THRESHER INJURY A CAUSE OF BALDHEAD IN BEANS[1]

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INTRODUCTION

Baldhead of beans (*Phaseolus vulgaris* L.), sometimes called snakehead, for a number of years has attracted the attention of seed growers and farmers, who have observed on seedlings the partial or entire absence of the primary leaves and the growing tip. Such plants, remaining dwarfed, are soon completely hidden by the foliage of the surrounding plants, and the erroneous impression is often gained from later inspections of the field that the plants have recovered and developed normally. Concern would not be aroused about the disease until similar seedlings were observed in a later planting or during another season.

Little information is available as to the history of baldhead, although interviews with seedsmen and growers have revealed the fact that it has been known for a number of years and is apparently on the increase. Because of the economic importance of baldhead and numerous inquiries as to its control, investigations were undertaken to determine its cause. What appeared a priori to be a simple problem proved in the end to be somewhat difficult and complicated. At first thought one might reasonably conclude that this abnormality is caused by insects, fungi, or bacteria; but certain relationships of baldhead to farm operations and its appearance in disease-free seed suggested that it could not be attributed to these agencies alone.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Inspection of bean fields in various parts of the United States revealed the fact that baldhead occurs practically wherever the crop is grown. The loss from baldhead plants, which make a poor growth and during the entire season produce at best only one or two imperfectly filled pods, is about equivalent to the percentage of affected plants at germination. This percentage varies according to the variety, the method of handling the crop, and the season. As a matter of fact, the amount of baldhead of any susceptible variety may vary from one season to the next as much as 5 to 10 per cent. Some varieties, such as Bountiful,[3] Refugee, and Improved Kidney Wax, are very susceptible, percentages of 10 to 30 not being uncommon.

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[3] The variety names used in this paper are those employed by the trade.

SYMPTOMS

Baldhead is caused by three distinct agencies, each producing well-defined characteristics. One type, which is by far the most common, is, as will be shown later in this paper, the result of mechanical injury. (Fig. 1, A–D.) The second type is caused by bacteria (fig. 1, E–G), and the third by insects. Although baldhead caused by insects has been investigated by Hawley [4] and has received no attention during these studies, it will be discussed briefly elsewhere.

Mechanical injury and bacterial infection produce quite different symptoms. In the case of mechanical injury the plumule may be entirely absent (fig. 1, B–D) or only vestiges of it remain. The plumule may at times remain attached to the epicotyl (fig. 1, A), although it is fractured just beneath the primary leaves, thus rendering further development impossible. These symptoms stand in striking contrast to those resulting from bacterial attack, in which case the entire plumule may be more or less completely destroyed (fig. 1, G) or the primary leaves may be badly mutilated, the terminal bud often being destroyed by the organism so that only remnants of the vascular foliar tissue remain. (Fig. 1, E. F.) Sometimes, in the absence of the terminal bud, the epicotyl elongates, often attaining a length of one-eighth (fig. 1, B, D) to three-fourths (fig. 1, A, C) of an inch. At this stage the plant may die, but more often buds develop (fig. 1, A, B) in the axils of the cotyledons, resulting in a compact growth of several leaves and branches with short internodes.

EXPERIMENTAL PROCEDURE

MATERIAL STUDIED

No investigations have been made for the single purpose of determining the entire range of plants subject to baldhead. Reports have been received of its occurrence on the different field and snap varieties of *Phaseolus vulgaris* and on *P. lunatus* L., the two species to which the investigations have been largely restricted. These studies were originally undertaken for the purpose of determining the cause of baldhead, and in so doing a number of different varieties, but by no means all, have been employed. Snap-bean varieties appeared to be especially subject to the disease, and for that reason most of the investigations were limited to them, a few varieties of the field type being used for comparison. From a more extended study of the different varieties it was found that field beans, as a group, are more resistant than the snap-bean varieties. Lima beans were not at first brought within the scope of the investigation, but a single germination test of one variety demonstrated a percentage of baldhead about equivalent to the snap-bean average. In view of this fact, three other varieties of Lima beans were brought under observation, as well as the Blackeye cowpea (*Vigna sinensis* Endl.) and the tepary bean (*P. acutifolius* var. *latifolius* G. F. Freeman).

GERMINATION

Preliminary experiments indicated that the presence of baldhead could be determined at about the time when the primary leaves of

[4] HAWLEY, I. M. INSECTS AND OTHER ANIMAL PESTS INJURIOUS TO FIELD BEANS IN NEW YORK. N. Y. (Cornell) Agr. Sta. Mem. 55, p. 945–1037, illus. 1922.

normal plants had attained a length about equal to that of the cotyledons. Beans germinated well in the several different materials tried, such as sand, sphagnum, soil, and between blotting papers.

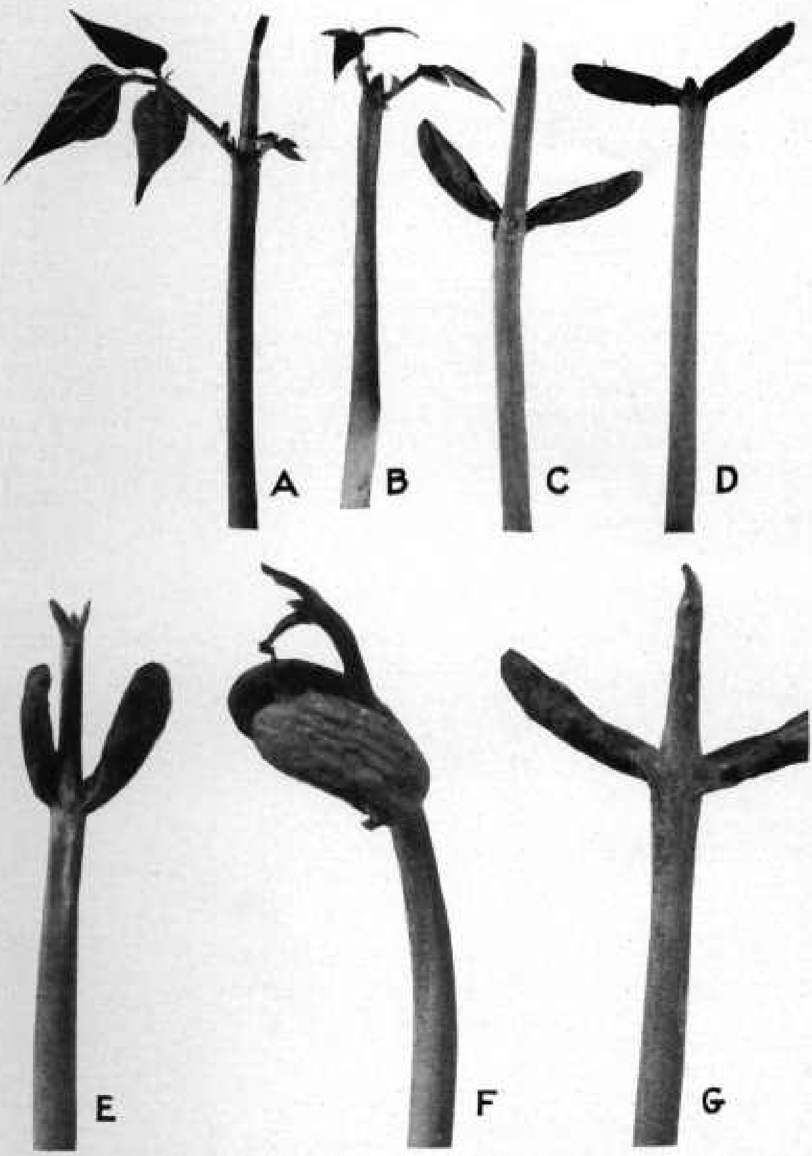

FIGURE 1.—Baldhead of beans as a result of: A–D, mechanical injury, which is characterized by the entire absence or only the vestiges of a plumule; E–G, injury caused by parasitic organisms, such as *Bacterium phaseoli*, which either destroy the entire plumule (G) or partially mutilate the primary leaves, leaving only ragged vestiges of the foliar tissue (E, F). E, F, G, slightly enlarged

The use of soil, sand, and sphagnum was objectionable because they were bulky or heavy and had to be sterilized each time before being used. Furthermore, they had no advantages over the following rapid and reliable method which was finally employed.

One hundred seeds, selected to insure apparent freedom from parasitic organisms, were disinfected for three minutes in a 1–1,000 solution of mercuric chloride and immediately rinsed in sterile water. The tests were conducted in moist chambers kept at laboratory temperature (22°–28° C.). In each moist chamber was placed a wire support, made of a square piece of heavy 4-mesh wire screen with the corners turned down about 1 inch; on this, blotting paper of proper size was laid. The seeds were then placed in the chamber so that they would not touch one another, and a second piece of blotting paper of the same size as the first was placed on top of them, after which all was thoroughly soaked with water. About one-fourth to one-half inch of water was poured into the moist chambers to maintain a relatively high humidity. Under these conditions most varieties germinated rather quickly, and at the end of five or six days radicles an inch or more in length had developed. At this stage the blotting papers were removed and the germinating beans were placed directly on the wire screen with the radicles inserted through the meshes and extending into the liquid below. Because of the paucity of food material in sterile distilled water, it was often replaced at this time by an equivalent quantity of Knop's solution. The presence of baldhead can be determined very effectively at this stage of development, but the seedlings were usually allowed to grow a few days longer until the primary leaves were one-fourth to one-half inch or even more in length, when a count was made of the affected plants.

RESULTS

EFFECT OF SEED MATURITY

In certain seed-growing districts of the West the season is comparatively short, so that varieties requiring a long season are sometimes frosted before all the seeds are mature—a contingency that was considered as having a possible causal relation to baldhead. With this in mind, some pods were gathered from plants in Virginia and in Colorado before the seeds were mature, and again from the same plants after the seeds had fully ripened. Although some of the immature seeds were badly shriveled, they germinated in most cases. The germination tests were made under similar conditions, with the result that there was no baldhead in either mature or immature seeds, showing that the stage of maturity is probably in no way associated with the malady.

INHERITABILITY

In 1926 seeds were collected from baldhead plants and threshed by hand, one part being tested for baldhead by germinating between blotting paper and the other planted in the field the following spring. No baldhead plants developed from any of these seeds. Second-generation seeds were also normal.

DESICCATION

Desiccation of the seeds, such as probably occurs in the arid regions of the West, resulting in injury to the plumule or epicotyl, was suggested as a possible cause of baldhead. An experiment was therefore designed to show whether such a relation existed. The varieties employed (Bountiful, Black Wax, and Kentucky Wonder Wax) contained a known percentage of baldhead and had been grown in Idaho and threshed by machine. Bountiful seeds, grown in Virginia, threshed by hand, and containing no baldhead, were used for comparison. Desiccators containing concentrations of sulphuric acid previously calculated to give relative humidities of 1.5, 10.5, 21.5, 33, and 45 per cent were used. At the end of each month for four consecutive months 100 seeds of each lot were removed from each of the desiccators and germinated. The details of the results will not be given, inasmuch as the very slight increase in baldhead in those lots exposed to low relative humidities fell easily within the range of experimental error. The Kentucky Wonder Wax and Bountiful varieties, originally containing no baldhead, might, after an exposure to desiccation for four months, show 1 or 2 per cent of baldhead. From these results it seems that desiccation alone has very little if any effect on the production of baldhead.

MACHINE-THRESHED COMPARED WITH HAND-THRESHED BEANS

Snap and Field Beans

Germination tests of beans grown in California, Idaho, and Colorado, in comparison with seeds grown at the Arlington Experiment Farm, Rosslyn, Va., revealed some striking differences. The eastern seeds were harvested by hand and threshed either by hand or by pounding with a stick and contained little or no baldhead, whereas the seeds from the West contained a considerable amount. In seeking for an explanation of this difference, the probable variations in methods of handling were considered. The western seeds, obtained from commercial sources, were presumed to have been threshed by machine. This presumption gave a clue to the possible cause and suggested the desirability of a series of comparative germination tests. The earlier investigations were followed by similar tests in which the seeds were collected in such a way as to yield a direct comparison between machine-threshed and hand-threshed seeds. A number of varieties known to be subject to baldhead were chosen for study, and the seeds were picked and threshed by hand. Seeds from the same crop were obtained after machine threshing, and both were subjected to comparative germination tests. Hand-picked and hand-threshed seeds were also compared with seeds threshed by large and small threshers and by a flail.

The conclusions are drawn largely from the results of laboratory germination tests, but in 1927 and 1928 plantings were made from the same lots of seeds in the field in Colorado and in Virginia with the result that those varieties that gave a high percentage of baldhead in the laboratory generally gave a correspondingly high percentage when planted in the field. As might be expected, there was some variation due to the fact that insects and predatory animals, such as rodents, birds, etc., were responsible for the destruction of some plants and plant parts in the field. The evidence indicates, however, that the laboratory studies are a reliable guide as to what can be expected under field conditions.

The results given in Table 1, which includes all those varieties where a direct comparison of different methods of threshing could be made, show that threshing with either a large or a small machine in some cases produces a high percentage of baldhead. Flailing out the seeds causes some damage, but considerably less than either type of machine threshing, while there were only two baldhead beans in all the hand-shelled beans tested.

TABLE 1.—*Variety, source of seed, and influence of method of threshing on the percentage of baldhead in beans*

Variety	Source	Percentage of baldhead resulting from threshing by—			
		Large machine	Small machine	Hand	Flail
Bountiful	Colorado	6.2		0	
Burpee's Stringless Green Pod	do	4		0	
Full Measure	do	13	1	0	
Improved Kidney Wax	do		6	0	
Stringless Green Refugee	do	8.2		0	
Davis White Wax	Idaho	19.2		0	
Full Measure	do	27.8		0	
Giant Stringless Green Pod	do	14.7		1	
Improved Kidney Wax	do	10.4		1	
Burpee's Stringless Green Pod	Wisconsin		18.5		0
Currie's Rust Proof	do		20		1
Early Stringless Refugee	do		23.3		5.5
Giant Stringless Green Pod	do		22.7		1.1
Hodson Wax	do		14.4		0
Improved Kidney Wax	do		20.6		3.6
Round Pod Kidney Wax	do		21		2.3
Sure Crop Wax	do		4	0	
Wardwell's Wax	do		12.7		0

For a comparative study of the percentage of baldhead in different lots of the same varieties of snap beans obtained from different sources, seeds were secured which were in most cases machine threshed. In a few lots shelling was done by hand; in others the information was not available, because the seeds were obtained from wholesale houses and from growers, but they are assumed to have been threshed by machine.

Table 2 shows that baldhead occurs in susceptible varieties of beans regardless of their source, if they are threshed by machine. Considerable variation occurs in seeds from different sources (Table 3), which is due probably not so much to any influence of the place of origin as to the condition of the pods when threshed. Some evidence has been collected which suggests that, if the vines and pods are damp when threshed the amount of baldhead is likely to be less.

LIMA BEANS

Like the snap and dry-shell types, Lima beans have been observed in some cases to develop a considerable percentage of baldhead in commercial field plantings, the fatalities often being so high as to arouse considerable concern on the part of growers and seedsmen. Only four varieties of Lima beans have been tested for baldhead, one of which (Henderson Bush Lima) was obtained from a seedsman in California and is definitely known to have been grown there. Three other varieties known to the trade as Fordhook Bush Lima, Emerald Isle Pole, and Sieva were purchased in Washington, D. C., from a seed dealer who had no information as to where the seed was grown or how it was threshed. It is not unlikely that they also came from California since most of the Lima-bean seed produced in this country is grown along the southern coast of California, and it is reasonably safe to assume that they were machine threshed.

TABLE 2.—*Percentage of baldhead in beans obtained from different sources when threshed by different methods*

Variety	Source	Percentage of baldhead resulting from threshing by—		
		Machine	Hand	Unknown method
Late Refugee	Idaho	18.5		
	Colorado	9.6		
Refugee, 1000-1	Virginia		0	
	Michigan			0
	do			5.1
Early Refugee	do			10.6
Bountiful	Idaho	23.8		
	Colorado	7.4		
	Virginia		0	
	Michigan			0
	do			2
	do			5
Red Valentine	Idaho	19.1		
	Colorado	14		
	Virginia		0	
	Michigan			5.5
	do			6
	do			4
Black Valentine	Idaho	15		
	Colorado	10.6		
	Virginia		0	
Kentucky Wonder Wax	Idaho	1.1		
	California	3		
Longfellow	Idaho	19.6		
	Virginia		0	
Black Wax	Idaho	22.1		
Black Wax Pencil Pod	California	8		
Prolific Black Wax	Colorado	9.4		
Great Northern	Idaho	1.1		
	do			0
Perry Marrow	New York			0
Well's Red Kidney	do			0
Michigan Pea Bean	Michigan			2
Robust	do			2
Improved Kidney Wax [a]	Wisconsin	24.5		
Red Kidney	California	25.5		
Bayo	do	11		
Cranberry	do	2		
California Pink	do	1		
Large White	do	8.5		
Genuine Small White	do	1.1		
Blue Pod Small White	do	2		
California Red	do	1.2		
Dutch Caseknife	do	18.9		
Lazy Wife	do	2.1		
Striped Creaseback	do	3		
Golden Cluster Wax	do	5.4		
King Mammoth Horticultural	do	12.2		
French Horticultural	Idaho	21.1		
Dwarf Horticultural	do	17.4		
Tennessee Green Pod	do	2.1		
Currie's Rust Proof	do	15.8		
Champion Bush	do	2		
Pinto	Colorado	1.5		
Red Mexican	Arizona			2.1

[a] Average of 6 lots, varying from 19 to 30 per cent baldhead.

TABLE 3.—*Summary of the percentage of baldhead in all varieties of beans from different sources when threshed by the different methods*

Source of seed	Number of seeds	Percentage of baldhead resulting from threshing by—		
		Machine	Flail	Hand
All sources	1,874			0.1
California	2,140	9.1		
Colorado	858	8.9		
Idaho	4,910	12.2		
Virginia	2,628		2.2	
Wisconsin	595	24.7		
Do	900	[a] 17.8		

[a] Threshed by small machine.

In germination tests similar to those conducted with the varieties of *Phaseolus vulgaris*, the following percentages of baldhead were obtained: Sieva, 2.17; Henderson Bush Lima, 11.11; Emerald Isle Pole, 13.67; and Fordhook Bush Lima, 15.95. These data show that Lima beans are liable to baldhead in percentages sufficiently large to result in considerable reduction in yield.

COWPEAS AND TEPARY BEANS

There was no baldhead in the Blackeye cowpeas tested. In the tepary bean there was 6.88 per cent of baldhead.

HISTOLOGY

An examination of the dry embryo or of the seed in a very early stage of germination, even before the integuments are ruptured, frequently reveals a fracture of the epicotyl just below the plumule, in which the latter may be partially or completely broken from the epicotyl. Figure 2, B, shows an early stage of germination of a seed in which the plumule is completely detached from the epicotyl. This should be compared with Figure 2, A, a normal seed germinated at the same time. Fractures such as those shown in Figure 2, B, are easy to detect by the unaided eye, but results indicated that baldhead sometimes occurs when the plumule and epicotyl appear to be normal, which suggested the possibility that an invisible injury to the tissues might occur. Consequently, permanent microscopic sections were made of normal and baldhead material. The seeds were germinated for a few days between blotting paper, and when the radicle had elongated slightly the cotyledons were carefully removed and the epicotyl with a portion of the hypocotyl was fixed in Carnoy's or formol-acetic-alcohol solution. After this they were carried through the usual processes of embedding, sectioning, staining, and mounting.

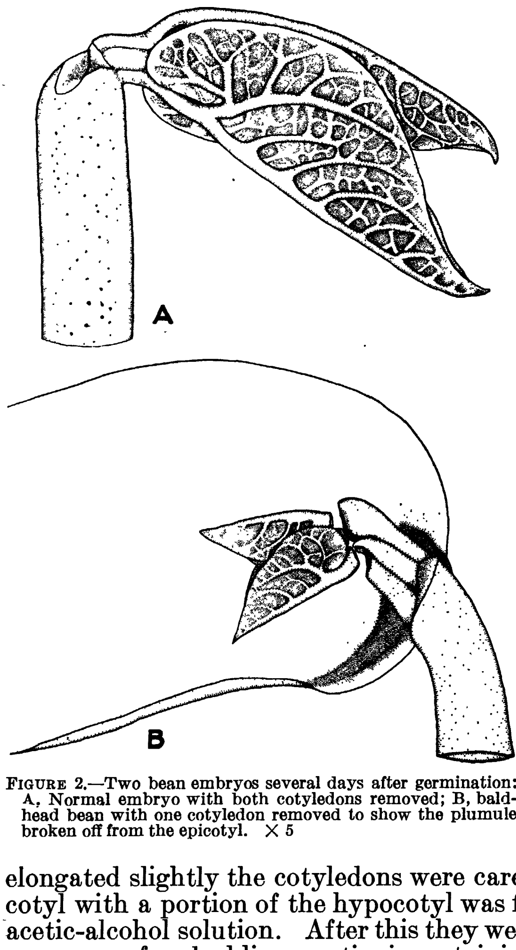

FIGURE 2.—Two bean embryos several days after germination: A, Normal embryo with both cotyledons removed; B, baldhead bean with one cotyledon removed to show the plumule broken off from the epicotyl. × 5

From among the many sections showing some type of injury, one was selected for the purpose of illustration. Figure 3, B, gives in outline a portion of this section, including a part of the two primary leaves (*c*), the terminal bud (*d*), and the region just below the plumule, included between the two dotted parallel lines. A cursory examination of this region shows that the tissue of the epicotyl just between the primary leaves is torn at both margins, the tear extending slightly in the direction of the terminal bud and toward the center (fig. 3, B, *a*), partially dismembering the two primary leaves and terminal bud from the remainder of the epicotyl. Sometimes the tissue in the region below the terminal bud (fig. 3, B, *b*) is torn in one or more places, resulting in the production of irregularly shaped cavities, which vary in extent and number but which are usually in the general location shown by *b*. Figure 3, A, is a photomicrograph of the region shown between the dotted lines of Figure 3, B, and is of about the same magnification, while Figure 3, C, is a detailed drawing of the arrangement of the cells of this region at a like magnification.

The fractures in the epicotyledonary region differ somewhat in general appearance, but all produce the same result—the plumule fails to develop and finally becomes detached from the rest of the epicotyl. Sometimes the tear extends from the margin almost to the center of the epicotyl, and the plumule is held in place by only a few rows of cells.

RELATION OF DIAMETER OF EPICOTYL TO VARIETAL SUSCEPTIBILITY

An examination of the embryo of an ungerminated bean seed (fig. 4) with a dissecting microscope revealed a considerable diminution in the diameter of the epicotyl just below the plumule, where most of the fractures leading to the production of baldhead plants take place. This fact suggested the possibility that there might be some relationship between the diameter of the epicotyl and susceptibility to baldhead, those embryos with a small diameter in the epicotyledonary region presumably being more liable to injury from the threshing machine than those with larger epicotyls. Measurements then were made through the smallest diameter of the epicotyl of 25 seeds each of 18 varieties, which were selected to include 6 each of those which would be classed as very susceptible, susceptible, and highly resistant. Those varieties in which there was no baldhead, or not more than 1 or 2 per cent, were classified as immune or resistant. The embryo was carefully removed from the cotyledons, and measurements were made at a magnification of approximately 57 diameters, with a camera lucida being used to project the images upon a millimeter rule on the top of a table.

While one may not be justified in attaching any great importance to these data, the results show that the epicotyledonary diameter of the very susceptible, susceptible, and highly resistant groups average 0.45, 0.49, and 0.55 mm., respectively, the maximum being 22.2 per cent greater than the minimum. Of course it does not necessarily follow that the epicotyl with a small diameter is more easily broken than one with a large diameter, although, everything else being equal, such would probably be the case. The fact remains, at least, that the highest percentage of baldhead was found to occur in those varieties with the smallest diameter of the epicotyl.

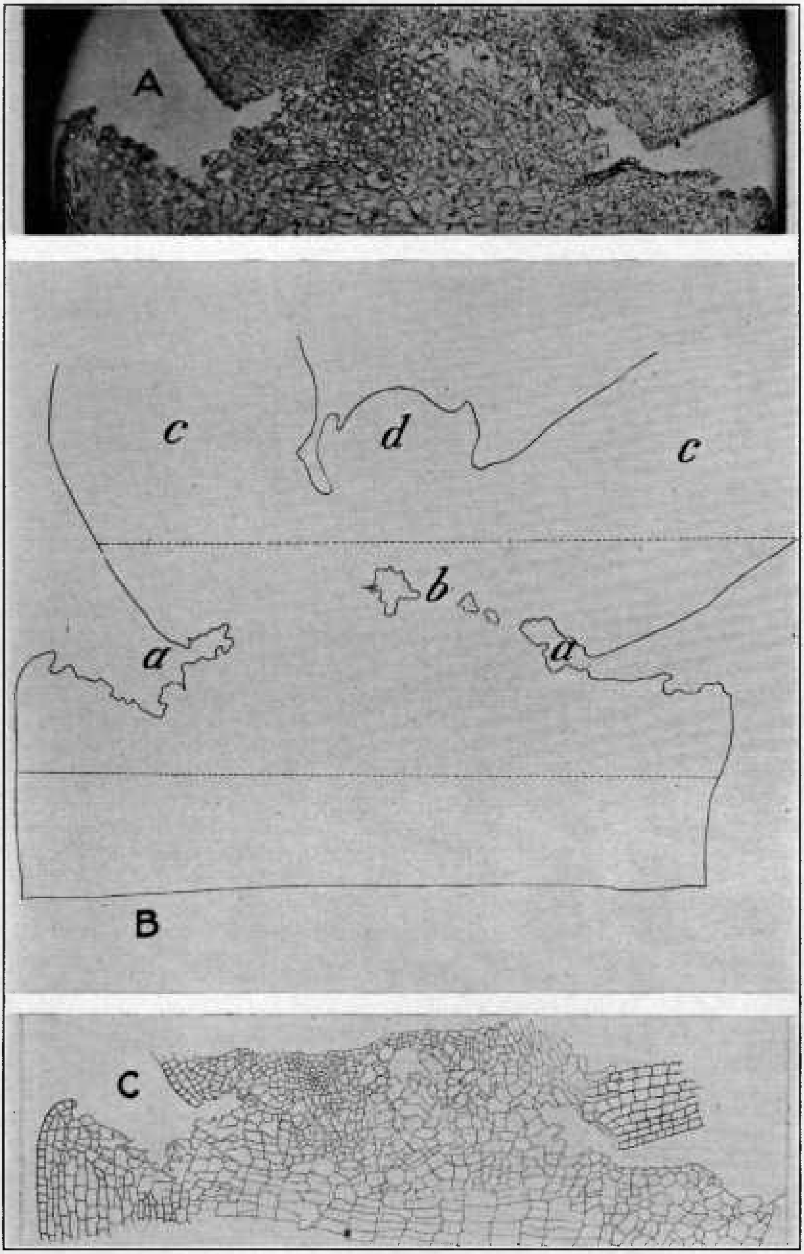

FIGURE 3.—Histology of baldhead: A, Photomicrograph of the area of a baldhead bean represented in B between the dotted lines; B, outline drawing, showing the primary leaves (*c*), the terminal bud (*d*), and the region where fractures occur (*a*, *b*); C, camera-lucida drawing, showing fracture and arrangement of cells in region covered by A. All about × 70

DISCUSSION

RELATION OF INSECTS TO BALDHEAD

According to Hawley,[5,6] the seed-corn maggot (*Phorbia fusciceps* Zett.) causes from 50 to 75 per cent damage to beans in New York and other States as a result of abscissing the plumule, thus causing the plants to develop baldhead, or tunneling into the cotyledons while the seed is still in the ground. The insect also attacks the stem beneath the ground. This led Hawley to conclude that the entire loss attributed to the maggot was not due solely to the injury to the plumule, but in part to the injury to the stem.

BACTERIA AND FUNGI AS CAUSAL FACTORS IN BALDHEAD

While agreeing with Hawley [7] that the seed-corn maggot is responsible for most of the baldhead, Burkholder [8] claimed that *Bacterium*

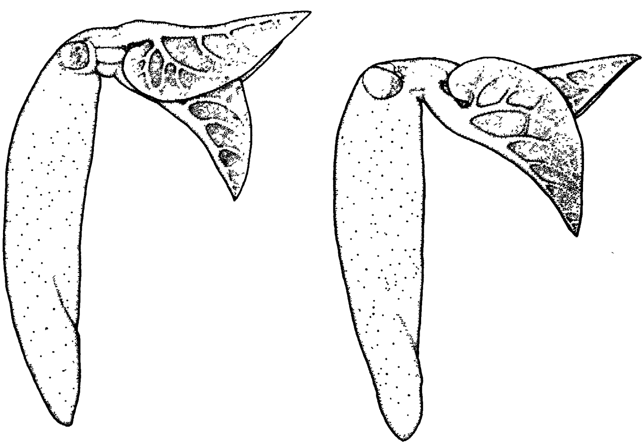

FIGURE 4.—Two embryos from dry beans, showing constriction in the epicotyl at the region where fractures caused by the threshing machine take place. × 5

phaseoli EFS., as well as *Thielavia basicola* Zopf and a species of Rhizoctonia, may cause the same type of injury, although he gave no evidence to show that he produced the disease by inoculation with any of these organisms. His conclusions appear to be drawn entirely from the fact that *Bact. phaseoli*, *T. basicola*, and Rhizoctonia were isolated from baldhead plants. As additional proof Burkholder cited the results of planting blighted bean seeds in the greenhouse, 20 per cent of one lot producing baldhead while other plantings gave varying percentages.

In this connection, attention should be called to the fact that a high percentage of baldhead may occur in seed produced in regions of the West where bacterial blight does not occur, and attempts to isolate bacteria from specimens from those regions have always resulted in failure. Furthermore, it has been the writer's experience that in

5 HAWLEY, I. M. Op. cit. (See footnote 4.)
6 HAWLEY, I. M. SOME NOTES ON PHORBIA FUSCICEPS AS A BEAN PEST. Jour. Econ. Ent. 12: 203–205, illus. 1919.
7 HAWLEY, I. M. Op. cit. (See footnote 6.)
8 BURKHOLDER, W. H. THE BACTERIAL BLIGHT OF THE BEAN: A SYSTEMIC DISEASE. Phytopathology 11: [61]–69. 1921.

many cases isolations from the tips of baldhead plants from badly blighted seeds yield neither the blight nor the wilt organisms.

While the conclusions of Hawley and Burkholder are not questioned, the seed-corn maggot, *Bacterium phaseoli*, *Thielavia basicola*, and Rhizoctonia are not the sole causes of baldhead. The association of an organism, such as *Bact. phaseoli*, with baldhead does not constitute complete proof of a causal relationship. The bean-blight organism may gain entrance to the seed through the micropyle,[9] so that when germination starts, infection on the inner faces of the cotyledons is not uncommon. By the time the seedling has emerged from the soil the denuded epicotyl of already injured seeds may have attained a length varying from one-eighth to three-fourths of an inch; it is quite probable that it might have come in contact with blight lesions of the cotyledons and become infected or that it acts as a carrier only.

MECHANICAL INJURY DUE TO CONDITION OF THE SOIL

Many growers attribute baldhead to a mechanical injury of the epicotyl as the seedling pushes through the soil. Such accidents are supposed to be greatly increased when the penetration of the soil by the seedling is made more difficult by a dry, hard crust. However, it is not the epicotyl, protected as it is by the cotyledons, which is broken, but the hypocotyl, so that no further development takes place. This injury is sometimes mistaken for baldhead.

THRESHER INJURY

The occurrence of baldhead in bean seeds free from pathogenic organisms and in seeds germinated in the laboratory under conditions precluding infection by parasites was convincing evidence that there was another cause quite apart from insects, bacteria, and fungi. In seeds of almost every snap-bean variety grown in the West a considerable percentage of baldhead was found. This suggested a relationship between western-grown seed and the malady, but the results of investigations showed that there was nothing inherent in western-grown seed that would render it any more susceptible to baldhead than seed grown elsewhere. Commercial bean seed is raised in a comparatively few regions, but in all cases it is handled in the same manner. In comparing the methods of harvesting seed the commercial method of machine threshing is the only essential difference, and here apparently lies the causal factor to which is attributed more baldhead than to all the other factors combined—injury to the epicotyl while the seeds are being threshed.

The germination of hundreds of bean seeds showed that baldhead occurs in certain varieties threshed by machine, while seeds of the same lot shelled by hand gave none on germination by the same method. A microscopic examination of permanently mounted material showed that a fracture of the epicotyl of beans destined to become affected with baldhead occurred just beneath the plumule in machine-threshed seed. However, inasmuch as no such wound is found in hand-shelled beans, the evidence seems quite conclusive that the break is caused by the beans being violently struck by the teeth of the thresher cylinder or hurled against the teeth of the concave during threshing. Some varie-

[9] ZAUMEYER, W. J. SEED INFECTION BY BACTERIUM PHASEOLI. (Abstract) Phytopathology 19: 96. 1929.

ties are difficult to shell and can only be threshed by speeding up the cylinders, which might reasonably be expected to result in the splitting of many seeds and the fracturing of the epicotyl of others. The degree of desiccation of the seed at the time of threshing has been suggested as being somewhat correlated with baldhead; that is, if the beans were very dry when threshed, injury was more likely to result.

In general, the dry-shell field beans, as a group, seem to be less subject to baldhead than the snap beans, although the comparison has not been carried far enough to justify the drawing of positive conclusions. Out of 13 varieties of field beans investigated, only 3—the Red Kidney, Bayo, and Large White—all grown in California, showed a percentage of baldhead sufficiently large to be of any economic importance. On the other hand, a considerable percentage of baldhead occurred in most varieties of snap beans, but there are a few exceptions, among which may be mentioned the Kentucky Wonder Wax, Tennessee Green Pod, and Lazy Wife.

Several theories have been proposed to explain the general dissimilarity between the dry-shell and snap-bean varieties, but all are untenable or can be negated by several exceptions. The growers of snap beans for seed purposes generally agree that stringless varieties are more difficult to thresh than stringy ones and that the difficulty of threshing is increased if the vines are cut before the pods are entirely ripe. As a consequence the seeds must be released from the pods by speeding up the cylinders or by more nearly closing the concave, both of which may cause some splitting and cracking of the seeds. In threshing the stringless varieties the pods break crosswise at each side of the seed, leaving the bean incased in a segment of the pod. The stringy varieties, among which are the dry-shell field beans, have a large amount of xylem paralleling the dorsal and ventral sutures along which the pods split instead of breaking into segments when struck by the cylinder, thus releasing the beans without too violent treatment. While there seems to be some evidence that baldhead is more prevalent in the stringless varieties than in the stringy ones, the correlation is far from being perfect, since a high percentage of baldhead is sometimes found in some of the stringy varieties and a low percentage in certain lots of some of the stringless ones.

While the stringiness of the bean may partially explain the occurrence of baldhead, undoubtedly other factors, such as the maturity of the crop when harvested and the degree of curing and desiccation of the vine and of the bean itself when threshed, may play important rôles. Information acquired from reliable sources indicates that beans cut a little too green are difficult to thresh, due to the fact that the pods dry tightly about the beans, especially if weather conditions are unfavorable for curing.

Much of the snap-bean seed is grown in the arid regions of the West, where the annual rainfall alone is insufficient to grow a crop and water is supplied by irrigation several times during the growing season. After the beans have reached a certain stage of maturity, water is withheld and the crop is allowed to ripen. It sometimes happens that the ripening process is started too soon, or that an unexpected period of warm weather occurs, so that the beans are subject to drought conditions and ripen prematurely. Under such conditions the pods shrink and tighten about the seeds, rendering their release during threshing extremely difficult and causing them to break into 1-seeded segments instead of cracking along the sutures. In the light of the evidence at hand, the indications are that not one but a combination of seasonal factors render the seed of certain varieties subject to injury by the threshing machine.

SUMMARY

Investigations have been made of baldhead in beans, a seedling abnormality in which the plumule is absent.

Germination tests of snap and field beans, together with histological studies of the epicotyledonary region of embryos from hand-threshed and machine-threshed beans, have shown that the epicotyl is fractured just below the plumule by the threshing machine. Baldhead rarely occurs in beans threshed by hand. Baldhead plants may develop buds in the axils of the cotyledons which may result in a few flowers and possibly one or two partially filled pods, but never a full yield.

The percentage of baldhead varies with the different varieties and ranges from 0 to 30 per cent. Among some of the snap-bean varieties 10 to 20 per cent is common. Baldhead occurs only to a very slight extent or not at all in many of the field or dry-shell beans studied.

The average diameter of the epicotyl in the embryonic stage was found to be less in snap beans susceptible to baldhead than in more resistant field beans.