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THE WHEAT JOINTWORM IN OREGON, WITH SPECIAL REFERENCE TO ITS DISPERSION
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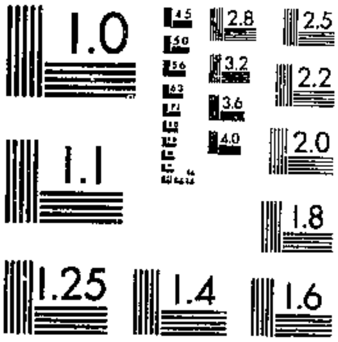
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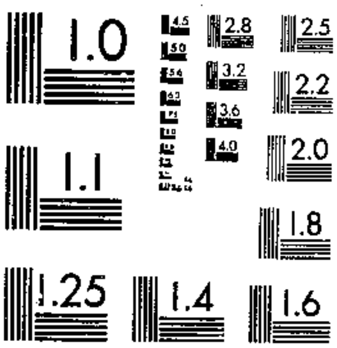
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The Wheat Jointworm in Oregon, With Special Reference to Its Dispersion, Injury, and Parasitization[1]

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CONTENTS

INTRODUCTION

Two different species of *Harmolita* have been described under the name *tritici*, one by Fitch (*8*)[3] in 1859 and the other by Riley (*15*) in 1882. *Harmolita tritici* (Riley, not Fitch) is now known to be a synonym of *H. grandis* form *minuta* (Riley), and the record of *H. tritici* from Washington Territory in 1882 by Riley (*16*) and also that from southeastern Washington by Riley and Howard (*17*) deal with *H. grandis minuta*. The record by Webster (*18*) in 1906 of the presence in southwestern Washington of a species suspected of being *H. tritici* probably referred to *H. vaginicola* (Doane), which at that time had not been recognized as a distinct species and which for many years has been found rather generally distributed over western Oregon and Washington.

The true wheat jointworm (*Harmolita tritici* (Fitch))[4] was first found in the Pacific Northwest in 1926, in two small areas in the

[1] Received for publication March 14, 1941.

[2] The author gratefully acknowledges the assistance and advice of L. P. Rockwood in the conduct of the work and the preparation of the manuscript; the cooperation of W. J. Phillips; the assistance of Max M. Reeher, whose surveys in connection with the hessian fly and the wheat midge have served as an additional check on the distribution of the jointworm; and of E. A. Porter, who, without compensation, from 1929 to 1934, took weather records in the Molalla, Oreg., district, made observations on the jointworm, and gave valuable counsel on various matters. Determinations of many of the parasites by A. B. Gahan and C. F. W. Muesebeck are also much appreciated.

[3] Italic numbers in parentheses refer to Literature Cited, p. 47.

[4] Order Hymenoptera, family Eurytomidae.

Willamette Valley in Oregon. These are the only areas in the Pacific Northwest in which it is known to occur. It is with the study of this insect and its parasites and their dispersion in these areas that the present bulletin is concerned. The investigations covered the period from the fall of 1926 to the fall of 1934.

It is not known how or exactly when the wheat jointworm was introduced into the Willamette Valley. The time of introduction was probably shortly before 1926, as is indicated by the small size of the colonies and the heavy infestation near the center of each colony that year. Further evidence that the introduction was recent is furnished by the many collections of wheat stems in connection with hessian fly work which were made in the Willamette Valley intermittently for many years and intensively for 8 years previous to 1926. These collections did not reveal the presence of the jointworm. Frequent surveys made in western Washington and less frequently in eastern Washington and Oregon before and after 1926 show with reasonable certainty that the jointworm is not even sparsely distributed over those areas. The presence of many of the species of parasites that occur in the Eastern States suggests that the insect was probably introduced into the Willamette Valley in infested straw from regions where these parasites were common. Some of these parasites, however, were found on native species of *Harmolita* in grasses and on the hessian fly, and it is possible that these species were already present at the time of the introduction of the wheat jointworm.

The Willamette Valley is a large and fertile district of varying topography, with wooded or partly cultivated hills, flat prairies, and rolling hillocks between. It lies between the Coast and the Cascade Ranges in Oregon and ascends in a southerly direction from about the latitude of Portland to a short distance south of Cottage Grove. The climate is humid, and most of the precipitation occurs as rain in the fall, winter, and spring. The summers are dry especially the months of July and August. In general, precipitation is heavier in the more elevated portions of the valley and decreases from the north to the south, ranging from 77.17 inches at Headworks, located in the hills east of Portland, to 46.23 inches at Forest Grove, 38.07 at Salem, and 37.79 at Eugene. Severe cold weather may occur for short periods in the winter months, especially in December and January, when rarely zero or lower temperatures may occur, but for the most part the winters are mild.

The wheat grown in the Willamette Valley is but a small portion of the total grown in the Pacific Northwest, but it is an important crop on most of the farms of the valley. The two separate jointworm infestations now cover considerable areas in this valley; and although the insect spread rather slowly during the 8 years following the discovery of the original infestations in 1926, it is believed that eventually it will invade all the main wheat-growing areas west of the Cascade Mountains. Doubtless the insect can exist also in the great wheat-growing districts of eastern Washington and Oregon, but it seems unlikely that it will ever become abundant there because the methods of wheat culture practiced in those sections, which include clean summer fallowing over very large areas and some stubble burning, are unfavorable to its increase. Farmers throughout the Willamette

Valley and elsewhere in the Pacific Northwest should be able to recognize the work of this insect in order to cope with it when it appears in damaging numbers or in territory hitherto uninfested.

DISTRIBUTION OF THE JOINTWORM IN OREGON

Figure 1 shows the distribution of the jointworm in Oregon in the fall of 1934.[5] Both colonies, for the most part, extended eastward from the right bank of the Willamette River. The northern, or Molalla, colony or infestation occupied most of the cultivated land of Clackamas County and the northwestern portion of Marion County. In 1928 the jointworm crossed the Willamette River in the Molalla

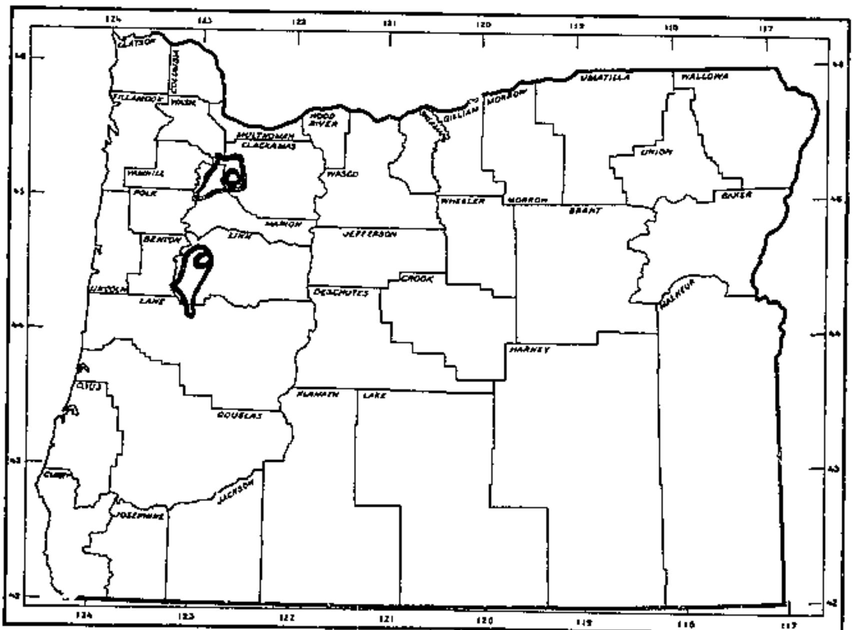

FIGURE 1.—Jointworm distribution in Oregon in the fall of 1934. Small, inner outlines show the original infestations in 1926.

colony at a point about 4 miles east of Wilsonville. At that particular point the boundary remained practically stationary for the next 6 years. This colony was roughly oval in shape and at that time was about 32 miles long and 24 miles wide.

In the southern, or Lebanon, colony most of the flat country of Linn County east of the Willamette River and south of Albany is infested. At the south end the infestation crosses the river and extends for a short distance into Lane County. The colony in 1934 was roughly oval, extending north and south and bearing slightly northeast and southwest, and was approximately 33 miles long and 16 miles wide.

[5] No work has been done on the wheat jointworm in Oregon since the author left there in 1935. Since that time, according to information received from E. A. Porter in September 1939, the wheat jointworm has been very scarce in Oregon, even in the center of the Molalla colony.

In the infested areas of Clackamas, Marion, and Linn Counties wheat is an important crop and has a definite place in the regular rotation with red clover, oats, or oats and vetch, and in some cases with a row crop, which most frequently is corn or potatoes. In Clackamas and Marion Counties the clover is usually planted in February in the fall-planted wheat, but occasionally it is planted with barley or winter gray oats. On less fertile soils the clover is sometimes planted alone. On the "white lands" of Linn County alsike clover is often substituted for red clover. In 1929 the yield of wheat for the three counties was as follows: Clackamas County, 462,459 bushels from 16,253 acres, or an average of 28.5 bushels per acre; Marion County, 730,425 bushels from 26,525 acres, or 27.5 bushels per acre; Linn County, 482,908 bushels from 21,873 acres, or 22.1 bushels per acre. For the Willamette District the yield for 1929 was 4,105,895 bushels from 158,857 acres, or 25.8 bushels per acre. The yield for the whole of Oregon for that year was 21,499,977 bushels from 1,074,600 acres, or 20.0 bushels per acre.[6]

DENSITY OF INFESTATION

The methods used in determining the density of infestation in various fields were in general similar, but they varied in details according to conditions and the immediate purposes. On the sample farm in the "sample farm area," which will be discussed later in connection with various studies, and on farms in the immediate vicinity of this farm the count from stubble collected soon after harvest was used Although binders chiefly were used during the period of the investigation, the stubble for the most part was left high; so usually the lower 3 joints and sometimes the fourth could be observed. If the field was small, 50 stems in a drill row were taken at each 25 or 50 paces; if the field was large, at each 100 paces. The first point of collection was some distance in from one corner of the field. Usually 500 to 1,000 stems were taken in each sample. Frequently other samples were taken later in the same fields for other purposes, but these were not used to establish the percentages of infestation, since sheep and cattle grazing in the stubble after harvest often broke down and trampled the stubs to such an extent that determinations of the infestations in late samples were not considered so accurate as in the earlier ones. These records were used, however, as checks on the earlier determinations, and if any large discrepancies were observed the populations could be further investigated. Discrepancies of any importance were rarely shown, however, and this indicated that for all practical purposes the samples were accurate.

In fields not in the immediate vicinity of the sample farm, and in fields outside the sample-farm area, most of the samples taken were smaller. The main purpose of many of the collections made outside the sample-farm area was to determine the yearly dispersion of the adults, and if jointworms were found readily only a small number of stems were examined, usually not less than 100 or more than 300, although fields of special interest often were sampled more thoroughly.

[6] From records of crops production for the State of Oregon for the year 1929, by Paul C. Newman, agricultural statistician.

In this type of survey usually 10 stems were taken at a time at points fairly close together and well distributed over the field. Samples relating primarily to dispersion were taken at any time between harvest and the initial emergence of adults the following spring.

The density of infestation in the various fields throughout the two infested areas between 1926 and 1934 showed considerable variation. Table 1 shows the average infestations for the Molalla colony for the years 1927 to 1934, inclusive. This average was taken from fields in the areas that had been infested for some time and does not include fields near the borders of the colony, which in most cases would be lightly infested. It should be explained that as the colony increased in size it was necessary to examine more fields near its borders than was the case earlier, in order to determine the boundaries, so sometimes fewer fields were examined in the main part of the colony. Thus for 1931–32 fewer fields appear in the table than for the previous years. These were located near the middle of the colony, or in the area that had been longest infested, and fields lying between the middle and the borders of the colony, which had been more recently infested, are not included. It is believed therefore that the infestations shown for 1931–32 are higher than they would have been if approximately the same number and the same diversity of fields had been included as in the previous years. The infestations shown by some of these fields mean considerable loss to the crop.

TABLE 1.—*Infestation by the wheat jointworm in the Molalla, Oreg., colony, 1927–34*

Year	Fields	Range in infestation	Culms infested	Year	Fields	Range in infestation	Culms infested
	Number	*Percent*	*Percent*		*Number*	*Percent*	*Percent*
1927	10	1.0–80	36	1931	5	13.0–80	61
1928	14	1.5–98	40	1932	5	31.0–70	49
1929	16	3.0–96	58	1933	10	[1] 0.0–70	8
1930	12	1.0–91	56	1934	9	0.0– 0.5	3

[1] Only 1 field had an infestation above 26 percent.

Table 2 indicates the history of the infestation in the heart of the Molalla colony from 1928 to 1934, inclusive. Fields listed in this table, except those noted, were in the neighborhood of the field in which the jointworm was first found and where infestation was high in 1926. An extensive study was made of the jointworm in this sample-farm area to determine the trend of the infestation and the effect on it of the climate, the parasites, and the farm practices. Since the data are relatively more complete on this area than on the rest of the colony, table 2 should give a more accurate history of the changes in population than table 1. Fields in this table denoted as nearby were all within a radius of approximately one-half mile of the sample field. Those denoted as more remote were between ½ mile and 3 miles of the sample field. Since wheat rarely is planted in the same field for 2 years in succession, the fields compared from year to year were only occasionally on the same plot of ground. More frequently, but not always, they were on the same farm.

TABLE 2.—*Culms infested by the wheat jointworm on farms in the sample-farm area, Molalla, Oreg., 1928–34*

Location	1928	1929	1930	1931	1932	1933	1934
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sample field	32.5	94.6	91.2	69.0	47.6	19.3	1.5
Nearby fields	38.0	98.0	38.3	68.2	30.0	8.4	0
Do		91.9	72.5	13.3	51.6	3.0	0
Do		29.6	69.4				6.5
Do		3.2	61.0				
More remote	90.4			79.5		70.5	
Do	98.1	94.0	17.5	79.7	45.2	25.3	6.5
Average	64.7	68.5	58.3	62.1	43.8	25.3	2.9

The highest infestation was reached in 1929. Infestation in the sample field has decreased since that time, with large decreases in 1933 and 1934. In other fields there has been a more or less irregular but decided decrease. These variations are to be expected, since the distances of the fields examined from unburied stubble, as well as the infestations in the stubble, varied from year to year. The average infestation for the area was lower each year after 1929, except in 1931, when it was slightly higher than in 1930.

The infestations in the Lebanon colony have not been followed so thoroughly as were those in the Molalla colony. Although the reduction in infestation here has been similar to that in the Molalla colony, the infestation has not been so high. The maximum was 80 percent, found in one field in 1928. As in the Molalla colony, there were great decreases in 1933; and in 1934 no infestation whatever was found except in a field at the southwestern border of the colony, which showed an infestation of 1 percent.

The conditions that brought about the greatly reduced infestations of 1933 and 1934 began in December 1932, when low temperatures without a snow covering killed most of the fall-sown wheat, together with much clover in the stubble of the previous season. Winter-sown wheat, of which there is, relatively speaking, considerable in this region and most of which is planted in February, survived. Infested stubble in which the clover was killed was plowed under early in the spring of 1933, and to compensate for the loss of the fall wheat much spring wheat was sown. This in many cases developed too late to become infested by the jointworm. In the spring of 1934, therefore, much of the stubble unburied at the time of the issuance of the jointworm was uninfested, or only lightly infested, and such fields of 1932–33 fall-sown and winter-sown wheat stubble as remained were widely scattered and had infestations below normal. The few adults issuing over a wide area from the few fields of lightly infested stubble resulted in an infestation in 1934 still lower than that of 1933.

SEASONAL HISTORY OF THE JOINTWORM

The adults of the jointworm, which superficially resemble small, black, flying ants, begin to issue from unburied stubble during the last 3 weeks of April or the first 3 weeks of May, and emergence may continue until the latter part of June. The females place their eggs only in the walls of jointed stems of wheat. These eggs hatch in about 2 weeks, producing minute, whitish, translucent grubs, or "worms," which feed in individual cells on the sap of the plant until the stems become dry. During this time the grubs molt several times, increase in size, and change in color, until at harvest they are approximately three-sixteenths of an inch long and one-fifth as broad, and yellow.

The grubs lie in their hard-walled cells until the first part of October when some of them pupate. Pupation of all individuals is not completed until December. The pupae remain unchanged over the winter and until shortly before emergence, when they turn jet black. Shortly after becoming black, the time varying with weather conditions, the pupae cast their skins, and the newly formed adults gnaw small circular holes in the walls of the stems and crawl out.

The time of emergence of the adults in the spring varies considerably. From 1927 to 1934, inclusive, the time of the first emergence, as determined by sweeping and examination of the stubble, ranged from April 5 to May 19. Field and laboratory observations have shown that the time of emergence is probably influenced more by temperature than by any other single external factor. In a laboratory room kept warm during the daytime, a few adults have been induced to issue as early as December 24, probably within a month or two after pupation. In the field, emergence is early in warm, sunny springs and late in cold, cloudy springs. From 1930 to 1934, inclusive, weather records, including maximum and minimum temperatures, precipitation, direction of the wind, and the character of the day, were kept at the northern infestation near Molalla. Attempts to correlate the issuance of *Harmolita tritici* with effective temperatures accumulated during the winter and spring, summing up degrees of mean temperatures above 40°, 43°, 45°, 48°, or 50° F., while showing plainly the accelerating influence of warmth, have not established any close correlation in the case of any of the temperatures mentioned. In years of late emergence there has always been a deficiency of accumulated temperature up to approximately April 1, compared with years of early emergence, but this deficiency has been more than made up, in the years of late emergence, by higher temperatures between April 1 and the time of emergence. In other words, if mean temperatures alone determined the time of emergence of *H. tritici* it would have occurred earlier in these years than was the case. The effect of temperature on emergence, however, seems to be more cumulative than immediate or transient. High temperatures did not produce emergence unless there had been a considerable early accumulation of effective temperature, and relatively low temperatures did not prevent it provided there had been such an accumulation.

There seems to be little relation between the time of first emergence and precipitation, within the range occurring in the Willamette Valley during the emergence period, except that first emergence has been associated most frequently with brief dry periods or occurred on days of little measurable rain. It is probable that *Harmolita tritici* issues more readily from stubble moderately dry than from stubble bearing contact moisture. It is not improbable that emergence is related to the date of pupation the preceding fall; but since pupation among a whole population takes place over a considerable period of time, and it would be difficult in the field to determine the exact date of pupation of any number of individuals, it would be difficult to demonstrate the existence of such relationship in field material.

Cool, rainy weather subsequent to the first emergence of *Harmolita tritici* prolongs the emergence. Warm, sunny weather has the opposite effect. In 1927, when the first adults issued on April 25 (rather early) and this date was followed by cool, wet weather, females were swept from growing wheat 37 days later, and stubble examination on this date indicated that, in some fields, only about one-half of the total adult population had yet emerged. In 1928, when the earliest issuance was followed by warm, sunny weather, sweeping and stubble examinations indicated that emergence was practically over within 23 days after the first adults were taken. It is rarely possible, however, to obtain in the field clear-cut records of the effect of the different weather factors on the whole emergence period, since most periods exhibit variable combinations of temperature, moisture, and sunshine.

The period of emergence and, consequently, the period when females are abroad, is important because of its relation to the infestation of wheat. Late-planted spring wheat as well as the spring-formed tillers of fall- and winter-sown wheat escape attack almost entirely. In the Willamette Valley most of the adults apparently disappear before the spring wheat is sufficiently developed to be acceptable to them, whereas the fall- and winter-sown wheat, with the exception of the spring-formed tillers just mentioned, has proved acceptable during the 8 years of the investigation. This situation apparently differs considerably from that in the Eastern States, where most of the adults appear to be active during the period when late-developing rather than early-developing wheats are in a suitable condition for oviposition

DISPERSION

The males and females of *Harmolita tritici* issue from the stubble during practically the same period, although a few males usually emerge before the first females. In warm, sunny weather the females immediately leave the stubble fields and may be taken from nearby fields of growing wheat when only a small proportion have issued. Males and females are readily taken in stubble as long as females are issuing, or unfavorable weather has hindered the females' departure. In fair weather males may still be found there toward the end of the period of emergence and later, after the females have entirely disappeared.

Observations in the spring of 1927 furnished the best example of the effect of cool, cloudy, wet weather on the movements of the females, since there was then an abundance of unplowed stubble as well as growing wheat and an absence of other discernible factors affecting their activity. In that season 11 days elapsed after the first issuance from stubble before the first females were taken from growing wheat. They were at no time swept in abundance from growing wheat, except the volunteer wheat in stubble, and both males and females were present in large numbers in stubble fields at all times.

In contrast with these conditions, in 1928, when it was warm and sunny at the time of the first issuance and subsequently, females were constantly abundant on growing wheat, and stubble yielded males almost exclusively.

It should be emphasized that when cool, rainy weather follows the first issuance, the emergence and oviposition period is prolonged. It is believed that this fact explains why heavy infestations, especially in those fields located close to stubble, sometimes follow springs that might be considered unfavorable to rapid emergence, dispersion, and oviposition.

The distance that *Harmolita tritici* can travel in a single flight is not known. Phillips (*8, p. 24*) states that they may be carried a mile or more by the wind. Much sweeping and many days of observation in the field during the flight periods of the years 1927–34 indicate that only a small portion of the total population fly as far as that in a season, and that migration for any considerable distance is accomplished by a series of much shorter flights. Even in warm periods the movements seem to be by shorter flights than might be expected. It is probable, however, that certain factors may increase the distance of migration from stubble. In warm, sunny weather during the period of adult activity, and in the absence of growing wheat in the immediate neighborhood, distances greater than 1 mile might be covered in a series of short flights in search of wheat, but observations are indefinite as to the extreme limits of migration.

Some idea of the nature of migration of the females from stubble to wheat may be gained from data obtained in sweeping an 18-acre field of growing wheat in the spring of 1929. This field was long and narrow, extending north and south, and was remote from stubble except for one small field adjacent to its northwestern corner, which undoubtedly was the main source of the jointworms that infested the field. On June 3, 19 days after the first adults had issued and stubble examination had indicated that about three-fifths of the flies had emerged, sweepings of 10 strokes each were made in all parts of the field of young wheat. The adults caught were almost exclusively females. Figure 2 shows the shape of the field, the number of adults caught per 10 strokes, and the general locations in which they were taken in the field.

Adults were much more numerous along the north edge of the field than elsewhere, and the numbers decreased perceptibly along this border toward the east and away from the stubble. More adults were found along the west side than along the east side, and they decreased in numbers along both these lines southward away from the stubble. Such findings 19 days after the first emergence would indicate slow movement away from the stubble and through the wheat. The spread of the females from the single source also is indicated to some extent by the determination of postharvest infestations throughout the field. These infestations were not so much lower in the portions of the field farther from the stubble as might have been expected from the results of the sweepings on June 3, doubtless because the adults were active long enough after that date to enable them by easy stages to infest the southern part of the field rather heavily. The final percentages of infestation in the various parts of the field are also given in figure 2. In this connection it should be pointed out that 1929 was a year of heavy infestation throughout both colonies; and while, except for the small field mentioned, there was no stubble close to the field swept, the abundance of heavily infested stubble in the colony in general doubtless furnished part of the adults which infested this particular field.

During the flight period adults of *Harmolita tritici* are frequently taken from oats and other crops, where they stop temporarily during

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migration to wheat. In 1927, a cool, wet season when migration from stubble was slow, adults were taken from oats throughout the flight period and sometimes in considerable numbers. Apparently the flight from stubble is at random except as influenced by winds, frequent stops and departures being made until wheat is reached or the adults die. Woods, towns, and rivers serve as obstructions to the

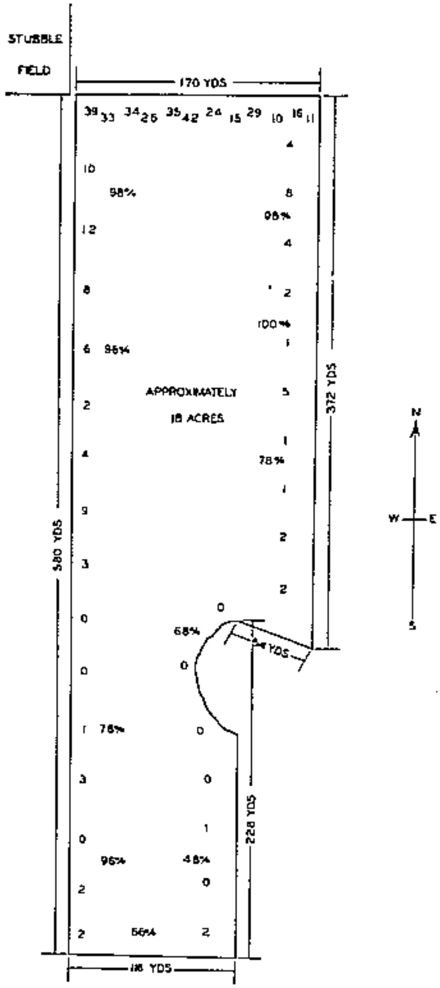

FIGURE 2.—Diagram of wheat field adjacent to a stubble field, showing the numbers of adults caught per 10 strokes of a net and the percentage of ultimate infestation in various parts of the field.

flight. Infestation in isolated fields in wooded districts usually is light even though the wooded district is in the heart of a colony. Reasonably open and fairly large areas in woods may become heavily infested, since after the insect becomes established sufficient stubble and growing wheat are present to permit normal migration from stubble to wheat within the area.

ENLARGEMENT OF COLONIES

Methods of Study

Several methods were used to determine the yearly boundaries of the colonies from 1926 to 1934, inclusive. The infested areas were delimited as accurately as possible shortly after they were discovered after the 1926 harvest, by examining stubble at various distances and in different directions from the field in which the infestation was first discovered. Considerable care was taken in later years in covering the fields in the vicinity of infested fields remote from the original infestation. After these fields were covered, the distance between the fields studied was increased. The stubble was examined at any time between harvest and the following spring. After one survey of each season the infested fields were located on detailed maps, and each succeeding survey was made in territory previously omitted, special attention being paid to those areas where, on the basis of previous surveys, the jointworms were to be expected. In this way the greater part of the Willamette Valley was covered each year.

The distribution of the jointworm was also checked by sweeping growing wheat and stubble fields in the spring during the period of adult activity, beginning in the localities where the jointworm was found in stubble examinations. Fields were swept from one to several times each season, a sweep of the net being taken at each pace through the field. The number of sweeps in each field ranged from 150 to 1,600 at each sweeping. In the strictly scouting work the number of sweeps was rarely less than 300 unless the adults were picked up very quickly. That the sweeping was thoroughly done is indicated by the large numbers of other species of *Harmolita* that were collected. These species included *H. vaginicola* (Doane), *H. lolii* Gahan, *H. holci* Phillips, and others, which, although rather widely distributed, were usually thinly scattered over the areas infested by them. The general plan of mapping the infested areas from the results of sweeping was essentially the same as in stubble examination.

In addition to the sweeping and examination of stubble, a search was frequently made in June along the tentatively established boundaries of the colonies and elsewhere for fallen wheat straws. If any were observed they were examined at once for jointworms.

The final boundaries of the colonies are based on findings by all three methods. Each of these methods proved useful. The search for fallen straws was especially productive in 1929, when there was considerable lodging of wheat. Although the use of the several methods has hindered the classification of the data on a comparative basis, as would have been possible if the method of stubble examination had been used exclusively, the combination of methods is considered definitely superior for the specific purpose of delimiting as closely as possible the jointworm colonies each year.

The Molalla Colony

The infestation in the Molalla district in 1926 was discovered on July 29. At that time it appeared to be roughly circular in outline and about 10 miles in diameter and lay between Molalla and Hubbard and extended to a point 2 miles north of Marquam on the south and

2 miles south of Canby on the north. Although the first season's work appeared very thorough and it was believed at that time that the boundaries set were fairly accurate, the large extensions in 1927 and 1928 and the rather slow progress since the latter year render this doubtful. As investigations progressed it became evident that it would be practically impossible to set exact limits to the insect's distribution in any single season in country traversed by many streams and containing many woods and no large unbroken areas given to the cultivation of wheat, and that the most accurate boundaries of the colonies would probably be those established theoretically from records of the previous several years as to fields infested and the

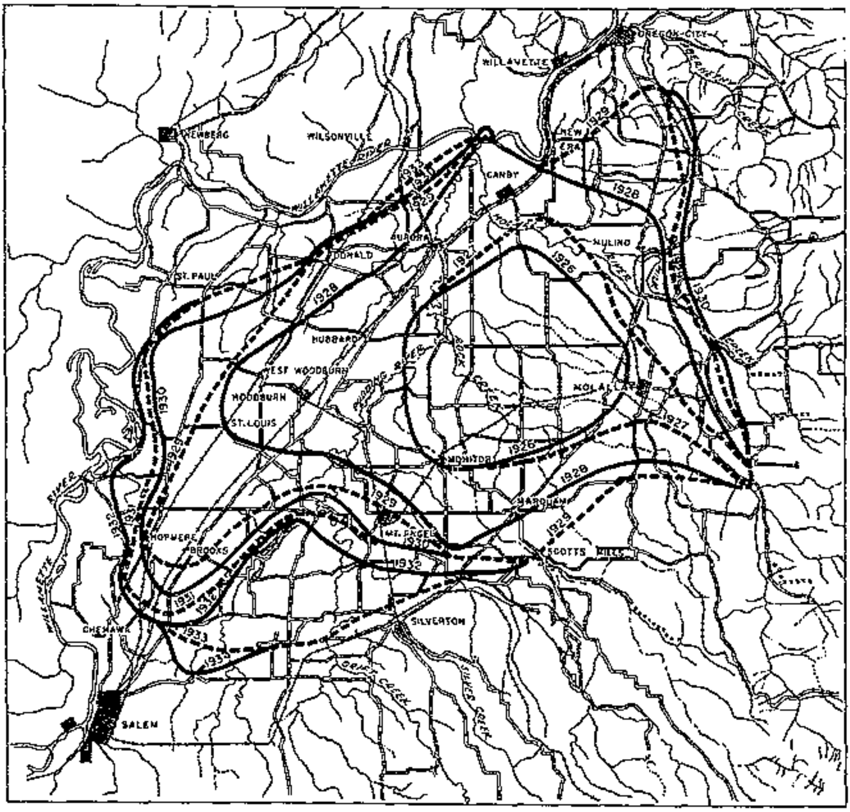

FIGURE 3.—Map showing the original extent of the Molalla colony in 1925 and the area occupied each succeeding year through 1934.

intensity of the infestation. The original Molalla colony and the area occupied each year afterwards through 1934 are shown in figure 3.

This colony by the end of 1934 was approximately 32 miles long and 24 miles wide. It had spread most rapidly northeastward and southwestward until it encountered obstructions in the form of woods and waste lands in the southwest and woods and hilly country in the northeast. After that time the spread was slow in these directions and faster westward, in which direction there were fewer obstructions to its progress.

If the boundaries set in 1926 are considered as accurate, the length of the colony increased $1\frac{3}{8}$ miles per year in opposite directions. During the same period the colony widened seven-eighths of a mile per year in opposite directions.

If the 1928 boundaries are considered as the true ones for that year—and in the writer's opinion they are more nearly correct than were those assigned for 1926—the colony lengthened from 19 miles to 32 miles in 6 years, an average of $2\frac{1}{6}$ miles per year, or $1\frac{1}{12}$ miles in opposite directions. During the same period it widened from 17 to 24 miles, an average of $1\frac{1}{6}$ miles per year, or $\frac{7}{12}$ of a mile in opposite directions. These last figures show that, although yearly records would indicate occasional migrations for considerable distances, the average extension of the infestation in any one direction at most has been but little over a mile per year.

In May and June, when scouting for *Harmolita tritici* was done largely by sweeping, it was observed that on the clear, warm days, when conditions for migration were most favorable, the ground winds were northerly, and that on cloudy or rainy days the ground winds usually were southerly. It is probable that these winds influenced the northerly and southerly trend in the migrations, but the topography and vegetation of the country were also favorable to the migrations in these directions.

The Lebanon Colony

The area occupied by the Lebanon colony is, in general, flatter and less wooded than the Molalla area. It would seem that the accurate determination of the boundaries of this colony from year to year would have been easier than in the Molalla district, but this was not so because of the scarcity of pure stands of wheat in some of the large areas, and the many fields devoted to the production of grass, hay, oats, and other crops, in any of which volunteer wheat might occur. Nevertheless, in spite of these differences the history of the enlargement has been similar to that of the Molalla colony.

The presence of the jointworm in this section was first noted late in the fall of 1926, but the boundaries that year were not determined. By 1927 the colony was found to lie south of Albany, extending from Lebanon to a point 1 mile east of Tangent. It was 8 miles long and $5\frac{1}{2}$ miles wide, the long axis lying in a northeasterly and southwesterly direction. Figure 4 shows the limits and location of the Lebanon colony from 1927 to 1934, inclusive. No separate boundaries are shown for 1934 because no extensions were found that year.

In the fall of 1934 the Lebanon colony was 33 miles long and 16 miles wide. Assuming that the boundaries given for 1928 are correct, in the following 6 years the colony increased in length from 15 to 33 miles, or 18 miles, an average of $1\frac{1}{2}$ miles per year in opposite directions. In width it increased from 8 to 16 miles in 6 years, or 8 miles, an average of $\frac{2}{3}$ of a mile per year in opposite directions. The topography of the country and the location of the original colony evidently prevented the equal spread in all directions, in some years most of the total increase apparently being in one direction and in other years in other directions. Most of the movement has been southerly and westerly, probably on account of the prevailing winds on days favorable to migration, but also because by 1927 the colony had been

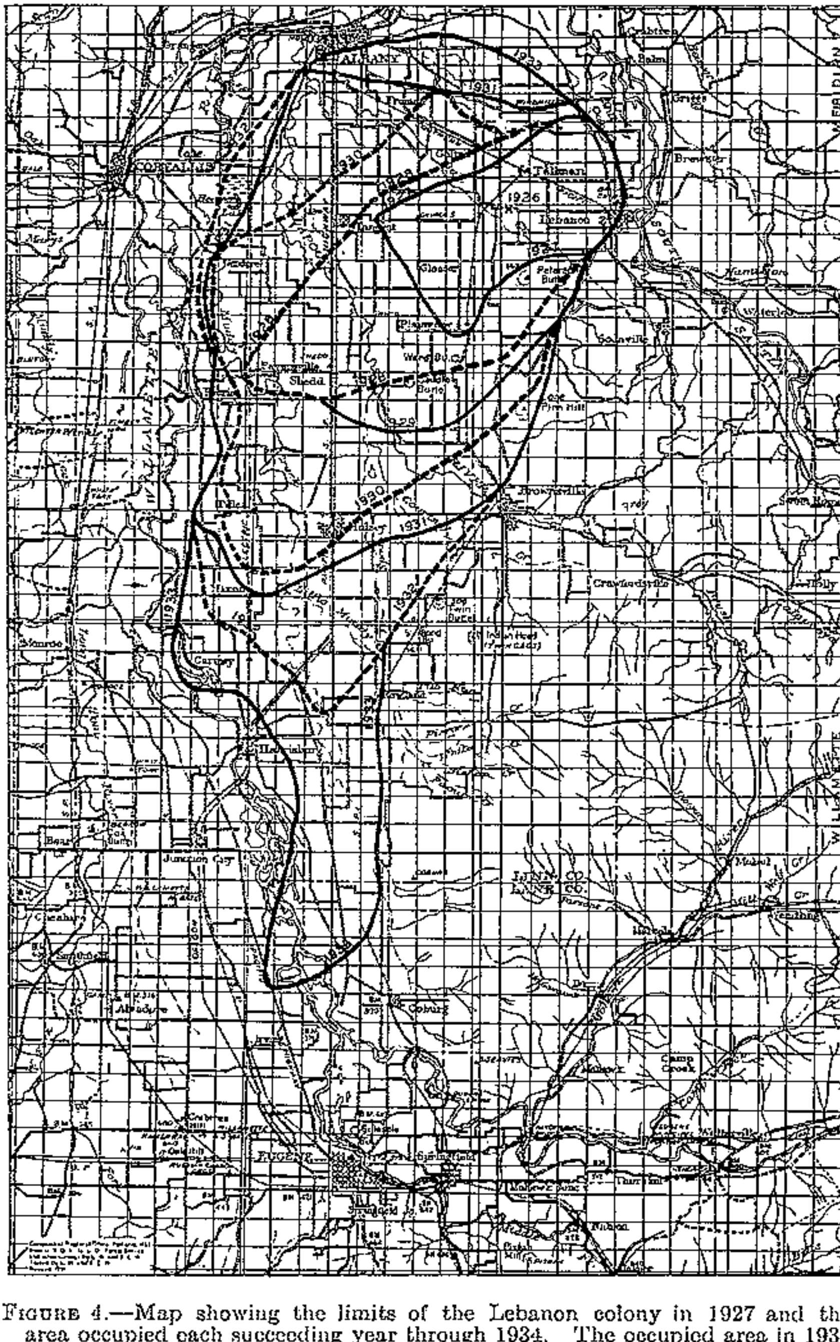

FIGURE 4.—Map showing the limits of the Lebanon colony in 1927 and the area occupied each succeeding year through 1934. The occupied area in 1934 was the same as in 1933.

checked on the east by foothills of the Cascade Range and on the north by the wooded broken country of the Santiam River and its tributaries. It seems probable that the scattered wheat in the more open country around Halsey and southward forced the insect to make longer than normal migrations in search of wheat.

Figure 4 shows that in 1933 an infestation was found northeast of Irving on the Pacific Highway about 9 miles south of the southern boundary for 1932. This infestation was on the left bank of the Willamette River. In the writer's opinion the jointworm must have been present in the region north of Coburg for some years, but, owing to the scarcity of wheat in that section, was rare and widely scattered and consequently had not been discovered.

RATIO OF MALES TO FEMALES

Owing to the fact that males tend to remain in the stubble fields and the females to scatter in search of growing wheat, it is impossible to obtain by sweeping any reliable estimates as to the relative numbers of males and females in the total emergence. Records of issuance in the laboratory, however, should be accurate, for although the males are more fragile than the females and it appears that the mortality just before emergence from the stems is a little higher among them than among the females, the same appears to be true in the field, and the proportions shown in the laboratory should be applicable in the field.

Records of issuance (table 3) from various lots of material from 1926 to 1933, exclusive of 1931, show that females generally outnumber the males. For the whole period 59.8 percent of the specimens reared were females. It may be noted in this table that the percentage of the females in the large emergence of 1928, 60.2 percent, was very close to the average for all the years.

TABLE 3.—*Emergence of adults of Harmolita tritici from cages in the laboratory, 1926–33*

Year	Males	Females		Year	Males	Females	
	Number	*Number*	*Percent*		*Number*	*Number*	*Percent*
1926	676	1,065	61.2	1932	144	376	72.3
1927	1,184	1,397	54.1	1933	271	400	59.6
1928	1,847	2,799	60.2				
1929	170	261	59.7	Total	5,178	7,713	59.8
1930	880	1,415	61.7				

OVIPOSITION

Since under favorable conditions the females leave the stubble fields soon after emergence and most of the males remain there, it is probable that mating is accomplished soon after the emergence of the females. Practically all the eggs are fully developed at the time of emergence and the preoviposition period is short, although this time has not been accurately determined by the writer. Since the Forest Grove, Oreg., laboratory is located outside the infested territory, it was not advisable to bring adults to the laboratory at the proper time for breeding work in cages, and all observations upon oviposition and related subjects were made in the field and on field material. Even when females were very abundant in the field, only a small portion of them seemed to be attempting to oviposit, and, in spite of the many days spent in the field during the flight period, in only a small number of cases was oviposition actually observed. In these instances, however, the procedure of females in oviposition was the same as noted by Phillips (*6*). On some days when many females were about, no oviposition seems to have been attempted.

In this bulletin the term "joint" is used to refer to the internode rather than to the node of the culm. It is probable that the joint selected for oviposition is usually rather soft, but it is not necessarily short; in fact, it may be well formed and fairly hard, as ovipositions have been observed in the long joints. The great number of examinations of infested wheat made during the eight seasons previous to and including 1934 would indicate that in the Willamette Valley most of the eggs are placed in the second and third joints, whether the season is early or late, and not, as might be expected, only in the higher joints when the wheat is high. The description of two specific attempts to determine this point in the field will serve to illustrate conditions as the writer found them.

In 1932 some good wheat 16 to 24 inches in height, examined on May 10, or 4 days after the first adults had issued, showed that the first joints were all long and hard, the second joints practically all hard (one exception in the sample), the third joint varying from hard to soft and ⅛ of an inch to 4 inches in length, and the fourth joint and those above all soft and short. If hardness of the joint prevented oviposition, practically no infestation would have been expected in the second joint, limited oviposition in the third joint, and heavy oviposition in the fourth joint and above. The findings, however, were not in accordance with these expectations, since 500 stems examined just before harvest showed 63 second joints, 190 third joints, and 34 fourth joints infested. These infested joints were in the strong main stems and not in the late spring tillers, and were, therefore, in the same class of stems as those examined on May 10.

On the same date, May 10, males and females of *Harmolita tritici* were introduced into two cloth field cages containing uninfested wheat from 3 to 4 feet high, at a time when in all probability the soft joints were the fourth joint or above. Examination of these stems at harvest showed infestations as follows: First cage: Second joint, 11; third joint, 31; fourth joint, 3. Second cage: Second joint, 12; third joint, 43; fourth joint, 4.

In considering these figures it should be borne in mind that most of the oviposition in the field would have taken place during a considerable period after the day on which the green wheat was examined, during which time the joints were lengthening and hardening rapidly. In the cages this would be true to a lesser extent, since adults of only one lot were introduced and these could have laid their eggs within a short time.

Although oviposition in most of the wheat examined occurred principally in the second and third joints, occasionally there was more than the usual oviposition in the first and fourth joints. With one or two exceptions, these variations from the normal have been slight, and in most cases have given little indication of the kind of joints preferred. In 1932 one field more advanced in growth than most of those in the vicinity showed much more oviposition in the first joint than in any of the others. This might indicate a preference for the harder joints, but there is evidence against this view. The one most notable exception to the general rule was a field in the Molalla district, which in 1931 showed practically all the infested joints to be above the second and most of the infestation to be in the fourth joint. This condition was general over the field and did not apply to a few plants only in a small area, as is usually the case with such variations. The previous history of the field was unknown, but its condition when examined approximated that of other fields in the vicinity which showed most of the oviposition in the second and third joints. No satisfactory explanation of this occurrence has been found.

The tendency of the jointworm infestation in field wheat in the Willamette Valley to be concentrated for the most part in the second and third joints might be explained by assuming a phenological relationship between the period of emergence of the adults and the development of the wheat. That some such relationship may exist is indicated by the tendency in Virginia and elsewhere in the Eastern States for the infestation to be heaviest in the late wheat. As these observations and many others on field wheat between 1926 and 1934 indicate, however, there seems to be a rather wide range in the stage of development in which fall- and winter-sown wheats are acceptable for oviposition in the Willamette Valley. Most of the selectivity shown there is in the avoidance of late or, for the most part, spring wheats. In this may be found a possible explanation of the many observations in the Eastern States that indicate that poor wheat is preferred for oviposition; for if late wheats were preferred in the Willamette Valley, as they appear to be in the Eastern States, the wheat making the least vigorous growth would be the most heavily attacked.

EGG CAPACITY OF THE FEMALES

To obtain definite information as to the reproductive ability of *Harmolita tritici*, two lots of females taken from stubble in cages were dissected and their eggs counted. The females were taken within a day or two after emergence when inspection showed that practically all their eggs were fully developed. In 1928 accurate counts of the egg contents of 199 females were obtained. The maximum number of eggs per female was 124, the minimum 33, the average 84.3, and the mode 99. Eighty-eight eggs occurred the next largest number of times, namely, 7. There is evidently great variation in egg capacity. In 1929, 84 females were examined and their eggs counted. The largest number of eggs found in a single female was 155, the smallest 51, and the average per female was 98.2. Egg capacities of 107 and 102 occurred most frequently, namely, 5 times each.

Early in these dissections it was observed that in general the egg capacity is correlated with the size of the female although some exceptions were noted. Inasmuch as the size of the female is determined by the size of the larva which produced it, feeding conditions during the larval period may be a determining factor in the reproductive ability of the adult. If such is the case, females issuing from poor wheat having thin-walled stems would be expected to have low egg capacities. The only evidence that is available to support such a theory is in the dissections just discussed. It is known that the females of 1928,

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having an average capacity of 84.3 eggs, came from relatively poor wheat, whereas those of 1929, having an average capacity of 98.2 eggs, came from strong, vigorous wheat with heavy stems.

If 90 eggs is considered as the average capacity of all females issuing over a series of years, which is roughly the average of the 2 years represented by the dissections, and approximately 60 percent as the average of the total issuance that are females, then the potential rate of reproduction of *Harmolita tritici* with 1 generation per year is 54 to 1. For various reasons actual increase in the field cannot approach this. In Oregon parasitism alone, as shown later, would at times reduce this rate of increase to about 15 to 1 and small samples have at times indicated a reduction to about 5 to 1.

DEVELOPMENT AND FEEDING OF THE LARVAE

The incubation period of the egg in Oregon has not been determined by the writer. In the Eastern States it is said by Phillips to be 10 days (*8, p. 4*).

The writer studied the larvae only in the field, and the development was not followed so closely as would have been possible in laboratory breeding. Phillips made detailed studies of the larva, and adequate figures of the first and last stages were given by him (*9*). It will be sufficient here to state that the larva molts three or four times before reaching maturity. The first instar is minute, frail, whitish, and translucent. It is subcylindrical, tapering at each end, and has a protruding head. The mouth is located below and back of the apex of the head. In specimens examined by the writer there has been considerable variation in the shape of the protuberant head, ranging from the broad conical type shown in Phillips' drawing to a very sharp conical type. This variation is probably due to the apparently flexible nature of the protuberant parts. The smallest first instar measured by the writer was 0.4582 mm. long and 0.0790 mm. wide. This one was probably just out of the egg. The largest was 0.8058 mm. in length and 0.1738 mm. in width. The latter was doubtless about ready to molt. As shown by the figures, the ratio of the length to the width is variable. The mature larvae are yellow, cylindrical and have a hemispherical head. They vary considerably in size, the maximum length being about 6 mm. and the minimum 3 mm. or less. The intermediate stages are very similar to the last except for size, and the color seems to become more yellowish at each molt. The setae are small and inconspicuous. The mandibles are small, triangular in outline, and brownish.

Owing to the long period during which females are abroad and ovipositing, the first instars may be found in growing wheat over a considerable period, especially in a cool, rainy season when issuance from the stubble is prolonged. The best records for occurrence in field wheat were made in 1928, a season when the adults were present for a relatively short period. The first first instars were taken on May 24 and the last newly hatched one on June 26.

Most of the observations on the feeding of the larvae have been made in field material and incidental to other work. Examination of this material indicated little or no rasping of the plant tissue by the larvae at any time. Newly hatched larvae have always been found bathed in the juice of the plant and frequently in cells at least several times the size of the larvae. Large larvae usually occupied the whole cell, and the juice was not so much in evidence; but even in these cases no frass was discernible in the cells from gross examination under the binocular microscope, and the walls of the cells appeared smooth and more or less polished. Apparently the larvae feed until fully grown almost entirely on the juice which flows into the cells.

In field material in Oregon the time required for a gall [7] to become well formed varies considerably, galls containing second instars sometimes being imperfectly formed whereas others containing first instars may be well formed and, to external appearances, complete. Sometimes prominent galls are not formed at all, but in Oregon field wheat prominent galls appear to be of more frequent occurrence than any other type.

The writer has stated that galls are sometimes formed before the hatching of the egg (*2, p. 4*). This assertion was based on the statement of Phillips (*6, p. 144*) and various observations on field material. Small first instars have frequently been taken from well-formed galls and on two occasions the minute larvae had, to all appearances, just issued from the eggs, having the shells adhering to them. While no unhatched egg has been dissected from a well-formed gall, it seemed reasonable that in the case of the two larvae just mentioned gall formation had begun before the hatching of the eggs. Eggs have occasionally been located in the stems by pale, oval spots of about the shape and size of jointworm cells. These have appeared to be the beginnings of cells and the gall tissue surrounding them. Well-formed galls have frequently been opened in which neither larvae nor eggs could be found. While it is probable that remains of eggs and first instars could be overlooked in some cases, their absence was so frequent that it seemed more likely that no eggs had been laid and that the stimulus which produced the galls had been received from punctures by the females in attempted ovipositions.

Phillips and Dicke have since shown that in wheat, in cages in the East, galls are not formed until after the egg has hatched (*11*), unless the loss of polarity which appears in cells above the eggs is accepted as the beginning of the jointworm cell and associated gall tissue (*11, pp. 369, 371*); and they state that the larva does not issue from the shell at once but feeds for some time through the hole in the shell (*11, p. 369*). The loss in polarity in the cells above the egg may be in part responsible for the formation of the pale spots which have been observed on the surface of the stem over the eggs and the feeding of the larva from within the shell may account for the two small larvae found in the well-formed galls mentioned above.

VARIETIES OF WHEAT AFFECTED

The varieties of wheat generally grown in the Molalla district during the period of this investigation were White Winter, Wilhelmina (White Holland), Kinney, Rink, Prohibition, Jenkin, and others. Kinney,

[7] There is a lack of uniformity in the use of terms referring to the galls and cells formed by *Harmolita tritici*. Sometimes the word "gall" is used to include the whole gall formation in an internode which surrounds a group of larvae in cells. Since small galls are formed by single larvae, and the gall formation in a whole or a large part of an internode seems to be caused by a merging of the gall tissue surrounding single larvae, the writer restricts the term "gall" to the gall formation around an individual cell, and the whole gall structure in an internode is referred to as a group of galls. Such definition will facilitate description of the growth of individual cells and the surrounding gall tissue.

Foisy, Rink, and Jenkin's Club are spring wheats, but in the Willamette Valley they are usually planted in the fall or winter. All these varieties are considered to have strong, straight stems, but there is much difference among them in the toughness and thickness of the wall of the stem. Kinney, which was grown more generally than any other in the sample area of the Molalla district, has an unusually hard, strong, and tough stem, especially for some distance above the nodes. In all the varieties mentioned, however, the wall of the stem is thick enough to permit the formation of firm, thick-walled cells and to insure a plentiful supply of sap.

Field studies over a period of 8 years have given no indication of the selection or avoidance by the jointworm of any of the wheats mentioned or of others grown in the infested territory; all varieties at one time or another have suffered considerable infestation. In some seasons differences were shown in the infestations in the different varieties, but similar differences have also been shown in fields containing the same variety. In short, all the apparent selection observed was correlated with the development of the wheat, the location of infested stubble, and the population of adult jointworms in the vicinity, and could not be attributed to the variety of wheat grown.

In their study of the oviposition of *Harmolita tritici* in relation to the development of the wheat in Virginia, Indiana, and Kansas, Phillips and Dicke (*11, p. 368*) found that the meristemic regions of the stem in Kansas wheat were "in a hardened condition and unsuitable for oviposition at the time of emergence of *Harmolita tritici*;" but, since *H. tritici* does not occur in Kansas, they estimated the probable time of emergence from the time of emergence of *H. grandis* form *grandis*. They suggest further (*11, p. 368*) that the condition of the meristem in Kansas plants could be due to varietal or climatic differences. When the writer studied the distribution of the wheat jointworm in Utah in 1931, the only infestations he found were confined to Turkey wheat near Tooele, Tooele County. The principal varieties of wheat grown in Kansas for many years have been Turkey and its derivatives. It would appear, therefore, that the conditions in the stems of Kansas wheat which render them unsuitable for oviposition by *H. tritici* are the result of climate rather than of the varieties of wheat grown.

INJURY

Injury to wheat and losses to the crop due to the jointworm are caused: (1) By a weakening of the stems through reduction in their diameter at the base or top of the group of galls so that considerable falling may occur, especially if high winds prevail when the wheat is tall and heading; (2) by a reduction in the number of kernels per head; and (3) by a reduction in the weight of the individual kernels. In the Williamette Valley, during the 8 years previous to and including 1934, loss caused by the falling of stems was not considerable except in 1929, when heavy infestations, with large numbers of jointworms per infested joint and high winds in June, caused considerable wheat to fall out of reach of the binder. The reduction in the weight of the kernels and especially in the number of kernels per head is difficult to estimate. It has been observed that in the Eastern States the jointworm prefers poor wheat in which to oviposit. If the poor stems within a field were selected for oviposition, comparisons of the weight of grain from infested and uninfested stems would greatly exaggerate the injury for which the jointworm was responsible. In Oregon, examination of stems sometimes showed the poorer ones more heavily infested, but this condition always proved to be strictly local within the field itself; and if careful examinations were made of all parts of the field, portions would be found in which the good stems seemed to have been preferred. Apparently the selection in these cases depended on the stage of development of the stems at the time the ovipositing females were present and not on the quality of the stem.

Only one case has been observed where conditions throughout a whole field indicated a preference by the jointworm for any particular kind of stems. In this case it was the strong stems and not the weak ones that were most heavily infested. In the writer's opinion, the strong stems were in a condition more favorable for oviposition at the time when the greatest number of adults were in the field. In fall- and winter-sown wheat, as previously stated, the late spring tillers, which are the poorer ones, were more frequently uninfested than infested. These tillers usually produced heads, and their inclusion in the weighings tended to reduce the difference in weight between infested and uninfested stems. A few of these late tillers could be found infested at any time, however, and these were probably oviposited in by the females last in the field.

It has seemed to the writer that the contradictory conclusions of various entomologists as to the injury caused by different species of *Harmolita* may have resulted from failure to recognize that apparent cases of selection may have no connection with the quality of the wheat stems, the stand of wheat, or the variety. It is more probable that the character of the stems infested depends mainly on the development of the plant at the time when most of the ovipositing individuals are present. That errors of this kind have been made is indicated by the disagreement among Russian entomologists regarding *Harmolita eremita* (Portschinsky), a pest of rye in Russia. Balachonow (*1*) states that a comparison of grain from injured and uninjured plants proved that the species is of no economic importance on rye. Ponomarenko (*14*) states that the species is very injurious and that the loss is not easily apparent because only the strong straws are infested. Medyakova (*4*) claims that this species is of no economic importance and that only stems that are already thin and poorly developed are attacked.

In his estimates of injury Phillips, by matching heads from infested and uninfested stems as to length and comparing the weights of the wheat from these heads, avoided the errors that would be caused if the jointworm selected poor stems for oviposition. From illustrations in Phillips' article (*7*) the writer estimated that these losses ranged from 12 to 30 percent (approximately), according to the number of joints infested per stem. In a later article Phillips (*8*) stated that the wheat from infested stems was inferior to that from uninfested stems, but he did not make clear whether most of the loss in weight was due to a reduction in the number of kernels per head or to a reduction in the size of kernels. Since heads of equal length would tend toward an equal number of kernels, it would seem that most of this loss of weight might be attributable to the smaller size of the kernels.

The writer considers that the injuriousness of *Harmolita tritici* has been clearly demonstrated by Phillips. The present work was supplementary to his, and an effort was made to learn the effect of the jointworm on the number of kernels per head as well as the size of the kernels. The method used throughout the work was as follows: A spot in a field was selected, uniform in character, which preliminary examinations had shown to contain about an equal number of infested and uninfested culms. The whole sample was taken from the one spot, including all the tillers of all the plants. The plants taken were thus equidistant from, and similarly oriented to, infested stubble, and were in a similar stage of growth, of similar stand, and on similar soil. Variations due to the conditions of the stand or its position with regard to stubble would thus be eliminated, and any selection made by the jointworm in this wheat would apply only to the individual tillers of the sample plants, which as stated has been manifest chiefly in avoidance of the late small tillers which produce small heads. In other words the samples were from poor stands, fair stands, or good stands of wheat; and the effect of the jointworms, as determined by the weight of the samples, was upon that one kind of wheat. The sample weights are figured on the basis of 100 heads of the wheat from each classification, that is, uninfested, 1 joint infested, 2 joints infested, and 3 joints infested. It was not expected that these results would be more than approximate, but it was felt that the averages obtained over a series of years would demonstrate injury, if any occurred, and give a fair estimate as to the amount. The percentage of reduction in the various samples weighed during the years 1929 to 1933, inclusive, and other data are given in table 4.

TABLE 4.—*Effect of extent of jointworm infestations on the yield of wheat in the Willamette Valley, Oreg.*

Year	Field No.	Weight of 100 heads of uninfested wheat	Loss in weight per 100 heads with—		
			1 joint infested	2 joints infested	3 joints infested
		Grams	*Percent*	*Percent*	*Percent*
1929	1	130.9	3.6		
	2	105.3	17.9	28.5	
	3	109.9	6.8		
1930	1	162.4	4.7		
	2	186.9	16.0	21.3	
	3	123.9	3.8		
	4	104.2	(1)		
1931	1	[2] 153.0	22.2	31.6	42.1
	2	138.3	12.3	17.0	
	3	109.5	[3] 6.1	29.7	
	4	98.9	15.8		
	5	134.4	10.8	[4] 18.5	
	6	175.7	17.6	[4] 33.1	
1932	1	[5] 76.2	[3] 3.2		
	2	100.1	[3] 5.3		
	3	[6] 151.5	15.4	30.8	46.2
	4	170.4	22.3		
	5	78.8	10.7		
1933	1	169.9	9.1		
	2	223.2	26.0		
	3	168.7	9.2		
	4	149.2	35.1		
Average			13.5	26.5	44.2

[1] This sample was from a field in which only the best stems were infested and an increase of 42.6 percent in weight was observed.
[2] This field showed infestation mainly in the high joints; infestation was uniform and the sample was taken from the whole field. Field infestation, 79.7 percent.
[3] Heads from these stems were matched with those from uninfested stems as to length.
[4] Sample too small. Not included in average.
[5] This included heads from an unusually large number of late tillers which were uninfested.
[6] On account of a very heavy infestation in this field it was not possible to find enough uninfested stems to make an estimate of the loss per 100 heads. It was necessary to use those with one infested joint instead of uninfested heads as the basis, and to use the difference between the weights of heads from stems with 2 and 3 joints infested as representing the percentage loss for each infested joint beginning with the first. The figures in the percentage loss columns therefore are computations.

Table 4 shows that, with 1 exception, all lots from infested stems showed a loss in weight. In the single exception, concentration of the jointworm in strong stems was so obvious that it would have been easily discernible even to the most inexperienced observer. In the cases where 2 joints were infested there was a greater loss of weight than in those where only 1 joint was infested, and in the 2 cases where it was possible to secure weights of 100 heads from stems with 3 infested joints there was a further loss. In 3 instances the heads from uninfested and infested stems were matched as to length and in all cases the grain from the infested heads weighed less than that from the uninfested heads. The average loss in 5 years with 1 joint infested was 13.5 percent, in 4 years with 2 joints infested it was 26.5 percent, and in 2 years with 3 joints infested it was 44.2 percent.

In 1933 a record was made of the weights of kernels and the numbers of kernels per head from uninfested and infested wheat in several of the preceding samples which had been kept on hand in the laboratory. Table 5 shows that there was a loss in the weight of the kernels of each sample, but that the greatest loss was in the number of kernels per head.

TABLE 5.—*Effect of extent of jointworm infestation in wheat on the weight of kernels and the number of kernels per head, Willamette Valley, Oreg.*

Sample No.	Reduction in comparison with kernels from uninfested stems in—					
	The weight of 1,000 kernels with—			The average number of kernels per head with—		
	1 joint infested	2 joints infested	3 joints infested	1 joint infested	2 joints infested	3 joints infested
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	4.4			22.5		
2		5.2	11.2		28.2	33.8
3	2.5			4.7		
4		1.0		17.9	25.0	

CONTROL OF THE JOINTWORM

The investigations in Oregon indicated no methods of control that have not been recommended previously. The writer, however, was able to check the utility of some of them. Crop rotation can be more readily modified for purposes of jointworm control in western Oregon than apparently has been possible in the Eastern States. It is believed that effective cooperation among farmers to this end can be more readily obtained if the extent of the damage that the jointworm can do is definitely demonstrated; for however familiar the farmers may be with the habits of the jointworm and with methods of controlling it, they are not likely to adopt remedial or preventive measures to reduce an injury the extent of which remains obscure. On several occasions heavily infested fields in the Molalla district have produced as high as 35 bushels to the acre, which was satisfactory to the growers until, as a result of studies of the effect of the jointworm on yield, it was shown them that from 20 to 30 percent of the potential yield was lost because of jointworm feeding.

The considerable information obtained on the dispersion of the insect, its reproductive capacity, and its habits in general, previously considered in this bulletin, is important in its relation to the effectiveness and interrelation of the parasites and other factors in natural and artificial control.

Apparently in western Oregon the habits of the insect are somewhat different from those in its eastern area of distribution, and climatic control is not the same. In Oregon the jointworm does not select poor wheat in which to oviposit, and summer-killing and winter-killing of the jointworm larvae and pupae in the stubble are relatively unimportant.

Natural Control by Parasites

If consideration of the large but variable loss among the adults attendant upon their spread to new fields is excluded, parasites appear to be the most important factor in natural control in Oregon. The various species of parasites and their relation to jointworm control were studied continuously between the discovery of the jointworm there in 1926 and the fall of 1934. Although the intensive study of the parasites as a group and their effect on the jointworm may be considered more or less complete, general observations to determine their status from year to year and life-history studies of certain species should be continued.

The problem of the parasitization of the jointworm has been attacked in two ways, (1) by a study of the life histories of the various species and (2) by a study of the combined effect on the jointworm of all the species. Since the life histories of many of the jointworm parasites have been studied elsewhere under controlled and field conditions, most of the study in Oregon has been upon the combined effect of all the parasites on the jointworm from year to year and the effect of parasitization of each species upon the others.

The life-history phase has been studied largely by field observations on the various species of parasites and, to some extent, by breeding in the laboratory. The second phase has been investigated by dissection of infested joints, usually in stubble, from selected fields at various times of the year and the determination of the extent of parasitization and the species involved. Considerable preliminary study was made of the eggs, larvae, and larval molt skins and head capsules of the parasites, and of the jointworm cells after they had been occupied by various parasites, so that the species in the cell could be determined with a high degree of accuracy at all stages of development and even after emergence. Some errors in determination doubtless were made, but these are thought to have been relatively rare and mostly in connection with issued parasites or first-instar parasites, some of which were crushed in dissection. In practically every case where there was doubt as to identity, only some rare species was concerned so an occasional error affected the recorded percentage of parasitization by any one important species very little, and the percentage of parasitization by all parasites combined not at all.

As is well known, it is very difficult if not impossible to obtain an absolutely accurate picture of parasitic activity in the field by field observation, by rearing parasites in cages, or even by careful dissection of field-collected material. The last method is probably the best, but changes are taking place in the field more or less continuously, sometimes with great rapidity, and because of the vast amount of work involved it is practically impossible to examine enough material from any one source at sufficiently frequent intervals to obtain all the desired information. In the case of the wheat jointworm this problem is particularly difficult because of the predatory activities of the parasite *Eurytoma parva* (Phillips), which not only devours many eggs and small larvae of *Harmolita tritici* in green wheat but also may continue to destroy large jointworms and other parasites in stubble. It should be pointed out, therefore, that while the writer believes that data such as those given later in table 6 are as accurate as could be obtained and more extensive than usual, the destruction for which the parasites were actually responsible during the complete life cycle of *H. tritici* was doubtless greater and probably considerably greater than that indicated by the figures.

The tables and charts which appear in this bulletin in this connection should be considered from the foregoing point of view. In spite of their limitations, however, it would be unwise to neglect a careful study of these data and pointless to disregard the additional destruction of jointworms which, as the investigation progressed, the writer observed to be effected in various ways, merely because it proved impossible to devise any means of measuring this additional destruction exactly. It should not be presumed that because the figures obtained from stubble examination do not and cannot be made to tell the complete story of parasitic activity, they are inaccurate. They represent very closely the conditions of parasitization at the time the collections were made, and only by a careful study of these collections, in conjunction with others from growing wheat, and by careful study of the habits of the parasites can some comprehension of the real value of the parasites be attained.

In 1926 and 1927 the infested joints were taken from various fields in the Molalla and Lebanon districts. From 1928 to 1933 the joints were taken from a sample area about 5 miles west of Molalla, which comprised two adjoining farms on similar soil.

Stubble of 1926 was examined in the fall, winter, and spring of 1926–27. The material dissected consisted of 154 infested joints which contained a total of 1,545 individual cells, an average of 10 cells per infested joint. The most important parasite found in this material was *Ditropinotus aureoviridis* Cwfd. Parasitization by this species ranged among the different lots from 7.8 to 51.5 percent, with an average of 22.8 percent. Other parasites, the most common of which was *Eupelmella vesicularis* (Retz.), increased the average parasitization to 23.7 percent.

Stubble collected between July 5, 1927, and April 27, 1929, had 170 infested joints, which contained a total of 1,569 cells, an average of 9.2 cells per joint. *Ditropinotus aureoviridis* was the most numerous of the parasites, parasitization ranging from 0.96 to 58.9 percent and averaging 18.0 percent. The low parasitization of 0.96 percent was in a relatively large sample taken July 5, 1927, before many adults of *D. aureoviridis* had issued from the overwintered stubble to parasitize the jointworms in the new wheat. If this collection were omitted from the calculations, the average parasitization by *D. aureoviridis* would be 26.7 percent. The parasite *Eurytoma parva* was first observed in these collections. It, together with a few eupelmids, raised the average parasitization to 18.8 percent with the July 5 collection included and to 27.7 percent if that collection is excluded.

In 1928 a more systematic study of parasitization was begun in the sample area of the Molalla district. It was the intention to make collections from a single farm, but as suitable wheat was not grown on the selected farm every year, it was necessary in some years to collect from an adjoining farm. Both farms were on similar soil and were similarly operated.

Three collections were made of 1928 stubble, one just subsequent to harvest, one late in the fall, and one the following spring shortly before the emergence of the first jointworm adults. Since the collection from the sample farm during the first year as well as supplementary studies showed practically no winter-killing of the jointworms or any of its parasites, or any material difference in parasitization between the late-fall and the early-spring collections, spring collections from the sample farm were omitted after the first year, and the effect of winter-killing was checked by studies of various supplementary collections.

It was desired to dissect about 2,000 galls in each examination, and with an average of 10 cells per infested joint, 200 joints would have been sufficient. Owing to variations in the extent of infestation and in the number of cells per infested joint, however, 2,000 cells were not always obtained in a single collection. In August 1932 a supplementary collection was made to obtain the desired number, but by this time changes had taken place in the extent of parasitization by some species. In general the field was covered systematically so that the sample would be representative, but sometimes most of the jointworm infestation was concentrated in certain portions of the field, so more of the examined material came from these portions than from others. Table 6 shows the parasitization in the sample area from the post-harvest examination of 1928 to late in the fall of 1933.

TABLE 6.—*Parasitization of Harmolita tritici in stubble on the sample farm, Molalla, Oreg., 1928–33*

Crop year	Time of collection	Infested joints	Cells occupied	*Harmolita tritici*	Parasitization of occupied cells					Average data on occupied cells per infested joint	
					Ditropinotus aureoviridis	*Eurytoma parva*	Eupelmids	Other parasites	Total parasites		
		Number	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*General average*
1928	Post harvest	200	2,139	2,027	2.8	2.3	0.05	0.05	5.2	10.7	8.9
	Late in fall	200	1,592	1,334	14.5	1.0	.70	0	16.2	8.0	
	Spring of 1929	200	1,598	1,358	13.1	.4	.15	1.40	15.0	8.0	
1929	Post harvest	143	2,068	1,802	8.5	1.4	.05	.05	10.0	14.5	13.8
	Late in fall	200	2,677	1,730	33.0	1.8	.26	.30	35.4	13.4	
1930	Post harvest	200	1,906	1,546	11.1	7.0	.06	.90	18.9	9.5	8.8
	Late in fall	200	1,601	715	50.0	2.5	1.60	1.20	55.3	8.0	
1931	Post harvest	201	1,893	757	21.0	36.0	2.70	.26	60.0	9.4	8.8
	Late in fall	216	1,750	568	29.2	32.8	5.40	.10	67.5	8.1	
1932	July 13	180	1,063	378	3.5	61.0	0	0	64.4	5.9	6.2
	Aug. 23	118	784	323	9.8	48.3	.38	.26	58.8	6.6	
	Late in fall	267	1,662	469	20.3	48.3	2.30	1.00	71.8	6.2	
1933	Post harvest	301	2,100	871	7.2	50.6	.00	.10	58.5	7.0	6.8
	Late in fall	290	1,891	656	10.5	52.1	2.10	.60	65.3	6.5	

In reviewing the data in table 6, which are graphically represented in figure 5, several important facts are noted. In figure 5 the *Harmolita* line is based on the difference between 100 percent and the percentage of total parasitization. Parasitization by *Ditropinotus aureoviridis* increased until the fall of 1930, when a maximum of 50 percent was attained. After that there was a gradual decrease in parasitization by this species until a minimum of 10.5 percent for late fall parasitization was reached in 1933. There was always an increase in parasitization by *D. aureoviridis* between harvest and late in the fall which, according to studies of its seasonal history, probably was brought about by additional oviposition by adults of the first

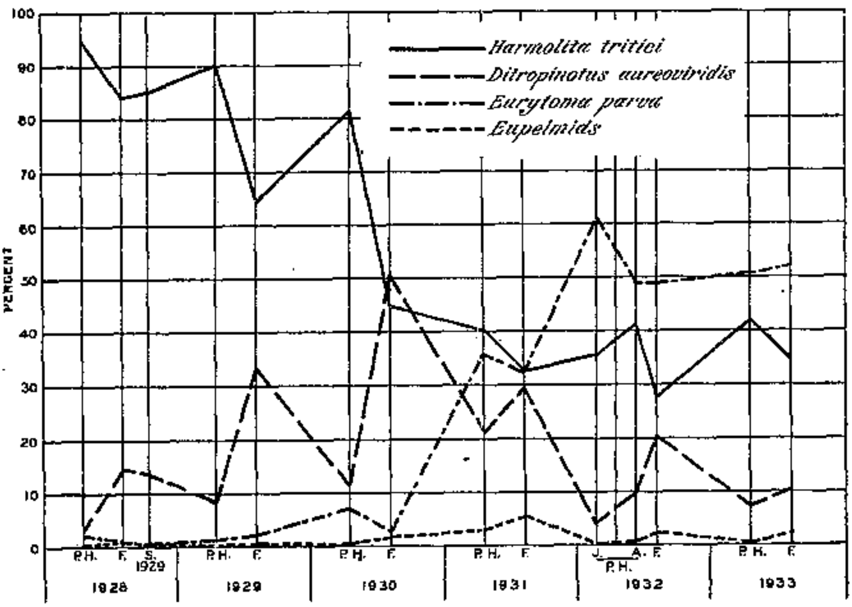

FIGURE 5.—Percent population represented by *Harmolita tritici* and its parasites in stubble on the sample farm, Molalla, Oreg. The percentage of *H. tritici* destroyed during its complete life cycle by all the parasites combined, and especially by *Eurytoma parva*, was actually greater than that indicated here: *S*, Spring collection; *PH*, postharvest collection; *F*, fall collection; *J*, July; *A*, August.

emergence and by some of the second emergence as well. Parasitization by *Eurytoma parva* was low from 1926 to 1930, inclusive, although there was some increase in 1930. In 1931, the year following the maximum parasitization by *D. aureoviridis*, there was a large increase in parasitization by *E. parva*. After that there was a more gradual increase which accompanied the decrease in parasitization by *D. aureoviridis*. The highest total parasitization, 71.9 percent, was attained in 1932.

From conditions in the 1932 stubble and the numbers of *Eurytoma parva* abroad in the spring of 1933, a heavier parasitization by this species was expected in the 1933 stubble. Winter-killing of wheat in December 1932, however, and late planting of spring wheat, as well as the plowing under of stubble in which the clover had been winter-killed, probably reduced the host population to such an extent that *E. parva* could not function most effectively. Since *Ditropinotus aureoviridis* parasitizes *E. parva* readily, it is doubtful whether the increase in parasitization by *E. parva* was the chief cause of the decrease in parasitization by *D. aureoviridis*.

It may be noted in table 6 that the general increase in parasitization has been accompanied by a decrease in the average number of occupied jointworm cells per infested joint, although this decrease cannot be correlated directly with the extent of parasitization each year. This reduction in number of cells per joint, which accompanies a considerable reduction in the total jointworm population, may be a direct result of increased parasitization. It should be pointed out, however, that a part of this reduction in the number of occupied cells per joint is more apparent than real and, as already mentioned, is caused by the predatory habits of the larvae of *Eurytoma parva*, which sometimes enter more than one cell and destroy more than one larva. Since the average number of living and destroyed jointworms, as well as of the various species of parasites, is based on the number of parasites, jointworms, and issuance holes present at the time of examination, the additional jointworms destroyed by single *E. parva* larvae, or their cells, are not included in table 6, and consequently the average number of occupied cells per joint given is somewhat lower than the true original number. These facts were brought out by the more thorough study of the cells which was conducted during the few years previous to and including 1934, which indicated that earlier examinations had failed to give an entirely correct idea of the original conditions of parasitization and the subsequent activities of the parasites in the material. The fall collections of 1931, 1932, and 1933 illustrate conditions shown by these more careful analyses, but beginning in 1930 all important collections were studied in this manner.

In the fall of 1931, as shown in table 6, 1,750 jointworms and parasites or their issuance holes were found. Careful cell examinations showed, however, that 148 additional jointworms had been destroyed by *Eurytoma* larvae that had entered more than 1 cell, so the original number of jointworms present was 1,898 and the average number of cells per infested joint (or original jointworms per joint) was 8.8 instead of 8.1, the figure given in the table. The examinations also showed that 148 additional individuals of *Eurytoma parva* had been destroyed by some of the other parasites present, acting in a secondary capacity, chief among which was *Ditropinotus aureoviridis*. The original parasitization by *E. parva* was therefore 38 percent instead of 32.8 and the total destruction of jointworms by that species (including those destroyed by *Eurytoma* entering more than 1 cell) was 45.8 percent. Since the jointworms which were destroyed by *Eurytoma*, which were in turn killed by secondaries, were accounted for by the secondaries which were present at the time of the examinations, their destruction did not alter the total parasitization, but the *Eurytoma* which entered more than 1 cell increased the total destruction in the original number of jointworms to 70.1 percent, instead of 67.5 as given in table 6.

In the fall collection of 1932 it was shown that the original number of jointworms present was 1,780 instead of 1,662 and the average number of cells per infested joint 6.7 instead of 6.2. The original parasitization by *Eurytoma* in the original *Harmolita* population was

49.4 percent and the total destroyed by that species (including those which entered more than 1 cell) 56.1 percent. The total destruction of *Harmolita* by all species of parasites was 73.7 percent.

Similarly, in the fall collection of 1933 the original number of *Harmolita* present was 1,978 and the average number of cells per infested joint 6.8. The original parasitization of *Eurytoma* was 53.1 percent and the total destroyed by *Eurytoma* 57.5 percent. *Eurytoma* which had entered more than 1 cell increased the destruction of jointworms to 66.8 percent.

The foregoing analyses of three fall collections show that only a small part of the decrease in the number of cells per joint over a series of years, insofar as this can be revealed by stubble examination, could be explained by the predatory activities of the *Eurytoma* larvae. Nevertheless, as studies of the activities of the parasite in green wheat show (see p. 25), there seems to be no way of finding out exactly how many jointworms any single *Eurytoma* larva has destroyed.

Infestation in the sample field in 1934 was so low (1.5 percent) that no study of parasitization could be made there. Two small samples were obtained from fields in the same general locality, one in July and the other in November. The first field showed a total parasitization of 60.3 percent, of which 9.4 percent was by *Ditropinotus aureoviridis*, 47.7 by *Eurytoma parva*, and the remainder by *Eupelmus allynii* (French) and *Decatoma amsterdamensis* Gir. The late-fall sample from a field with 6 percent of the straws infested showed a total parasitization of 88.2 percent, of which 37.8 percent was by *Ditropinotus aureoviridis*, 30.2 by *Eurytoma parva*, 11.7 by *Eupelmus allynii*, and the remainder by *Eupelmella vesicularis*, *Decatoma amsterdamensis*, and others. *Eurytoma* larvae that entered more than one cell increased the total destruction to 90.1 percent, the highest yet found in Oregon. Since heavily infested stubble was very scarce in 1934, it is believed that the increase in parasitization by *D. aureoviridis* shown here was caused in part by the adult parasites which issued from various grasses, especially velvet grass (*Holcus lanatus* L.) and *Elymus*, where it parasitizes *Harmolita holci* Phillips and *H. oregon* Phillips (*10, pp. 19, 14*), and that the increase on the part of *Eupelmus allynii* was caused by those issuing from the hessian fly.

Samples were also obtained in 1934 from a field at the southern border of the Molalla colony in July, August, and October. These showed an average total parasitization of 52.4 percent, 33.5 by *Eurytoma parva*, 13.5 by *Ditropinotus aureoviridis*, and 5.4 percent by eupelmids, *Decatoma amsterdamensis*, and undetermined species.

The few samples obtained in 1934, while small, were sufficient to indicate that the reduction in infestation by *Harmolita* had reduced the percentage of total parasitization very little if at all. It seems improbable that this will be further reduced even if *Harmolita tritici* should remain scarce for some years to come.

Although the work in Oregon has given rather complete data on the extent of parasitization in a limited area and over a period of years and these data are believed to give a reasonably accurate picture of the parasitization, the existence of other controlling factors which seem unmeasurable makes an estimate of the exact value of the parasites difficult. Valid inferences, however, can sometimes be drawn from data which are but roughly quantitative.

To obtain as accurately as possible the increase or decrease in the jointworm population in the sample field from year to year from the data given in table 6, the average number of cells per infested joint must be considered as well as the percentage of the culms infested (table 2), and a figure obtained for each year that will represent in a relative sense the actual population of the field. Thus, beginning in 1929, when the population was highest in the sample field, the samples showed a culm infestation of 94.6 percent and an average of 13.8 galls per infested joint.[8] By using 100 culms as the unit from which the actual population was obtained, a figure sufficiently large to permit adequate comparisons with years of smaller populations is obtained. Thus out of 100 culms, 94.6 percent, or 94.6 culms, were infested, and this number multiplied by 13.8 gives approximately 1,305 as the number of occupied cells per 100 culms, which may be considered in a relative sense as the population of the field. Cell occupants, however, consist of parasites as well as jointworms, and this figure cannot be taken as the jointworm population in the fall of the year, when heavy parasitization has taken place, but may be considered as the spring jointworm population before parasitization.

In 1929, with a fall parasitization of 35.4 percent, the fall jointworm population would be 64.6 percent of 1,305, or approximately 843. Since in Oregon there has been but slight winter mortality of the jointworm in unplowed stubble, the latter figure represents approximately the number of adults, both females and males, that would issue from 100 culms and be capable of reproduction in the spring. As explained under the section on egg capacity, the potential rate of increase for a general population of *Harmolita tritici* is 54 to 1. The potential offspring of the fall population of jointworms would thus be 45,522, and the effective rate of reproduction for the original spring population of 1,305 would be 34.9 to 1. It may be seen that the effective rate of reproduction here is inversely proportional to the parasitization.

Similarly, in 1930 the sample field, with an infestation of 91.2 percent and an average of 8.8 occupied cells per infested joint, had a cell or spring jointworm population of approximately 803, or 61.5 percent of the 1929 spring population. With a fall parasitization of 55.3 percent, the fall population of jointworms was 358.9, or 42.6 percent of the 1929 fall population (843), and the potential rate of reproduction in the original spring population was reduced from 54 to 1 to a theoretical effective rate of 24.1 to 1.

By continuing these calculations for the later years figures are obtained on which figure 6 is based. This chart represents the 1929 spring jointworm population and the fall jointworm population of that year as 100 percent, and the populations of the later years as percentages of the populations of 1929. The percentage of parasitization and the rate of reproduction after parasitization are also shown. Although parasitization could not be studied in the sample field in 1934 because of low infestation by *Harmolita tritici*, an estimate was made of the relative population of *H. tritici* for the spring of that year. This is based on an infestation of 1.5 percent in the sample field and

[8] In these calculations it is necessary to consider each infested culm as containing only one infested joint, since the determinations of culm infestation were made in the field and at other times than the dissections, and no counts of the number of infested joints per culm were made at these times. Since, in general, the number of infested joints per stem diminishes with a diminishing percentage of infested straws, the actual reduction in population between 1929 and 1934 must have been greater than is shown in the figures.

the assumption that the number of occupied cells per joint was the same as in the previous year, i. e., 6.8 percent. This would give 10.2 as the *Harmolita* population per 100 culms, which is 0.78 percent of the spring jointworm population of 1929.

From figure 6 it is seen that beginning in 1929, with a 100-percent population and a parasitization of approximately 35 percent, there has been a steady decrease in the jointworm population. The effective reproductive rate has remained below 34.9 to 1 and the declining rate of reproduction and, in general, the declining population have been accompanied by an increase in parasitization. However, even at the highest degree of parasitization (in 1932), the effective rate of reproduction was 15.2 to 1. It is apparent, therefore, that without the influence of other factors the steady reduction in population would

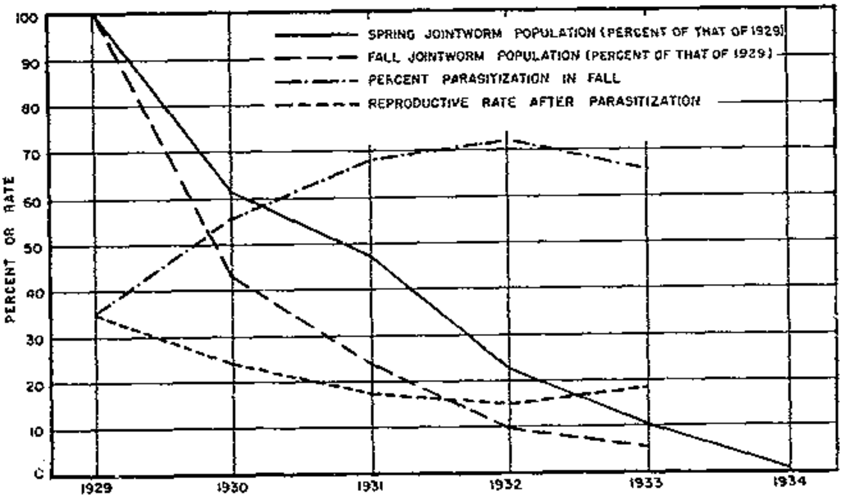

FIGURE 6.—Trends in jointworm populations, parasitization, and reproduction rate from 1929 to 1934, inclusive, as indicated by stubble dissection. The extent of destruction of *Harmolita tritici* by parasites during its complete life cycle was doubtless greater and the rate of reproduction less than that shown. Spring and fall jointworm populations in succeeding years are shown as percentages of the spring and fall populations, respectively, in 1929. Actual percentages of parasitization are shown.

not have occurred. Because of the slight winter mortality of the jointworm in Oregon and the practically complete emergence of individuals successfully surviving the winter, this reduction apparently occurs during the flight period. In other words, out of 35 females which issue in the spring, an average of about 1 succeeds in finding wheat and depositing its full quota of eggs. There were no marked departures in weather conditions in any of the years considered except in December 1932, when unusually cold weather without a snow covering killed much fall- and winter-sown wheat. This freeze affected most the jointworm populations of 1933 and 1934, but omitting these years from consideration there remains sufficient evidence to indicate that under normal conditions of wheat culture very heavy mortalities of *Harmolita* occur.

Such being the case, it would seem that under some conditions a parasitization of 35 percent in an infested area may be sufficient to put the jointworm population on a descending scale. As previously stated, it is impossible to measure with exactness the effect of parasites in field control of insects because of the multiplicity of other unmeasurable controlling agencies, and no pretenses are being made of having done so. Nevertheless, with an insect that shows a decrease in population under conditions where enough adults issue in the spring to allow, theoretically, a 35-to-1 increase, it is obvious that any parasitization which reduces by one-half, one-third, or even less the normal potential reproductive rate of 54 to 1 is important. Whatever the errors in measurement may have been, they are certainly less serious than leaving factors only roughly measurable out of consideration entirely, a practice which sometimes leads to assertions that parasitization must reach some such percentage as 98 or 99 before it is of value. To control completely the jointworm alone, parasitization theoretically would have to reach 98.15 percent, but from the foregoing it is obvious that no such parasitization is necessary under field conditions. It might be supposed that, since the data discussed are those taken from the sample field only, they are valuable only as a history of the population of that field, but supplementary studies of parasitization and population in other fields throughout the Molalla colony show that the history of the sample field is essentially the history of the colony and that conclusions drawn from the study of the field may be applied generally to the colony.

Seasonal Histories and Habits of the Parasites

Eurytoma parva Phillips

Prior to 1931 *Eurytoma parva* was of slight importance as a parasite of *Harmolita tritici* in Oregon, the highest parasitization found before that time being 7 percent. In 1931 parasitization by this species increased very abruptly to approximately 36 percent. The highest parasitization found in fair-sized collections was 61 percent in the July collection from the sample field in 1932, but this was higher than the average for the field of that year, which was 52.5 percent, and the average was practically the same in 1933.

The life history of this species has been given and the egg and the various instars described and illustrated by Phillips (*9*). Briefly, there is a single generation annually. The adult places its eggs in the walls of the wheat stem in or near a jointworm cell or egg. Ordinarily, after devouring the egg or newly hatched jointworm, the parasite larva feeds on plant tissue until it is full-grown, but frequently, after it attains large size and the wheat stems are drying, it cuts its way from one cell to another and devours such other larvae as are encountered. It remains in the stubble in the last instar.

It seems possible that the newly hatched larva of *Eurytoma parva* could destroy large jointworms and also large larvae of other parasites provided they were stung to quiescence by the adult *Eurytoma*. In the field, however, this must occur rarely if at all because, in spite of the thousands of cases of parasitization by *E. parva* observed by the writer, neither the destruction of large larvae by small parasite larvae nor the stinging of large larvae by the adult *Eurytoma* has been observed. Apparently the stimulus for oviposition by *E. parva* is supplied only by eggs or newly hatched larvae or a recent oviposition puncture of *Harmolita tritici*, and the destruction of large jointworms and their parasites occurs only after large larvae of *E. parva* assume a predatory role and seek out and devour them. Since previous activity on the part of *H. tritici* is required before *E. parva* will deposit eggs, the latter must be regarded as a true parasite, the larvae of which have become adapted to feeding on plant as well as animal tissues and which in their later instars may become predators.

The jointworm cells occupied by full-grown or nearly full-grown larvae of *Eurytoma parva* are usually larger than the normal cells of *Harmolita tritici* owing to the feeding on plant tissue or excavating in a search for animal food by the parasite larvae, and considerable quantities of frass are found scattered through the cells, especially when the larvae cut from one cell to another. In wheat approaching maturity the presence of *E. parva* is often easily detected by the external appearance of the cells, which are large and usually pale and cut so close to the surface of the stem that only a thin layer of tissue remains. The question naturally arises whether under these conditions *E. parva* is not doing more damage to the wheat than *H. tritici* alone would do. As indicated above, however, it would seem that little additional damage is done to the wheat kernels, since most of the enlargement of cells and the tunneling by *E. parva* appear to take place after the wheat is drying or approaching maturity. Nevertheless, other things being equal, it seems probable that, on account of the cell enlargement and tunneling, lodging of wheat in fields infested with *H. tritici* that is heavily parasitized by *E. parva* would be greater than would be the case in fields in which *H. tritici* was lightly parasitized.

In the field *Eurytoma parva* pupates sometime between the middle of March and the middle of April, depending on weather conditions. The first emergence of the adults is usually from several days to approximately 2 weeks later than the first emergence of *Harmolita tritici*, but in 1933 the first emergence of the two insects apparently took place on the same day. Adults may be taken from the field from 1 to 2 months after the first emergence. In a year of late emergence they have been swept from the field as late as July 13, and eggs may have been laid until that date. The parasites have been found ovipositing and very numerous about June 15, but the peak of abundance is usually reached before that date. From 1931 on, with the exception of 1934, adults, both males and females, have been very numerous in the sweepings, and in 1933 and 1934 they exceeded *H. tritici* in numbers at all times. Issuance, in cages, from stubble of 1930, 1932, and 1933 totaled 3,921, of which 2,171, or 55.4 percent, were females.

Under the discussion of Natural Control by Parasites many records are given of more than one jointworm having been devoured by a larva of *Eurytoma parva*. In relatively few cases was the actual destruction of any of those larvae seen, but empty cells with tunnels leading ultimately to a cell occupied by a single *Eurytoma* larva indicated that this larva had moved from one cell to another, destroying such other larvae as were in its path. In some cases it is possible that it was not *Harmolita tritici* but other *Eurytoma* larvae which were destroyed, but if so the *Eurytoma* larvae were destroyed in very early stages, as in very few cases were remains of large larvae of *E. parva* found in cells occupied or traversed by larvae of *E. parva*. Frequently the cell in which *E. parva* was found occupied a space that would normally accommodate two or more cells of *H. tritici*.

In the study of these cells and tunnels the question frequently arose as to whether what appeared to be a single cell occupied by *Eurytoma parva* might not have represented more than one *Harmolita* cell with all traces of partitions obliterated by the feeding of *E. parva*. In the writer's opinion this actually occurs, but as it was impossible to determine the number of cells originally present, it was necessary to record only the cells actually seen in whole or in part. It was also consistently noted throughout the dissections that in an infested joint parasitized by several *Eurytoma* larvae the total population, including parasites and jointworms, tended to be less than in unparasitized joints in the same material. This reduction in number was often greater than could be accounted for by the records of additional cells entered by single *Eurytoma* larvae. The inference is that some of the *Harmolita* were destroyed when they were so small and the cells so soft or imperfectly formed that no trace of the *Harmolita* or its cell remained. If so, then *E. parva* is a much better destroyer of *H. tritici* than the records of parsitization in table 6 show, and a large part of the reduction in the number of cells per joint which has accompanied the increase in parasitization is directly attributable to the work of this parasite as well as to the loss of *Harmolita* adults during migration, as suggested in the discussion of the effect of parasitization on population.

Dissections of green wheat containing eggs and young larvae of *Harmolita tritici* and *Eurytoma parva* add weight to the above inference. For example, on May 31, 1934, 5 infested joints taken from a sample of 89 stems were dissected with the following results: Joint 1 contained 2 eggs and 10 larvae of *E. parva*. The larvae were found in small pockets scattered in the wall of the stem without relation to the exact location of the joint-worm cells. There were also 1 first and 1 second instar of *H. tritici*, the first instar being in a well-formed cell. Joint 2 contained protuberant galls in which nothing could be found. Joint 3 had 5 eggs and 15 larvae of *E. parva*. As many as 4 larvae were found in or near a single cell; in this case two larvae were dead, apparently destroyed by the other two. In many instances no trace of *Harmolita* was found, but in one cell two *Eurytoma* larvae were found destroying a single *Harmolita*. When *Eurytoma* larvae were found in the jointworm cells, minute tunnels were seen leading from the pockets in the wall of the stem in which the *Eurytoma* eggs had been placed. This joint also contained 4 *Harmolita* larvae, 1 first instar and 3 second instars, with an egg of *Eurytoma* near each. Joint 4 contained 11 larvae and 3 eggs of *E. parva*. All were in 5 cells as follows: (1) 1 first and 2 second instars, (2) 1 first instar and 1 egg, (3) 2 first and 1 second instar (4) 2 first instars, (5) 2 first instars and 2 eggs. A sixth cell contained miscellaneous eggshells. Joint 5 contained 1 minute first instar of *Harmolita tritici* with a sharply protuberant head in a strongly protuberant gall near a node. There were 2 other empty cells.

Since, as shown in the dissections just described, the eggs of *Eurytoma parva* frequently are laid in abundance more or less promiscuously throughout an infested joint, and the hatching larvae tunnel freely in the walls of the stems and feed on plant tissue, jointworms, and its own species, it is evident that no exact record of the numbers of jointworms or parasites destroyed in their early stages is shown by any stubble examination. It appears even more difficult to guess correctly from the appearance of the cells and the larvae in green stems, while the larvae are hatching and still small, what will be the ultimate fate of any *Harmolita* in infested joints parasitized by *E. parva.* In this connection a determination of parasitization made later in the season in the field from which the above stems came showed a parasitization by *Eurytoma* of only 30.2 percent and an average number of cells per infested joint of only 6.3.

According to the laboratory records *Eurytoma parva* has not been reared from any other species of *Harmolita* inhabiting grains or grasses in Oregon and, so far as has been determined, no primary host other than *H. tritici* has been found elsewhere.

Ditropinotus aureoviridis Crawford

The life history of *Ditropinotus aureoviridis* has been published by Phillips and Poos (*12*), who also gave drawings of the egg and the larval instars. The seasonal history in Oregon differs somewhat from Phillips' account. Here the parasite passes the winter in the jointworm cell as a full-grown larva, the first pupae are formed sometime between the first of June and the last week in June, and the earliest emergence occurs from the second week in June to the first week in July. Most frequently the earliest pupation was in the first half of June. The earliest emergence recorded was June 7, 1928, and the latest the first week in July in 1929. The exact time of first emergence in 1929 is not known, but by June 20 of that year no pupae had been found. In all other years some pupae were found before June 15.

Considerable accumulations of effective temperatures apparently have little effect in accelerating the pupation of overwintering larvae of this species. Confinement of infested joints in the laboratory under conditions of warmth which brought out *Harmolita tritici* and *Eurytoma parva* very early had no similar effect on *Ditropinotus aureoviridis.* In fact, emergence of *D. aureoviridis* under these conditions was consistently later than in the field, most of it occurring after the middle of July. Apparently in the overwintering generation of larvae a long diapause is an intrinsic necessity little influenced by ordinary climatic conditions. It is possible that after a considerable period has been spent in diapause high temperatures may accelerate emergence, especially after pupae have been formed. From 1929 to 1932, inclusive, there appeared to be some correlation between the time of emergence in the field of host and parasite in that early or late emergences of *H. tritici* were followed by corresponding early or late emergences of *D. aureoviridis.* In 1933 and 1934, however, when the latest and earliest emergences of *H. tritici* over the 8-year period occurred, first emergence of *D. aureoviridis* occurred on the same date. It is apparent that all the factors influencing the emergence of *D. aureoviridis* cannot be explained by the climatic records on hand.

In this discussion and in those following in connection with the life history of other jointworm parasites, a generation is considered to begin with the first egg and to end with the last adult. The first generation of any season is considered to have begun when the first eggs have been laid by the adults emerging from overwintering stubble, although, as will be apparent from what follows, all adults of *Ditropinotus aureoviridis* and of some of the other parasites in the first or spring emergence are not of the same genealogical rank.

Ditropinotus aureoviridis has one complete and a partial second generation per year in Oregon. Adults emerging from overwintering stubble in the spring lay their eggs in the jointworm cells in growing wheat, and these eggs begin the first generation. Usually, however, there is only a small emergence of adults from this wheat the same year, most of them emerging the following spring. In these instances the single generation is not completed until the following spring, in which case adults of the spring emergence belong to the first generation of the preceding year. The emergence of the relatively few adults from the new wheat the first year begins sometime after the middle of July and increases in August and September. Females of this emergence lay eggs in the jointworm cells in stubble and thus begin a second generation. Apparently all the larvae from these eggs become full-fed the same season, but no adults of this generation have been observed to issue before the following spring. It is apparent, therefore, that adults of the spring emergence, or for that matter of any other emergence, are not of the same genealogical rank. That the occurrence of a single complete and a partial second generation per year is the rule with *D. aureoviridis* in Oregon is also shown by the following facts: In stubble collected and examined in the latter part of July or later there were always many more larvae than emergence holes of that species; and if larvae were taken from growing wheat before there had been any emergence whatever from it and were reared in wooden cells, only a few changed to adults that season, most of them remaining over the winter as hibernating larvae to emerge the following spring or summer. These habits were manifested repeatedly, except in one experiment where breeding was conducted in field cages and a much larger emergence of first-generation adults occurred the first year than is customary in the field.

The conditions of this experiment were as follows: In the spring of 1929, before any adults of *Harmolita tritici* or *Ditropinotus aureoviridis* had emerged, 2 cloth cages enclosing approximately 4 square feet each were erected over winter wheat growing in the field. Eleven days after the first adults of *H. tritici* had issued, 20 females and 10 males of this species were placed in each of the cages. As soon afterward as sufficient adults of *D. aureoviridis* from overwintering larvae could be obtained from the field, 20 females and 5 males of this parasite were added to 1 cage. It should be understood at this point that while most of these adults were of the first generation of the preceding year, they laid the eggs of the first and not the second generation of the current year. When first-generation adults of *D. aureoviridis* issued in the first cage, 22 females and 4 males of these were added to the second cage. The essential data from the rearings are given in table 7. It may be noted that in the first cage 89, or 75.4 percent, of the 118 total emerging adults of *Ditropinotus* issued in the summer or fall as first-generation adults that year. This, to judge from field studies, is a much larger proportion than occurs in field material. It may also be noted that *D. aureoviridis* formed the largest part of the total issuance from these stems, namely, 118 from a total issuance of 188, or 62.8 percent. This shows a higher parasitization by this single species than has been observed in the field. From cage 2 there was no issuance in 1929, that is, a second generation was not completed that year. There was a small emergence from this cage the following season and a large emergence of *H. tritici*.

TABLE 7.—*Emergence of Ditropinotus aureoviridis from Harmolita tritici in field cages in Oregon*

Date	Cage 1								Cage 2							
	Harmolita tritici				*Ditropinotus aureoviridis*				*Harmolita tritici*				*Ditropinotus aureoviridis*			
	Placed in cage		Emerged		Placed in cage		Emerged		Placed in cage		Emerged		Placed in cage		Emerged	
	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
May 26, 1929	20	10							20	10						
July 3, 1929					20	5										
Aug. 20, 1929							22	4					22	4		
Fall of 1929							58	5								
Spring of 1930			40	30							111	72				
July 1930							23	6							7	1
Total emergence			40	30			103	15			111	72			7	1

Contrary to the observation of Phillips and Poos in the East (*12, p. 413*), males of *Ditropinotus aureoviridis* normally occur in Oregon in both the first and second emergences, although they are always in the minority.

Emergence of *Ditropinotus aureoviridis* from overwintering stubble is prolonged in both the field and the laboratory, but it appears to cover a longer period in the laboratory. A few first-generation adults have been known to issue in the field before all the overwintering generation had issued. On account of the usually small size of the second emergence and its overlapping with the first, it was impossible to obtain by sweeping any definite records of its first appearance or duration. It is usually possible to catch adults in varying numbers by sweeping at any time between the first issuance of the overwintered generation and the advent of freezing weather in the fall.

As shown in table 6, there was always an increase in parasitization by this species between harvest time and late in the fall. This increase was probably due to oviposition by adults of both emergences. Observations in the laboratory indicate that females of *Ditropinotus aureoviridis* have great difficulty in penetrating with their ovipositors stubble of any of the varieties of wheat grown in the Molalla district. Many examinations have shown that eggs and small larvae of this species are scarce in stubble late in the summer and in the fall. These two facts suggest that the increase in parasitization occurring between harvest and fall is the result of a small proportion of successful ovipositions taking place over a long period of time. The cage experiments just discussed illustrate this situation to some extent. When 20 females and 5 males were placed in a cage of uncut green wheat infested with jointworms, offspring to the number of 118 were obtained, but when 22 females and 4 males were placed in a cage of stubble after the jointworm galls had hardened, only 7 females and 1 male resulted. The low issuance in the latter case was not caused by mortality during the winter, as dissection of a sample from this lot the fall before showed a very low parasitization.

Cells occupied by *Eurytoma parva* are larger and thinner walled than the normal jointworm cells and would be more easily penetrated by the ovipositor of *Ditropinotus aureoviridis*. This probably accounts for the high secondary parasitization of *E. parva* by *D. aureoviridis*. Phillips (*9, p. 751*) has suggested that *E. parva* is not readily parasitized by secondaries owing to its great activity and strong jaws, which would enable it to destroy the first instars. The writer has found, however, that in the case of *D. aureoviridis* as well as in that of *Eupelmus allynii* the *Eurytoma* apparently is stung to quiescence before oviposition, a frequent habit among external hymenopterous parasites.

Ditropinotus aureoviridis is frequently a secondary parasite on pupae and unissued adults of its own species and occasionally on the larvae. As a secondary parasite it feeds more commonly on *Eurytoma parva* than on any of the eupelmids, but its preference is difficult to determine since in most of the years of the investigation *E. parva* was much more numerous than all the eupelmids combined.

In a sample collected August 16, 1933, *Ditropinotus aureoviridis* was secondary in 32 out of 151 cases, 28 through *Eurytoma parva* and 4 through *D. aureoviridis*. In a sample collected in the same field on November 8, 1933, it was secondary in 53 out of 201 cases, 52 through *E. parva* and 1 through *Eurytoma* sp. (probably *phoebus*). In a collection of October 28, 1933, it was secondary in 56 out of 337 cases, all through *E. parva*. There were other samples in which secondary or tertiary parasitism through its own species was much higher than in these cases.

In Oregon, *Ditropinotus aureoviridis* has been found as a primary parasite also on *Harmolita grandis* from wheat, *H. holci* from velvet grass, and *H. oregon* from *Elymus*. Phillips and Poos (*12*) reared it from field collections of *H. vaginicola*, *H. grandis*, *H. atlantica* Phillips and Emery, and *H. secalis* (Fitch).

Eupelmella vesicularis (Retzius)

The eupelmid parasites of *Harmolita tritici*, as shown by table 6, have played a minor role as destroyers of this pest. In the earlier years of the investigation *Eupelmella vesicularis* appeared to be the most abundant eupelmid, but during the later years *Eupelmus allynii* and *Calosota metallica* Gahan increased in importance while *E. vesicularis* declined. However, with the prevalence of low parasitization by all three species, no striking differences were apparent.

Under the name of *Eupelminus saltator* (Lind.) Phillips and Poos (*13*) have described and illustrated the egg and larval instars and given the life history of *Eupelmella vesicularis*. In the laboratory these authors have bred the species through six generations in 1 year. No continuous breeding work was done by the writer, but it is evident from rearing and dissection of field material that no such number of generations occurs normally in Oregon. From material collected in July there is frequently a partial emergence in July, and also later during the same year, but there may be no emergence from similar material until the next July or later. In the field this species emerged earlier in the spring than *Ditropinotus aureoviridis*, *Eupelmus allynii*, or *Calosota metallica*, sometimes by the middle of April, and occasionally parasitized larvae or pupae of these species in the overwintering stubble. It seems possible, therefore, that some of the adults issuing from the new wheat in July may already be the offspring of adults of the first emergence. Since early emergence of this parasite does not occur from *Harmolita* hosts in the laboratory, it seems probable that those individuals emerging early in the field come from puparia of the hessian fly (*Phytophaga destructor* (Say)). In collections made in August and September it is also more common to find immature larvae of *Eupelmella* (as well as of *Eupelmus allynii*) than of *D. aureoviridis*. These facts suggest that the number of generations per year may be more variable than is the case with *D. aureoviridis*.

As is well known, this parasite has a long list of hosts, including the hessian fly, many species of *Harmolita*, and other species among the Diptera, Hymenoptera, Coleoptera, Lepidoptera, Homoptera, and Orthoptera. In Oregon, in addition to the hessian fly and *H. tritici*, the author has reared it as a primary parasite from *H. holci*, *H. oregon*, *H. grandis*, *H. phalaridis* Phillips, an undetermined *Harmolita* from timothy, and as an external parasite of the cocoon stages of the dock weevil (*Hypera rumicis* (L.)). It has also been found as a secondary or tertiary parasite of *H. tritici* on most of the species considered here, but usually on *Eurytoma parva* or *Ditropinotus aureoviridis*.

Eupelmus allynii (French)

Phillips and Poos (*12*) have described and illustrated the egg and larval instars and have given the life history of *Eupelmus allynii*. These authors have reared the species through five generations in a year. In Oregon there appears to be only one complete and a partial second generation per year in the field. In the laboratory the adults of the first complete new generation begin to emerge in August, continuing to do so through September and October. A part of them do not issue the first year, however, but pass the winter as full-grown larvae and begin to emerge in August of the second year, continuing emergence through October. In the field adults may be taken as early as the middle of June. Some or all of these may be from the hessian fly.

This species is parasitic on a large number of other species of *Harmolita*. Phillips and Poos (*12*) list nine *Harmolita* hosts and two others of the genus which are probable hosts. In Oregon, in addition to *H. tritici* and the hessian fly, it has been reared from *H. holci* and an undetermined *Harmolita* from timothy. It is also frequently secondary on *H. tritici* through *Ditropinotus aureoviridis*, *Eurytoma parva*, and other eupelmids.

Calosota metallica Gahan

The parasite *Calosota metallica* was a minor one among the eupelmids. Its habits are similar to those of *Eupelmus allynii*, both as to the time of emergence in the field and in the laboratory and in the number of generations per year. The larva is similar in habitus to *Eupelmella vesicularis* and *Eupelmus allynii*. The first instars while alive are difficult to distinguish from *E. vesicularis* and *E. allynii* because of their small size, but later instars are easily separated by the absence from *C. metallica* of the heavily sclerotized and toothed labrum.

In Oregon *Calosota metallica* has been reared from the hessian fly and from *Harmolita tritici, H. holci*, and *H. grandis*. In addition it is a secondary parasite of *H. tritici* through *Eurytoma parva* and *Ditropinotus aureoviridis*.

Decatoma amsterdamensis Girault

The parasite *Decatoma amsterdamensis* was first observed in Oregon in 1933, when it was reared in the laboratory from stubble of 1932 wheat from the Molalla district. It had increased in number by 1934 but was still scarce. None were taken from the field by sweeping. Such larvae as were observed were external on the host. Because of its recent appearance and scarcity no thorough study of its seasonal history could be made. There appears to be at least a partial second generation, since some adults issued from new stubble in August. In the laboratory this species issued from overwintered stubble as early as April 1 and as late as May 23. The winter is passed as a full-grown larva in the jointworm cell. Although apparently it is normally a primary parasite, it has been reared as a secondary through *Eurytoma parva* and was found as a tertiary on *Ditropinotus aureoviridis*.

The full-grown larva is somewhat swollen in appearance, whitish, and in unstained specimens mounted in "liquid of Faure" and examined under a low-power microscope appears smooth with no pronounced bristles or setae. The mandibles are strong and heavily chitinized and possess a strong basal tooth. The mandibular arch, labrum, and labium are very lightly sclerotized. These characters distinguish the full-grown larva from larvae of *Eurytoma parva, Ditropinotus aureoviridis*, or any of the three eupelmid parasites previously discussed.

Eurytoma phoebus Girault

A parasite that has appeared rarely in jointworm cells as a parasite of *Harmolita tritici* and *Eurytoma parva* is *Eurytoma phoebus*. It was most numerous in stubble from one field in the Molalla district in 1933. The larva of this species resembles *Decatoma amsterdamensis* rather closely in that it is also whitish and has strong mandibles with a basal tooth and weakly sclerotized mandibular arch, labrum, and labium. It can be distinguished from that species, however, by the presence of a moderate number of setae and hairs. In the laboratory a female from the field, after stinging the hosts to quiescence, laid five eggs on larvae of *E. parva*, three on one on October 2, 1933, and two on another a day or two later. No other eggs were obtained although the female lived until October 23. Three of the eggs hatched in 2 days, and one of the larvae was seen to devour one of the unhatched eggs.

One of the three completed larval development in 15 days after hatching, cast its meconium in 19 days, or slightly less, pupated in about 24 days, and issued 56 days after hatching. The adult, a full-sized female, died within a few days without laying any eggs.

Other Parasites

A few pteromalids, probably of several species, have been reared from jointworm cells. Some of these came from cages containing stubble, and it could not be determined whether they were primary parasites or not. Others were removed from the galls and reared in wooden cells. From examination of the galls from which they were taken, it did not appear that they had destroyed larvae of *Eurytoma parva, Ditropinotus aureoviridis*, or any of the eupelmid parasites, but host remains were were not found. Remains of jointworms are easily overlooked or lost, especially if the larvae are destroyed while small. It seems probable, therefore, that they were primary parasites in the cases observed. The larvae of these species, so far as noted, are whitish, appear somewhat swollen, and possess weak mandibles without basal teeth and a weakly sclerotized head capsule. The bodies bear some minute setae. This combination of characters will serve to distinguish them from the other parasites discussed.

Unfortunately most of the adults obtained were males, and their exact determination could not be made. One of the species, however, doubtless belongs to the genus *Eupteromalus*.

Artificial Control

No method is known of destroying the wheat jointworm in growing wheat without also destroying the crop. The available control measures are therefore preventive rather than remedial. Plowing under of the stubble, in the fall, winter, or early spring prior to emergence of the adults, is the most practical method of control. To be entirely effective, however, the plowing under of most of the stubble in an infested neighborhood would be necessary. This can rarely be effected, and the degree of success is dependent on the extent to which the farmers will cooperate to this end. In some seasons there may be some emergence from stubble which might be brought to the surface in the spring by disking or harrowing of the land for other crops, such as corn or potatoes, but issuance would be so slight as to be almost neligible in any case; and ordinarily very little stubble is brought to the surface by these operations if it has been properly buried.

EXPERIMENTS WITH BURIED STUBBLE

Plowing under of wheat stubble has not been generally recommended as a control measure, since prevalent crop rotations frequently have made it impracticable. Data on this subject have been given by Phillips (*7, pp. 12–13; 8, p. 25*).

When the writer began work on the jointworm problem there was little published information as to the fate of the jointworms after they were plowed under, and Oregon farmers soon raised the questions as to whether spring plowing of the stubble was effective in control and whether there would be any issuance from stubble which had been plowed under in the fall, part of which might be brought back to the surface by replowing or cultivation in the spring. To settle some of these points several experiments were conducted in the fall and winter seasons of 1926–27 and 1928–29.

On October 21, 1926, two lots of wholly infested stubble were buried at depths of 4 and 8 inches in the soil at the edge of an infested field in the Molalla district. At intervals during the winter some of this stubble was dug up. One portion of each lot was dissected, and an effort was made to determine the number of living and dead jointworms as well as of the parasite *Ditropinotus aureoviridis*. Another portion was placed in an emergence cage and the subsequent emergences recorded. At that time it was thought that it would be possible to distinguish in the dissections the living, hibernating insects from the dead ones. In some cases this was possible, but comparison with the emergence from material corresponding to that examined showed that the mortality was always underestimated.

As there is much rain in the Willamette Valley during the winter, the buried stubble would be in a moist condition for so long a time that sooner or later even the most resistant galls would be penetrated. Water in the cells bleached the pupae and caused them to swell. These swollen pupae usually showed no movement but many of them proved to be alive. It was impossible from microscopic examination to be certain that the insects were dead until they had lost their turgidity and had become flabby, but comparisons with the issuance records indicated that many of them must have been dead before this condition was reached. The parasite *Ditropinotus aureoviridis*, which hibernates as a larva in the jointworm cells, was much more resistant than *Harmolita tritici*. The record of dissections and issuances for the two seasons is given in table 8.

TABLE 8.—*Results of examinations of wheat stubble buried at different depths and recorded emergence from caged lots of similar material*

Date of removal from soil	Dissected material					Later emergence from caged material					
	Wheat joints examined	*Harmolita tritici*		*Ditropinotus aureoviridis*		Wheat joints caged	*Harmolita tritici*		*Ditropinotus aureoviridis*		Other insects
		Living	Dead	Living	Dead		Females	Males	Females	Males	
WHEAT STUBBLE BURIED 4 INCHES DEEP											
1927	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	
Jan. 10	5	34	[1] 1	12	[1] 2						
Feb. 3	0	40	8	22	0	10	11	6	1	0	
Feb. 25	4	33	1	6	0	10	0	2	2	0	
Mar. 17						10	0	0	0	0	*Eupelmella vesicularis* (1).
WHEAT STUBBLE BURIED 6 INCHES DEEP											
1929											
Jan. 10	10	104	2	31	0	15	32	17	51	0	*Eupelmella vesicularis* (1).
Feb. 21	10	81	10	31	2	16	34	17	26	2	Do.
Mar. 12	10	56	4	40	3	16	15	2	0	0	A pteromalid.
Apr. 3	10	2	[2] 84	27	3	16	0	0	0	0	
Apr. 17						20	5	1	40	1	*E. vesicularis* (2). *Eurytoma parva* (2).
WHEAT STUBBLE BURIED 8 INCHES DEEP											
1927											
Jan. 10	15	107	7	22	5						
Feb. 3	9	45	10	26	[1] 2	10	15	3	4	0	*Eupelmella vesicularis* (2). *Calosota metallica* (1).
Feb. 26	8	46	15	10	7	10	1	0	3	0	Pteromalids (2).
Mar. 17	11	118	1	7	0	10	0	0	0	0	
Mar. 30						10	0	0	8	0	

[1] 1 parasitized.
[2] Probably some alive.

Examination of this table shows that in 1927 there was but slight emergence of *Harmolita tritici* from the stubble removed February 26 and none from that removed March 17. Eight females of *Ditropinotus aureoviridis* issued from stubble dug up as late as March 30. In 1929 no jointworm adults issued from stubble left buried until April 3, but six issued from that left buried until April 17. Eight times as many *Ditropinotus* females as *Harmolita* females issued from this last lot.

On April 17, 1927, 50 infested joints were buried to a depth of 8 inches in the field and covered with a cloth cage. On the same day 2 cages, one covering approximately 1 square foot and the other covering approximately 4 square feet, were set up over heavily infested stubble that had been buried by plowing in the preceding fall. In the spring of 1929, 50 infested joints were buried 6 inches in the soil and covered with a similar cloth cage. Frequent examinations until late in the season showed no issuance from the stubble in any of these cages.

These experiments indicate that in some seasons all the jointworms in stubble buried in the fall are killed long before the normal time of issuance of the jointworm but that in other seasons a small portion may survive until about the normal time of issuance. Consequently there might be a slight emergence from stubble brought to the surface of the ground by farm operations in the spring. The field experiments also indicated that the adults failed to make their way to the surface of the ground from buried stubble even if the stubble is buried shortly before the normal time of emergence. It may be noted that in these last experiments all the stubble buried in the spring was buried by hand in order to confine within a small area a much larger number of jointworms than would be found in field-plowed stubble and thus have a better check on emergence. Observations indicated that the plowed stubble offered less opportunity for escape of the adults than the hand-buried stubble, chiefly because the soil in a plowed field settled evenly and compactly while in the hand-buried stubble it tended to settle unevenly and occasionally away from the sides of the holes. It is believed therefore that since none issued from the hand-buried stubble the possibility of emergence from well-plowed stubble is even more remote.

Although no records are available of the rainfall for the years 1926 to 1929 in the Molalla district where these experiments were conducted, the records for Forest Grove, where rainfall is similar, show 41.72 inches of rain from November 1926 to the end of March 1927 and only 21.52 inches for the corresponding period in 1928–29. It seems probable, therefore, that the jointworm galls in buried stubble became saturated earlier and remained so longer in 1926–27 than in 1928–29. This probably explains why the jointworms were all dead by March 17 in 1927 and a few survived until April 17 in 1929.

An objection to the plowing under of wheat stubble is the custom among farmers of using fall- or winter-planted wheat as a nurse crop for red clover, but the clover could be planted with grains other than wheat. Winter barley is considered by the Department of Farm Crops of the Oregon Agricultural Experiment Station to be a better nurse crop for clover than wheat, and Winter Turf (Oregon Gray) oats is also considered good for this purpose. Neither of these grains is attacked by this or other species of jointworms in Oregon. Careful planning on the part of farmers should enable them to substitute one of these grains as a nurse crop for clover; in fact, this is frequently done with no intention of controlling the jointworms. An alternative is to plant clover alone. This also is a fairly common practice in some localities, especially in sections where the soil is not the best and does not hold moisture well during the dry summers. Since it has been demonstrated that the jointworm is so injurious, some such system of crop rotation should be adopted in the areas now infested. If this were done, the wheat jointworm problem would be practically eliminated.

In spite of these recommendations many farmers still leave much wheat stubble standing. In these cases it is advised that all wheat be planted as far away as possible from the stubble. This is not recommended as a method of complete control, but the writer feels that this practice would reduce infestations, especially in those seasons when the weather is unfavorable for migration and when unplowed stubble is not abundant. To maintain the jointworm population at a high level an abundance of stubble and suitable growing wheat appear necessary. Therefore, counting on the valuable work of the parasites, the plowing under of as much stubble as possible and planting of wheat as far from unplowed stubble as possible are likely to be more than paid for by reduced infestations and better crops.

BURNING THE STUBBLE

Since jointworm galls are usually well above the ground, clean burning of the stubble is effective in destroying the jointworms. In the Willamette Valley stubble as well as strawstacks are frequently burned merely to get rid of the trash or to avoid the difficulty of burying high stubble by plowing. Stubble usually can be burned clean if desired, but sometimes farmers do not attempt to burn a field completely. While burning of a large portion of the stubble of a field makes substantial reductions in the number of jointworms surviving, it could be burned completely with a little more effort, and this is advised. Since there are many woodlands and much valuable property in the Willamette Valley, extreme caution should be exercised in burning stubble. Soil conservation and crop-rotation practices now being recommended must also be considered in connection with the burning of stubble for the purpose of reducing jointworm infestations.

It has been reported that the rough treatment given jointworms in straws passed through threshers is so great that few adults issue from them (*5, p. 274*). This is probably true, but living jointworms have been found in threshed straws in Oregon, and when determined effort is being made to control jointworms the strawstacks should be burned to avoid possible infestation from them. However, since most of the jointworms are left in the stubble in the Willamette Valley and much stubble is left unburied, burning of strawstacks would have little effect upon whole jointworm populations under present conditions.

Cooperation among farmers in jointworm control is essential if control according to any of the recommended methods is to be made most effective.

SUMMARY

The wheat jointworm (*Harmolita tritici* (Fitch)) was first found in the Pacific Northwest in 1926 occupying two small areas in the Willamette Valley of Oregon, one near Molalla, Clackamas County, and the other near Lebanon in Linn County. How and when the jointworm was introduced into this region is not definitely known.

In the infested areas wheat is an important crop and has a definite place in the regular rotation with red clover, oats, or oats and vetch, and in some cases with a row crop, frequently corn or potatoes.

Infestation in the northern, or Molalla, colony was heavy early in the period of investigation but by 1934 the average infestation of this area had declined to 3 percent. The trend of the infestation in the southern colony was similar, but the early infestations were not so high.

Emergence of *Harmolita tritici* apparently is influenced more by temperature than by any other single external factor. Emergence is early in warm, sunny springs, and late in cool cloudy springs, although a considerable accumulation of effective temperature in the late winter months is necessary to induce emergence.

Records of emergence of *Harmolita tritici* in cages from 1926 to 1933, inclusive, indicate that approximately 60 percent of the total are females.

Dispersion from stubble in the spring is slow in cool, rainy weather and rapid in warm, sunny weather. Males tend to remain in the stubble fields at all times, but the females generally disperse by means of short flights, and their progress is very slow through fields of growing wheat. Flight appears to be at random except as influenced by winds.

Study of the enlargement of the colonies indicated that the average dispersion was a little over 1 mile per year.

Oviposition in wheat in the Willamette Valley was largely confined to the second or third joints, whether the season was early or late. Fall- and winter-sown, or the early developing, wheats rather than the spring-sown, or late developing, wheats were preferred for oviposition, with the result that in Oregon the good rather than the poor wheat was more frequently heavily infested.

The average oviposition capacity per female from 1927 and 1928 stubble was 84 and 98.2 eggs, respectively. If 90 eggs is taken as the average capacity per female, the potential rate of reproduction of *Harmolita tritici* from a general population is 54 to 1.

None of the varieties of wheat grown in the Willamette Valley seemed to be preferred or avoided by adults for oviposition.

Jointworm feeding in wheat reduces the size of the kernels and the number of kernels per head. The greater loss is in the number of kernels per head. The average loss by both means for culms with one infested joint from 21 fields was 13.5 percent, with 2 infested joints from 6 fields 26.5, and with 3 infested joints from 2 fields, 44.2 percent.

Detailed studies of the parasitization of the jointworm in a limited area near Molalla, Oreg., between 1928 and 1934 indicated that if the potential rate of reproduction of *Harmolita tritici* of 54 to 1 is reduced by parasites to a theoretical effective rate of 35 to 1 or lower, destruction exerted by other natural factors was sufficient to place the jointworm population on a descending scale. Predatory habits of the larvae of *Eurytoma parva* Phillips made it impossible to measure with great accuracy the total destruction caused by all the parasites, but it was doubtless greater than that indicated by the available data. It is apparent that high parasitization was instrumental in reducing the jointworm population between 1929 and 1934.

The most effective parasites were *Eurytoma parva* Phillips and *Ditropinotus aureoviridis* Crawford. The former has a single generation per year. Eggs are laid in a jointworm cell or in the plant tissue outside the cell. Newly hatched larvae burrow through the tissues and devour larvae or eggs of *Harmolita tritici* or other *Eurytoma* larvae they may encounter. After the *Eurytoma* has destroyed the jointworm or other larvae in the cell it feeds on the plant tissue. Upon approaching maturity it frequently tunnels from one cell to another and destroys the occupants. *Ditropinotus aureoviridis*, in the Willamette Valley, has one complete and a partial second generation per year. The host may be *H. tritici*, *E. parva*, another *D. aureoviridis*, or some other species. Other parasites of lesser importance were *Eupelmella vesicularis* (Retz.), *Eupelmus allynii* (French), *Calosota metallica* Gahan, *Decatoma amsterdamensis* Girault, *Eurytoma phoebus* Girault, and some undetermined pteromalids.

In the Willamette Valley most of the jointworms in fall-plowed stubble are dead long before the normal time of emergence of the adults. In some seasons a few may survive until about the normal time of emergence, and if some of the buried stubble is brought to the surface by spring cultivation there may be a slight emergence. In experiments with burying by hand the adult did not issue from buried stubble even when it was buried shortly before the time for emergence. Apparently, therefore, early spring plowing of stubble is about as effective as fall plowing in destroying jointworms.

Since red clover frequently is planted with wheat as a nurse crop, much stubble is left standing and this is a constant source of infestation. To avoid this situation, winter barley or Winter Turf (Oregon Gray) oats should be substituted for wheat as a nurse crop for clover.

Where stubble has not been plowed, efforts should be made to plant wheat as far as possible from infested stubble.

To avoid burying high stubble, some farmers burn their stubble fields, a practice which kills the jointworms in them. If this is done, burning should be so thorough that no standing stubble is left. There is little difficulty in burning the stubble completely. As there is much valuable property and many woodlands in the Willamette Valley, extreme caution should be used in the burning of stubble. Consideration should also be given to the soil-conservation and crop-rotation practices recommended for the district concerned before burning of stubble is resorted to.

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