RESPONSES OF THE STRAWBERRY TO MALEIC HYDRAZIDE AND GIBBERELLIC ACID

by

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ABSTRACT

Greenhouse and field experiments were conducted with maleic hydrazide and gibberellic acid on the British Sovereign variety of strawberry at the University of British Columbia.

Treatment with maleic hydrazide resulted in an increase in number of leaves and crowns per plant and an increase in mother plant vigour over control plants which were allowed to runner freely. In these respects the maleic hydrazide-treated plants responded similarly to those which had had their runners removed by hand. Length of runners and number of runner plants were effectively reduced. Top-root ratio on a fresh weight basis was decreased as a result of suppression of total top growth but there was no effect on root growth. Chemical analysis of plant tops 16 days after treatment with maleic hydrazide indicated increases in the percentages of dry weight, ash, sugar, starch (fresh weight) and in the carbohydrate-nitrogen ratio; and a decrease in the percentage of total nitrogen (dry weight). No change in total dry weight of tops was recorded.

Field applications of 10 ounces of maleic hydrazide (active ingredient) per acre did not give adequate results with four applications at three-week intervals. Three applications at 25 ounces per acre at three-week intervals gave excellent runner control and mother plant vigour was

equal to that of plants receiving hand runner removal. Two applications at 40 ounces per acre gave very good runner control but mother plants were not as vigorous as those receiving three applications at the 25-ounce per acre rate.

No effect of gibberellic acid application was noted on numbers of leaves, crowns, runners or flowers. Increase in fresh weight of tops, no change in roots and increase in top-root ratio were recorded 16 days after treatment, while total dry weight of tops was not affected. Two months after treatment, no effects were observed on fresh weight of tops, roots or top-root ratio. Flower truss emergence and flowering were hastened but did not result in earlier maturation of fruit. The percentage of fruit-set was reduced resulting in a reduction of weight of crop. Size of berry was also reduced. Other effects of gibberellic acid were an increase in sugar content of fruit when it was applied shortly before berry maturity and increases in length of peduncle and petiole if applied when these structures were making active growth. Chemical analysis of plant tops 16 days after treatment indicated decreases in the percentage of dry matter, sugar, starch (fresh weight) and in carbohydrate-nitrogen ratio. There was no change in the percentage of ash and nitrogen (dry weight) in plant tops.

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INTRODUCTION

The strawberry, *Fragaria* spp., is the leading small-fruit crop grown in British Columbia. The principle centers of production are the Lower Fraser Valley where the acreage in 1957 was 1544 and the Vancouver Island Area where the acreage in 1958 was 242 (43). Next in importance is the Kootenay area with 154 acres (1954) followed by the Okanagan area with 129 acres (1954). The total production in the Province in 1955 was 627,600 crates with a total farm value of $2,345,000.

In view of the importance of the strawberry crop in British Columbia it is evident that any changes in cultural practices which would make production more economical would be welcomed.

In recent years two growth regulating compounds have been discovered which show beneficial effects when applied to various crop plants. They are maleic hydrazide and gibberellic acid. The former compound is a growth inhibitor, while the latter is a growth stimulant.

Under coastal conditions the system of planting strawberries that has proved by far the most popular and satisfactory is the hill system in which only the mother plant is permitted to grow, all runners from it being removed at least five times during the first season. This is one of the most tedious jobs in the culture of strawberries and requires about 50 man-hours of hand labour per acre. In the second season, however, little or no runner removal is necessary. It is apparent, therefore, that the use of a chemical growth inhibitor would be of value if it eliminated the need for hand removal of runners and yet allowed production of a profitable crop.

For the past several years research with maleic hydrazide to inhibit runner growth has been in progress in the United States and varying degrees of success have been reported. Most of this work has been done under different climatic conditions with varieties adapted to other areas, and for the purpose of limiting runner-plant numbers in a matted row. It is evident, therefore, that research with maleic hydrazide under Lower Fraser Valley conditions, with the popular local variety, and on the basis of the hill system could prove rewarding.

In addition to research aimed at facilitating production and reducing production costs, efforts are continually being directed to developing cultural techniques which will increase yield per acre. One of the possibilities presenting itself today is the application of growth stimulants. The stimulant may cause a direct effect by increasing cell division or cell enlargement, resulting in production of larger fruit when applied at the time of fruit development, or it may have an indirect effect by aiding in establishment of the young plant and increasing the leaf area when applied soon after planting when the plant is making vegetative growth. Another effect may be to increase the number of flowers initiated and developed.

In view of the promising results reported by various workers who have used gibberellic acid on several crop plants, it appeared desirable to determine whether the strawberry plant also would respond favourably to this chemical.

LITERATURE REVIEW

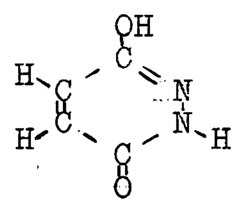
A. MALEIC HYDRAZIDE

1. The Chemical

(a) Active Ingredient

Maleic hydrazide was first reported as a growth inhibitor by Schoene and Hoffmann (42) in 1949. Its remarkable property of retarding overall plant growth without obvious morphological abnormalities soon became the object of intensive investigation.

Maleic hydrazide is a white crystalline solid having a chemical formula of 6-hydroxy-3-(2H)-pyridazinone and a structural formula of



It is slightly acidic in character and forms salts readily with alkalies. The free compound is completely water soluble at 0.2 per cent (2000 ppm) but does not dissolve completely at 1 per cent. More concentrated solutions can be made using an amine or other alkali salt of the compound.

(b) Absorption and Translocation

Absorption of maleic hydrazide occurs through all parts of the plant, both roots and tops, and from the point of entry may be translocated up or down to accumulate in regions of meristematic activity (37).

The rate of absorption was found by Zukel, et al. (51) to be directly proportional to the amount of the chemical remaining on the leaf surface. These workers called the time for 50 per cent absorption the "half life" or t½ value in hours.

Relative humidity has a great effect on the absorption rate, the maximum rate of absorption occurring at 100 per cent relative humidity. As an example of this marked effect, Zukel, et al. (51) observed that Johnson grass held at 40 per cent and 100 per cent relative humidity gave t½ values of 128 and 2 hours respectively. They also noted that variation in temperature at controlled humidity had less effect than variation in humidity, and that surfactants did not generally improve absorption rate.

(c) Residual Effect in Soil

Because of its rapid breakdown, maleic hydrazide should not present a problem of residual toxicity in the soil. Experiments by Levi and Crafts (29) indicated that this compound can sterilize the soil against plant growth if used in large quantities. However, under warm, moist conditions they found that decomposition was too rapid for the chemical to be considered effective even as a temporary soil sterilant. They also demonstrated that maleic hydrazide is readily leached from all types of soils except Aiken clay loam, a soil containing kaolinitic clay.

2. Responses to Maleic Hydrazide

Studies by Naylor and Davis (37) on eleven species belonging to five distantly related families of plants shows that maleic hydrazide has markedly similar effects on monocotyledonous and dicotyledonous plants.

(a) Growth

Maleic hydrazide has been found to have a pronounced but temporary inhibiting effect on plant growth, the length of the inhibiting period appearing to be directly proportional to the concentration used (42). Seedlings are most sensitive to the chemical, but it can inhibit growth at any stage up to maturity without killing the plant. Generally, a spray of 0.4 per cent concentration will cause all meristematic growth to be much reduced or to be completely inhibited (37). Thus the effect of maleic hydrazide is manifest chiefly in the actively growing tissues. Soon after application of the compound, cell division is greatly retarded but growth continues for some time owing to the enlargement of cells already formed (37). At lower rates the effect is unique in that growth inhibition is obtained with little visible harm to the plant, growth returning to normal after the effect wears off (42). At higher rates new growth after the effects had subsided was found to be abnormal in some plants. Several authorities (10, 12, 21, 42) have reported that roots as well as shoots are inhibited by maleic hydrazide. Two of these workers (10, 12) found inhibition of root growth to be greater than shoot growth.

(b) Root-Top Ratio

Although root as well as top is affected by maleic hydrazide, the degree to which each is inhibited does not appear to be the same for all plants studied. Naylor and Davis (37) observed that wheat roots were not affected; that oat roots were inhibited almost as much as tops; and that maize roots were inhibited more than tops. Mikkelsen et al. (34) noted that applications of the chemical increased the root-top ratio in sugar beets, while Greulach (20) reported that root-top ratio in tomato to be decreased. It was noted in culture solutions by Levi and Crafts (29) that the change in root growth was inversely proportional to that of shoot growth in the presence of the compound; roots were stunted while shoots continued to grow and when shoot growth was completely inhibited roots lengthened.

(c) Dry and Fresh Weights

Generally, there is a reduction in fresh weight and an increase in the percentage of dry matter, but a decrease in total dry matter in plant parts when treated with maleic hydrazide. At high rates the fresh and total dry weights are greatly reduced owing to the severe stunting or even death of the plant. On the other hand, when it was applied at optimum rate and at the optimum stage of growth to barley Currier et al. (14) found total dry weight to be increased even though fresh weight was reduced, owing to accumulation of fructosan.

Also, Mikkelsen, et al. (34) observed that maleic hydrazide applied at optimum dosage and time, resulted in an increase in yield per acre of sugar beet roots.

(d) Pigments

Pigmentation of plants treated with maleic hydrazide is markedly changed. Several days after treatment, young leaves have been observed to become chlorotic (20, 37, 42) but this condition is often preceded by production of a noticeably darker green colour than in untreated plants (20, 37). When the effects wear off, the leaves return to their normal green colour. Another pigment effect observed is the appearance of red colour in the leaves due to anthocyanins. This condition has been noted in young plants of grass species (13), in young tomato plants (20), and in corn (37).

(e) Apical Dominance

Loss of apical dominance is a common occurrence in some plants treated with maleic hydrazide. Naylor and Davis (37) indicated that at low concentrations of the compound, axillary buds of seedlings began to grow very soon after treatment and that virtually all axillary buds grew at the same rate, though the cotyledonary buds developed a little after the others. Other workers, Beach and Leopold (2) and Powell and Andreasen (40) working with chrysanthemums found that maleic hydrazide sprays caused cessation of terminal growth and stimulated development of laterals similar to the effect caused by pinching out the central growing point. Apical dominance was observed to be destroyed both on potato tubers and on individual sprouts in experiments by Patterson, et al. (38) using maleic hydrazide as pre-harvest sprays.

(f) Flowering and Fruiting

Effects of maleic hydrazide have been noted on flowering and fruiting of some plants. Ferres (18) found that maleic hydrazide concentrations of 10 to 1500 ppm sprayed on raspberries, strawberries, black currants and apples just before, during or after bud burst did not delay flowering, but with raspberry and strawberry, they retarded the development and ripening of the fruit. Kennard, et al. (25) observed that the material applied in spring to black raspberry delayed blossoming and fruit maturation for several days without reducing yield or damaging the plant permanently. Flowering of sunflower, peanut, and tobacco was largely prevented by maleic hydrazide sprays (37) and the formation of flower primordia in winter barley was completely inhibited (26). Sweet corn treated at a critical stage was shown by Moore (35) to produce sterile tassels and stubby ears with functional silks.

(g) Chemical Composition Changes

Very marked changes in chemical composition occur in plants treated with maleic hydrazide. Free amino acids have been found to be increased (19, 31, 39, 41) while effects on total protein have been observed to vary by one worker (19); it increased in potato, slightly decreased in sugar beets, and greatly decreased in pinto beans. In bean plants (14), in the seedling roots, stems, and leaves of oats, maize and soybean (10) and in wheat seedlings (41), starch accumulation was a distinct response to maleic hydrazide treatment. Sucrose content, also, was found to be significantly increased in wheat seedlings (41), in sugar beet roots (34) and in most other plants studied. In addition to increases in starch and sucrose, increases in reducing sugars have also been reported (39). The above changes in carbohydrate content in growing plants appear to result mainly from the continuance of photosynthesis after inhibition of growth (41).

In potato tubers both reducing and non-reducing sugar percentages were found by Paterson (38) to be lower than controls in tubers stored at 45°F. when treatment had been applied to foliage prior to harvest. He suggests that the chemical may control the degradation of starch to sugars. In studies of the same nature, Highlands, et al. (22) reported no significant reduction in the accumulation of reducing sugars.

3. Runner Inhibition of Strawberries

Chemical control of runners in strawberries in recent years has been receiving considerable attention and maleic hydrazide has so far given the most promising results. In general it has been found that this compound applied at rates of 1000 ppm and 2000 ppm considerably reduced runner elongation and plant stand in matted rows. It resulted in plants with larger, more-branched crowns with more leaves and roots than unsprayed, matted row controls. Consequently the treated plants produced significantly larger early and total yields and larger-sized fruit (15, 16, 23). Denisen (16) found that three applications of maleic hydrazide (10 days between the first and second application; 30 days between the second and third) produced a yield and berry size comparable to those of hand-pruned plants. He found that this substance increased berry size by 12 per cent over matted row early yields and 18 per cent for total yields while berry yields were 30 per cent higher than for matted rows for early yields and 15 per cent higher for total yields. Hitz and Brown's results (23) were not as encouraging; maleic hydrazide application did not prove as effective as hand pruning and plant spacing but did produce larger yields than unsprayed plants with no runners removed.

Current emphasis in this use of maleic hydrazide in areas where systems of strawberry culture other than the hill system are used, is on allowing the new planting to form almost sufficient runner plants for an optimum population, then to spray to prevent over crowding by late-formed runner plants (24) which would not initiate flower buds and thus would act as weeds. In an experiment in which maleic hydrazide was applied at two rates it was found that the number of plants per square foot of matted row was reduced from 13.2 to 7.5 by the lower rate of the chemical used and to 4.7 by the higher rate (16).

The time of appearance of new growth indicates that sprays of maleic hydrazide at 1000 ppm should be applied every three weeks if the plant population is to be rigorously controlled (23). The latest time at which sprays can be applied will be determined by the specific varietal response to floral initiation, since it was observed by Brown and Hitz (7) and by Denisen (15) that when applied during fruit-bud differentiation the compound reduces yields the following spring.

Following the application of maleic hydrazide to the plants, Denisen (17) found that runners continued to form for about one week at which time elongation ceased. He also noted that stoppage of growth was followed by the formation of a peculiar "hook" at the runner tip and then by gradual death of the runner. When the effects wore off 3 to 4 weeks after application, growth resumed normally. An additional symptom was the chlorosis of the newly formed leaves which also disappeared 3 to 4 weeks after application.

Studies by Brown and Hitz (7) using radioactive maleic hydrazide and subsequent exposure of radioautographs in charting areas of greatest accumulation of the chemical showed that when mature leaves of plants actively promoting runner growth are treated, the chemical soon begins to accumulate in the runner tips and in young leaves, building up in these areas; the result was that the crowns of treated plants and even the new growth originating from them subsequent to treatment, showed little or no radioactivity. Thus accumulation of the radioactive material was greatest where growth was most active. This point is further substantiated by their finding that maleic hydrazide was also capable of concentrating in regions of blossom initiation in the crown tip when that region became physiologically active, and in such quantities as to interfere with blossom initiation. They also found that once the chemical had accumulated in the growing tip of a runner, it was unable to move appreciably toward a crown or plant already formed.

Chemical analysis of plants showed that the percentage of nitrogen (dry weight) in leaves, petioles, crowns and roots was not altered significantly by the maleic hydrazide treatments (15).

B. GIBBERELLIC ACID

1. The Chemical

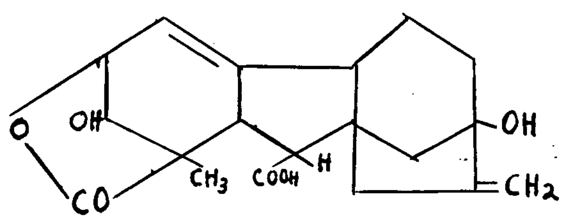
(a) Source

In all countries where rice is grown, a disease of rice caused by the soil-borne fungus Gibberella fujikuroi (Saw) Wr (conidial state: Fusarium moniliforme Sheld) has been recorded and is known as the bakanae disease. An early and characteristic symptom of this disease is the rapid elongation of stems and leaves of infected seedlings, in comparison to normal plants.

In 1926 it was discovered by Kurosawa (27) that cell-free filtrates of pure cultures of G. fujikuroi when applied to healthy rice seedlings produced symptoms characteristic of the disease. Recently three growth-promoting metabolites have been isolated from filtrates of the fungus--gibberellins A_1, A_2 and gibberellic acid. Each of these compounds was found to have similar physiological properties, causing growth stimulation and other effects on many other plants besides rice plants. Gibberellic acid is produced in mugh larger quantities in cultures of the fungus than are gibberellins A_1 and A_2 and is therefore the most widely used of the three.

(b) Active Ingredient

Gibberellic acid is a colourless tetracyclic dihydroxy lactonic acid, $C_{19}H_{22}O_6$, with a structural formula of



Although the acid form is very insoluble in water, it forms salts with alkalies and these are readily soluble in water. The potassium salt is commonly used today.

(c) Absorption and Translocation

Movement of gibberellic acid within plants is not the polar movement that is characteristic of auxin. It has been shown that treatments by single drop applications, with lanolin paste, by spraying or as a solution applied to the roots, were all effective on the entire plant regardless of what part of the plant was treated (45).

Soil application of gibberellic acid would not appear to be suitable, since strong evidence has been produced by Brian, et al. (3) that it is broken down by the activity of the soil microflora.

(d) Sensitivity of Plants to Gibberellic Acid

Response to gibberellic acid varies greatly with the species. Some plants are not affected by sprays of 1000 ppm whereas others are sensitive to less than 1 ppm. The response to a single dose is temporary. Growth is accelerated immediately after application and eventually the growth rate slowly subsides to that of untreated plants. The size of the dose applied does not greatly influence the newly established rate of growth, but does influence the time over which this accelerated growth is maintained (4). To maintain an increased growth rate over the whole life cycle of a plant, gibberellic acid must be applied at fairly short intervals.

2. Responses to Gibberellic Acid

A wide variety of effects are exhibited by gibberellic acid. Extensive study with this compound on a great number of crop plants is being conducted.

(a) Growth

The most obvious response is stem elongation. This was evidenced in both woody and herbaceous plants and was most pronounced when the substance was applied to stems that had just begun to elongate. Some treated plants developed very thin stems, while in others the stems thickened as elongation occurred and finally reached a greater diameter than those of untreated plants (33). Elongation was most strikingly displayed by dwarf peas, dwarf mutant corn, bush beans and Cupid sweet peas (4, 6, 8, 45). For example, bush beans when treated formed twining vines and grew as pole types (8). The tall varieties of these plants respond little or not at all to treatment with the chemical. The increase in height of dwarf pea plants was due solely to increase in internode length, not internode number (45). In contrast to this, an increase in node number as well as internode elongation was noted in some woody plants (32).

(b) Fresh and Dry Weights, Root-Top Ratio

When gibberellic acid promotes elongation it does not always cause a parallel increase in dry weight. Marth, et al.(33) investigating the response of soybean plants to the compound at 10 ppm observed a 32 per cent increase in dry weight over control one week after treatment but at the end of the second week there was no difference between treated and control plants in both fresh and dry weights. Root dry weights were 18 per cent lower than controls. These data show that increased top weight was associated with reduced root growth, causing a marked change in ratio of root weight to shoot weight. This effect is substantiated by various other workers. Brian, et al., (3) demonstrated consistent increases in dry weight of shoots in wheat and in nearly all cases the fresh weight also with corresponding decrease in root dry weights.

(c) Yields

Investigating the use of gibberellic acid on peas, runner beans, black currants, potatoes, carrots, turnips, and lettuce, Morgan and Mees (36) found that in no case was the crop yield increased, decreases being recorded in the cases of potatoes and carrots. Bukovac and Wittwer (8) claim elongation of internodes in the vegetable crops studied. There were some accompanying increases in dry weight of tops but root growth decreased correspondingly. Grain yields of rice were recorded by Sumiki (46) to be decreased, while the yield of grain of winter wheat showed no increase in an experiment by Morgan and Mees (36). Recent research by the latter workers (36) on dry matter and crude protein yields of grass indicated an increase in the first cutting after application of gibberellic acid but a corresponding decrease in the second cutting and no significant difference in the third, giving no net increase in yield over two or more cuts. If a second application of the compound were made after the first cutting, decrease in yield was prevented. Third and fourth applications after the second and third cuts, respectively, gave a net increase in yield over 4 cuts. Repeated applications, however, led to a progressive thinning of the sward.

In further work by the above authors (36) it was noted that gibberellic acid and fertilizer acted quite independently in increasing the yield of dry matter and crude protein obtained when the grass was cut. When applied together, their effects were additive.

(d) Leaf Responses

Among the effects of gibberellic acid on leaves, chlorosis has been observed to be common. Under some conditions increases in nutrients resulted in reduced chlorosis (28, 45). Leaf number in most cases remained the same but size varied with the plant; in some the leaves were of larger size while in some they were smaller (45). Also, leaf shape was affected in various ways: some were more elongate, some were broader, some smooth-margined instead of normally indented, and some were rough-surfaced instead of normally smooth.

(e) Seedling Responses

Seedlings of seeds treated with gibberellic acid have been observed to emerge from the soil faster and to grow taller than seedlings from untreated plants (28). The seeds of many species, however, did not respond this way even when treated at high concentrations (28).

(f) Apical Dominance

With respect to apical dominance somewhat conflicting evidence has been forwarded. Brian and Hemming (5) produced evidence that gibberellic acid increased apical dominance by inducing growth in the main axis and inhibiting development of laterals in dwarf bean and Cupid sweet pea. The bunchy growth habit was replaced by a clinging habit. Marth et al. (33) on the other hand, noted that in several kinds of plants, including citrus and snapdragon, the main stems of treated plants first elongated, then decreased with simultaneous increase in elongation of laterals producing a bunchy type of growth.

(g) Flowering and Fruiting

Gibberellic acid has been demonstrated to accelerate or to retard the flowing of a number of species of plants, but there is no evidence that it could initiate flower primordia. Accelerated stem elongation, however, was sometimes accompanied by more rapid flower development than in controls. Gibberellic acid at 10 to 100 ppm hastened flowering 10 days to 4 weeks in stocks, petunia, larkspur, English daisy, China aster and gerbera (30). Other annuals such as zinnias, beans, and peas have flowered several days ahead of non-treated plants (28). Treated pepper plants, on the other hand, flowered 30 days later than did controls (33). With long-day annuals such as lettuce, endive, radish, spinach, dill, and mustard flowering was induced under non-inductive environments of short photoperiod and low temperature (47, 48, 49). In head lettuce the head was completely eliminated and viable seed was produced 10 to 30 days earlier than controls (49).

The most remarkable effects on flowering are on biennial plants that require specific cold treatment to induce flowering. Conclusive evidence has been forwarded that gibberellic acid promotes flowering in biennials such as carrots, collards, cabbage, kale, celery and beets in a non-inductive environment and thus advances flowering time. However, with the possible exception of carrots, complete induction of flowering did not occur unless the plants were grown at temperatures approaching those normally inductive for flowering (9). Carrots were induced to flower over a wide range of non-inductive temperatures in both long and short photoperiods (47). Carrots seeded in May flowered in October without being exposed to temperatures below 60°F. Flowers were normal and set seed when pollinated (49). These results suggest that the normal cold requirement for flowering in biennials may be partially, or in a few instances completely, replaced by application of gibberellic acid.

Treatment with gibberellic acid did not increase the number of fruits that developed when tomato and bean plants were sprayed with it at flowering time, nor did it hasten the rate of development of the bean pods (33). An important effect on tomatoes was that gibberellic acid spray at 10 ppm induced parthenocarpic fruit development (49). This effect has been noted on other crops as well.

(h) Pollen Germination and Tube Growth

Gibberellic acid has been observed to affect pollen germination and tube development. Chandler (11) in a study of pollen from plants of 16 different species observed that: pollen from 9 plants produced no germination in either control media or media to which gibberellic acid had been added; pollen from 10 plants germinated on all media but tube growth was inhibited by all concentrations of the chemical, causing coiling, enlarging of tips and exuding of cytoplasm; pollen from 1 plant germinated only in gibberellic acid media; pollen from 7 plants showed an increase in percentage germination and marked increase in tube length in treated media.

(i) Chemical Changes

Changes in chemical composition due to gibberellic acid treatment show definite trends for some components. In a study of rice seedlings Yabuta (50) observed that application to rice seedlings had no effect on moisture, ash, and total nitrogen content, but total sugar decreased while reducing sugars were similar to the control. Sumiki (46) claimed an increase in moisture content and fresh weight at an early period and dry weights at a later period. Also, he found that in rice leaves sucrose and starch decreased, hemicellulose and cellulose increased, and reducing sugars remained unchanged. Working with wheat and pea, Brian et al. (3) noted that on a dry weight basis content of ash, nitrogen, phosphorus and potassium were reduced in the shoots while carbon concentration was increased. Since sugars and starch have generally been found to be reduced, the increase in carbon concentration may be due to increases in hemicellulose and cellulose.

OBJECT

The object of the experimental program now to be described was to determine the growth responses and the chemical effects of maleic hydrazide and gibberellic acid on the strawberry. Special attention was given to runner inhibition, since hand removal of runners is an expensive operation to the grower. Owing to the great variety of effects attributed to the action of gibberellic acid on many types of plants, it was decided to ascertain whether there were any beneficial effects of this chemical on strawberry growth and particularly on the growth of the variety of commerce, "British Sovereign".

MATERIALS AND METHODS

The experimental work was conducted in the greenhouse, field and laboratory at the University of British Columbia. Four experiments were set up:

A. Greenhouse Experiments	1.	Maleic Hydrazide
	2.	Gibberellic Acid
	3.	Maleic Hydrazide and Gibberellic Acid
B. Field Experiment		Maleic Hydrazide

In all experiments the British Sovereign variety of strawberry was used. The maleic hydrazide formulation used was MH-40 (sodium salt of maleic hydrazide--40 per cent active ingredient). The gibberellic acid formulation used was Gibrel (potassium salt of gibberellic acid--82 per cent active ingredient).

A. GREENHOUSE EXPERIMENTS

1. Maleic Hydrazide

On November 20, 1957 young runner plants were removed from the sand in which they had rooted below potted mother plants grown in a greenhouse artificially illuminated to give a 17-hour photoperiod and maintained at a 65 to 70°F. temperature. These runner plants were potted in sterilized, potting soil in 6-inch clay pots (one plant per pot). Supplementary illumination was given from 4:00 p.m. to 9:00 p.m. and from 4:00 a.m. to 8:00 a.m. giving a 17-hour photoperiod. On March 17, 1958 the lighting schedule was changed to give a 3-hour light period from 11:00 p.m.

to 2:00 a.m. in place of the morning and evening light periods. The temperature was maintained at 65 to 70°F. Normal watering, fertilizing and control of insects and diseases were carried out. Flower trusses were removed when necessary.

The treatments were as follows with rates given in terms of parts per million of active ingredient and with dates of application indicated:

			Mar. 12	Apr. 3	Apr. 24
A.	MH	@	1000 ppm		
B.	MH	@	1000 ppm	+ 500 ppm	
C.	MH	@	1000 ppm	+ 1000 ppm	
D.	MH	@	500 ppm		
E.	MH	@	500 ppm	+ 500 ppm	
F.	MH	@	500 ppm	+ 500 ppm	+ 500 ppm
G.	Runners removed every 3 weeks				
H.	Control				

The pots were arranged in plots with 5 pots per plot in a randomized complete block design with two replications.

On March 12, 1958, when runners began to form, the first applications were made. The potted plants were removed from the greenhouse to prevent spray contamination, spaced evenly in a 3-foot by 5-foot rectangular area (15 square feet) and 200 cc. of the maleic hydrazide solution applied evenly over this area (200 cc. per 15 square feet is equivalent to 129 Imperial gallons per acre). A small trombone-type sprayer emitting a fine spray, was used, so that at the above rate the plants were wetted just to the point of run-off.

The number of crowns per plant was recorded at the time of the first application (March 12) and length of runners was taken at intervals from this time until June 14, 1958. Number of leaves per plant, crowns per plant, runners per plant, runner-plants per plant and vigour rating of plants were recorded on June 14, 1958. On August 2, 1958 the weight of runners and weight of mother plant tops per plot were recorded. The roots were washed free of soil, left until surface water had dried and then weighed.

2. Gibberellic Acid

On November 14, 1957, certified British Sovereign runner-plants were received, stored cool in damp peat-moss and planted on November 20, 1957, in 6-inch clay pots in a sterilized potting mixture. Temperature control, additional light and general care were given as for the above experiment with maleic hydrazide.

The treatments were as follows in parts per million formulation (as Gibrel).

A. GA @ 100 ppm when plants were established--Dec. 9
B. GA @ 500 ppm when plants were established--Dec. 9
C. GA @ 100 ppm when first trusses emerged --Dec.30
D. GA @ 500 ppm when first trusses emerged --Dec.30
E. GA @ 100 ppm when first fruit began to ripen--Jan.27
F. GA @ 500 ppm when first fruit began to ripen--Jan.27
G. GA @ 100 ppm when runners began to form --Feb.18
H. GA @ 500 ppm when runners began to form --Feb.18
I. GA @ 100 ppm repeated at above 4 stages
J. Control

The pots were arranged in plots with 5 pots per plot in the randomized complete block design with 2 replications.

Using the same procedure as outlined above for the maleic hydrazide experiment, the treatments were applied at the dates indicated above.

Dates were recorded of first flower truss emergence, first bloom, first ripe fruit and first runner for each plant. Flower trusses were shaken each day to assist pollination. Recordings were also made of the number of flowers per plant, the number of flowers to set and develop fruit and the length of peduncle from crown to highest flower. As the fruit ripened, the number and weight of fruit per plot were taken. Sugar content of fruit ripening in the period from February 19 to March 10, 1958, was measured by means of a hand refractometer, one drop of juice being squeezed from each berry and individual recordings made on each fruit. On April 21, 1958, the following recordings were made: numbers of leaves, crowns, runner plants and runners per plant. Runner weights and mother plant top weights were recorded on April 22, 1958 and on the same day the roots were washed free of soil, and allowed to stand until all surface water had dried; then the weight per plot was recorded.

3. Maleic Hydrazide and Gibberellic Acid

Runner plants from good British Sovereign stock were potted in sterilized potting soil in 6-inch clay pots on August 3, 1958 and placed in the greenhouse. Artificial lighting from

10:00 p.m. to 1:00 a.m. was given from September 20 until the plant material was taken for analysis. The temperature was maintained at 65 to 70°F.

When the plants were well established (October 4) the runners were removed and fertilizer was applied. The plants were arranged in a randomized complete block design with 6 replications and 5 plants per plot. Treatments were as follows:

A.	Maleic hydrazide	@	1000 ppm	(active ingredient)
B.	Gibberellic acid	@	500 ppm	(Gibrel formulation)
C.	Control			

The above treatments were applied on October 8, 1958. On October 24, the plants were severed at soil level, dead leaves were removed, soil was brushed from the leaves and the fresh weights of tops per plot recorded. The 5 plants per plot were then ground and mixed thoroughly and the following samples taken:

Sample I 25 grams

Sample II two 10-gram aliquots--placed in tared crucibles

Sample III 25 grams--placed in 100 cc. of 98 per cent alcohol

The roots were washed free of soil and fresh weights recorded.

Sample I was dried to constant weight at 53°C and the dry-weight determined. One gram of the dry material was analyzed by the Kjeldahl method (1) for total-nitrogen content. Sample II was ashed and Sample III was analyzed for total sugars and starch following the method of Lane and Eynon (1).

B. FIELD EXPERIMENT--Maleic Hydrazide

On May 1, 1958 certified British Sovereign plants were planted on a light sandy soil that had just been manured, plowed, disked and harrowed. Plant spacing was 24 inches in the row and 48 inches between rows. Irrigation, insect and disease control and cultivation were carried out according to normal field practices. On May 17, plants that failed to grow were replaced.

The treatments were as follows, (dosages expressed in terms of active ingredient):

A. MH @ 10 oz./acre + 10 oz./acre repeated 3 times
B. MH @ 25 oz./acre + 25 oz./acre repeated 2 times
C. MH @ 25 oz./acre + 10 oz./acre repeated 3 times
D. MH @ 40 oz./acre + 40 oz./acre
E. MH @ 40 oz./acre + 25 oz./acre repeated 2 times
F. MH @ 40 oz./acre + 10 oz./acre repeated 3 times
G. Hand removal of runners
H. Control

Equivalents: 10 oz./acre = 500 ppm applied at 200 cc./15 sq.ft.
25 oz./acre = 1250 ppm applied at 200 cc./15 sq.ft.
40 oz./acre = 2000 ppm applied at 200 cc./15 sq.ft.

The plots were laid out in a randomized complete block design with 4 replications as in Figure 1. Border rows were left around the entire planting and a guard row was left running north and south between the blocks. There were 10 record plants per plot.

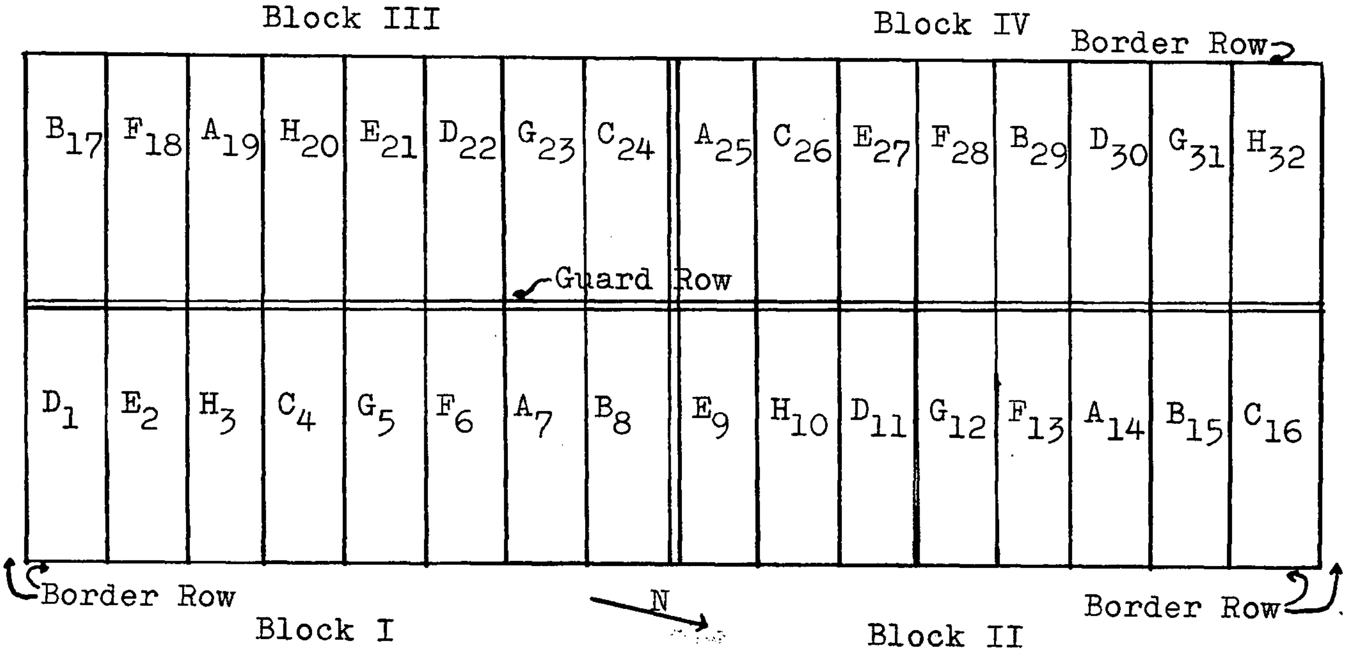


Figure 1 Plot plan of maleic hydrazide field experiment

The treatments were applied with a 3-gallon knapsack sprayer with a flat-fan type nozzle calibrated to deliver 84 gallons per acre; two passes were made at approximately 2 miles per hour walking speed and with the spray nozzle held 18 inches above the plant. The tank was brought to a firm pressure before each plot was sprayed.

All flower trusses were removed on June 14, 1958. On July 1, 1958 all runners were removed. Applications of the treatments were made on the following dates:

Treatment	First	Second	Third	Fourth	Fifth
	July 1	July 19	Aug.11,12,16	Aug.29	Sept.24
A	10	10	10	10	
B	25	25	25		
C	25	10	10	10	
D	40	40			
E	40	25	25		
F	40	10	10	10	
G	R	R	R	R	R

Three plants from each plot were chosen at random and runner lengths measured at intervals. On November 8, 1958, when growth had ceased, final runner measurements were made and the number of runner plants were recorded. All runners and runner plants were then removed, leaving only the mother plants in the field.

On November 15, 1958 the 3 plants per plot that had been recorded for runner lengths were transplanted into 160-fluid-ounce cans with minimum disturbance to the roots by leaving as much soil as possible clinging to them. These plants were then placed in the greenhouse in the same order as in the field. Supplementary light was supplied in the mornings and evenings to give a 16-hour photoperiod. The temperature was maintained at 65 to 70^{o}F.

In the greenhouse each plant was rated for vigour. Height and breadth and the numbers of crowns per plant were recorded. Dates were taken of first flower truss emergence, first bloom and first ripe fruit for each plant. Recordings were also made of numbers of flowers per plant, number and weight of ripe fruit per plot (early and total yield).

Since the quantity of fruit per plot was too small to permit individual plot analyses, the berries from the 4 replicates of each treatment were combined. The juice was pressed through cloth, centrifuged and decanted. Percentage sugar was then determined with a hand refractometer. Acidity was determined by diluting 2 cc. of juice to 60 cc. with water and titrating with N/50 sodium hydroxide using phenolphthalein as an indicator.

Data from the above four experiments were evaluated by the analysis of variance method for randomized complete block designs (44) and the least significant difference calculated. The 5 per cent level of confidence was accepted in the test for significance. Examples of the calculations are given in Appendices 1, 2 and 3.

RESULTS

A. GREENHOUSE EXPERIMENTS

1. Maleic Hydrazide

In the statement of the results of this experiment, treatments will be referred to by the figures for the parts per million of maleic hydrazide applied. For example treatment 1000+500 will refer to the treatment receiving 1000 ppm maleic hydrazide in the first application and 500 ppm maleic hydrazide in the second application.

The effects of maleic hydrazide on the number of plant parts were very marked in some of the treatments. Treatments 1000+500, 1000+1000 and treatment 500+500+500 gave significant increases in numbers of leaves per plant over the control but no significant increases over the hand runner removal treatment (Table 1). Increases in numbers of crowns per plant recorded for the 1000+1000 and 500+500+500 treatments were greater than those for the control, but not greater than those for hand runner removal. The number of runners was significantly higher in plants of the hand-runner-removal treatment than in plants of any of the other treatments, and lower than the control plants for treatment 1000+1000.

Rapid runner growth did not commence until about April 10. Figure 2 gives the growth curves for the runners of each treatment.

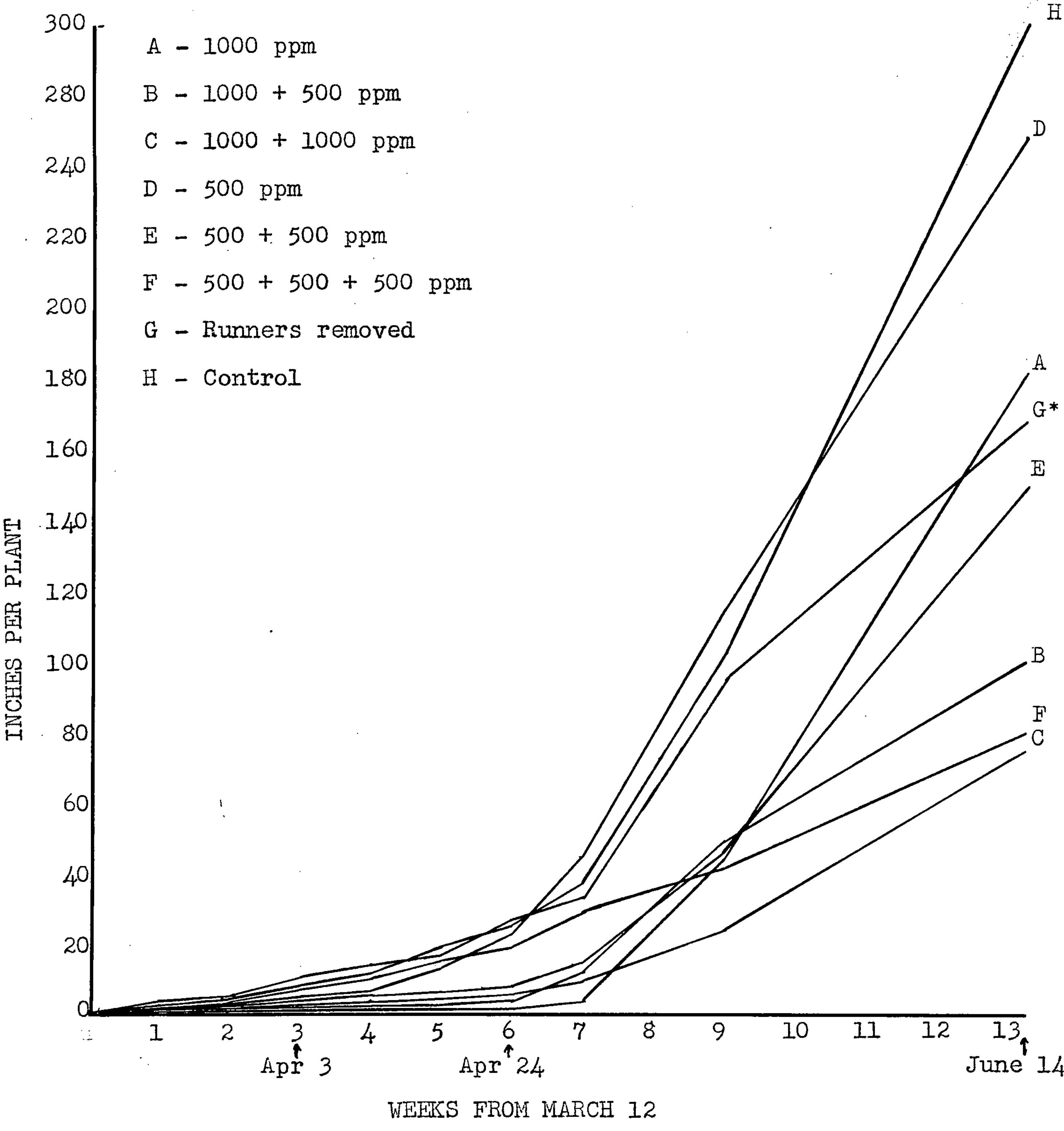


Figure 2 Growth curves of runner lengths as affected by maleic hydrazide treatments (Dates of treatments: Mar.12, Apr.3, Apr.24)

* Accumulative runner lengths

Table 1 Effects of maleic hydrazide treatments on number of plant parts

Treatment	No. of leaves per plant	Increase in no. of crowns per plant from Mar.12 to June 14	No. of runners per plant
1000ppm	31.8	2.4	4.6
1000+500	37.8*	2.9	4.1
1000+1000	39.8*	3.8*	3.9*
500	33.4	3.0	6.4
500+500	26.6	2.3	4.8
500+500+500	38.4*	3.3*	5.6
Runners removed	32.0	2.9	10.9*
Control	27.6	1.7	6.9
LSD 5%	8.65	1.50	2.94
LSD 1%	12.80	2.22	4.36

Increases in runner length per plant from March 12 to June 14 are given in Table 2. All the treatments except the 500 ppm rate gave significant reduction in runner length with treatments 1000+1000, 500+500+500, and 1000+500 giving the greatest reduction (Fig. 3). Runner weights per plot were significantly lower than the control only in plots of the latter three treatments (Table 2).

Table 2 Effects of maleic hydrazide treatments on extent of runnering

Treatment	Increase in runner length per plant (inches)	Weight of runners in grams per plot	Number of runner-plants per mother plant
1000ppm	181.1**	233.0	6.8*
1000+500	101.0**	126.5*	3.4**
1000+1000	75.2**	101.5**	1.5**
500	245.8	195.0	10.2
500+500	148.6**	174.5	5.3**
500+500+500	79.8**	87.0**	2.1**
Runners removed	164.0**[a]		
Control	299.6	263.5	12.3
LSD 5%	55.73	106.13	3.65
LSD 1%	82.45	160.77	5.52

[a] Accumulative length

Figure 3 Plants treated with MH at 500+500+500 (left) and the control (right)--taken on July 1 (110 days after first application) showing the reduction in runnering due to the treatment.

The number of runner-plants per mother plant was reduced by all of the maleic hydrazide treatments with all reductions being significant except for the treatment of 500 ppm (Table 2). The three treatments giving the most effective runner-plant reduction are the same as those giving the greatest reduction in runner length and weight.

The weights of mother plant tops (without runners) per plot and the ratings of relative vigour of mother plants showed increases over the control for those plants receiving the treatments which gave the most marked runner suppression and for the plants receiving the hand runner removal treatment, however, these increases were not significant. See Figure 4.

Figure 4 Plants of treatments MH at 1000+1000, hand runner removal, and control (left to right) indicating the relative vigour of the mother plants 110 days after first applications were made

Total weight of tops per plot (including runners) and weight of roots per plot showed no significant differences from the control, but the top-root ratios of plants of the 1000+1000 and 500+500+500 treatments showed significant decreases when compared to the control as is shown in Table 3. (Root weights of these two treatments approached a significant increase above that of the control plants).

Visual observations indicated that, in general, after the maleic hydrazide was first applied, the runners that had already emerged a short distance grew several centimeters more and then stopped. If the runners had reached the first node,

Table 3 Effects of maleic hydrazide on the relationship of total tops to roots (fresh weight)

Treatment	Weight of entire tops in grams per plot	Weight of roots in grams per plot	Top/root ratio
1000 ppm	553.0	60.0	9.24
1000+500	561.0	64.0	8.75
1000+1000	521.0	76.0	6.86*
500	571.0	68.5	8.54
500+500	474.5	50.0	9.49
500+500+500	534.5	87.0	6.13**
Runners removed		76.5	
Control	577.5	63.0	9.18
LSD 5%	NS	NS	1.77
LSD 1%	NS	NS	2.69

they continued growth to the second node, formed very small, pale green leaves and a very short branch runner (1 to 3 cm long) and growth then stopped. If the runners emerged soon after treatment they grew several centimeters and then stopped. Once the runners had stopped growing they did not recommence, and approximately two months after the first application some began to die from the tip back to the crown. This gradual death of runners was most evident in plots with the higher rate of maleic hydrazide and those receiving two and three applications. Some of the inhibited runner-plants, however, sent out new runners as did the mother plants after the retarding effects had worn off while older runners from these runner-plants and mother plants remained static.

Other effects of the chemical were the chlorosis of young leaves (usually the leaf margins were lighter in colour), stunting of leaves and some crinkling of leaves. These foliar effects appeared soon after treatment and remained for a period of time after which normal growth began again. This period was from two to three weeks for the low rate and three to four weeks for the high rate, the wrinkling of the leaves was apparent for some time after normal colour returned. The above symptoms were more marked in plants receiving the high rate of maleic hydrazide.

2. Gibberellic Acid

The gibberellic acid treatments applied when the plants were established (December 9) hastened flower truss emergence as is indicated in Table 4. The 500 ppm rate and one of the 100 ppm rates caused emergence 5.5 days earlier than the control, while the other 100 ppm rate caused only 3 days increase in earliness and this latter difference was not significant.

Table 4 Effects of gibberellic acid on earliness of occurrence of reproductive and vegetative structures. Recorded in days from potting (November 20)

Treatment	Emergence of flower truss	First bloom	First ripe fruit	Emergence of first runner
100 ppm-plants established	39.0	49.5	88.0	76.5
500 " " "(Dec 9)	36.5*	47.0	90.5	79.0
100 ppm-truss emergence	41.5	52.5	91.0	76.5
500 " " " (Dec 30)	41.0	53.0	103.0**	75.0
100 ppm-fruit ripening	42.0	53.0	90.0	81.0
500 " " " (Jan 27)	42.5	52.0	90.5	88.5
100 ppm-at runnering	42.5	53.5	90.5	89.0
500 " " " (Feb 18)	44.0	55.0	90.0	81.5
100 ppm-repeated at 4 stages	36.5*	45.5*	86.5	75.5
Control	42.0	52.0	89.0	78.5
LSD 5%	4.67	5.49	5.29	NS
LSD 1%	6.17	7.89	7.60	NS

Date of first bloom was advanced 6.5 days over the control by the treatment which had at the time received two applications at 100 ppm (December 9 and 30). The treatment of 500 ppm (December 9) caused a 5-day advancement of flowering but this was not significantly different from the control (Table 4).

Although flower truss emergence and flowering were advanced by the above treatments, there were no significant differences in the time of ripening of fruit in plants receiving those treatments compared to the control plants as shown in Table 4. The treatment of December 30 at 500 ppm, however, caused a clearly significant delay in ripening of first fruit but this was due to the failure of the first flowers to set.

Data in Table 4 also indicate that emergence of runners was delayed by the treatment of January 27 at 500 ppm and by the treatment of February 18 at 100 ppm, but these differences were not significant when compared to the control.

The number of flowers per plant was not significantly increased or decreased by any treatment (Table 5) but the percentage of flowers to set fruit was greatly affected. All the treatments applied on or before January 27 (when the first fruit was beginning to ripen) caused a reduction in the percentage of flowers to set with only the two treatments of December 9 and 30 at the high rate and the repeated application at the low rate giving significant reductions

(Table 5). The high rate applied December 30 gave the highest reduction in fruit-set, averaging 30.8 per cent fruit-set

Table 5 Effects of gibberellic acid on flowering characteristics

Treatment	Number of flowers per plant	Percentage of flowers to set fruit	Length of peduncle (inches)
100 ppm-plants established	3.90	65.1	9.1
500 " " " (Dec 9)	3.80	47.4**	11.5*
100 ppm-truss emergence	3.80	71.0	11.2*
500 " " " (Dec 30)	4.35	30.8**	14.6**
100 ppm-fruit ripening	3.50	71.6	9.7
500 " " " (Jan 27)	3.70	67.5	9.4
100 ppm-at runnering	4.25	76.4	9.1
500 " " " (Feb 18)	3.60	78.6	8.8
100 ppm repeated at 4 stages	3.70	45.4**	9.3
Control	3.60	82.1	9.5
LSD 5%	NS	20.90	1.40
LSD 1%	NS	30.02	2.02

compared to 82.1 per cent for the control. In plants of this treatment the first flowers as well as some later flowers failed to set while in plants of the other treatments failure of flowers to set occurred only in the later formed flowers.

The 500 ppm rate of gibberellic acid applied on December 30 (when the flower trusses were emerging) caused the length of the peduncle to increase to an average of 14.6 inches compared to 9.5 inches for those of the control (Table 5, Figure 5). The low rate on the same date caused a less-marked increase in peduncle length but yet significantly different from the control, as also did the high rate applied December 9.

Figure 5 Plant of gibberellic acid treatment at 500 ppm applied Dec. 30 (when first trusses were emerging) (right) and control plant (left); illustrating the increase in peduncle length due to the treatment

Fruiting characteristics were markedly affected by the early gibberellic acid treatments. Weight of fruit per plot (Table 6) was greatly reduced by the 500 ppm treatments of December 9 and 30 and by the 100 ppm rate repeated at the above two dates. The number of berries per plot (Table 6) was decreased by the latter two treatments. Table 6 further indicates that the average weight per berry was decreased by the three above-mentioned treatments. Most of the small berries had a very poor set of seed and some were abnormally shaped owing to the failure of seed to set evenly around the receptacle.

Table 6 Effects of gibberellic acid on fruit yield and fruit characteristics

Treatment	Weight of fruit (gr./plot)	No. of fruit per plot	Av. Wt. per berry (grams)	Percentage sugar in fruit
100 ppm-plants established	41.1	12.5	3.33	9.3
500 " " "(Dec 9)	18.9**	8.5	2.25**	8.8
100 ppm-truss emergence	39.3	12.5	3.15	9.0
500 " " " (Dec 30)	9.5**	6.0*	1.60**	10.3**
100 ppm-fruit ripening	46.0	12.0	3.83	9.5
500 " " " (Jan 27)	49.3	12.5	3.94	10.1**
100 ppm-at runnering	51.3	12.5	4.16	9.6
500 " " " (Feb 18)	57.8	13.5	4.29	9.1
100 ppm repeated at 4 stages	19.2**	7.5*	2.54**	8.3*
Control	49.7	13.5	3.75	9.1
LSD 5%	15.20	5.45	0.70	0.64
LSD 1%	21.83	7.83	1.01	0.93

The average percentage of sugar in the fruit as shown by Table 6 was higher in berries of the treatments of 500 ppm applied December 30 and January 27 than in berries of the control while it was lower than those of the control in berries from plants receiving the treatment of 100 ppm repeated three times prior to fruit harvest. It must also be noted that the percentage of sugar increased as the fruiting season advanced and that plants of the latter treatment produced berries only in the earlier part of the season while plants of the 500 ppm treatment of December 30 produced berries only in the later part of the season.

Recordings of the number of runners per plant and the number of runner-plants per mother plant demonstrate that there was no significant increase or decrease in either of these characteristics (Table 7). An increase in runner length per plant over the control was exhibited by plants treated with 500 ppm gibberellic acid on December 30 (Table 7). Growth curves of runners over the period from February 3 to April 21 are presented in Figure 6. Only those showing greatest deviation from the control have been graphed.

Table 7 Effects of gibberellic acid on runnering

Treatment	Number of runners per plant	Number of runner-plants per plant	Runner Length per plant (inches)
100 ppm-plants established	5.7	11.6	241.6
500 " " " (Dec 9)	5.4	11.6	247.1
100 ppm-truss emergence	5.4	12.5	254.5
500 " " " (Dec 30)	6.0	15.4	307.2*
100 ppm-fruit ripening	6.6	13.6	296.5
500 " " " (Jan 27)	6.2	13.1	290.0
100 ppm-at runnering	6.3	11.1	257.5
500 " " " (Feb 18)	6.2	10.1	254.9
100 ppm repeated at 4 stages	6.6	14.0	301.8
Control	5.6	12.4	261.0
LSD 5%	NS	3.02	46.09
LSD 1%	NS	4.33	66.23

To estimate the vigour of mother plants records were made of the number of leaves per plant, the number of crowns per plant and the weight of mother plant tops (without runners). None of these indices showed any significant differences due to the treatments.

Leaf petiole length was markedly increased while the chemical remained active in the plant. Only the young leaves exhibited marked increases in length. Mature leaves were not affected and leaves emerging after the effect had worn off grew to their normal height.

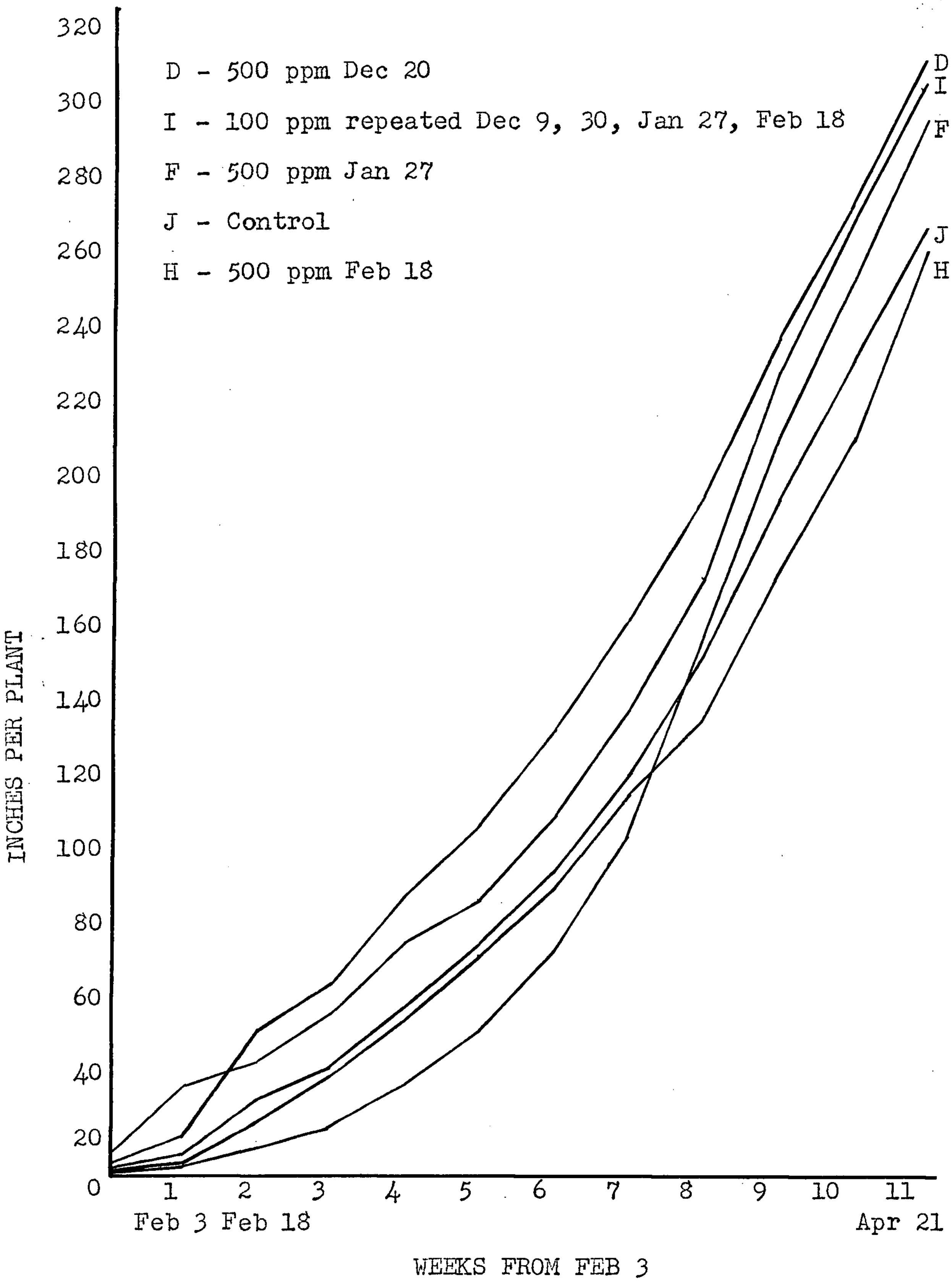


Figure 6 Growth curves of runner lengths as affected by gibberellic acid treatments. (Feb. 18 is date of last treatment)

In total top weight per plot, total root weight per plot, and top-root ratio (fresh weight) no significant differences from the control were displayed.

Of peculiar occurrence was the extension of the crowns as runner-like projections in many of the treated plants. Some of the crowns were extended about double their normal length while others were extended up to as much as several inches as is illustrated in Figure 7. These extensions were very thick and all new growth of runners and leaves occurred at their terminals, none from the bases. The

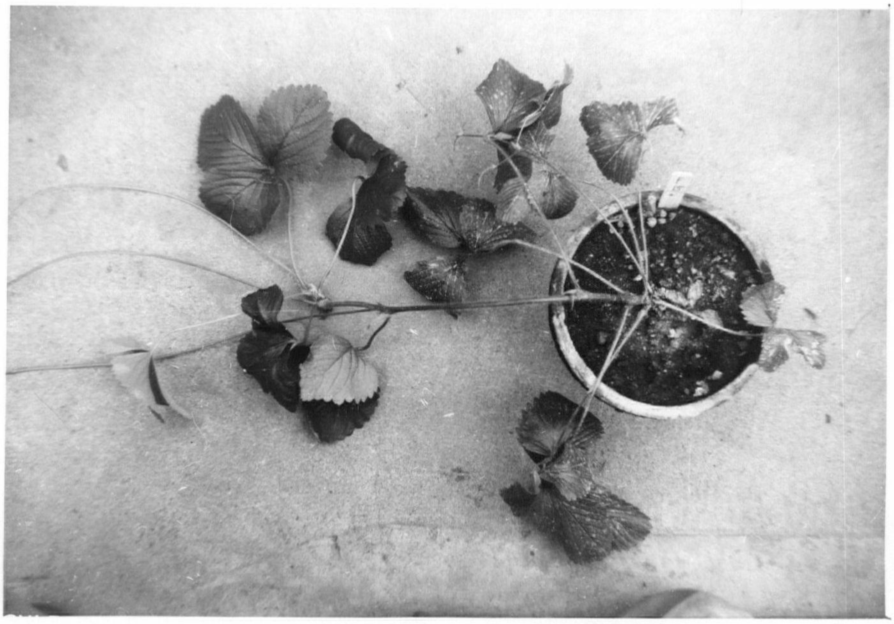


Figure 7 Plant receiving gibberellic acid at 500 ppm applied January 27 (just before fruit began to ripen) showing thick, runner-like extension of the main crown. Note that all new growth is from the end of the extension. Photographed April 22

terminals of the larger crown extensions formed root initials similar to those on runner plants. This abnormal extension occurred very noticeably only in plants receiving the higher rate of gibberellic acid and only slightly in plants receiving the repeated low rate. Greatest extension occurred in plants of the treatments of the high rate applied January 27 and February 18.

3. Maleic Hydrazide and Gibberellic Acid

Sixteen days after the treatments were applied the plants were removed for analysis. At this time the symptoms caused by the chemicals were showing very noticeably; the plants treated with maleic hydrazide showed a very marked stunting and chlorosis of new leaves, while plants treated with gibberellic acid showed extensive elongation of petioles on new leaves (Figure 8).

Figure 8 Effect of spray treatments 16 days after application showing plants from left to right--gibberellic acid at 500 ppm, control, and maleic hydrazide at 1000 ppm. Note the larger runners and larger young leaves on the plant of the former treatment and the lack of runner growth and very small new leaves on the plant of the latter treatment.

Fresh weight of tops, as indicated by Table 8, was significantly increased by the gibberellic acid treatment but it was decreased by the maleic hydrazide treatment.

Root weights were not significantly different from the control, although the maleic hydrazide-treated plants approached a significant increase (Table 8). Thus, the decrease in top weight with an increase in root weight produced a decrease in top-root ratio. The gibberellic acid produced a significant increase in top-root ratio owing to the increase in top weight with no corresponding increase in root weight.

Table 8 Effects of maleic hydrazide and gibberellic acid on top and root weights. Recorded 16 days after treatment

Treatment	Fresh Weight of tops(grams per plot)	Fresh Weight of roots (grams per plot)	Top/root ratio (fresh weight)	Dry Weight of tops (grams per plot)
MH @ 1000 ppm	78.63**	25.6	3.09**	23.58
GA @ 500 ppm	130.86**	22.0	5.97**	27.80
Control	103.26	22.4	4.62	24.95
LSD 5%	12.19	NS	0.58	NS
LSD 1%	17.34	NS	0.82	NS

Recordings of total dry weight of tops per plot display no significant differences from the control (Table 8).

From Table 9 it is evident that maleic hydrazide caused a significant increase in the percentage of total solids in the plant tops over the control while gibberellic acid caused a significant decrease. It follows that the percentage of moisture was decreased by the former and increased by the latter treatment.

Table 9 Effects of maleic hydrazide and gibberellic acid on total solids, moisture, and ash content of strawberry plant tops. Determined 16 days after treatment

Treatment	Percentage total solids	Percentage moisture	Percentage ash (fresh weight)	Percentage ash (dry weight)
MH @ 1000 ppm	29.9**	70.1**	2.53**	7.84
GA @ 500 ppm	21.3**	78.7**	1.92	8.62
Control	24.1	75.9	2.07	8.15
LSD 5%	1.27	1.27	0.29	NS
LSD 1%	1.81	1.81	0.41	NS

When compared on a fresh weight basis the percentage of ash in the maleic hydrazide-treated plants was significantly higher than in the control plants, but on a dry weight basis the ash content was lower, although not significantly so (Table 9). On fresh and dry weight bases gibberellic acid-treated plants showed no significant effects.

The percentage of sugar and the percentage of starch were both significantly increased by the maleic hydrazide treatment but both were significantly decreased by the gibberellic acid treatment when compared to the control (Table 10).

Table 10 Effects of maleic hydrazide and gibberellic acid on carbohydrate and nitrogen relation. Determinations on samples taken 16 days after treatment

Treatment	Percentage total sugars (fresh wt.)	Percentage starch (fresh wt.)	Percentage nitrogen (dry wt.)	Carbohydrate/ nitrogen ratio
MH @ 1000 ppm	2.97**	6.05**	1.99**	15.18**
GA @ 500 ppm	1.96**	3.39**	2.33	10.83*
Control	2.26	4.22	2.28	11.84
LSD 5%	0.21	0.50	0.11	0.75
LSD 1%	0.29	0.71	0.16	1.06

The percentage of nitrogen on a dry weight basis showed a highly significant decrease due to the maleic hydrazide treatment while there was no significant difference exhibited between the gibberellic acid-treated plants and control plants (Table 10). The carbohydrate-nitrogen ratio was greatly affected by the maleic hydrazide treatment as a highly significant increase over the control was exhibited. The ratio was significantly decreased by the gibberellic acid treatment (Table 10).

B. FIELD EXPERIMENT - Maleic Hydrazide

In the statement of the results of this experiment, treatments will be referred to by figures for the ounces of maleic hydrazide per acre applied. For example, treatment 25+10+10+10 will refer to the treatment receiving 25 ounces of maleic hydrazide per acre in the first application and 10 ounces per acre in the subsequent three applications.

Maleic hydrazide displayed a marked effect on the runnering on the strawberry plants. Table 11 indicates that all of the spray treatments caused highly significant reductions in runner length per plant and number of runner-plants per mother plant. The number of runner-plants per mother plant closely paralleled the runner lengths per plant. Treatments 25+25+25, 40+25+25, and 40+10+10+10 showed the greatest runner reduction and their effectiveness was very similar. Treatment 40+40 also gave good control but falls somewhat below that of the three above-mentioned treatments. Plants receiving the two remaining treatments, 10+10+10+10, and 25+10+10+10, exhibited a marked reduction in runnering compared to the control but considerably less reduction than that due to the other treatments.

Table 11 Effects of maleic hydrazide (field applications) on runnering in the strawberry. Recorded at the end of the growing season (November 8)

Treatment	Length of runners per plant (inches)	Number of runner-plants per mother plant
10+10+10+10 oz./acre	179.0**	13.3**
25+25+25	42.8**	3.0**
25+10+10+10	127.7**	8.9**
40+40	83.7**	6.9**
40+25+25	40.7**	2.8**
40+10+10+10	52.5**	2.8**
Control	574.0	50.2
LSD 5%	39.46	3.02
LSD 1%	54.06	4.14

Figure 9 sets forth the growth curves for runner length over the entire season. From this figure it is apparent that the period of active runner growth extended throughout July, August and September. Very little growth was produced after September 22 and it will be noted that some of the curves fall slightly after this date owing to the death of a number of runners caused by the treatment in question. The small arrows on the curves indicate the date of each application. Observing these arrows on the curve for treatment 10+10+10+10, one finds that the 10 ounce per acre rate reduced growth rate of runners but, at the intervals used, a considerable amount

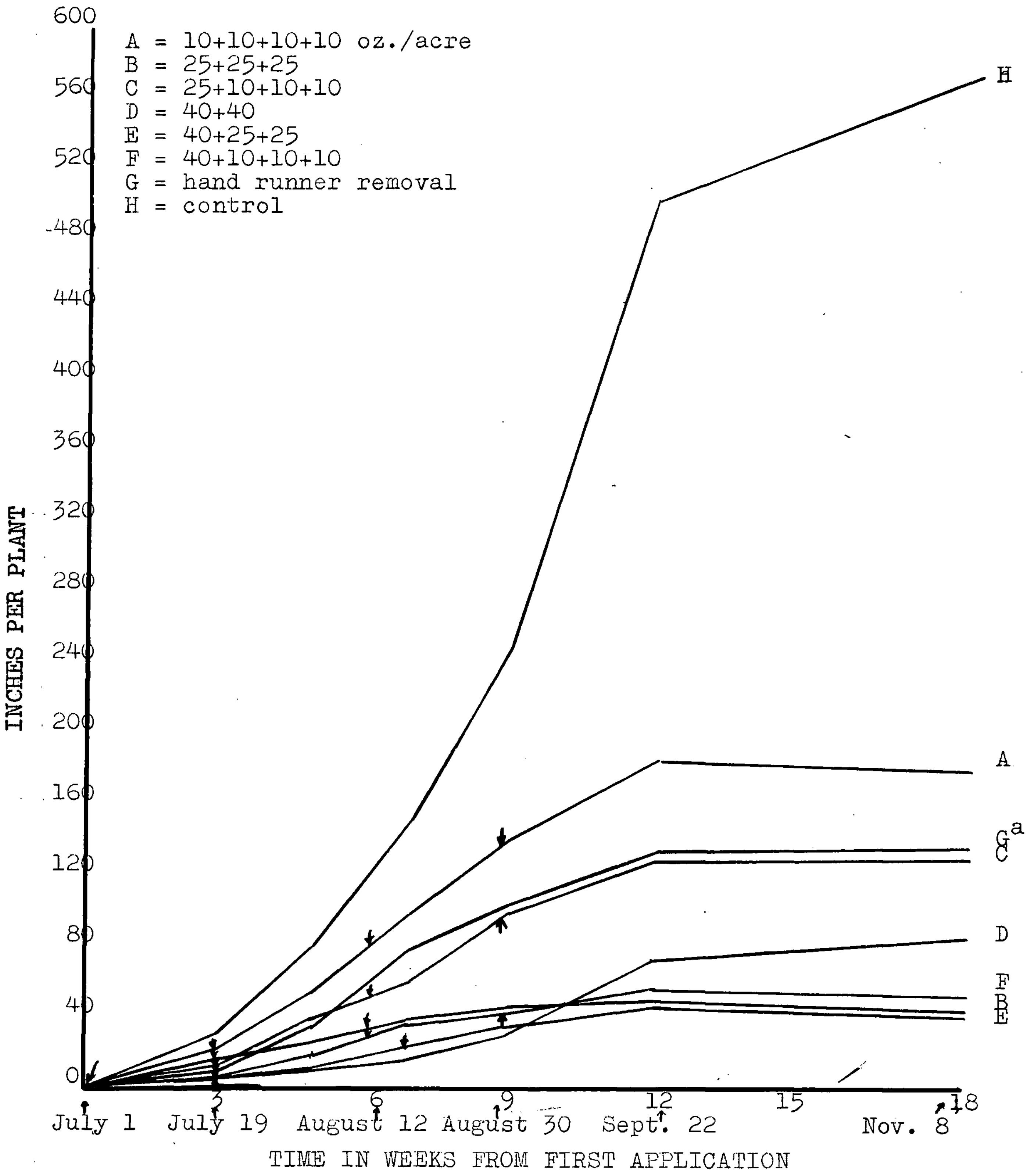


Figure 9 The effects of maleic hydrazide (field applications) on growth of runners throughout the season in inches of runner growth per plant (arrows indicate date of applications)

[a] Accumulative lengths

of growth was yet produced. Similarly, the treatment using three applications of 10 ounces per acre after an initial 25-ounce application allowed considerable growth in the intervals between applications but the growth rate was lower than that in the above treatment. Pursuing this comparison, it is apparent that the treatment consisting of 10-ounce per acre applications after the initial 40-ounce application caused a very much lower growth rate of runners than did the above two treatments. Treatments 25+25+25 and 40+25+25 caused growth rates which were very similar. Treatment 40+40, however, received its last application July 19, approximately three weeks before the last application of the latter two treatments, and it will be noted that this last application began to lose its effect after one month; growth rate of the runners surpassed that of the latter two treatments and caused the final runner length to be greater.

Figures 10 and 11 show the eight plots in the first replicate as they appeared at the end of the growth season (October 27, 1958). It will be noted that runner control was excellent in all plots when compared to the control. It will also be noted that the runner-plants that did form from the treated plants are very close to the mother plant and make one large clump of crowns. This is further displayed by Figure 12.

To estimate the vigour of the mother plants at the end of the growing season relative vigour ratings were made,

Figure 10 Effects of maleic hydrazide on runner growth. Plants from left to right are from treatments: 25+10+10+10, control, 40+25+25, and 40+40 (ounces of MH per acre). Photograph taken Oct. 27, 1958 after runner growth had ceased

Figure 11 Effects of maleic hydrazide on runner growth. Plants from left to right are from treatments: 25+25+25, 10+10+10+10, 40+10+10+10, and hand runner removal. (Ounces of MH per acre). Photographs taken Oct. 27, 1958 after runner growth had ceased.

Figure 12 Effect of maleic hydrazide on runner growth. Plants from left to right are from treatments: hand runner removal, 25+10+10+10 ounces of MH per acre, control. Note runner reduction caused by the spray treatment and the relative vigour of plants of the first two treatments. Also note that runner-plants formed by the sprayed plants are very close to the mother plant.

height and breadth measured, and the number of crowns per plant counted. These three indices all indicated a significant reduction of vigour in plants of treatment 10+10+10+10 compared to plants of the hand runner removal treatment but no significance difference from the control (Table 12). Although the other spray treatments did not cause any significant difference from the hand runner removal treatment in the three indices noted, the following treatments caused significant increases in number of crowns per plant above that of the control: treatments 25+25+25, 40+40, 40+25+25 and 40+10+10+10.

Table 12 Effects of maleic hydrazide (field applications) on vigour of mother plant at end of growth season

Treatment	Vigour Rating after potting 10 = very vigorous 1 = very poor	Height X Breadth after potting (inches)	Number of crowns per mother plant
10+10+10+10 oz./acre	7.1[aa]	17.6[a]	1.7[a]
25+25+25	8.4	23.6	3.8*
25+10+10+10	7.6	18.0	2.2
40 + 40	7.7	23.9	3.1*
40+25+25	7.9	19.7	4.1*
40+10+10+10	8.0	21.7	3.7*
Hand runner removal	8.7	23.9	3.0
Control	7.7	19.6	1.9
LSD 5%	1.16	6.15	1.16
LSD 1%	1.58	8.37	1.58

[a] Significantly different from hand runner removal treatment.
* Significantly different from the control.

The above results observed on runnering and vigour completed the field studies and the following are the results of greenhouse studies on the fruiting characteristics carried out on the same plants potted and grown in the greenhouse.

No significant differences were observed in date of emergence of flower trusses, date of first bloom, and date of ripening of first fruit.

Owing to a severe pathological or physiological disorder, crowns and flower trusses began to rot on many of the plants soon after the trusses began to emerge. This unfortunate occurrence appeared in plants irrespective of treatment. The number of flowers per plant were recorded for the first six weeks of the fruiting season but from then on accurate recordings were not possible. These results are given in Table 13. From this table it is evident that the treatments causing production of the largest number of flowers were: hand runner removal, 25+25+25, 40+10+10+10, and 40+25+25 in order of increasing numbers. The latter treatment showed a significant increase above the control. None of the treatments showed a significant difference from the hand removal treatment.

Table 13 Effect of maleic hydrazide (field applications) on the number of flowers. (In first 6 weeks of fruiting season)

Treatment	Number of flowers per plant
10+10+10+10 oz./acre	10.3
25+25+25	12.3
25+10+10+10	8.9
40+40	8.8
40+25+25	14.0*
40+10+10+10	13.0
Hand runner removal	11.5
Control	10.7

LSD 5% 3.19 1% 4.34

Fruit production occurred over a nine-week period but heaviest production was recorded in the first four weeks. Weight of fruit, number of berries and average weight per berry were determined for the fruit produced in the first four weeks but no significant differences were exhibited. Total yield per plot and total number of berries per plot showed no significant differences (Table 14). Average weight per berry over the whole fruiting season was significantly increased over the control by all treatments except treatment 40+10+10+10 and only this treatment and the control caused plants to have significantly smaller berries than those of the hand runner removal treatment (Table 14).

Analysis of the fruit produced in the first four weeks of the fruiting season indicated no significant differences in sugar and acid content (Table 15). However,

Table 14 Effects of maleic hydrazide (field applications) on total fruit production

Treatment	Yield in grams per plot	Number of berries per plot	Average weight per berry (grams)
10+10+10+10 oz./acre	46.87	17.5	2.66*
25+25+25	57.82	20.5	2.87**
25+10+10+10	39.05	14.5	2.67*
40+40	44.60	15.7	2.83**
40+25+25	64.72	23.7	2.80**
40+10+10+10	51.12	20.2	2.54[a]
Hand runner removal	44.15	14.7	3.02**
Control	35.32	15.5	2.24[a]
LSD 5%	NS	NS	0.39
LSD 1%	NS	NS	0.54

the sugar-acid ratio was significantly increased over the hand runner removal treatment but not over the control by treatments 10+10+10+10 and 25+10+10+10. The other treatments produced no differences from either the control results or the hand runner removal treatment results.

Table 15 Effects of maleic hydrazide (field applications) on fruit quality

Treatment	Percentage sugar	Percentage acid	Sugar/acid ratio
10+10+10+10 oz./acre	9.0	.79	11.58[a]
25+25+25	8.4	.88	9.73
25+10+10+10	9.6	.83	11.56[a]
40+40	8.9	.89	10.10
40+25+25	9.3	.93	10.05
40+10+10+10	8.8	.90	9.80
Hand runner removal	8.6	.86	10.20
Control	9.2	.88	10.61
LSD 5%	NS	NS	1.19
LSD 1%	NS	NS	1.62

[a] Significantly higher than for the hand runner removal treatment

DISCUSSION

A. GREENHOUSE EXPERIMENTS

1. Maleic Hydrazide

Although runner formation began before March 13, vigorous runner production did not begin until about April 10 (Figure 2). As a result, the plants which received only one early application of 500 ppm did not show a great reduction in runner formation because most of the effect of the treatment had worn off before April 10.

In the two-month period from April 10 to June 12 the plants which received the 500+500+500, 1000+500 and 1000+1000 treatments had their runner growth markedly suppressed. If treatment of these plants had commenced on April 10 instead of March 13 a much longer period of runner suppression would have resulted.

The greenhouse-grown plants in this experiment during the two month period of April 10 to June 12 were in a stage of growth similar to outside-grown plants during the July-August period. It would seem justifiable to conclude that the three treatments mentioned above if applied in the field correspondingly later would suppress runner growth throughout the growing season under field conditions.

The plants which received the effective treatments (maleic hydrazide at 500+500+500, and 1000+1000) had an increased number of leaves and crowns and top weight of mother plants. As the plants receiving these treatments also showed the least runner formation it is apparent that the mother plants gained in vigour from use of food reserves that would normally have gone into production of runners. Plants which received treatment 1000+500 showed a similar but somewhat lesser response to the treatments than the foregoing, whereas the plants which received the 500 only, 500+500 and 1000 treatments had runner formation suppressed but slightly. These treatments were not considered sufficiently effective to be of value and could be referred to as non-effective treatments.

Plants which had their runners removed by hand showed a similar response to those which received the 100+100 and 500+500+500 treatments. The mother plants were larger and more vigorous than the control mother plants which had been allowed to runner freely. This response substantiates the value of the hill system of training for the British Sovereign variety of strawberry in contrast to the matted row system.

Plants which received the effective treatments had their top-root ratio decreased. Despite the fact that the total top weight was not increased by these treatments in comparison to the control plants, the roots were increased. This could indicate a stunting of the top in relation to the root or it could mean an increased stimulation of the roots. It would appear that as a result of the treatments, a large percentage of the increased vigour of mother plant due to non-formation of runners, was channelled into root growth rather than to runner growth. The advantage of a large root system as a mechanism for obtaining increased soil nutrient supplies and in particular for resisting drought conditions is apparent.

The stoppage of runner growth after application of maleic hydrazide, the dying back of runners, and the foliage symptoms produced by the chemical agree with the observations of Denisen (17). He found that runners continued to form for about one week after application and that stoppage of growth was followed by gradual death of the runner. He also noted that the chlorosis of newly-formed leaves cleared up three to four weeks after application.

2. Gibberellic Acid

The hastening of flower truss emergence and flowering caused by the early treatments of gibberellic acid is in agreement with the results observed on various other species of plants by workers such as Leben and Alder (28) and Livingstrom, Wittwer and Bukovac (30).

Even though truss emergence and flowering were hastened by some treatments, the date of fruit-ripening was not significantly different for plants of any of the treatments except that of December 30 at 500 ppm and this occurred because the first flowers failed to set fruit.

The reduction of fruit-set on all plants treated with gibberellic acid before the first berries were ripe was a marked response to the chemical. In view of the fact that Chandler (11) observed that gibberellic acid caused inhibition of pollen tube growth, coiling and enlarging of tube tips and exuding of cytoplasm in pollen of ten of the plant types studied it is reasonable to suspect that this might have occurred on the strawberry pollen tubes. Another possible reason for this lack of fruit set could be that the gibberellic acid caused an earlier or later maturation of the anthers, resulting in pollen production at a time when the stigma was not receptive. Owing to the changes in constituents in a plant treated with gibberellic acid, such as the reduction of the content of sugars, it is possible that the plane of nutrition of the fruiting structures was altered sufficiently to disrupt the normal processes.

Yield of fruit per plot, number of fruit per plot and average weight per berry appear to follow the same trends as the fruit set; in plants which displayed poor fruit set, the above characters were also poor. The smaller size of berry may have been caused by a smaller number of seeds set on the receptacle .

The increases in sugar content of fruit in plants treated with gibberellic acid at 500 ppm at time of truss emergence and in plants treated at 500 ppm when the fruit was ripening indicate a beneficial effect on fruit quality. Although decreases in sugar content of leaf tissue have been reported by several authorities (46,50), no reports have been noted of effects of gibberellic acid on sugar content of fruit. No explanation can be forwarded for the decrease in sugar content of fruit in plants which received repeated applications of gibberellic acid at 100 ppm.

Differences in vegetative growth were not great except in the case of plants treated December 30 at 500 ppm. These plants produced more extensive runner growth than the control plants, but since this was the treatment that gave the poorest yield of fruit, it may be expected that this increase in runner growth was attributed to diversion of the materials normally used for fruiting to vegetative growth.

Owing to the fact that greatest stimulation of peduncle growth was exhibited in plants treated when flower trusses were emerging it is evident that the growth promoting effect only occurred on tissues making active growth while the chemical effect was still present. Similarly, it was observed that leaf petioles were stimulated in the young stages of growth while mature leaves were not affected.

Lack of significant differences in top-root ratio and lack of the presence of any marked trends leads to the possible conclusion that if any differences in top-root ratio had been present earlier, they had been obscured by the restoration of normal top-root balance.

3. Maleic Hydrazide and Gibberellic Acid

The decrease in fresh weight of tops due to maleic hydrazide treatment is in accordance with the general response to the chemical. The increase in root weight over the control (although not significant) is contrary to the general trend, but Naylor and Davis (37) observed that roots of some plants were not affected while Mikkelsen, et al. (34) observed that maleic hydrazide caused an increase in sugar beet root yield when applied at optimum rate and time. The increase in root weight and decrease in top weight caused a decrease in the top-root ratio which agrees with the findings of the above authors in their work on various crops.

The increases in fresh weight and dry weight (not significant) of tops caused by the gibberellic acid treatment substantiates Marth, et al. (33), Bukovac and Wittwer (8), Morgan and Mees (36) in their findings with many of the crops studied. Although no significant decrease in fresh weight of roots was recorded in this experiment, gibberellic acid genereally caused below-normal root growth (3,33,36). The increase in top-root ratio caused by the gibberellic acid is in agreement with the findings of the above authors.

The increase in the percentage of ash on a fresh weight basis in the maleic hydrazide-treated plants may possibly be explained by the fact that the percentage of moisture was lower in these plants while total dry weight was very near that of the control. That the percentage of ash on fresh and dry weight bases was not significantly altered by the gibberellic acid treatment upholds the results observed by Yabuta (50) in his studies with rice seedlings. However, Brian, et al. (3) recorded a reduction of ash content on a dry weight basis in wheat owing to gibberellic acid treatment.

Increases in percentage total sugars and starch in the maleic hydrazide-treated plants follow the trends pointed out by various research workers (10,14,34,39,41). Since Fults and Payne (19) found total protein nitrogen to be decreased in sugar beets and pinto beans owing to maleic hydrazide treatment, the decrease in total nitrogen found in this experiment is not unique. However, Denisen (15) found no significant difference in percentage nitrogen in any part of the strawberry plant.

Decreases in percentage total sugars and starch attributable to treatment with gibberellic acid agree with the results of Yabuta (50) and Sumiki (46) in their analysis of treated rice seedlings. The former author found no increase in total nitrogen content due to gibberellic acid treatment, which corresponds to the results produced in this experiment.

It is a generally accepted fact that plants in a condition of moderate carbohydrate and high nitrogen content may display strong vegetative growth, no flowering or producing only sterile flowers. The lower-than-normal carbohydrate-nitrogen ratio resulting from the gibberellic acid treatment may be an explanation for the poor set of fruit from the flowers produced by plants treated with gibberellic acid in the greenhouse experiment previously mentioned.

B. FIELD EXPERIMENT - Maleic Hydrazide

The effects of maleic hydrazide on length of runner growth, number of runner-plants and number of crowns per plant observed in this experiment uphold the results of the greenhouse experiment described earlier and also support the work of several authorities on this subject (15,16,23).

Treatments 25+25+25, 40+25+25, and 40+10+10+10 appear to have been the most promising treatments. There were no significant differences noted between these three treatments in any of the aspects recorded and there were no significant differences between plants of these treatments and plants of the hand runner removal treatment with exception that treatment 40+10+10+10 produced smaller berries than this treatment. Treatment 40+40, although it gave excellent runner control, gave an indication that its effects on plant vigour and flowering were not as desirable as those of the above-mentioned three treatments, possibly owing to the large accumulation of the chemical in the short period of time. Treatments 10+10+10+10 and 25+10+10+10 gave fair control of runners but showed no improvement above the control plants in vigour, number of crowns and number of flowers. However, both treatments caused production of larger sized fruit and a higher sugar-acid ratio. Since these two treatments fall below the aforementioned three treatments in most respects, it is apparent that the low rate may not suffice unless applications were made at shorter intervals.

Owing to the loss of many fruits through the dying of flowers as a result of pathogenic attach or physiological disorder, recordings made on early and total yield showed no significant differences in weight of berries and number of berries. However, the significant increases in berry size caused by the spray treatments substantiate the results obtained by several authors (15,16,23) in previous experiments in the use of maleic hydrazide to inhibit runners on strawberry plants.

The increase in sugar-acid ratio caused by treatments 10+10+10+10 and 25+10+10+10 is unexpected owing to the failure of the other spray treatments to show similar trends.

The problem of runner control has been dealt with from one point of view up to this point in this paper in that only the mother plant has been studied for its fruiting potential. In the field experiment only the mother plant was transplanted to be observed in the greenhouse. It was earlier mentioned in the results of the field experiment and illustrated by Figures 10, 11 and 12 that many of the treated plants produced runner plants very near the mother plant and often they were large in size. These runner plants could have been looked upon as additional crowns on the mother plant. If they had been grown on with the mother plants, increases in yield may have resulted. This possible procedure of retaining the few runner plants that do form on treated plants is not far removed from the procedure followed by research workers in many areas whereby an optimum number of runner-plants is permitted to form in the early part of the season and further runner-plant formation is then inhibited by spray treatments (24).

A comparison of runner growth of plants treated with maleic hydrazide in the greenhouse with that of plants treated in the field indicates that greater effect was exhibited by the greenhouse treatments than by the corresponding field treatments; where the repeated 500 ppm treatment gave good runner suppression in the greenhouse, the corresponding 10 ounce per acre treatment in the field gave only moderate suppression. This may in part be caused by differences in environmental conditions, particularly in relative humidity which was found by Zukel (52) to greatly affect absorption rate of the chemical. Although the effects were less marked in the field than in the greenhouse, the effects were similar in all respects.

CONCLUSIONS

Certain of the maleic hydrazide treatments were decidedly beneficial and they hold promise as a practical means of controlling runners in strawberries. Excellent runner control was achieved and at the same time the mother plants were stimulated to the same degree of vigour as that of plants which had their runners removed by hand. From the grower's point of view this would be a means of eliminating the large amounts of hand labour normally required to cut off runners.

The fact that the top-root ratio was reduced is another point in favour of maleic hydrazide treatment since the increase of root in relation to top may result in an increase in droughht resistance.

The increase in carbohydrate content of the tops caused by maleic hydrazide treatment may also be paralleled by an increase in the roots which would insure the storage of an adequate supply of food material over the winter as well as favour the initiation of flower buds in the fall.

Three applications of 25 ounces of maleic hydrazide (active ingredient) per acre at three-week intervals from the beginning of runnering appeared to be the best treatment.

In contrast to maleic hydrazide, the over-all effects of gibberellic acid were detrimental , despite the fact that 16 days after treatment the plants responded beneficially in respect to stimulation of growth of tops.

Because of its severe reduction of fruit-set, gibberellic acid treatment may be considered undesirable when applications are made shortly before or during the fruiting period of the strawberry. However, since these results were produced in the greenhouse, one may hesitate to conclude that the chemical would have similar effects on fruiting under normal field conditions; there may be an interaction of the compound with high temperature, as the night temperature in the greenhouse was 65 to 70°F. whereas the night temperatures in the field during the normal fruiting season may fall below 40°F. Furthermore, these results do not eliminate the possibility of the use of this chemical on strawberries in the first season of growth when they are becoming established, since applications would be made well in advance of flowering. One factor, however, that must be taken into account is that an increase in top-root ratio was recorded, which indicates the possibility that drought resistance may be reduced.

The earlier flowering attributed to action of gibberellic acid may be beneficial in some areas but in the Fraser Valley this would be undesirable owing to the risk of late spring frosts.

The increase in sugar content could be beneficial in the fruit of some varieties of strawberries but the British Sovereign fruit is not lacking in sweetness.

The lengthening of peduncles could have the effect of overcoming the tight bunching of fruit close to the crown such as occurs in some varieties of strawberry. Thus, picking would be facilitated. The British Sovereign variety however produces peduncles which are sufficiently long.

SUMMARY

Experiments with maleic hydrazide and gibberellic acid were conducted with strawberry plants, variety British Sovereign, at the University of British Columbia both in the greenhouse during the winter months and in the field during the summer.

Maleic hydrazide treatments resulted in excellent runner control of plants without imparing their vigour. The British Sovereign variety of strawberry is grown in British Columbia using the hill system of training which involves the hand removal of runners from the parent plant. Use of maleic offers an economical means of saving large amounts of hand labour normally required for runner removal.

Despite various marked responses of the British Sovereign strawberry to gibberellic acid, it reduced fruit-set and yield. Therefore its use would not be advisable as a commercial practice.

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APPENDIX I An example of calculations for statistical analysis.

Effects of gibberellic acid on weight of fruit in grams per plot of 5 plants.

Treatment	Block I	Block II	Treatment totals	Treatment means
100 ppm-plants established	42.6	39.7	82.3	41.1
500 " " " (Dec.9)	17.2	20.7	37.9	18.9
100 " truss emergence (Dec.30)	35.2	43.5	78.7	39.3
500 " " " "	10.5	8.5	19.0	9.5
100 " fruit ripening (Jan.27)	41.4	50.7	92.1	46.0
500 " " " "	49.6	49.0	98.6	49.3
100 " at runnering (Feb. 18)	57.9	44.7	102.6	51.3
500 " " " "	55.2	60.4	115.6	57.8
100 " repeated at 4 stages	23.8	14.7	38.5	19.2
Control	40.0	59.5	99.5	49.7
Block totals	373.4	391.4	764.8	

Total SS = $(42.6)^2 + (17.2)^2 + (59.5)^2 - \frac{(764.8)^2}{20} = 5297.11$

Treatment SS = $\frac{(82.3)^2 + (37.9)^2 + (99.5)^2}{2} - \frac{(764.8)^2}{20} = 4874.74$

Blocks SS $\frac{(373.4)^2 + (391.4)^2}{10} - \frac{(764.8)^2}{20} = 16.20$

Error SS 5297.11 - (4874.74 + 16.20) = 406.17

Analysis of Variance Table

Source	df	SS	MS	F (calc.)	F (table)
Total	19	5297.11			
Treatment	9	4874.74	541.64	12.00	3.18
Blocks	1	16.20	16.20	0.36	5.12
Error	9	406.17	45.13		

Standard error of difference between means = $\sqrt{2 \times \frac{45.13}{2}} = 6.718$

LSD @ 5% = 2.262 x 6.718 = 15.20
LSD @ 1% = 3.250 x 6.718 = 21.83

APPENDIX II An example of calculations for statistical analysis.

Effects of maleic hydrazide and gibberellic acid on percentage ash on a fresh weight basis.

Treatment	Block I	II	III	IV	V	VI	Treatment totals	Treatment means
MH @ 1000 ppm	2.96	2.51	2.38	2.42	2.44	2.49	15.20	2.53
GA @ 500 ppm	1.54	1.83	1.88	2.11	1.91	2.23	11.50	1.92
Control	1.87	2.06	2.00	2.07	2.19	2.23	12.42	2.07
Block totals	6.37	6.40	6.26	6.60	6.54	6.95	39.12	

$$\text{Total SS} = (2.96)^2 + (1.54)^2 + (2.23)^2 - \frac{(39.12)^2}{18} = 1.84$$

$$\text{Treatment SS} = \frac{(15.20)^2 + (11.50)^2 + (12.42)^2}{6} - \frac{(39.12)^2}{18} = 1.24$$

$$\text{Block SS} = \frac{(6.37)^2 + (6.40)^2 + (6.95)^2}{3} - \frac{(39.12)^2}{18} = 0.10$$

$$\text{Error SS} = 1.84 - (1.24 + 0.10) = 0.50$$

Analysis of Variance Table

Source	df	SS	MS	F (calc.)	F (table)
Total	17	1.84			
Treatments	2	1.24	.62	12.40	4.10
Blocks	5	.10	.02	.40	3.33
Error	10	.50	.05		

Standard error of difference between means = $\sqrt{2 \times \frac{.05}{6}} = 0.129$

LSD @ 5% = 2.228 x 0.129 = 0.29

LSD @ 1% = 3.169 x 0.129 = 0.41

APPENDIX III An example of the calculations for the statistical analysis for the field experiment.

Effects of maleic hydrazide (field applications) on the number of crowns per plant. (Ave. of three plants)

Treatment	Block I	II	III	IV	Treatment totals	Treatment means
10+10+10+10 oz./acre	2.0	1.3	2.3	1.3	6.9	1.7
25+25+25	3.0	5.0	3.3	4.0	15.3	3.8
25+10+10+10	2.0	2.3	3.0	1.7	9.0	2.2
40+40	4.3	3.3	2.0	3.0	12.6	3.1
40+25+25	5.0	3.7	4.0	3.7	16.4	4.1
40+10+10+10	4.7	2.3	3.0	4.7	14.7	3.7
Hand runner removal	3.7	2.7	2.3	3.3	12.0	3.0
Control	2.0	1.3	1.3	3.0	7.6	1.9
Block totals	26.7	21.9	21.2	24.7	94.5	

Total SS 2 $(2.0)^2 + (3.0)^2 + (3.0)^2 - \frac{(94.5)^2}{32} = 38.44$

Treatment SS = $\frac{(6.9)^2 + (15.3)^2 + (7.6)^2}{4} - \frac{(94.5)^2}{32} = 22.99$

Block SS = $\frac{(26.7)^2 + (21.9)^2 + (21.2)^2 + (24.7)^2}{8} - \frac{(94.5)^2}{32} = 2.43$

Error SS = 38.44 - (22.99 + 2.43) = 13.02

Analysis of Variance Table

Source	df	SS	MS	F (calc.)	F (table)
Total	31	38.44			
Treatment	7	22.99	3.28	5.29	2.49
Blocks	3	2.43	0.81	1.31	3.07
Error	21	13.02	0.62		

Standard error of difference between means = $\sqrt{\frac{2 \times .62}{4}} = .557$

LSD @ 5% = 2.080 x .557 = 1.16

LSD @ 1% = 2.831 x .557 = 1.58