THE EFFECTS OF SOIL TEMPERATURE AND SUPPLEMENTAL LIGHT ON INITIATION AND DEVELOPMENT OF FLOWER BUDS IN GLADIOLUS (GLADIOLUS GRANDIFLORUS)

by

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INTRODUCTION

Flowering is one of the most complex problems in plant physiology. For obvious reasons, flowering has been studied largely in plants which rapidly respond to changes in environmental factors. Chief among these factors are temperature, photoperiod, light intensity, light quality, and content of atmospheric gases. The importance of photo- and thermo-phases to flower induction is well known. Research studies have shown that low-light intensities and short days during the fall, winter, and spring seasons are limiting factors in the culture of many greenhouse crops. To control these deficiencies of natural light, supplemental light of low intensity is used as a day length control of flowering in some photoperiodic flower crops. Therefore, growers are able to produce these crops on a year around basis.

Gladiolus is the foremost spring-planting bulbous flower. The modern varieties are hybrid descendants of crosses developed by nineteenth century European horticulturists from South African species, Saundersii (Muller, 1964). In the United States, production of gladioli as well as outdoor chrysanthemums and foliage plants have located in Florida because of the mild weather year-around. It is cultured as an outdoor crop and is important in year-around use by the floral industry. Because they are in demand throughout the year, winter production is a necessity. The states of Florida and California at present are the suppliers of gladiolus for winter use. Therefore, in the north, the greenhouse forcing is of much interest for a commercial scale contribution.

This study concerns the interaction between supplemental light of different intensities and soil temperatures on the forcing of gladiolus corms during the winter months.

LITERATURE REVIEW

In retrospect, little research has been done on gladiolus. During 1930's there were studies on the cultivation, fertilization, disease and insects control, corm production and development of new varieties. Because of economical conditions, there has been little done with gladiolus in greenhouse lately. Some research has been done on the determination of optimum ranges of environmental cues such as light and temperature on gladiolus. However, the interactions of light and temperature are complex and have not been carefully analysed. Many data suggest the typical vernalization, the effect of moderately low temperature, the effect of varying day and night temperature (thermoperiodism) and interactions of temperature with photoperiod all integrate.

Post (1950) has pointed out that flower bulbs differentiate as the stems develop regardless of day length. The reduction of light intensity by growing plants under aster cloth increased stem length and flower size. However, Laurie and Poesch (1932) and Balch (1935) found that varieties responded differently, but most varieties flowered better when given supplemental light. Weinard and Decker (1939) have also concluded that earliness of flowering may be stimulated and flower yield was increased by the use of supplemental light during winter months. Meantime, they also found that there was a relatively large proportion of 'blind' shoots which depended to a certain extent upon the variety. They concluded that the use of supplemental light was not recommended for economic reasons. Laurie, Kiplinger and Nelson (1958) observed that the light factor was more important in the development of the flowering shoot (spike). Stimulation of growth through the use of additional light at critical period is of value, but they report the expense is too great to warrant commercial practice. In this respect, R. van der Veen and G. Meiger (1959) have also mentioned that in forcing bulbs of gladioli and Lilium regale, very high intensity is essential for well-developed flowers and it is therefore not economical to force these plants under supplemental light. In the areas where gladioli are available at reasonable prices all times of the year it is hardly feasible to use space or supplemental light in green-house for gladioli. Though, there are probably some sections of the country where these conditions do not exist and planting of gladioli might be made to bring in enough income to justify the space or the cost that they use. White (1930) working with four varieties, found that these varieties planted in December responded to supplemental light with an increase in number of flower stalks. Gilbert and Pemner (1935) found that the number of flowers was significantly increased when supplemental lighting was used. The light intensity from 100-watt lamps was sufficient to bring about the desired results and, in some case the light from a 50-watt lamp brought about decided increases in the number of blooms. Supplemental lighting during the later portion of growth period did not bring about flowering in any case. It was suggested that supplemental light begin soon after first leaves appeared above ground. There were indications that once flowering began, supplemental lighting could be discontinued. Furthermore, Gilbert <u>et</u>. <u>al</u>. (1935) stated that when cultivars which normally have short growing periods were growing without supplemental light, they would give good flower yields if the early forcing period contained a large number of cloudless days. However, only little or no shortening of the period was ascribed to increased illumination.

Soil temperature in some literature reports was shown to accelerate flowering. Laurie et. al. (1958) have stated that the use of bottom heat will cause flowering in late April. They suggested raising soil temperature by means of using electrical cable or steam coils to 65°-70° F. will result in earliness of flowering by serval weeks. Emsweller and Tavernetti (1934) also noted that increase in soil temperature hastened flowering. The effect of supplemental light on gladiolus is more dependent on light intensity than light duration . Fisher (1969) reported that the lengthening of photoperiod by supplemental light was shown to have little effect on flowering of the corms planted February 11 at 39° N. latitude.

The investigation by Jones (1930) on the time of formation of flower buds was his basis for employing supplemental light to increase the day length of fall, and early winter. He found that it is desirable to use supplemental light when winter blooming of gladiolus in the greenhouse is desired. A 63 percent increase in flower yield was secured with cultivar 'Crimson Glow' when planted in January and grown under 100-watt light. The work by Wassink (1960) on investigating the effect of light intensity on growth and development of gladiolus showed that stem dry weight was dependent on high light intensity. Stem length was much less influenced by light intensity than was stem dry weight. Flowering was much reduced at low light intensity. He also found that there was a close relationship between the formative effect of light intensity on leaf shape and energy level of the plant under certain conditions. This morphogenic effect of high light intensity is interesting besides those of low amounts of photosynthetically active and inactive radiation. The relative stem development thus seems much more light-intensity-dependent than the relative new corm development, a useful adaptation for persistence under unfavorable light conditions. Laurie (1937) has concluded that light is important in the development of the flower shoot. His report described that unless the light of sufficient intensity and duration is available when leaves are 8-10 inches high, flower development ceases and blasting occurs. Stimulation of growth through the use of additional light is satisfactory only if the intensity is high enough to simulate sunlight which would mean the use of 500-1000 watt lamps and some 100 or more foot-candles.

In connection with the failure of flower bud development, several reports have indicated that some plants often initiate more flower primordia than are finally developed. Some reports refer to 'bud blasting' as browning or dying of unopened flower buds (Cherry, 1965) or the loss of buds at the stage of anthesis (Box, 1967). The phenomena of bud blasting was well-known in many cormous or bulbous plants. It could occur when some environmental factors are out of balance with plant requirements, or be caused by insects or diseases, fumigation (ie. for lily, freesia), or even be caused by the pot being too small and soil too heavy to accommodate the roots (ie. for gloxinias). The factor most commonly at fault is insufficient humidity. A water deficiency or sudden moisture deficit was reported as a cause for lily blasting (Smith and Langhans, 1961), over-watering in the early stage or under-watering in the late stage was one of the causes of browning tips for freesia (Laurie et. al., 1958). The next most common cause of blasting is insufficient light, though this can be recognized as absence of budding rather than bud blasting (Cheery, 1965). The third is temperature extremes either too high or too low (Hartsema, 1961; Cherry, 1965; Kamerbeek, 1966). The examples of unfavorable light conditions as a cause for bud blasting has been reported in Dutch iris (Krabbendam, 1966); low light intensity cause a reduction in bud count or plant came blind in Floridi or Georgia lilies (Laurie et. al., 1958). It also has been reported that at higher temperature and in longer photoperiods or even when the latter resulted in a higher amount of daily light energy, the number of influorescences and flowers that did not complete their development, increased in Brodiaea laxa Wats (Fortanier, 1967). High nitrogen for freesia and soil nitrate levels above 55 ppm for Creole lily can cause tip burn or blasting (Eastwood, 1952; Laurie, 1958). Mastalerz (1965) has demonstrated that abortion was increased by any factor or combination of environmental factors which allowed a depletion of carbohydrates or impeded the translocation of carbohydrates to developing buds. Competition for nutrients among developing buds has been suggested as a cause for bud abortion, too. Further, the light intensity at time of bud initiation was reported responsible for the carbohydrate level which determined the number of buds initiated and further, the bloom count (Einert and Box, 1967).

For gladiolus, Post (1950) has indicated that burned tips on the buds resulted from lack of water for the developing spikes, or from thrips injury. Pridham (1929) has reported that all plant growth was responsible for differentiating flower spikes but flower spikes often abort a few inches from the bulbs if the days are short or if the light intensity is low and temperature is high. The above mentioned report by Laurie in 1937 also supports the fact that light is responsible for bud blasting in gladiolus.

MATERIAL AND METHODS

Planting Techniques:

Corms of gladiolus used for this study were received in December, 1969. They were stored at temperature of 40° F.. Two plantings were made for these experiments. The first planting was started on December 16, 1969, and second planting was on February 18, 1970. For both plantings, the experimental material and methods were similiar. In an effort to induce earlier flowering and to improve flower quality, 1024 uniform corms of gladiolus were selected and de-eyed for each planting. All growing points except one were removed from the corms.

De-eyed corms were planted in eight blocks in a greenhouse which was kept with a 55° F. night and 65-75° F. day temperatures. These eight blocks were separated into sixteen plots in which every four plots were under the same supplemental light regime. Four supplemental light regimes used were:

SL1- no additional lighting for the first 50 days, then followed with a high intensity illumination at night (150-250 ft.-c. from GRO-LUX fluorescent lamps).

SL2- the same high light intensity of supplemental lighting at night during the first 50 days, then no illumination through the rest of the experimental period.

SL3- low light intensity of 8-15 ft.-c. by using incandescent lamp from planting till harvest.

SL4- no additional lighting throughout the whole experiment.

All supplemental illumination was given from 5:00 PM. to 10:00 PM.

daily during their illumination periods. The lamps used were kept one foot above the top of plants. Black muslin curtains were used to separate the nightly illumination from each light regime.

Under each different supplemental light regime, three soil temperatures were maintained. Bottom heats of 60° F., 70° F. and 80° F., respectively, were controlled with electric cables under the soil plus an extra plot was used as a "check".

The soil media used for every plot consisted of 1/5 organic matter (peat), 1/5 of perlite and 3/5 sterilized loam soil.

Two varieties, Pink Friendship and White Friendship, were used in this study. Thirty-two corms of each variety were planted in each plot at 4 x 6 in. spacing at a depth of 4 inches.

Methods of Investigation and Data Taken:

In the early growth stage, two plants from each plot were randomly sampled per week to determine the date of first bud initiation and to examine the bud differentiation and to count the number of buds initiated with a dissectting scope.

When 1/3 of the florets per spike were blooming, the plants were cut at the ground level. The measurements for plant weight, height of plant, number of buds developed and the judgement of the plant quality were made immediately after cutting. Data taken for the items investigated were as follows:

1) The date of bud initiation - the day when buds were first visible.
2) The number of buds initiated - the number of buds formed

when they were well-differentiated.

3) The date of flowering - the first day when 1/3 of the florets on spike were blooming.

4) The number of buds flowering - the number of florets and buds well-developed to flower.

5) The weight of plant - fresh weight of cut plants measured to the nearest gram.

6) The height of plant - the length of the stem with flower spike to nearest inch.

7) Plant quality - various factors were concerned in this judgement. The weight and height of plant, the diameter of stem (thickness), the hollowness of stem, the color, the shape and size of florets, and the space between florets and the length of spike head were considered for grading the quality in this study.

RESULTS AND DISCUSSION

The results of this experiment will be discussed among the difference in each supplemental light regime and each soil temperature range, also the interaction of these factor combinations. The results also will be shown under two different varieties, Pink Friendship and White Friendship. However, no further comparison and discussion will be done between these two varieties.

An analysis of variance was used to test the significance of effects of light, soil temperature and their interaction.

Table 1 shows that there were significant differences in the plant fresh weights for two varieties among four supplemental light regimes. For the two varieties , the plants which grew under SL2 gave the greatest weight. The second greatest were those under SL3, while the least were under SL1 and SL4. This result was attributed to higher light intensity and more radiant energy supplied in the early growing stage (vegetative phase) of the gladiolus. The rate of photosynthesis is approximately proportional to the light intensity (Meyer, Anderson and Böhning, 1960). The short day condition thus restricted photosynthesis in vegetative growth and decreased the plant weight in regimes of SL1 and SL4.

Table 2 shows the effect of soil temperatures upon plant weight. It indicated that higher soil temperature exerted a retarding effect on growth. This is probably due to the reduction of absorption of water and mineral nutrients etc., and decreased

Table 1. The effect of supplemental light on the mean plant weight in grams of two gladiolus varieties.

Supplemental Light Regimes	Varieties	
	White Friendship	Pink Friendship
SL1	105.81 bc[1]	106.50 b[1]
SL2	130.75 a	136.84 a
SL3	113.56 b	114.41 b
SL4	99.06 c	105.73 b
$LSD_{.05}$	11.03	12.90

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

Table 2. The effect of soil temperatures on the mean plant weight in grams of two gladiolus varieties.

Soil Temperature Ranges	Varieties	
	White Friendship	Pink Friendship
Check	133.19 a[1]	141.39 a[1]
80^{o} F.	89.91 b	83.16 c
70^{o} F.	95.16 b	102.41 b
60^{o} F.	130.94 a	136.53 a
$LSD_{.05}$	11.03	12.90

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

metabolic activity of root cells, thus resulting in lower plant weight. At 80° F. soil temperature, a great reduction on the rate of growth was found.

No significant difference was shown in each treatment for supplemental light and soil temperature interaction on plant fresh weight for both gladiolus varieties in this study.

The shoot length (in inches) was much less influenced by light intensity than was plant weight. This is somewhat similar to the observation by Wassink in 1960. No significant difference among four supplemental light regimes was shown on Pink Friendship. Neither did the soil temperature affect shoot length. However, in White Friendship variety, SL2 was more effective on shoot length than were SL1, SL3 and SL4 which were of no significant difference at all (see Table 3). This is probably due to the indirect effect of supplemental light on stem growth. The rate of stem growth is determined by the extent of mitotic activity in the pith zone of meristem. While the mitotic activity in the pith zone of apex is accelerated under influence of gibberellin (Gukasyan, Chailakhyan and Milyaeva, 1970). It also appeared that light may promote the formation of gibberellin in plants (Leopold, 1964).

Soil temperature did influence the shoot length on White Friendship variety. Table 3 shows that this gladiolus variety favors growing at soil temperature of about 60° F..

The interaction of both soil temperature and supplemental light demonstrated a very significant effect upon the shoot length,

Table 3. The effect of supplemental light, soil temperature and their interactions upon the mean height (inches) of plants for White Friendship variety.

Supplemental Light Regimes	Soil Temperature (°F.)				S.L. Mean
	Check	80	70	60	
SL1	50.38	39.66	37.20	47.64	43.72 b[1]
SL2	57.98	41.59	42.71	55.20	49.37 a
SL3	43.76	40.55	40.09	43.31	41.93 b
SL4	44.64	37.05	40.76	44.99	41.86 b
Soil Temperature Mean.	49.19 a[1]	39.71 b	40.19 b	47.78 a	

LSD at .05
Supplemental light regimes = 2.76
Soil temperature ranges = 2.76
Supplemental light x Soil Temperature = 5.50

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

especially the soil temperature. The higher soil temperature depressed the plant elongation, even under high light intensity illumination. Under low light conditions, the lower soil temperature was helpful in increasing plant height. Neverthless, the table shows that with lower soil temperature under high light intensity in early stage of forcing it would be favored for the elongation of stems in gladiolus and increased stem length much more than either factor alone.

The analysis of variance among bud counts showed that soil temperature had no influence on the number of flower buds initiated. However, supplemental light did significantly affect it.

Table 4. The effect of supplemental light on the number of flower buds initiated.

Supplemental Light Regimes	No. of Buds Formed
SL1	16.0[1]
SL2	19.0
SL3	18.9
SL4	16.0
$LSD_{.05} = 0.2$	

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

Reviewing the results shown above, supplemental light in the early stage of forcing obviously affected the bud formation. As the bud count was done at about 40-50 days after corms were planted, when the flower buds were well-differentiated, it was apparently indicated that at this early stage the longer light duration and higher light intensity were favorable for bud initiation. The mean number of buds initiated per plant was reduced under no supplemental light conditions. This resulted in a lower bud count in SL1 and SL4. In other words, it was probably due to a lack of enough light intensity to provide sufficient carbohydrates. Generally, increasing light intensity will result in greater photosynthesis in plants. It is believed that the formation of flowers in many florist crops, such as African violet, cineraria, geranium, is dependent upon the accumulation of sufficient carbohydrates. Though light duration and temperature affect flower bud initiation, the development of flower buds is also dependent on the food supply (Laurie, et. al., 1958). Thus the supplemental light in the early part of forcing may be said to be the most critical factor. This is also found in forcing lilies in greenhouse (Einert and Box, 1967). In this experiment, soil temperature showed no effect on the number of buds initiated. The interaction of both factors also showed no significant influence on bud initiation.

However, it did appear that supplemental light and soil temperature had very significant effects on the number of buds developed. Table 5 and Table 6 show their effects individually. The results suggested that the soil temperature around 60^{o} F. was better for flower bud development. Soil temperature higher than 70^{o} F. was unfavorable for flower bud development under relatively low light conditions in the greenhouse. This study leads further support to observation by Laurie et. al. that though the somewhat warmer soil temperature is probably not injurious to the roots, it promotes rapid drying of soil, necessitating frequent watering. Heating the soil or the water even slightly above 70^{o} F. in winter may inhibit growth of most florist crops. In regard to effect of supplemental light, the number of buds flowering was found more affected in SL1 and SL2. Results shown in Table 5 indicate that SL2 had more bloom count than SL1, although light was turned out in the late stage. And, with comparing both number of buds initiated and the number flowering, the bloom count may be said to be proportional to the number of buds initiated or formed. The exception in SL3 will be discussed later on. In most case the amount of food within the corms probably governs the number of buds that initiate since the corms of small size have few flowers compare with larger sizes (Oven, 1928; Pridham, 1933). Moreover, it was found that decrease in sugar levels in corms in the stage of spike appearance may be indicative of larger food requirements for the growth of flower spike. In addition, a more prounced swelling of new corm was evident at this stage. a rapid decrease in starch during the first 6 weeks after planting verified the fact that large amounts of sugar had been utilized, since sucrose and glucose were low in proportion to the quantities of starch that have been hydrolyzed (Grove, 1939). So it may be desirable to begin fertilization at the time buds have formed to ensure an adequate supply of foods for their development like lilies need. From nutritional studies it may be concluded that

Table 5. The effect of supplemental light on the number of flower buds developed in two gladiolus varieties.

Supplemental Light Regimes	Varieties	
	White Friendship	Pink Friendship
SL1	13.34 ab[1]	13.19
SL2	14.31 a	14.31
SL3	12.31 b	12.94
SL4	12.78 b	13.66
$LSD_{.05}$	1.36	N.S.[2]

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

2. N.S. = No Statistical Difference

Table 6. The effect of soil temperatures upon the number of flower buds developed in two gladiolus varieties.

Soil Temperature	Varieties	
	White Friendship	Pink Friendship
Check	14.44 a[1]	15.69 a[1]
80° F.	12.09 b	11.22 c
70° F.	11.84 b	12.75 b
60° F.	14.38 a	14.44 a
$LSD_{.05}$	1.36	1.41

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

the amount of readily digestible total carbohydrates at time of flower development determine the number of buds developed. The light intensity at time of bud initiation and development is responsible for carbohydrate level which determines the number of buds initiated and developed as reported. So we may say that the supplemental light with high intensity either in the early stage of bud formation or the late stage of bud development is a critical factor governing the number of buds that completely develop. Thus, the high intensity supplemental light is necessary for growth and flowering in gladiolus. It rather appears that the importance of high intensity supplemental light in the late stage is indebted to their prevention of buds from abortion or blasting.

The interaction of supplemental light and soil temperature may be seen in Fig. 1. Lower soil temperature with high light illumination gave the best flower production. High soil temperature with short day combination gave the poorest flower production. To the contrary, the high light intensity illumination given during the period of flower development prevented bud reduction at higher soil temperatures.

In this experiment it was also found that many buds in the top of spike turned brown and died. This phenomenon was found after May 15. Table 7 shows the number of plants blasted. The reason may be explained by the increase in temperature in the atmosphere which caused a humidity decrease. High soil

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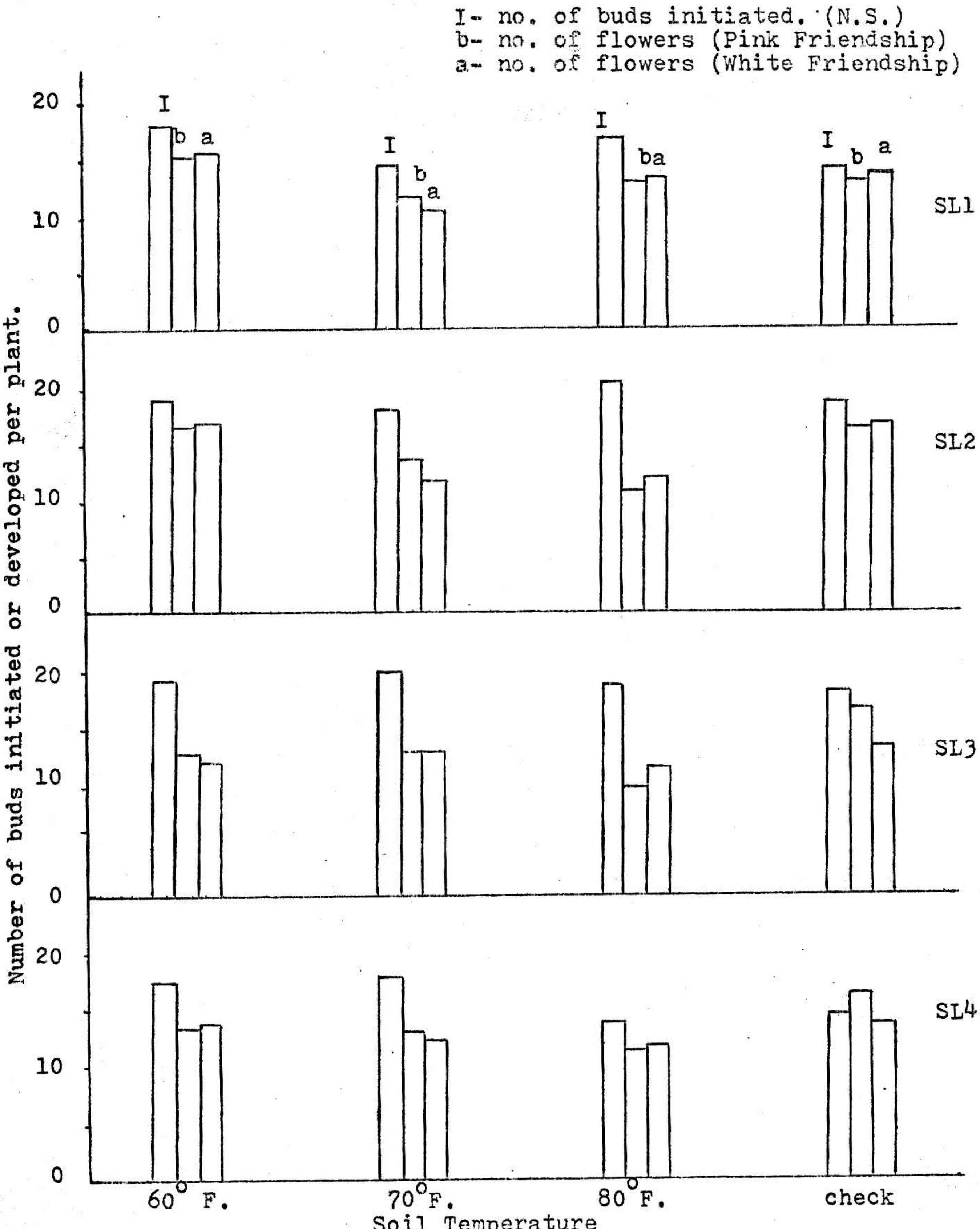

Fig. 1. The interaction of supplemental light and soil temperatures on bud count and bloom count in two gladiolus varieties.

Table 7. Effect of soil temperatures and supplemental light on flower bud blasting in two gladiolus varieties.
* The following is the number of plants blasted in each treatment.

Supplemental Light Regimes	Varieties	Soil Temperature (°F.)				Total in Supplemental Light Regime	
		Check	80	70	60		
SL1	Pink Friendship	1	3	3	0	7	11
	White Friendship	1	1	1	1	4	
SL2	Pink Friendship	0	4	9	0	13	22
	White Friendship	0	2	6	1	9	
SL3	Pink Friendship	0	9	10	1	20	41
	White Friendship	4	8	8	1	21	
SL4	Pink Friendship	0	3	2	2	7	21
	White Friendship	1	5	4	4	14	
Total in Soil Temperature Ranges	Pink Friendship	1	19	24	3		
	White Friendship	6	16	19	7		
		7	35	43	10		

temperature promoted drying of soil which may have blocked water absorption of root systems. Water stress thus probably caused blasting, the dying back of buds on spike. This may explain why at higher soil temperatures more buds blasted. Light in this case was hard to explain, however, it was evident that the supplemental lighting with high intensity decreased the number of buds blasting in SL1.

Comparing the bud count and bloom count under each light regime, Fig. 2. shows that the percentage of abortion in SL1, SL2, SL3 and SL4 were 16.6%, 24.67%, 34.7% and 20.12% respectively. In regard to supplemental light, it may be seen that the least abortion was under the early short days and that high light intensity in late stage could decrease abortion. Continuous lighting by incandescent lamp resulted in high rates of abortion in SL3. The explanation for this was complicated. Perhaps it was not only due to light and soil temperature, but other factors were also involved. Statistical analysis indicated soil temperature had an interaction on supplemental light. Even in talking about light, the intensity, duration and quality may be also involved. The serious abortion in SL3 may be assumed due to the duration of illumination which was so long (continuously) that it resulted in a higher amount of radiant energy and caused the florets to be unable to complete their development like in Brodiaea laxa Wats (Fortanier, 1969). It was reported that from 75 to 85 percent of the power consumed by a incandescent lamp is dissipated as heat through infrared radiation. The heat

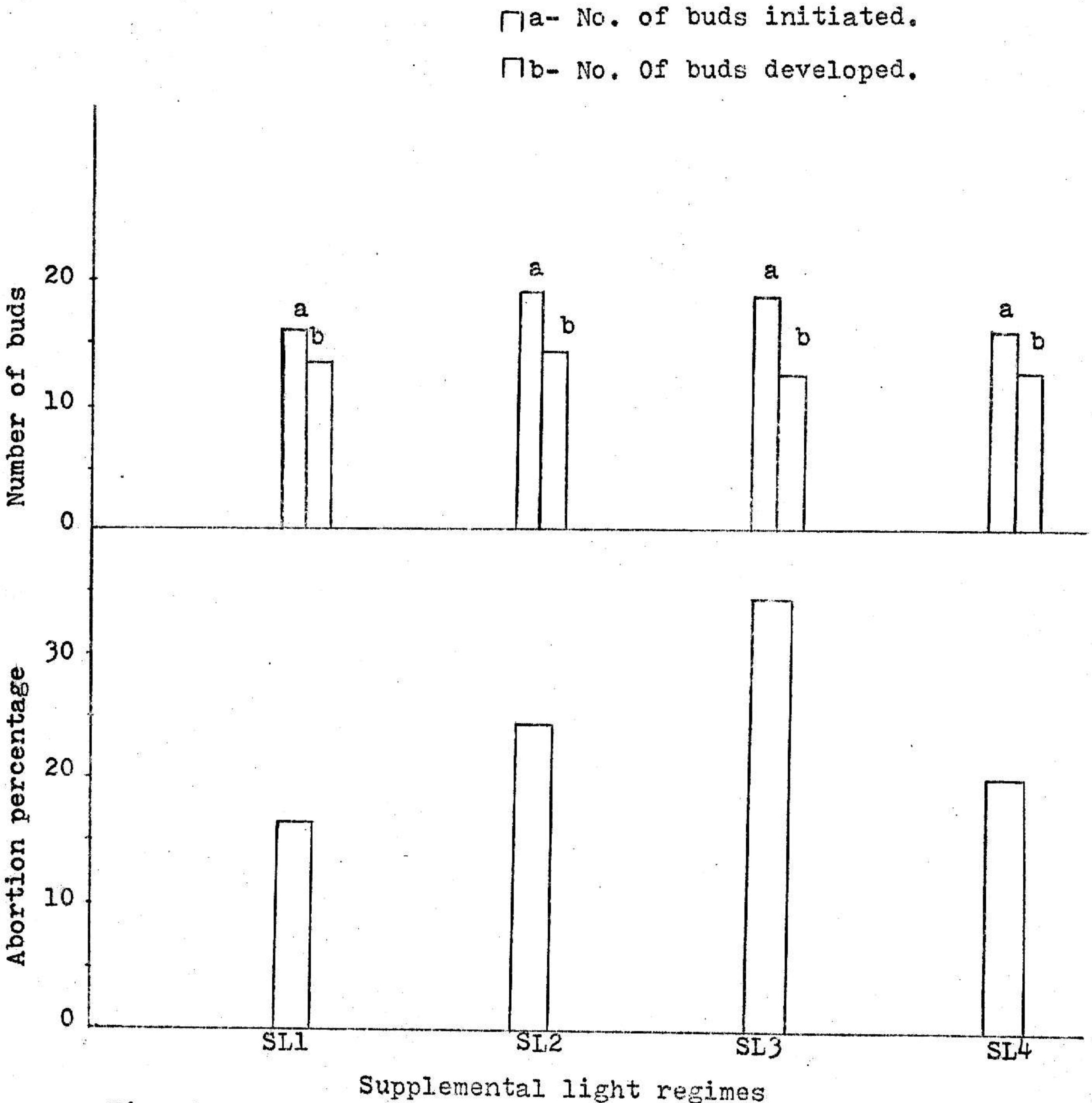

Fig. 2. Percentage of bud abortion in White Friendship var. under each supplemental light regime.

could have accumulated and increased the temperature around plants to an unfavorable degree. It was probably the combination of the heat from incandescent lamp and high soil temperature that caused a water deficiency, therefore, the burned tips appeared. It may also be suspected that the results could have been influenced by the difference in light quality or the internal chemical change which are not included in this study.

In summing up, the term abortion in this study was refered to as the absence of budding or the failure of developing buds by plants at maturity. Perhaps the reason for bud abortion or bud blasting may be explained on nutritional basis. It might be assumed that the plants could only support a certain number of flowers regardless of the number of buds that were set. The competition for nutrients among the developing buds resulted in some bud abortion. Environmental cues may be the main factor in regulating flowering (Leopold, 1964). The statistical analysis indicated that bloom count was not only regulated by supplemental light as it did on bud count, the interaction of soil temperature also was responsible for bud development. Fig. 1 showed that 60° F. or check soil temperature range generally had less abortion. At higher soil temperatures the abortion gap was large. The supplemental light in late stage (SL1) played an important part in reducing bud abortion. Under SL1 regime the abortion number at every soil temperature range was apparently reduced when compared to other supplemental light regimes. Especially in the 'check' plot which soil temperature was about

65° F., the bud count and bloom count was about the same. This probably is due to late supplemental lighting facilitating photosynthesis for manufacture of carbohydrates for the developing buds, thus decreasing abortion. The high abortion percentage in SL2 may be due to the reduction of photosynthesis which was caused by turning out supplemental light. Supplemental lighting in early growth stage may have stimulated vegetative development. When lights were turned off in SL2, available light for photosynthesis may have been reduced. Translocation of organic compounds, etc. may have shifted 'sinks' thereby increasing bud abortion rates. For SL3, too, though lighting was still on, the light intensity was too low to activate photosynthesis efficiently. Laurie et. al. have stated that light intensity of 5-10 ft.-c. was too low for any significant photosynthesis activity. Furthermore, the radiant heat emitted from incandescent lamps may also increase temperature surrounding plants and promoted respiration. The consumption of food supply increased and no replacement was supplied, therefore, causing very serious abortion percentage in SL3.

As shown in Table 8 and Table 9, supplemental light and soil temperature influenced time of flowering. High soil temperature and early short days accelerated flowering. Earliness of flowering occured when gladiolus was forced at high soil temperature. As regarding supplemental light, the flowering was accelerated in SL1, while delayed in SL3. The interaction of soil temperature and supplemental light showed in Fig. 3 suggested

Table 8. The effect of supplemental light on time of flowering (days) in two gladiolus varieties.

Supplemental Light Regimes	Varieties	
	White Friendship	Pink Friendship
SL1	83.21 d[1]	80.00 d[1]
SL2	87.56 b	83.69 c
SL3	93.66 a	89.72 a
SL4	86.19 c	85.16 b
$LSD_{.05}$	1.20	1.16

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

Table 9. The effect of soil temperatures on time of flowering (days) in two gladiolus varieties.

Soil Temperature	Varieties	
	White Friendship	Pink Friendship
Check	87.47 b[1]	86.00 b[1]
80^{o} F.	83.38 d	82.91 c
70^{o} F.	86.22 c	81.00 d
60^{o} F.	93.56 a	88.66 a
$LSD_{.05}$	1.20	1.10

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

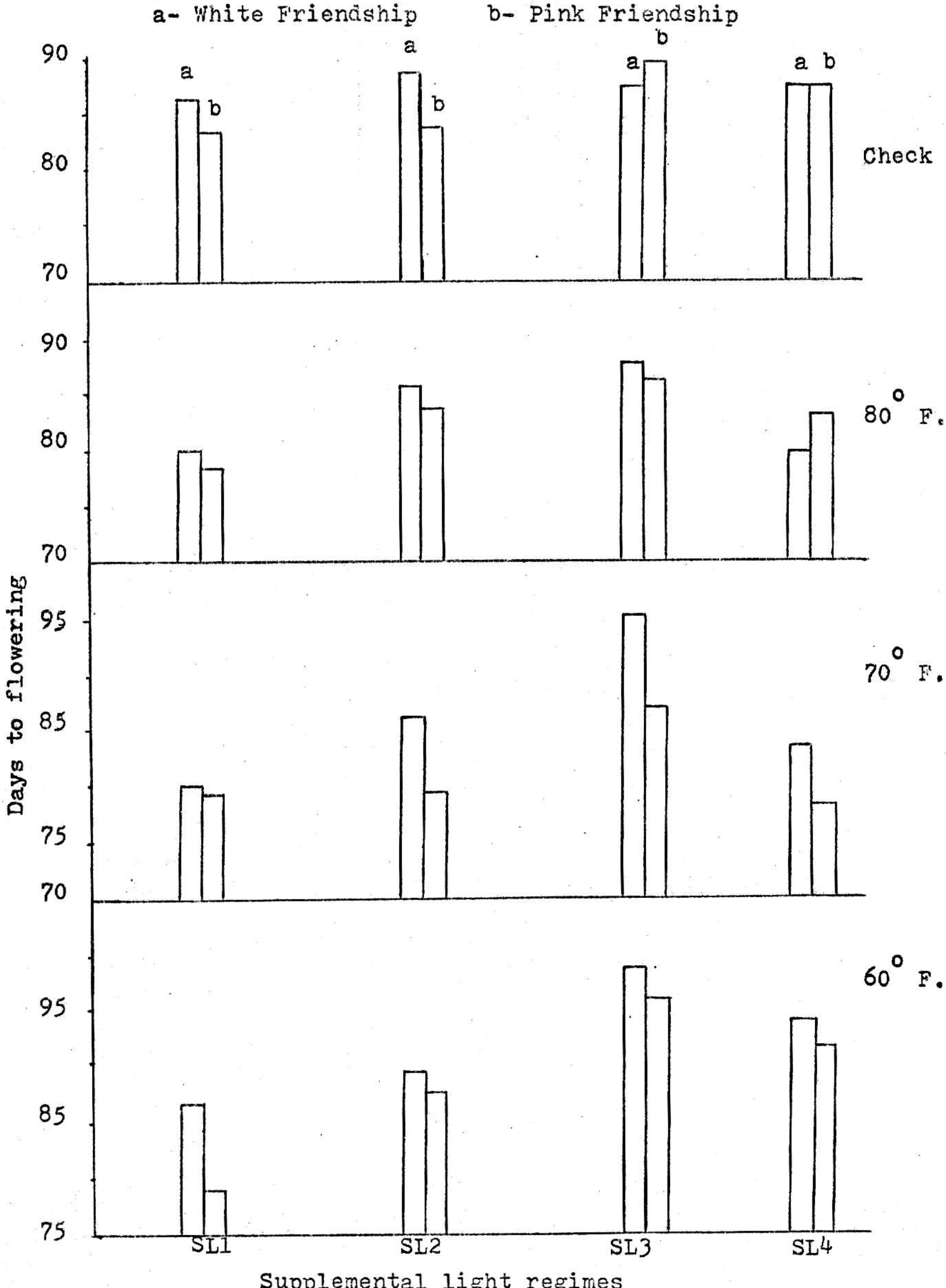

Fig. 3. The interaction of supplemental light and soil temperatures on time of flowering in two gladiolus varieties.

that the combination of SL1 with 70^{o} F. or 80^{o} F. soil temperature will speed up flowering. The data shows that short days at the normal time of bud initiation seemed to promote even earlier initiation. The additional lighting at night seemed to delay initiation. So we may say that short day tend to speed up bud initiation. The results had somewhat agreement with personal correspondance with Prof. R.O.Magie. He stated that long nights seem to force these gladiolus varieties, causing them to bloom 60-70 days instead of the 90 days it takes in north during the summer. However, the light intensity at the period of flower bud development seems to hasten flowering quantitatively.

When considering quality in gladiolus many factors were included. The plant weight, plant height, and number of flower buds on spike were principal criteria involved and were measured. Other factors such as flower size, flower color, floret space, stem thickness, and vigorousness were observed but not measured.

Table 10 and Table 11 show plant quality at different soil temperatures and different supplemental light regimes. Both factors significantly influenced plant quality. Further, their significant interaction on plant quality is exhibited in Fig. 4.

In this study it seems that plant weight was more related to plant quality than length as it usually does. Generally speaking, most of the plants in this experiment were tall enough, but most stems looked thin. This somewhat agrees with Howell's statement (1968) that the gladiolus in greenhouse will grow much taller than those grown outside. They need some support before

Table 10. Plant quality* influenced by soil temperatures in two gladiolus varieties.

Soil Temperature	Varieties	
	Pink Friendship	White Friendship
Check	3.95 a[1]	3.86 a[1]
80° F.	2.61 c	3.03 b
70° F.	3.02 b	3.86 b
60° F.	3.92 a	3.94 a
$LSD_{.05}$	0.37	0.39

Table 11. Effect of supplemental light on plant quality* in two gladiolus varieties.

Supplemental Light Regimes	Varieties	
	Pink Friendship	White Friendship
SL1	3.14 b[1]	3.13 c[1]
SL2	3.44 ab	3.80 a
SL3	3.58 a	3.52 ab
SL4	3.34 ab	3.25 bc
$LSD_{.05}$	0.37	0.39

1. Values in the same column with a common lower case letter are not significantly different as determined by Fisher's LSD.

* The scale used to measure quality was as follows:

A+ = 4.5 = excellent
A = 4.0 = good
B = 3.0 =
C = 2.0 = poor
D = 1.0 =

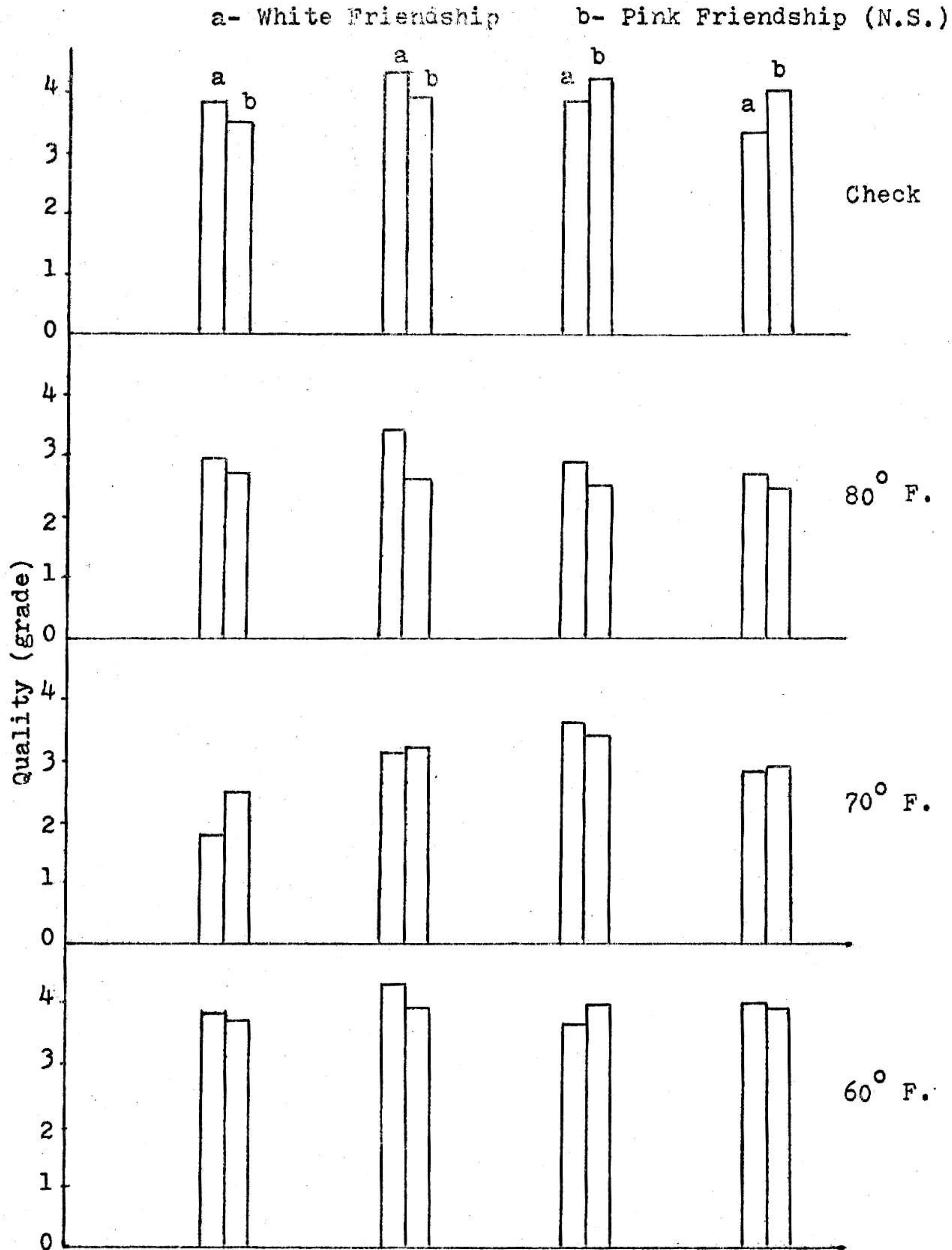

Fig. 4. Interaction of supplemental light and soil temperatures on the plant quality of two gladiolus varieties.

blooming. Many of stems in this experiment were produced too 'soft' to support flower spikes. The lack of rigidity was the result of stem hollowness.

Stem weakness (thin) was found more in high soil temperature and early short day conditions (SL1 and SL4). Generally, at higher soil temperature ranges it was found that more buds aborted or tips burned, plants were also weaker and spikes were shorter. Under early non-lighted conditions (SL1 or SL4) the stems were thin and florets were smaller and plants looked weak. The plant quality generally was reduced by early short day or high soil temperature. By contrast, under supplemental light regimes (SL2 or SL3) or at low soil temperatures around 60° or 65° F. the plant quality was generally good. Plants from SL2 mostly were excellent, flower spikes were good, flower size was big and plant stems were adequate. The plants under SL3 were about the same with those from SL2, but usually florets were smaller and spikes were shorter.

Fig. 4 indicated that under early short days (SL1 or SL4) a low soil temperature would increase its quality. High soil temperatures (70° or 80° F.) usually gave the poorest quality, especially in early short days. However, the supplemental lights prevented the quality reduction. Fig. 4 also demonstrated that SL2 gave the best quality comparing every soil temperature range; and soil temperature of 60° F. was also favorable for good quality production. The interaction of both apparently produced the best quality and increased the quality more than when these factors were alone. Supplemental lighting at the early stage of forcing was helpful in increasing quality in gladiolus. The effect of supplemental light in this case seems to be due to light intensity. High light intensity increased plant quality. The increase was associated with the increased rate of growth in term of fresh weight and also the increased number of flower buds.

CONCLUSION

Data and observations obtained in this study show that there are significant difference in flowering and overall quality of gladiolus produced under soil temperatures around 60°-65° F. as compared with 70° or 80° F..

Lower soil temperatures produced higher plant fresh weight, more flower production, and consistently better quality compared with at high soil temperatures. However, earliness of flowering in gladiolus appears to be brought about by high soil temperature. High soil temperature gave poor bud formation and reduction in number of buds developed. Further, high soil temperature also increased bud abortion and blasting.

The results indicated that supplemental light on forcing gladiolus in winter months was critical. It was shown that the quantity of light available for photosynthesis is the major factor to determine bud initiation and development. The supplemental light in early part of forcing was found to have marked effects on the number of buds initiated (in SL2 and SL3).

The supplemental light with high intensity by fluorescent light given during the period of bud development was found to accelerate blooming and to prevent bud abortion and blasting. High light intensity was found critical for photosynthetic activity which is responsible for carbohydrate level and correlates to the rate of growth and flower bud initiation and development. The increased plant weight and flower production resulted in a good quality.

It is of interest that plant height was less dependent on supplemental light,however, gladiolus grown in the high intensity of fluorescent light (150-250 ft.-c.) produced increased shoot elongation.

The low light intensity by incandescent lamp (8-15 ft.-c.) in this study seems not enough for an adequate photosynthetic light. It did have an effect on the number of buds formed, but continuous lighting resulted in a serious bud abortion at stage of flowering. Continuous supplemental illumination from incandescent light delayed time of flowering, too.

Photoperiod, in constrast to light intensity and soil temperature, was found to have little or no significant effect on the rate of bud initiation and development. The early short days seem to shorten the time of flowering. However, it shows that the illumination by high intensity of fluorescent light during the period of bud formation to flowering accelerated flowering. It seems that high light intensity promoted the rate of flower bud development.

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THE EFFECTS OF SOIL TEMPERATURE AND SUPPLEMENTAL LIGHT ON INITIATION AND DEVELOPMENT OF FLOWER BUDS IN GLADIOLUS (GLADIOLUS GRANDIFLORUS)

by

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The main object of this investigation was to attempt the separation and the interaction of effects of supplemental light and bottom heat control on initiation and development in the greenhouse gladiolus, varieties Pink Friendship and White Friendship. The flower bud abortion and blasting were also studied.

Supplemental lights were given to extend daylength and to give higher light intensity to supplement the short day conditions in winter time or early spring. Electrical cables underneath corms were set up to control bottom heat. Plants were forced in greenhouse with four soil temperature levels (60° F., 70° F., 80° F. and check) and within four light regimes (with high intensity of 150-250 ft.-c. supplemental lighting in early growth stage, in late growth stage, with low intensity of 8-15 ft.-c. supplemental lighting throughout whole growth period, and natural short day condition).

Flower bud formation was increased under supplemental illumination of high intensity with fluorescent light was found beneficial both in the early stage and the late stage of forcing. In the early part, it had marked effect on increasing bud count, bloom count and plant weight. In the late stage, the period of bud development, it accelerated flowering and reduced bud abortion and blasting. Low intensity lighting by incandescent lamp increased the number of buds initiated, but increased bud abortion and blasting. The extended daylength had little or no significant effect on time of flowering. Natural early short days seemed to hasten time of flowering. Continuous lighting by incandescent light delayed flowering. However, high intensity illumination by fluorescent light at time of bud development promoted the rate of bud development and resulted in early flowering. Plant height was less dependent on light intensity.

Soil temperature 70° or 80° F. accelerated flowering, but were not recommended. They decreased plant weight, bloom count and plant quality; and increased bud blasting. The soil temperature around 60° F. was the most acceptable with regard to number of flowers and plant quality. There was a correlation between plant quality and plant weight and number of flowers. It appeared that at 60° F. soil temperature or underearly supplemental light regime better plant quality was found.

The interaction of supplemental light and soil temperature increased plant quality much more than either factor alone. Supplemental lighting with high intensity prevented bud abortion and blasting at high soil temperatures. Soil temperature at 60° F. increased plant quality in every light regime.