	2696.96***	94.66	0.00	18.37*	0.005
Error a	12	86.81			4.65	0.006
Sizes	4		30815.72***	3312.27***		11.269***
T x S	16		394.39***	39.78***		0.004*
Error b	60					0.002
Error p	72		78.97	7.72		
Totals	19 or 99					
CV, % (a)		8.6			8.1	5.9
(b)						3.4
(p)			14.6	13.9		

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Table A.25. (Continued)

Treatments and Sizes	Empty fruits, %		Abnormal fruits, %	
	Hand counted	Vacuum counted	Hand counted	Vacuum counted
Treatments				
Untreated check	19.0	14.2a	26.0	21.6a
Tipped primary	18.0	16.4ab	24.0	21.8a
Held upright	17.6	18.1b	23.3	23.9ab
Lodged early	17.3	18.3b	24.8	25.7b
Lodged late	15.2	13.3a	23.9	22.1a
Screen sizes, 64th inch				
5-7	48.0d		58.3d	
7-9	20.4c		29.2c	
9-11	9.7b		15.8b	
11-13	5.6a		10.6a	
13-15	3.4a		8.2a	
Grand means	17.40	16.06	24.41	23.00
Source DF	MS	MS	MS	MS
Replicates 3	48.29	12.65	49.56	13.23
Treatments 4	38.18	81.12**	21.51	49.28+
Experimental error 12	30.77	68.00***	51.69	59.81**
Sampling error 60		20.87		23.59
Sizes 4	6712.38***		8494.28***	
T x S 16	28.71+		20.52	
Error b 60	17.91		25.30	
Totals 79 or 99				
CV, % (a)	31.9		29.4	
(b)	24.3		20.6	
(se)		28.4		21.1

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Table A.25. (Continued)

Treatments and Sizes		Empty in lot, %	Abnormal in lot, %	Total empty, %	Total abnormal, %
Treatments					
Untreated check		2.53	3.76	12.6	18.8
Tipped primary		2.11	3.25	10.5	16.7
Held upright		1.83	2.86	9.1	14.3
Lodged early		2.55	3.97	12.8	19.9
Lodged late		2.09	3.65	10.4	18.3
Screen sizes, 64th inch					
5-7		1.70b	2.10b		
7-9		4.02d	5.88d		
9-11		3.27c	5.35d		
11-13		1.71b	3.26c		
13-15		0.41a	0.90a		
Grand means		2.221	3.499	11.10	17.49
Source	DF	MS	MS	MS	MS
Replicates	3	0.24	1.09	1.22	5.43
Treatments	4	1.95	3.94	9.75	19.70
Error a	12	1.16	2.74	5.78	13.71
Sizes	4	40.76***	89.32***		
T x S	16	1.08	2.18*		
Error b	60	0.72	1.12		
Totals	19 or 99				
CV, % (a)		48.4	47.3	21.7	21.2
(b)		38.3	30.3		

Values with the same letter do not differ significantly at the .05 level of probability.
+, *, **, *** Statistically significant at .10, .05, .01, and .005 levels of probability, respectively.

Table A. 26. Treatment x fruit size first-order interaction means for the 1970 lodging study. All interactions shown were significant in the analyses of variance at the .05 level of F or greater.

Attributes	Screen sizes, 64th inch				
Treatments	5-7	7-9	9-11	11-13	13-15
Size class, g					
Untreated check	10.6	57.4	100.4	98.8	33.5
Tipped primary	8.5	48.7	90.4	97.6	48.1
Held upright	8.6	52.2	103.9	100.9	33.8
Lodged early	14.2	75.9	108.4	88.0	25.4
Lodged late	14.2	80.4	113.6	86.8	25.4
$LSD_{.01}$ = 16.55 g for single comparisons between any two means.					
Size class, %					
Untreated check	3.5	19.1	33.4	32.9	11.2
Tipped primary	2.9	16.6	30.8	33.3	16.4
Held upright	2.9	17.3	34.7	33.8	11.4
Lodged early	4.5	24.3	34.8	28.3	8.2
Lodged late	4.4	24.9	35.4	27.3	8.0
$LSD_{.01}$ = 5.28% for single comparisons between any two means.					
100 Fruit weight, g					
Untreated check	0.448	0.809	1.216	1.675	2.317
Tipped primary	0.422	0.835	1.236	1.730	2.452
Held upright	0.415	0.824	1.255	1.724	2.318
Lodged early	0.451	0.788	1.216	1.698	2.335
Lodged late	0.448	0.808	1.250	1.740	2.314
$LSD_{.01}$ = 0.1059 g for single comparisons between any two means.					
Abnormal in lot, %					
Untreated check	2.08	6.11	6.28	3.37	0.94
Tipped primary	1.63	4.48	4.49	4.02	1.65
Held upright	1.74	4.82	4.14	2.90	0.68
Lodged early	2.51	7.66	5.82	3.24	0.64
Lodged late	2.53	6.34	6.00	2.79	0.60
$LSD_{.01}$ = 2.389% for single comparisons between any two means.					

Table A. 27. Simple correlation coefficients between fruit and lot attributes of sugarbeets for the 1970 lodging study. Comparisons were totaled over all subsamples and sizes.[1]

	Attributes	2	3	4	5	6	7	8	9
1.	Yield, lb/A	-.49*	.12	.26	.01	-.18	-.27	-.26	-.37
2.	Fruit count/10 g		-.01	-.44	.14	.07	.31	.01	.43
3.	100 Fruit weight, g			-.04	-.19	-.01	-.02	-.11	-.18
4.	Empty fruits, % (hand counted)				.74**	.22	.13	.69**	.40
5.	Abnormal fruits, % (hand counted)					.24	.30	.68**	.79**
6.	Empty fruits, % (vacuum counted)						.90**	.13	.18
7.	Abnormal fruits, % (vacuum counted)							.24	.36
8.	Empty in lot, %								.80**
9.	Abnormal in lot, %								

[1] Values of r necessary for significance where n = 20 are: .444 and .561 at .05 (*) and .01 (**) levels of probability, respectively.

Table A. 28. Fruit and lot attribute means and analyses of variance for the 1970 Crocker seed sizing study. Small sugarbeet fruits were significantly more empty and abnormal than large fruits.

Screen sizes, 64th inch		Size class, g	Size class, % of entire lot	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %	Empty in lot, %	Abnormal in lot, %
5-7		1.0a	0.4a	0.485a	80.0d	88.0e	0.32a	0.35a
7-9		18.8b	7.4b	0.688b	51.0c	70.0d	3.77c	5.14b
9-11		63.8c	25.2c	1.061c	25.5b	42.8c	6.48d	10.79c
11-13		109.0d	43.1d	1.500d	14.5a	27.2b	6.26d	11.77c
13-15		60.ac	23.9c	1.965e	8.5a	20.0a	2.04b	4.83b
Grand means		50.55	20.00	1.1397	35.90	49.60	3.774	6.574
Source	DF	MS	MS	MS	MS	MS	MS	MS
Samples	3	50.32	0.00	0.000	83.27*	27.20	2.12	0.68
Sizes	4	7151.18***	1120.37***	1.450***	3489.70***	3313.32***	28.48***	88.62***
Error	12	56.28	7.85	0.001	18.27	11.82	0.92	1.93
Total	19							
CV, %		14.8	14.0	3.2	11.9	6.9	25.4	21.1

Values with the same letter do not differ significantly at the .05 level of probability.
*, *** Statistically significant at .05 and .005 levels of probability, respectively.

Table A.29. Agronomic, fruit and lot attribute means and analyses of variance for the 1970 commercial seed sizing study. Ten samples were obtained from the West Coast Beet Seed Company and analyzed for several factors that may contribute to empty and abnormal fruit.

Lots and Sizes		Size class, g	Size class, % of all lots	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
Lots						
1		50.7	20.0	0.987	1.8a	8.2a
2		49.8	20.0	1.112	4.2ab	10.4a
3		73.1	20.0	1.229	7.8ab	16.0ab
4		45.1	20.0	1.178	17.8abc	23.2abc
5		42.3	20.0	1.106	22.8bcd	32.4bcd
6		45.2	20.0	1.224	27.4cde	37.8cd
7		50.2	20.0	1.688	29.6cde	38.2cd
8		52.6	20.0	1.185	36.8cde	42,0cd
9		39.5	20.0	1.134	38.8de	44.6d
10		48.3	20.0	1.141	43.4e	48.0d
Screen sizes, 64th inch						
5-7		5.9a	1.9a	0.407a	57.5d	66.8d
7-9		65.3b	23.1b	0.698a	33.4c	42.7c
9-11		96.1b	39.5c	1.082b	16.1b	22.0b
11-13		68.6b	29.8bc	1.801c	6.0ab	12.9ab
13-15		12.5a	5.7a	2.004c	2.2a	6.0a
Grand means		49.68	20.00	1.1986	20.04	30.08
Source	DF	MS	MS	MS	MS	MS
Lots	9	421.47	0.00	0.172	1100.08***	1064.76***
Sizes	4	15124.38***	2551.54***	4.753***	5169.13***	6119.77***
Error	36	2122.18	223.39	0.149	179.41	188.88
Total	49					
CV, %		92.7	74.7	32.2	58.1	45.7

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Table A. 29. (Continued)

Lots and Sizes	Empty in all lots, %	Abnormal in all lots, %	Total empty, %	Total abnormal, %
Lots				
1	0.26a	1.67a	1.3	8.4
2	0.19a	1.19a	1.0	6.0
3	2.28abc	4.22ab	11.4	21.1
4	1.06ab	1.59a	5.3	7.9
5	1.93ab	3.38ab	9.7	16.9
6	3.16abcd	4.72ab	15.8	23.6
7	3.95abcd	5.89ab	19.7	29.5
8	6.58cd	7.50b	32.9	37.5
9	4.83bcd	6.26ab	24.1	31.3
10	7.04d	8.18b	35.2	40.9
Screen sizes, 64th inch				
5-7	0.84a	0.97ab		
7-9	5.89b	8.07c		
9-11	6.57b	8.71c		
11-13	2.19a	4.05b		
13-15	0.17a	0.50a		
Grand means	3.129	4.460	15.64	22.31
Source DF	MS	MS		
Lots 9	30.05**	31.28*		
Sizes 4	85.82***	147.64***		
Error 36	9.50	14.01		
Total 49				
Deviations			12.24	12.51
Means $\pm t_{.05} s_{\bar{x}}$			8.76	8.95
CV, %	98.5	83.9	78.3	56.1

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Table A. 29. (Continued)

Lots	X-ray germ, %	Germ by lab, %	Date planted 7/1/69+	Date sprayed 6/1/70+	Date swathed[1] 6/21/70+
1	91.6	97	25	6	45
2	94.0	94	27	6	48
3	78.9	92	42	11	38
4	92.1	93	39	7	48
5	83.1	93	51	2	63
6	76.4	72	46	3	59
7	70.5	72	51	3	58
8	62.5	57	54	8	49
9	68.7	63	54	8	55
10	59.1	55	47	8	52
Grand means	77.69	78.8	43.6	6.2	51.5
Deviations	12.51	16.75	10.48	2.82	7.44
Means $\pm t_{.05} s_{\bar{x}}$	8.95	11.98	7.50	2.02	5.32
CV, %	16.1	21.3	24.0	45.5	14.4

Paired t-test comparison of X-ray vs. laboratory germination: t = 5.391*** with 9 df.

[1]Date swathed shows maturity in days from peak anthesis. Samples 1 and 2 were grown in the Medford, Oregon, area where peak anthesis was estimated as June 11.

*, **, *** Statistically significant at .05, .01, and .005 levels of probability, respectively.

Values with the same letter do not differ significantly at the .05 level of probability.

Table A.30. Simple correlation coefficients between fruit and lot attributes of sugarbeets for the 1970 commercial seed sizing study, averaged over ten lots of seed.[1]

Attributes	2	3	4	5	6	7
1. Size class, g	.97**	.52**	-.26	-.26	.48**	.65**
2. Size class, %		.95**	-.28	-.28	.50**	.65**
3. 100 Fruit weight, g			-.62**	-.64**	-.20	-.15
4. Empty fruits, %				.99**	.29*	.18
5. Abnormal fruits, %					.28	.19
6. Empty in all lots, %						.96**
7. Abnormal in all lots, %						

[1]Values of r necessary for significance where n = 50 are: .288 and .372 at .05 (*) and .01 (**) levels of probability, respectively.

Table A.31. Simple correlation coefficients between lot quality and agronomic practices on sugarbeets for the 1970 commercial seed sizing study, averaged over ten lots of seed.[1]

Attributes	2	3	4	5	6	7
1. Total empty, %	.98**	-.98**	-.96**	.77**	.23	.24
2. Total abnormal, %		-.99**	-.94**	.79**	.19	.25
3. X-ray germination, %			.94**	-.79**	-.19	-.25
4. Laboratory germination, %				-.70*	-.14	-.31
5. Date planted					-.87**	.54
6. Date sprayed						-.83**
7. Date swathed						

[1]Values of r necessary for significance where n = 10 are: .632 and .765 at .05 (*) and .01 (**) levels of probability, respectively.

Table A. 32. Plants and fruit attribute means and analyses of variance for the 1969 DeFord chemical spray study. Five different chemicals were applied once to sugarbeets at peak anthesis on June 20 and 21. Data are based on four uniform, healthy plants per plot.

Chemical	Molar rates	Windrowed dry matter, %	Yield, g/plot	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
Check		32.2	138.	1.582c	12.8a	14.7a
DDT	10^{-3}	29.5	217.	1.725d	15.7ab	17.7abc
	10^{-6}	31.0	186.	1.588c	26.3de	28.3e
	10^{-9}	31.0	143.	1.597c	25.5de	27.5e
Endothal	10^{-3}	32.7	135.	1.542bc	26.5de	27.7e
	10^{-6}	33.8	147.	1.584c	13.3a	15.5a
	10^{-9}	30.8	141.	1.572c	16.0ab	19.2abcd
IPC	10^{-3}	30.3	96.	1.467b	21.2bcd	21.8cd
	10^{-6}	33.5	144.	1.477b	14.5a	16.3abc
	10^{-9}	30.8	143.	1.571c	12.8a	15.2a
2, 4-D	10^{-3}	33.0	112.	1.172a	51.7g	54.2g
	10^{-6}	32.5	111.	1.540bc	39.8f	42.7f
	10^{-9}	30.4	165.	1.591c	13.5a	15.7ab
GA_3	10^{-3}	30.3	189.	1.780d	28.3e	29.5e
	10^{-6}	31.8	176.	1.908e	21.8cd	23.8de
	10^{-9}	31.5	99.	1.508bc	17.5abc	21.3bcd
Grand means		31.56	146.5	1.5753	22.33	24.44

Source	DF	MS	MS	MS	MS	MS
Replicates	2	81.29***	10125.81*	0.075***	79.76*	107.28**
Treatments	15	4.71	3415.91	0.147***	702.60***	708.42***
Experimental error	30	8.82	2035.39	0.072***	76.63***	75.39***
Sampling error	48			0.005	20.88	19.44
Totals	47 or 95					
CV, %		9.4	30.8	4.4	20.5	18.0

Values with the same letter do not differ significantly at the .05 level of probability.
*, **, *** Statistically significant at .05, .01, and .005 levels of probability, respectively.

Table A. 33. Fruit attribute means and analyses of variance for the 1970 Gilmour chemical spray study. Five different chemicals were applied once to sugarbeets at late anthesis on July 2 (delayed by irrigation and rain). Data are based on four uniform, healthy plants per plot.

Chemical Molar rates	Yield, g/plot	100 Fruit weight, g	Empty fruits, %		Abnormal fruits, %	
			Hand counted	Vacuum counted	Hand counted	Vacuum counted
Check	156	1.674bcde	5.5a	14.3abcd	6.5a	20.0cde
DDT						
10^{-3}	112	1.588a	7.0a	11.2ab	11.7cd	17.7abcde
10^{-6}	96	1.822g	5.8a	13.0abc	9.5abcd	16.2abcd
10^{-9}	76	1.612abc	7.7a	18.7a	11.0bcd	21.7e
Endothal						
10^{-3}	104	1.645abcd	4.8a	11.7abc	9.0abc	16.2abcd
10^{-6}	127	1.721def	5.7a	17.2cd	6.8a	19.0bcde
10^{-9}	111	1.796fg	5.3a	12.8abc	6.7a	16.0abcd
IPC						
10^{-3}	117	1.723def	5.3a	11.7abc	7.7abc	15.5abcd
10^{-6}	124	1.600ab	5.2a	10.2ab	7.0ab	13.7ab
10^{-9}	117	1.803fg	5.3a	9.7a	10.0abcd	13.3a
2,4-D						
10^{-3}	79	1.755efg	12.0b	28.3e	13.3d	34.7f
10^{-6}	116	1.798fg	5.2a	11.0ab	6.8a	12.5a
10^{-9}	117	1.754efg	5.8a	15.7bcd	9.8abcd	21.0de
GA_3						
10^{-3}	99	1.710de	5.8a	11.5abc	9.3abc	14.2ab
10^{-6}	116	1.735ef	7.0a	11.2ab	9.0abc	15.7abcd
10^{-9}	114	1.680cde	5.7a	11.8abc	7.2ab	14.7abc
Grand means	111.3	1.7134	6.20	13.74	8.83	17.62
Source DF	MS	MS	MS	MS	MS	MS
Replicates 2	3787.58**	0.433***	19.20+	76.57*	92.39***	62.54*
Treatments 15	1060.31	0.034***	17.92***	128.71***	24.69**	168.79***
Experimental error 30	693.89	0.056***	15.49***	40.24**	25.11***	52.31***
Sampling error 48		0.004	6.28	17.66	8.94	16.80
Totals 47 or 95						
CV, %	23.7	3.6	40.4	30.6	33.8	23.3

Values with the same letter do not differ significantly at the .05 level of probability.
+, *, **, *** Statistically significant at .10, .05, .01, .005 levels of probability, respectively.

Table A.34. Simple correlation coefficients between yield and fruit attributes of sugarbeets for the two chemical spray studies.[1]

Attributes	1	2	3	4	5	6
1. Yield, g/plot		.55**	-.26	-.26		
2. 100 Fruit weight, g	.13		-.38**	-.38**		
3. Empty fruits, % (hand counted)	-.40**	.13		.99**		
4. Abnormal fruits, % (hand counted)	-.43**	-.12	.81**			
5. Empty fruits, % (vacuum counted)	-.25	.25	.62**	.38**		
6. Abnormal fruits, % (vacuum counted)	-.27	.15	.66**	.50**	.93**	

[1] Values of r above the diagonal are for the 1969 DeFord study, where male sterile plants were sprayed at peak anthesis on June 20 and 21. Values of r below the diagonal are for the 1970 Gilmour study, where the same hybrid [SL(100363 x 12163)] was sprayed at late anthesis on July 2 (delayed by irrigation and rain). Values of r necessary for significance for both studies where n = 48 are: .288 and .372 at .05 (*) and .01 (**) levels of probability, respectively.

Table A.35. Plant and fruit attribute means and analyses of variance for the 1970 greenhouse growth regulator study No. 1. Bolting measurements began on May 1 (week 1). Sugarbeets were sprayed at peak anthesis on June 5 (week 6), and harvested at full maturity on August 15.

Growth regulators at 1000 ppm		Stalk height, inches				Yield, g/plant	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
		Week 2	Week 4	Week 6	Week 7				
Alar-85		17.2	45.2	56.8ab	54.8ab	17.5ab	0.992	22.0	27.5
Ethrel		20.5	41.2	51.8a	51.8a	11.2a	0.971	41.5	47.8
MH-30		27.2	55.5	62.2b	63.0c	22.5ab	1.052	23.8	30.2
2,4-D		27.5	51.5	56.2ab	56.5abc	19.2ab	0.896	29.2	33.5
TIBA		23.8	46.2	56.6ab	56.2abc	20.0ab	0.960	40.8	43.8
Check		21.8	51.8	61.5b	62.0bc	28.0b	1.211	4.2	6.2
Grand means		23.00	48.58	57.50	57.38	19.75	1.0137	26.92	31.50
Source	DF	MS	MS	MS	MS	MS	MS	MS	MS
Replicates	3	752.78***	482.72***	137.44**	75.49+	40.94	0.151	936.28	772.00
Treatments	5	63.80	109.37	59.80+	74.88*	122.60+	0.047	765.97	858.60
Error	15	56.84	60.46	22.71	23.12	50.58	0.075	891.81	901.27
Total	23								
CV, %		32.8	16.0	8.3	8.4	36.0	27.0	111.0	95.3

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, **, *** Statistically significant at .10, .05, .01, and .005 levels of probability, respectively.

Table A. 36. Plant and fruit attribute means and analyses of variance for the 1970 greenhouse growth regulator study No. 2. Bolting measurements began on May 1 (week 1). Sugarbeets were sprayed at early anthesis on June 5 (week 6) and harvested at full maturity on August 15.

Growth regulators at 1000 ppm		Stalk height, inches				Yield, g/plant	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
		Week 2	Week 4	Week 6	Week 7				
Alar-85		8.8	39.8	62.8	65.2	16.0b	1.143b	18.8	24.5a
Ethrel		7.8	43.2	62.5	63.5	14.2ab	0.868ab	60.2	69.0bc
MH-30		3.8	37.0	63.8	71.2	16.2b	1.132b	60.8	70.5bc
2,4-D		8.5	39.0	59.8	63.2	5.5a	0.583a	62.5	74.2c
TIBA		7.0	40.8	61.8	63.5	15.2b	0.987ab	52.0	55.8abc
Check		8.8	39.8	63.0	66.8	23.5b	1.065b	27.2	31.2ab
Grand means		7.42	39.92	62.25	65.58	15.12	0.9632	46.92	54.21
Source	DF	MS	MS	MS	MS	MS	MS	MS	MS
Replicates	3	94.39+	230.94+	24.94	24.17	60.38	0.059	273.61	339.82
Treatments	5	14.77	16.97	7.70	38.17	132.48*	0.180+	1454.37	1838.34+
Error	15	37.79	73.61	33.01	54.17	34.21	0.078	995.68	663.12
Total	23								
CV, %		82.9	21.5	9.2	11.2	38.7	28.9	67.3	47.5

Values with the same letter do not differ significantly at the .05 level of probability.
+, * Statistically significant at .10 and .05 levels of probability, respectively.

Table A. 37. Fall stand counts per meter of row for the 1970 field growth regulator study. There was a drastic reduction of stand over time but it began to stabilize by the sixth week after sugarbeets were planted on September 8, 1969. When data were analyzed without randomization, there were highly significant differences between evenly-spaced plots. When data were analyzed with randomization, these stand differences were statistically removed.

Spaced		Analyzed without randomization					Analyzed with randomization				
plots		Week 2	Week 3	Week 4	Week 5	Week 6	Week 2	Week 3	Week 4	Week 5	Week 6
1		83.1b	63.6c	55.2c	50.9b	47.6c	70.8	62.4	56.0	54.1	51.2
2		50.7a	33.9a	29.2a	27.4a	23.1a	71.1	53.1	49.9	45.3	41.8
3		56.5a	43.1b	39.2b	35.8a	34.3b	71.0	61.6	53.7	48.9	45.9
4		73.8b	66.9c	63.1c	59.0bc	53.9c	63.3	51.4	46.7	42.2	39.0
5		79.1b	77.1d	72.1d	67.1c	65.2d	67.0	56.0	52.7	49.7	46.2
Grand means		68.64	56.91	51.78	48.04	44.82	68.64	56.91	51.78	48.04	44.82
Source	DF	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
Replicates	8	222.54*	118.66	152.97+	145.84	106.07	222.54	118.66	152.97	145.84	106.07
Plots	4	1832.69***	2862.47***	2745.33***	2399.59***	2446.25***	105.97	219.02	116.72	183.14	196.26
Error	32	93.41	82.83	79.27	78.90	68.66	309.25	413.26	407.85	355.96	349.91
Total	44										
CV, %		14.1	16.0	17.2	18.5	18.5	25.6	35.7	39.0	39.3	41.7

Values with the same letter do not differ significantly at the .05 level of probability.

+, *, *** Statistically significant at .10, .05, and .005 levels of probability, respectively.

Table A.38. Plant and fruit attribute means and analyses of variance for the 1970 field growth regulator study. Sugarbeets were sprayed with four different chemicals at various rates at three separate flowering stages on June 4, June 24 and July 13.[1]

Stages, Treatments and Rates in ppm		21-Day growth, inches	Maximum height, inches	Harvest height, inches	Lodging ratings, 1 to 9	Color ratings, 1 to 7
Growth stage sprayed						
Early bolt		14.72	48.0a	47.8a	3.5a	2.8
Peak anthesis			53.3b	51.1b	4.9b	2.7
Post anthesis			55.9b	54.2c	6.2c	2.9
Treatments						
Alar-85	500	18.0def	55.7de	53.8ef	6.6e	3.1d
	1000	17.5def	56.6e	54.9f	6.3de	2.7bcd
	1500	20.7f	55.0cde	53.3def	5.9cde	2.9cd
Ethrel	500	12.5abc	52.2bcd	50.9bcd	4.9bcde	2.6abcd
	1000	9.9ab	51.1bc	50.0bc	3.7ab	2.0a
	1500	8.6a	50.0ab	49.1abc	3.1a	2.2ab
MH-30	2000	15.6cd	53.0bcde	51.6cde	4.3abc	3.0cd
	4000	14.0bcd	49.8ab	48.7ab	3.6ab	3.7e
	6000	11.0ab	46.9a	46.9a	4.3abc	4.3f
TIBA	500	15.9cde	51.0bc	51.1bcd	5.1bcde	2.4abc
	1000	13.0bc	51.0bc	49.6bc	4.8abcd	2.2ab
Untreated check		20.1ef	56.9e	52.9def	6.3de	2.6abcd
Grand means		14.72	52.43	51.06	4.91	2.81
Source	DF	MS	MS	MS	MS	MS
Replicates	2	4.59	19.79	3.11	1.12	0.08
Stages	2		582.34***	367.44***	66.73**	0.58
Error a	4		16.33	11.39	2.55	
Treatments	11	46.04***	84.95***	50.03***	12.32***	3.94***
St x Tr	22		40.39***	24.90***	4.40+	2.35***
Error b	66		14.81	6.04	2.53	
Error p	22 or 70	5.45				0.29
Totals	35 or 107					
CV, % (a)		15.9	7.7	6.6	32.6	
(b)			7.3	4.8	32.4	
(p)						19.3

Stages, Treatments and Rates in ppm	Yield lb/A	Count/ 5 g	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
Growth stage sprayed					
Early bolt	1700a	611b	1.236a	30.1c	35.0b
Peak anthesis	1978b	507a	1.261a	25.3b	32.4b
Post anthesis	2747c	488a	1.384b	8.9a	13.8a

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Table A.38. (Continued)

Stages, Treatments and Rates in ppm		Yield, lb/A	Count/ 5 g	100 Fruit weight, g	Empty fruits, %	Abnormal fruits, %
Treatments						
Alar-85	500	2485efg	441a	1.347c	10.2abc	15.3ab
	1000	2825fgh	458ab	1.392c	8.4ab	12.2a
	1500	3138h	441a	1.398c	7.0a	11.9a
Ethrel	500	2057cde	509ab	1.329c	14.2bc	20.1bc
	1000	1840bcd	499ab	1.326c	14.2bc	20.7bc
	1500	1618abc	557bc	1.326c	16.3c	23.6c
MH-30	2000	1457ab	610c	1.177b	42.7d	48.6d
	4000	1164a	729d	1.065a	54.3e	61.8e
	6000	1127a	801d	0.992a	59.4e	64.1e
TIBA	500	2886gh	443a	1.403c	9.8ab	14.8ab
	1000	2314def	504ab	1.367c	11.9abc	17.7abc
Untreated check		2790fgh	432a	1.403c	8.8ab	14.3ab
Grand means		2141.8	535.3	1.2938	21.44	27.10
Source	DF	MS $X10^3$	MS $X10^3$	MS	MS	MS
Replicates	2	34.08	12.59	0.073	593.46***	615.84***
Stages	2	10585.74***	157.62***	0.454*	8952.59***	9582.14***
Error a	4			0.032		
Treatments	11	4425.45***	131.06***	0.349***	6547.80***	6757.93***
St x Tr	22	726.91***	63.46***	0.160***	1750.71***	1716.39***
Error b	66			0.016		
Error p	70	296.68	9.69		69.69	85.77
Subsample	1			0.011+	0.78	13.50
St x Su	2			0.002	7.28	25.68+
Tr x Su	11			0.006+	8.94	7.91
St x Tr x Su	22			0.006*	15.13	19.11*
Error c	72			0.003	12.90	10.74
Totals 107 or 215						
CV, % (a)				13.8		
(b)				9.9		
(p)		25.4	18.4		38.9	34.2
(c)				4.4	16.8	12.1

[1] The 21-day growth refers to actual stalk growth beginning at the early bolt spraying.
Lodging ratings = 1 to 9 with 1 as no lodging and 9 as complete lodging.
Color ratings = 1 to 7 with 1 as dark green and 7 as extremely yellow and chlorotic.
Values with the same letter do not differ significantly at the .05 level of probability.
+, *, **, *** Statistically significant at .10, .05, .01 and .005 levels of probability, respectively.

Table A. 39. Growth stage sprayed x treatment interaction means for the 1970 field growth regulator study. All interactions shown were significant in the analyses of variance at the .10 level of F or greater. Spray dates were June 4, June 24, and July 13.

Attributes	Alar-85, ppm			Ethrel, ppm			MH-30, ppm			TIBA, ppm		Untreated
Stage sprayed	500	1000	1500	500	1000	1500	2000	4000	5000	500	1000	check
Maximum height, inches												
Early bolt	55.3	55.3	57.7	48.3	46.0	40.3	46.3	40.0	37.3	48.3	44.7	56.7
Peak anthesis	54.7	55.0	51.7	53.0	52.3	54.7	55.0	54.3	50.7	49.7	53.3	55.7
Post anthesis	57.0	59.3	55.7	55.3	55.0	55.0	57.7	55.0	52.7	55.0	55.0	58.3
$LSD_{.01}$ = 8.95 in. for single comparisons between any two means.												
Harvest heights, inches												
Early bolt	53.3	56.0	54.0	48.0	46.7	42.0	45.3	40.7	40.0	48.7	46.7	52.7
Peak anthesis	51.3	52.7	52.0	51.3	51.3	51.3	52.7	50.7	50.0	50.7	49.3	50.0
Post anthesis	56.7	56.0	54.0	53.3	52.0	54.0	56.7	54.7	50.7	54.0	52.7	56.0
$LSD_{.01}$ = 6.12 in. for single comparisons between any two means.												
Lodging ratings, 1 to 9												
Early bolt	6.0	6.0	5.3	2.7	1.7	1.0	2.0	1.7	1.0	5.3	3.3	6.3
Peak anthesis	7.3	6.7	5.7	6.0	4.3	2.7	4.0	3.3	4.3	4.3	4.3	6.3
Post anthesis	6.3	6.3	6.7	6.0	5.0	5.7	7.0	5.7	7.7	5.7	6.7	6.3
$LSD_{.01}$ = 3.67 ratings for single comparisons between any two means; 1 = no lodging and 9 = completely lodged.												
Color ratings, 1 to 7												
Early bolt	3.0	2.3	2.3	2.3	1.0	1.0	4.0	5.0	6.3	1.7	2.0	2.3
Peak anthesis	3.3	2.7	3.0	2.3	2.3	2.3	2.0	3.0	3.3	3.0	2.0	3.0
Post anthesis	3.0	3.0	3.3	3.0	2.7	3.3	3.0	3.0	3.3	2.7	2.7	2.3
$LSD_{.01}$ = 1.21 ratings for single comparisons between any two means; 1 = dark green and 7 = extremely yellow.												
Yield, lb/A												
Early bolt	2723	2898	3098	1862	1273	729	244	128	107	2605	1949	2788
Peak anthesis	2441	2469	2898	1921	1633	1520	1373	1060	1011	3026	2093	2288
Post anthesis	2290	3109	3419	2388	2616	2606	2754	2303	2262	3026	2900	3293
$LSD_{.01}$ = 1223.5 lb. for single comparisons between any two means.												

(Continued on next page)

Table A.39. (Continued)

Attributes	Alar-85, ppm			Ethrel, ppm			MH-30, ppm			TIBA, ppm		Untreated
Stage sprayed	500	1000	1500	500	1000	1500	2000	4000	6000	500	1000	check
Fruit count/5 g												
Early bolt	420	461	457	414	493	678	895	1034	1174	451	431	422
Peak anthesis	485	467	484	428	498	555	493	623	637	419	555	435
Post anthesis	417	446	381	684	505	434	440	530	593	458	526	440
$LSD_{.01}$ = 218.9 counts for single comparisons between any two means.												
100 Fruit weight, g												
Early bolt	1.339	1.443	1.435	1.297	1.258	1.250	0.961	0.743	0.635	1.521	1.524	1.428
Peak anthesis	1.382	1.350	1.311	1.369	1.374	1.302	1.204	1.062	0.913	1.288	1.251	1.324
Post anthesis	1.320	1.384	1.449	1.320	1.347	1.427	1.364	1.389	1.429	1.400	1.325	1.458
$LSD_{.01}$ = 0.2272 g for single comparisons between any two means.												
Empty fruits, %												
Early bolt	13.5	12.5	7.2	11.8	13.7	21.0	67.3	92.8	90.7	11.3	12.0	7.5
Peak anthesis	9.3	6.0	9.0	17.8	18.8	17.8	50.7	60.5	79.2	11.3	13.8	9.8
Post anthesis	7.7	6.7	4.8	12.8	10.0	10.0	10.2	9.7	8.5	6.8	10.0	9.2
$LSD_{.01}$ = 13.53% for single comparisons between any two means.												
Abnormal fruits, %												
Early bolt	18.0	15.0	13.5	17.2	22.2	27.7	70.8	95.8	92.2	18.0	16.7	12.7
Peak anthesis	16.2	9.7	12.8	25.7	25.0	26.8	59.5	73.8	88.0	15.5	22.2	14.3
Post anthesis	11.8	11.8	9.5	17.5	15.0	16.3	15.5	15.8	12.0	10.8	14.2	16.0
$LSD_{.01}$ = 15.07% for single comparisons between any two means.												

Table A. 40. Simple correlation coefficients between plant and fruit attributes of sugarbeets for the field growth regulator study. Plants were sprayed with four different chemicals at various rates at three separate growth stages during June and July of 1970.[1]

	Attributes	2	3	4	5	6	7	8	9
1.	Maximum height, inches	.84**	.59**	-.19	.65**	-.47**	.47**	-.49**	-.47**
2.	Harvest height, inches		.60**	-.19	.74**	-.58**	.55**	-.55**	-.53**
3.	Lodging ratings, 1 to 9			-.12	.61**	-.40**	.47**	-.48**	-.47**
4.	Plant color ratings, 1 to 7				-.25*	.54**	-.59**	.54**	.49**
5.	Yield, lb/A					-.67**	.71**	-.74**	-.75**
6.	Fruit count/5 g						-.78**	.76**	.74**
7.	100 Fruit weight, g							-.89**	-.87**
8.	Empty fruits, %								.99**
9.	Abnormal fruits, %								

[1]Values of r necessary for significance where n = 108 are: .195 and .254 at .05 (*) and .01 (**) levels of probability, respectively.