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Date of Planting Studies of Winter Wheat and Winter Barley in Relation to Root and Crown Rot Grain Yields and Quality

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DATE OF PLANTING STUDIES OF WINTER WHEAT AND WINTER BARLEY IN RELATION TO ROOT AND CROWN ROT, GRAIN YIELDS AND QUALITY

C. R. Fenster, M. G. Boosalis and J. L. Weihing[1]

SUMMARY

Root and crown rot of winter wheat in western Nebraska is a stress-related disease commonly caused by either or both of the soil-borne fungi *Helminthosporium sativum* P K and B and by *Fusarium roseum* f. cerealis (Lk.) Snyder and Hansen, Graminearum, Culmorum, Avenaceum. Moisture stress during fall, winter and/or spring predisposes winter wheat plants to invasion by these fungi.

Date-of-planting studies were conducted at various locations in western Nebraska over a period of 15 years. Plant samples taken during fall, winter and spring from various planting dates were examined for root and crown rot and isolations were made to determine the causal organism(s).

These investigations led to in-depth studies on the interrelationship of soil temperature, moisture and type, to survival and infection by the pathogen. Surprisingly, it wasfound that *H. sativum* conidia would germinate at 32^{o} to 36^{o}F and cause infection which was manifested as root lesions after 3 to 4 weeks.

From these studies, it was found that date of planting influenced the extensiveness and intensity of root and crown rot. A "rule of thumb" for determining the best seeding date to minimize this disease and thereby increase yield was developed. For specific areas in western Nebraska with 4,000 feet as the base elevation and Sept. 10 as the base date, each 100-foot difference in elevation means one day difference in planting time. The higher the elevation, the earlier the best planting date. The lower the elevation, the later the best planting date.

It is estimated that the application of this information has increased wheat yields 5 bushels per acre annually in western Nebraska. This represents an annual yield increase of wheat in western Nebraska of 5 million bushels or about $6,250,000.

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INTRODUCTION

The high plains of western Nebraska became "wheat country" during World War II. Geographically, this area is west of a general north-south line extending through North Platte, excluding the Sandhills. It is a treeless area whose elevation gradually rises from 2,500 feet in the east to 5,400 feet in the southwest corner of the Nebraska Panhandle. It covers roughly an east-west distance of 200 miles.

Average yearly precipitation in the region is inverse to elevation, being higher in the east, 20 inches, and lower in the west, 13 inches. Soils vary from excellent silt loams to coarse sands or calcareous outcroppings. The region commonly experiences drought and strong winter winds.

Snow cover is undependable and when snow does fall it is usually accompanied by strong cold winds. Winter temperatures vary considerably, temperatures of zero or below occurring occasionally.

Warm periods, especially during February and March, are common. During those periods winter annual crops begin to grow. Extreme cold temperatures following a warm period frequently will cause winter injury to the growing plant. Diurnal temperatures vary considerably due to low humidity.

In early cultivation of these lands, continuous cropping and poor cultural practices quickly depleted subsoils of their extra moisture and crop failure became common. The one-year fallow system between successive wheat crops was introduced in the 1930s. The area survived, revived and became a stable hard red winter wheat producing area.

The region must be recognized as a "stress region." It is in this environment that the crown and root rot disease of winter wheat best develops. It is an insidious, persistent and inconspicuous disease which each year reduces wheat yields to some degree. In extreme cases, entire fields or large areas of fields may die out in the spring because of root and crown rot disease. Mostly it is an unseen subtle disease, one that reduces vigor and impairs the functioning of roots and crown.

The western Nebraska wheat farmer has always had to choose between the lesser of two evils when selecting a wheat planting date. Planting early gives good plant establishment that aids in the control of wind erosion but it can result in a serious depletion of soil moisture reserves because of heavy fall growth. In the spring, root and crown rot abounds because of drought stress. Late planting conserves moisture but if there is too little soil protection due to insufficient plant growth, residues and surface roughness, serious wind erosion and winter injury result. These stresses set the base for root and crown rot.

This study was undertaken to determine the nature of root and crown rot of wheat and to ascertain the proper time to plant winter wheat so as to conserve moisture, minimize root and crown rot and thereby maximize yield. Studies conducted for 15 years at several locations in western Nebraska reveal that planting date is a significant factor for higher yields, *particularly in certain years.*

LITERATURE REVIEW

Relationship of Cultural Factors to Root and Crown Rot

The influence of date-of-seeding on yield of winter wheat in the Great Plains area was studied periodically by researchers at nine locations from 1908 to 1924. Martin (30), who summarized results, concluded that the optimum date-of-seeding was essentially independent of soil type, annual precipitation, variety and rate-of-seeding but was somewhat related to temperature at planting time.

He further concluded that in the Northern Great Plains a heavy growth before winter was of no advantage and could be detrimental through exhaustion of soil fertility and moisture. Early seedings did not prove successful because of excessive fall growth. Very late seedings produced even poorer yields than early seedings because of poor plant development and late maturity. Wheat plants which barely emerged in the fall would frequently winter kill.

In his analysis, Martin (30) found that at most stations the optimum date-of-seeding occurs when the daily mean temperature lies between 50 and 62^{O}F. In conclusion he stated that "medium" seeding dates are most favorable.

Martin's report did not take into account any measure of root and crown rot intensity in relation to date-of-planting. However, there have been a number of investigators who have studied this relationship. All came to the conclusion that root and crown rot is greatest in early seedings and it progressively diminishes the later the seeding of winter wheat (7, 24, 25, 36, 40, 41).

Regarding the magnitude of yield losses caused by common root and crown rot of winter wheat, Canadian workers devised a method of relating symptom expression to yield loss. This consisted of collecting plants at random from a field, classifying them on the basis of subcrown deterioration and measuring the yield per plant (30). An average for three years showed that a slight, moderate and heavy attack by common root and crown rot reduced the yield of individual plants 25.7, 37.5 and 53.3%, respectively. Yields were decreased as a result of a reduction in the number of fruiting tillers and kernels per spike.

Sallons (38) summarized the annual survey results of numerous fields from 1934 to 1943 and determined that the loss from common root rot in Saskatchewan was 5.14 bushels per acre. This amounted to about 1/3 of the actual yields harvested, thus illustrating the great importance of this inconspicuous disease.

Where accurate and continuous records were kept for a period of 23 years (38), data showed there was a gradual increase in common root rot from 1930-1953 in wheat lands of Saskatchewan. In this area weather factors, particularly rainfall, appeared to have been most important during good crop periods, at which time root rot either declined or remained relatively static, but during poor crop periods it tended to increase markedly.

The relationship of soil temperature at planting time to subsequent root and crown rot intensity was studied by Robertson, *et al.* (36). They observed at Akron, Colo., a strong correlation between high soil temperature at planting time and subsequent high incidence of root and crown rot. Of course, the high to low temperature at planting time followed the same sequence of early to late planting dates.

In their opinion, the high temperature was contributory to a high incidence of root and crown rot which was one of the main factors reducing yields in earlier plantings. They found that a soil temperature of 65°F at planting time was optimum. Temperatures above this point caused yields to be increasingly depressed because of the severity of root and crown rot. Below this temperature yields were depressed because of lack of plant development.

Although rates-of-seeding had a significant effect in differences in yields at Akron, Colo., they apparently did not influence root and crown rot intensity.

There are some differences of opinion as to the effect of tillage procedures on crown and root rot. Canadian studies (38) indicate that there is less root and crown rot following a moldboard plow vs a stubble mulch tenchique. United States investigators (22, 41) report that there is no difference. Sprague (43) reported that a firm seed bed is better than a loose one for the control of root and crown rot.

Seed treatments have proved valuable where pathogens were present on or in the seed. They have only limited application in the control of cereal root and crown rot (39).

Causal Organisms Involved in Root and Crown Rot

The organism most commonly reported as the cause of common root and crown rot is *Cochliobolus sativus* (Ito and Kurib.) (until recently, more commonly known as *Helminthosporium sativum* PBK (39). It has a perfect stage, *Cochliobolus sativum* (Ito and Kurib.) Drecshler ex Dastur.

The second most commonly reported organism is *Fusarium roseum* f. *cerealis* (Lk.) Snyder and Hansen, Graminearum, Culmorum, Avenaceum.

Broadfoot (8) made isolations from 43,305 plants having common root and crown rot which were obtained from a number of experiment stations in Canada. About 50% of the plants yielded either *H. sativum* or *Fusarium* species, or both. The predominance of *H. sativum* or *Fusarium* species varied from year to year, neither being exceptionally greater. The crop sequence or cultural practice used did not appear to significantly effect the relative prevalence of either *H. sativum* or *Fusarium* species in the crown tissue of wheat at any given station in any year.

Broadfoot felt the most significant result obtained was the indication that climatic conditions and possibly the soil at a station determined the prevalence of *H. sativum* and *Fusarium* species.

Other diseases of the roots, crown and/or culm base which occur but are greatly subordinate in importance to the ubiquitous common root and crown rot are: Take-all *(Ophiobolus graminis* Sacc.), strawbreaker footrot *(Cercosporella herpotrichoides* Fron) and sharpeye spot strawbreaker *(Rhizoctonia solani* Kuehn). None of these were involved in the trials reported.

ROOT AND CROWN ROT OF WINTER WHEAT AND BARLEY IN WESTERN NEBRASKA

Information on root and crown rot of wheat and barley reported here is based on cooperative research done between the departments of Plant Pathology and Agronomy the past 15 years. Most of the studies deal with root and crown rot of these crops in western Nebraska. The incidence, severity and seasonal development of the disease was determined from plant specimens collected monthly from September through April in several commercial fields and from experimental plots in western Nebraska.

Experimental plot studies were concerned primarily with dates of planting, firmness of seed bed, fungicide seed treatment and leaf rust in relation to root and crown development. The primary pathogen investigated was *Helminthosporium sativum.* Other studies were concerned with *Fusarium* spp.

Nature of the Disease

Symptoms of root and crown rot of winter wheat and barley, also called common root rot, generally appear first on the roots in November and early December. At this time the plants have well developed primary roots and secondary crown roots. Between these two root systems is the subcoronal internode, which elevates the young plants to the surface of the ground (Fig. 1).

Small brown to black lesions occur on primary and secondary roots. These lesions are variable in length, ranging from less than 1/8 inch to over one inch and they may develop on any part of the root. In some seasons, as in 1965, the first lesions develop at the tips and at the base of the secondary roots (Fig. 2). A more random distribution of lesions usually appears on the primary roots in November and early December.

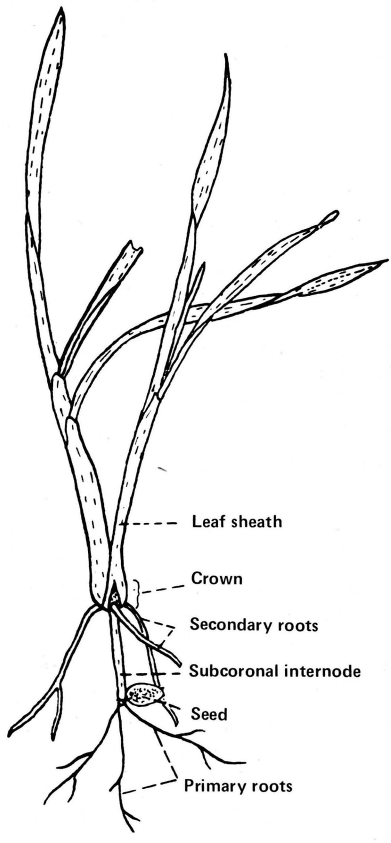


Fig. 1. Picture of wheat root system.

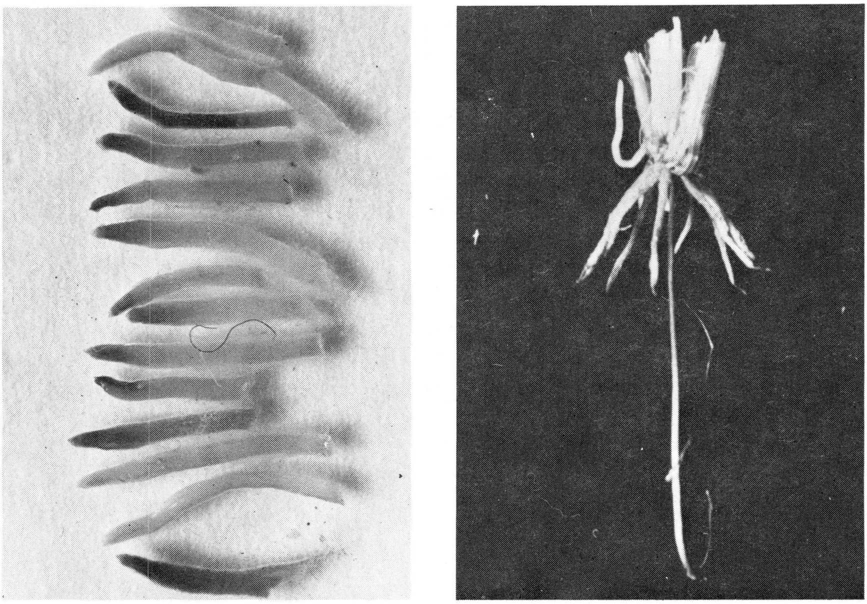


Fig. 2. Lesions at the tips of young crown roots of wheat collected in January, 1965.

A few lesions, generally on primary roots, may be seen on a few plants prior to November and as early as late September. On the other hand, 5 to 10% of the primary and secondary roots of wheat and barley plants may have lesions in November and early December.

At this time less than 1% of the plants may have subcoronal internodes partially or completely black. A negligible number of plants have crowns that are slightly discolored on the inside. Only a small portion of the crown is dark brown or black but still sound and capable of producing new roots. The extent and severity of the disease on the subcoronal internode and crown in November and December may vary from season to season.

Prolonged moisture stress coupled with relatively high soil temperature in the fall are important factors conducive to early development of the disease on the underground organs of the plant. The subcoronal internode invariably turns black in the late fall or early winter.

Isolations from black subcoronal internodes usually yield *Helminthosporium sativum* and less frequently *Fusarium* spp. Some of the isolates of *H. sativum* from these plant organs caused root and crown rot of wheat when tested in the greenhouses. The source of the inoculum for infection of the subcoronal internode and the reason why this tissue generally becomes infected with *H. sativum* are not know. It may be that *H. sativum* spreads to the crown from the infected subcoronal internode.

The onset of symptom development on subcoronal internodes is hastened with prolonged drought and high soil temperatures in the fall and early winter.

Root and crown rot of wheat and barley may continue to develop and become severe during the winter. Symptoms of the disease in the winter are similar to those previously described for roots, crowns and subcoronal internodes except that they are generally more pronounced and extensive (Fig. 3). In addition to these symptoms, however, some of the disease crown roots become thicker and distorted. This type of symptom is similar to that caused by organic toxic substances in residues produced by microorganisms (32,33). In some years, 1965 for example, 80-90% of the total roots of over 50% of the plants in many fields were killed by the disease by early February. The crowns may also be severely diseased by February and turn dark brown to black and become soft and spongy (Fig. 3).

When severe damage occurs in the crown, the plant will not recover even though weather conditions are optimum. With regard to this disease, the crown tissue is the most vulnerable part of the plant. It is this tissue that generates new crown roots and tillers and through which photosynthate food and soil nutrients and water are translocated to the leaves and roots. Thus, plants with severely damaged crowns fail to develop new crown roots to meet the needs of the growing plant for water and soil nutrients.

On the other hand, plants with moderately or even with severely diseased roots but with healthy crowns may recover from the disease by producing new

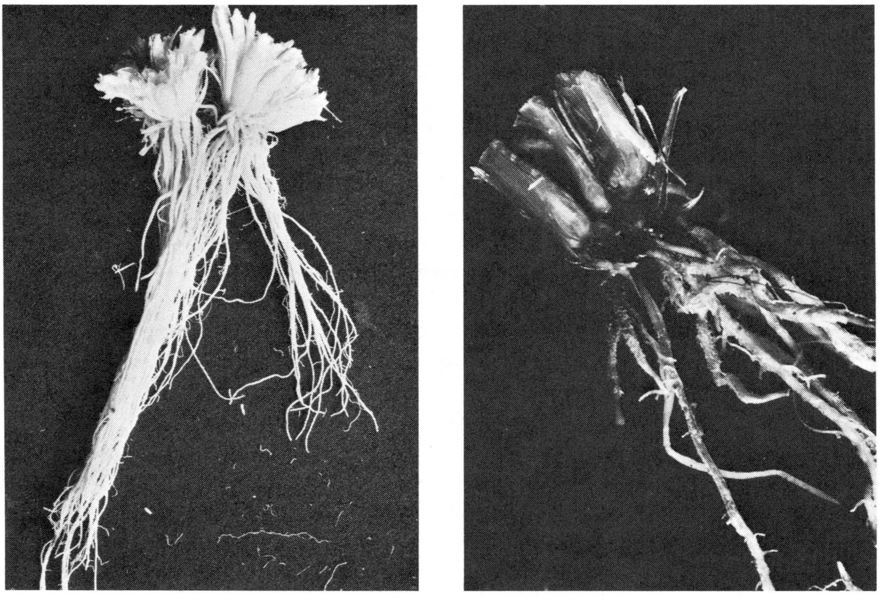


Fig. 3. Root and crown rot of wheat in February. A) Healthy roots and crowns. B) Severe root and crown rot.

crown roots in the spring. Recovery of these plants is most rapid when cool, moist weather prevails in the spring.

Plants killed in winter and early spring by crown and root rot are frequently referred to as being "winter killed." Winter killing may be erroneously ascribed as due entirely to low soil temperature or to drought. Such a diagnosis discounts the important role of soil-borne fungi in causing this complex disease.

In some instances root and crown rot may be blamed on the so-called "atmospheric static electricity" that purportedly builds up during protracted periods of dry, hot weather accompanied by blowing soil and dust in spring or early summer. In this case, it is the inclement dry weather that imposes a tremendous water stress on those plants whose severely diseased roots and crowns cannot absorb sufficient soil moisture, thereby resulting in permanent wilting and death of the plant. Atmospheric static electricity may only be coincidental with drought conditions and has nothing to do with root and crown rot.

Symptoms on the aerial parts of wheat and barley that may be associated with root and crown rot are wilting, stunting and chlorosis (yellowing of the leaves).

Preemergent and postemergent damping-off of wheat and barley seedlings caused by root and crown rot fungi is generally not a serious problem in western Nebraska. The reason for this relates to the effective control of this phase of the disease by treating the seed with fungicides. Uneven, thin strands of wheat and barley in the fall are due principally to low soil moisture and wind erosion which kill the plants and culminate in "blowing-out" of the plants.

Nature of the Pathogen and the Disease

Root and crown rot of winter wheat in western Nebraska is caused principally by *Helminthosporium sativum* P K and B (sexual stage known as *Cochliobolus sativus*) (Ito and Kurib). Drech. ex Dastur and by *Fusarium roseum* Lk. emend. Snyd. & Hans. F. sp. *Cerealis* (CK1.) Snyd. & Hans. 'Culmorum'. Other fungi isolated from diseased primary and crown roots of wheat and barley were *Fusarium* spp. such as *Fusarium oxysporum, Fusarium moniliforme, Phythium* sp. and *Rhizoctonia solani*. Results from pathogenicity tests in the greenhouse indicated that some isolates of the second group of fungi were also pathogenic on wheat. Studies were made in the greenhouse to determine the virulence of *Helminthosporium sativum* on Cheyenne wheat grown under stress conditions caused by lack of soil moisture and temperature. Soil used in this test was obtained from several commercial wheat fields in western Nebraska. One lot of soil was sterilized twice for two hours on two consecutive days. The sterilized soil and one lot of the unsterilized soil was infested with a pure culture of *H. sativum* grown on sterilized wheat roots (4).

About 10 grams of the inoculum was thoroughly mixed with the soil per each five-inch pot. An equal amount of sterilized wheat roots was incorporated in the soil of the control treatment. Five wheat seeds treated with Panogen were planted two inches deep in each pot and incubated at $20^{o}C$. *Soil moisture* was maintained at 45% of the soil's moisture holding capacity (MHC). Three plants were allowed to grow in each pot. After the seedling had formed the second leaf, one set of plants was kept at 5 to 8^{o}C and watered to 45% MHC.

The second set of plants was subjected to moisture and temperature stress by watering the plants once every 10 days to 45% MHC and by raising the temperature to 25^{o}C for 60 hours every 10 days just prior to watering the plants. Three months after the start of the stress treatments, the plants were examined for root and crown rot.

The highest incidence of root rot occurred with plants in the inoculated sterilized soil subjected to water and temperature stress. About 40% of the crown roots had lesions caused by *H. sativum.* None of the plant crowns in this treatment showed symptoms of the disease. About 10% of the subcoronal internodes showed black discoloration and yielded *H. sativum.*

The second highest incidence of the disease was noted with plants grown in inoculated unsterilized soil subjected to water and temperature stress. Close to 15% of the crown roots of all plants had lesions incited by *H. sativum.* None of the crowns of the plants were diseased and only a few of the subcoronal internodes were black and infected with *H. sativum.*

A negligible amount of root rot was detected on plants grown in sterilized inoculated soil, in unsterilized inoculated soil and uninoculated sterilized or unsterilized soil that was not subjected to water or temperature stress.

The results of these studies and of the field surveys indicate that *Helminthosporium sativum* is a weak parasite capable of attacking the roots and crowns of debilitated plants. Moisture and temperature stress are only two factors that may increase the susceptibility of roots and crowns to *H. sativum.* Other factors that may also render the plants vulnerable to root and crown rot include wind erosion, other infectious diseases such as leaf rust, septoria leaf blight and injury caused by insects such as Hessian Fly (3).

Diseased roots and crowns of wheat and barley grown in the field are usually infected by more than one fungus. The most common fungi isolated from the same diseased root or crown were *H. sativum* and *Fusarium* spp. More research is needed to determine the role of these and other microorganisms in the development of root and crown rot of wheat grown under various environmental stress conditions.

During some seasons no fungi could be microscopically detected or isolated from diseased roots and crowns of wheat collected in the late fall or early winter. Very few crown roots surface disinfected with 1% solution of sodium hypochlorite or 0.5% solution of mercuric bichlorite for 30 seconds or treated only by thoroughly washing the roots in running tap water yielded fungi. It appeared that such diseased crown roots, exhibiting symptoms similar to those caused by fungi, were caused by some noninfectious agent(s).

Ecology of Helminthosporium Sativum in Soil

Knowledge of the behavior of pathogens causing root diseases in their natural soil habitat is requisite to understanding the complex development of disease epidemics and to effecting sound control measures against these intractable diseases.

Survival of soil-borne pathogens in the absence of a suitable host is accomplished in several ways. This may involve the production of sexual or asexual spores, or specialized vegetative structures such as mycelia and sclerotia in the soil or on or in plant residues from diseased plants or from non-infected plants. These fungus structures will not germinate or commence to grow until a suitable environment is provided. Such an environment generally includes adequate soil moisture, a favorable temperature and sufficient nutrients.

The soil-borne fungus *H. sativum* may survive in soil as conidia, (asexual spores) or as mycelia or as both structures (5, 9, 10, 12, 13, 15, 21, 23, 28). Nearly all of the conidia of *H. sativum* as well as the conidia of many other soil-inhabiting fungi do not germinate in soil even though soil moisture and temperature are favorable for germination. Although these spores are not dormant, they remain inactive in natural soil without losing their viability or virulence. This phenomenon, the inability of fungus spores to germinate in soil under conditions considered to be favorable for germination, is termed "soil fungistasis." The origin and nature of soil fungistasis is currently the subject of intensive research and controversy both as to origin and nature.

The three most widely accepted explanations of the nature of soil fungistasis in inhibiting fungus spore germination are:

The fungistatic substance is a diffusible or volatile substance which is most likely of a microbial origin present in all soils (1, 19, 2, 20, 26).

An alternative possibility accounting for soil fungistasis concerns microbial competition for nutrients or the lack of nutrients in the spore environment, causing the germination inhibition (27, 29).

Still another group of workers (14) believes that more than one mechanism may operate in the germination of fungus spores in soil. These mechanisms may involve both the fungistatic substances and nutritional factors in affecting spore germination in soil.

Further research is needed to resolve the nature of the soil fungistatic factor.

But regardless of the exact mechanism(s) of soil fungistasis, it is an important factor in the successful survival of *H. sativum* in soil and in the outbreak epidemics of root and crown rot of wheat and barley. In this connection, results from our studies showed that the conidia of *H. sativum* may survive in the fine sandy clay loam soil of southwestern Nebraska for over four years. Over 65% of the spores of this pathogen placed in soil from black fallow or stubble mulch wheat fields survived after incubating outdoors for one year. Less than 30% of these conidia were viable after two years in soil. And less than 1% retained their viability after four years in soil. Many of the conidia incubated in the sandy clay loam soil four years were still virulent. This was shown by placing the four-year-old conidia on roots of wheat seedlings and incubating these plants in sterilized soil under water and temperature stress conditions as previously described. Many of the inoculated roots developed symptoms of the disease and yielded *H. sativum.*

The unusual longevity of conidia in soils of western Nebraska coupled with a continuous cropping of wheat in that area may account in part for the frequent and severe outbreaks of root and crown rot of wheat in that area.

In contrast to the prolonged longevity of conidia of *H. sativum* in the sandy clay soil of western Nebraska, the conidia quickly lost their viability in the "finer textured" organic silty clay loam soils of southeastern Nebraska. The viability of the conidia diminished very sharply after six months in the soil of eastern Nebraska. Only a few viable conidia were recovered after one year in this soil.

Some of the conidia incubated in both soil types were converted directly to chlamydospores as previously reported by Meronuck and Pepper (34). Over 20% of the surviving conidia incubated 2 years in soil from southwestern Nebraska showed chlamydospores from natural soils of western Nebraska (Fig. 4). Further research is needed to determine the relationship between chlamydospore formation within conidia of *H. sativum* and the survival of this pathogen in soil.

Germination of conidia of *H. sativum* occurs in soil and on the roots of wheat. Two distinct modes of conidial germination and sporulation of *H. sativum* were observed in our studies in amended and unamended soil from southwestern Nebraska (5). Normal germination and sporulation of conidia similar to that on synthetic media were common in soil amended with potato dextrose broth (PDB), potato broth, dextrose broth, cornmeal or wheatmeal (Fig. 5).

Precocious sporulation was distinguished by a single spore borne at the tip of stout unbranched or sparsely branched germ tubes (Fig. 5).

The highest percentage of germinated conidia, 50-63%, sporulating precociously was noted with conidia incubated in soil for 7 to 180 days at 3^{o} and $22^{o}C$ before amending the soil with PDB. The treatment of incubating conidia in soil outdoors for 300 and 400 days then amending with PDB was not conducive to precocious sporulation. Less than 4% of the conidia germinated in the control treatment using water as the amendment. A negligible number of the conidia in soil amended with water sporulated precociously.

We have noted recently that a small percentage, less than 1%, of the conidia placed adjacent to the roots of wheat will germinate and sporulate precociously. The great majority of germinated conidia in the immediate vicinity of roots, the rhizosphere, produced extensive mycelia on the surface of the roots. In some cases, however, the germinated spores produced small amounts of mycelia before entering the roots.

More recently we have also recovered a few germinated conidia of *H. sativum* showing precocious sporulation from the rhizosphere of wheat collected in November from fields in western Nebraska.

It would appear then that several factors favor precocious sporulations of the germinated conidia of *H. sativum* in soil. Precocious sporulation may be contingent on the genetic constitution of the fungus. Furthermore, the length of incubation of conidia in soil and the type of nutrients available to the germinating conidia may also affect the mode of sporulation.

The significance of our observations on the mode of conidial germination and sporulation of *H. sativum* in soil is obvious since the saprophytic behavior of

Fig. 4. Chlamydospores within conidia of *Helminthosporium sativum.* A-B) Conidia recovered from field soil of western Nebraska. Note germination of chlamydospores. C) Non-viable conidium recovered from field soil. Note holes in conidial wall.

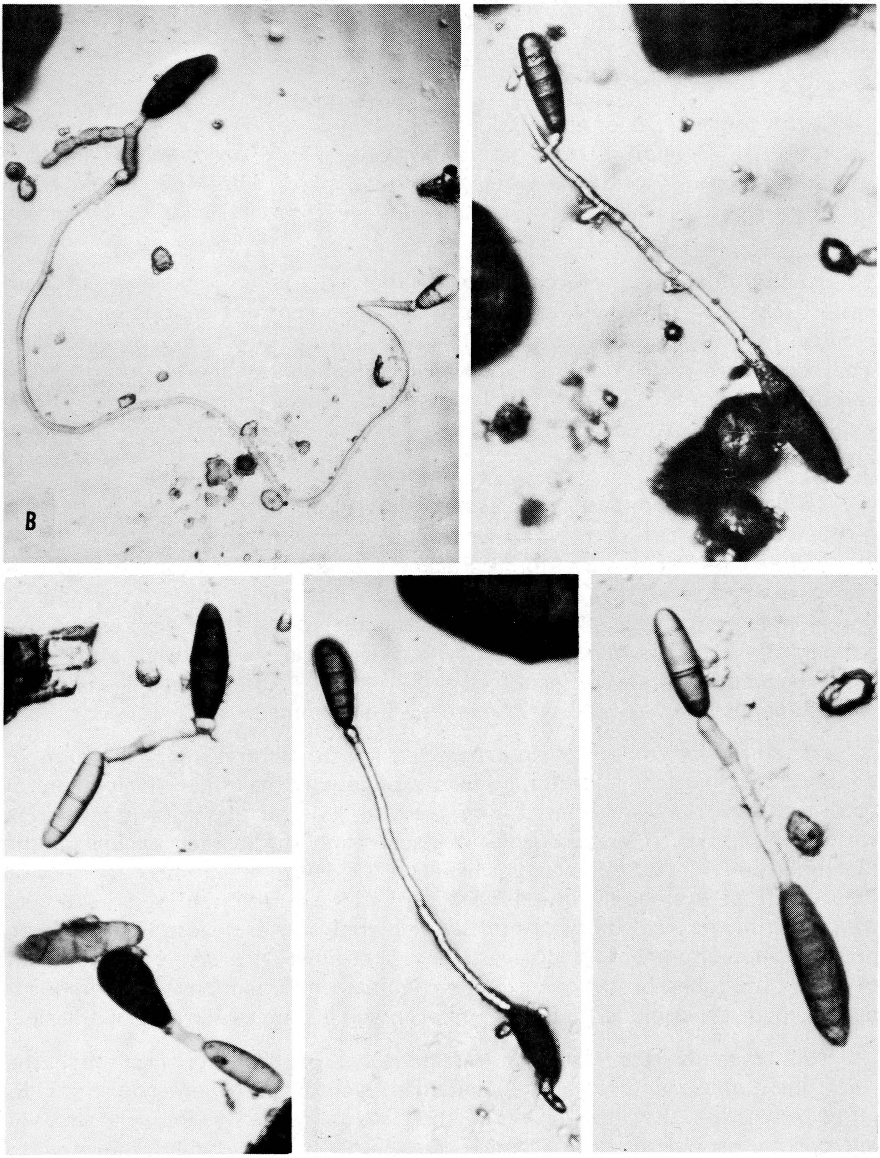


Fig. 5. Precocious sporulation from conidia of *Helminthosporium sativum* germinated in unsterilized soil amended with potato-dextrose broth. A) Normal sporulation on hypha from germinated conidium. B-E) Germinated conidia with germ tubes of variable lengths bearing single conidia at their tips. F) Sporulation from conidium derived from precocious sporulation.

soil-borne pathogens is closely related to the development of root diseases. Accordingly, those factors affecting longevity and the mode of germination and sporulation of fungus propagules in soil also may affect the incidence and severity of root diseases.

With normal types of sporulation, many conidia of *H. sativum* are borne on conidiophores developing from branched hyphae. A soil environment conducive to regular type of sporulation would, therefore, increase the inoculum potential of the fungus many times more than an environment favoring precocious sporulation.

On the other hand, precocious sporulation may be an important safeguard against drastic reduction of inoculum in a soil environment conducive to initial conidial germination but inadequate to sustain further growth and development. The occurrence and variability of spore germination and sporulation in soil in response to different environmental factors and especially nutrition may partly explain the inconsistency of crop rotation systems and soil amendments in alleviating root diseases.

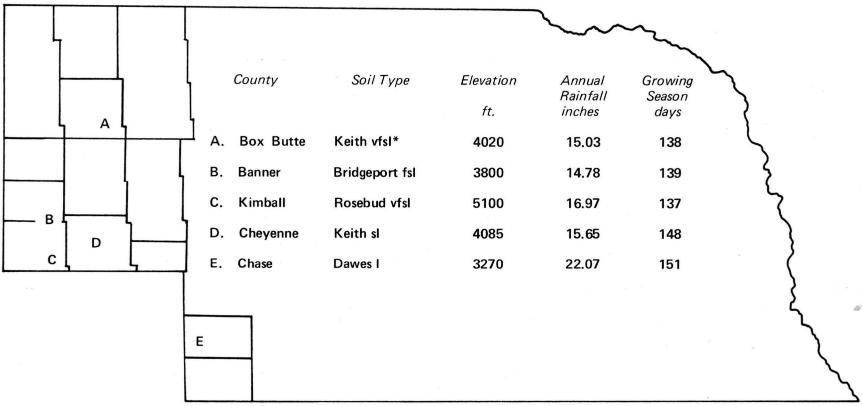
Results from our recent studies also show that the conidia of *H. sativum* germinate on or near the roots of wheat grown in sterilized or natural soil from western Nebraska kept at 32^{o} to 36^{o}F and cause lesions on the roots after 3 to 4 weeks incubation at this low temperature. In this study, the crown roots of young wheat kept at 32^{o} to 36^{o}F were inoculated with conidia kept at this temperature and then the plants were transplanted in sterilized or natural soil. The inoculated plants were incubated at 32^{o} to 36^{o}F in a growth chamber for approximately five weeks before the roots were examined.

The ability of conidia of *H. sativum* to germinate and infect the roots of wheat at this low temperature may help explain why the initial development of root and crown rot develops during the late fall and in the early winter in western Nebraska. It is reasonable to assume that the marked decline of the metabolic activities of microorganisms in the field at temperatures near freezing may result in overcoming the fungistatic factor. Negation of soil fungistasis coupled with the availability of nutritive materials in the rhizosphere of wheat, provides an environment conducive to spore germination. Further development of the germ tubes or the roots may culminate in infection and subsequent development of lesions on roots of wheat in soil at temperatures near freezing.

More recently the Canadian researchers (35) have reported that the rhizosphere of a spring wheat line contained microorganisms antagonistic to *H. sativum* whereas the rhizosphere of the parental wheat variety was free of microorganisms antagonistic to this pathogen. It would be interesting to determine whether such differences in antagonistic microorganisms exist between winter wheat varieties showing differences in their susceptibility to root and crown rot caused by *H. sativum.* It would also be useful to ascertain whether soil temperature and moisture affect the development of antagonistic microorganisms in the rhizospheres of these wheat varieties.

EFFECT OF VARIOUS PLANTING DATES OF WINTER WHEAT AND WINTER BARLEY ON YIELD, GRAIN TEST WEIGHT, PROTEIN CONTENT AND SOIL MOISTURE USE

Planting dates for winter wheat and barley have been under investigation at various locations in western Nebraska since 1953. Initial studies were conducted at Imperial, Nebr., from 1953 to 1957. Data from these studies indicated Sept. 25 to be the optimum date of planting. Since many farmers were seeding as early as Aug. 15, in the Panhandle area, further studies were started in Box Butte, Kimball, Banner and Cheyenne Counties. These locations were selected on the basis of soil type, elevation, rainfall and length of growing season (Fig. 6).



	County	*Soil Type*	*Elevation* ft.	*Annual Rainfall inches*	*Growing Season days*
A.	Box Butte	Keith vfsl*	4020	15.03	138
B.	Banner	Bridgeport fsl	3800	14.78	139
C.	Kimball	Rosebud vfsl	5100	16.97	137
D.	Cheyenne	Keith sl	4085	15.65	148
E.	Chase	Dawes l	3270	22.07	151

*The letters v, f, s, and l mean, respectively, very, fine, silt, loam.

Fig. 6. Locations, including soil type, elevation, annual precipitation and length of growing season, included in dates of seeding studies.

Experimental Procedure

Five dates of seeding at 10-day intervals were used at all locations. At Imperial, Aug. 25 was the first seeding date followed by Sept. 5, 15, 25 and Oct. 5. At all other locations, Aug. 20 was the first seeding date, followed by Sept. 1, 10, 20, and 30.

Cheyenne winter wheat and Kearney winter barley were the varieties employed throughout all studies and they were planted at the rates of 45 lb/A and 40 lb/A, respectively.

From 1958 to 1966, dates of seeding were compared on both black fallow and stubble mulch fallow in Box Butte and Kimball Counties.

From 1957 to 1960, plant growth of wheat was evaluated each Dec. 1 and April 1 to determine the amount of ground cover at the beginning and end of the winter dormant period. Plant growth was determined by harvesting plant material from a nine-square-foot area. Samples were washed and ovendried at 120°F for 72 hours. Seed test weight was determined by Boerner apparatus and the percent protein by the Kjeldahl method at 13.5% moisture. At Imperial and in Kimball and Banner Counties two replications in randomized blocks were used. In Box Butte and Cheyenne Counties four replications in a randomized block were used.

Results

The average grain yields, test weights and percent protein of winter wheat at the various locations and seeding dates are summarized in Tables 1, 2 and 3 respectively.

Table 1. The effect of date-of-planting and elevation on yield of winter wheat in western Nebraska.

County	*Elevation*	*Year trial conducted*	*Average yield planting dates*				
			8/25	9/5	9/15	9/25	10/5
Chase	3200	1953-57	22.3*a	27.4 ab	31.4 bc	36.1 d	28.7 bc
			8/20	9/1	9/10	9/20	9/30
Banner	3800	1956-68	27.7*a	31.1 a	35.3 ab	37.6 b	34.5 ab
Box Butte	4020	1958-68	22.4 a	25.8 ab	29.3 b	27.4 b	24.4 a
Cheyenne	4085	1961-68	21.7 a	22.6 a	25.2 b	25.6 b	22.9 a
Kimball	5100	1955-64	27.1 c	28.7 c	26.5 bc	22.2 b	15.7 a

*Figures with the same letter are not significantly different at the .05 level.

Chase County
Elevation — 3200 feet above sea level

Year harvested	*Date of planting*				
	Aug. 25	*Sept. 5*	*Sept. 15*	*Sept. 25*	*Oct. 5*
			Bushels per acre		
1953	17.3	24.9	32.2	32.0	24.8
1954	36.5	41.3	46.1	47.1	50.8
1955	18.9	21.8	23.6	22.9	21.4
1956	17.4	21.0	27.8	41.1	19.2
1957	23.9	28.2	32.2	38.3	40.8
1958	18.5	27.4	27.1	35.3	14.3
Avg.	22.1*a	27.4 ab	31.5 bc	36.1 d	28.6 bc

*Figures with the same letters are not significantly different at the .05 level.

Banner County
Elevation — 3800 feet above sea level

Year harvested	*Date of planting*				
	Aug. 20	*Sept. 1*	*Sept. 10*	*Sept. 20*	*Sept. 30*
			Bushels per acre		
1956	35.9	45.7	57.0	48.8	48.1
1957	37.4	37.0	38.7	44.5	35.8
1959	30.4	34.0	32.5	40.4	33.5
1960	32.4	35.9	37.4	40.2	35.0
1961	23.0	24.0	24.5	21.2	19.8
1962	19.6	22.1	26.7	32.9	34.0
1963	30.8	33.5	37.8	42.5	43.8
1966	19.5	23.8	35.2	46.4	43.7
1967	20.2	22.2	24.8	32.7	32.2
1968	27.5	32.7	38.9	26.1	18.6
Avg.	27.7*a	31.1 a	35.3 ab	37.6 b	34.5 ab

*Figures with the same letters are not significantly different at the .05 level.

Box Butte County
Elevation — 4020 feet above sea level

Year harvested	Date of planting				
	Aug. 20	*Sept. 1*	*Sept. 10*	*Sept. 20*	*Sept. 30*
			Bushels per acre		
1958	26.2	32.7	37.4	40.6	40.5
1959	35.9	34.9	46.5	40.2	36.8
1960	34.4	43.6	40.0	29.7	30.4
1961	23.3	30.5	33.5	30.9	21.9
1962	17.9	19.1	17.0	7.4	3.6
1963	9.2	7.9	7.7	12.5	11.7
1964	6.6	13.3	21.3	24.6	24.8
1965	21.0	22.7	25.6	23.6	19.0
1966	23.4	24.9	31.3	32.1	28.3
1968	26.2	28.7	32.2	32.0	26.8
Avg.	22.4*a	25.8 ab	29.3 b	27.4 b	24.4 a

*Figures with the same letters are not significantly different at the .05 level.

Cheyenne County
Elevation — 4085 feet above sea level

Year harvested	Date of planting				
	Aug. 20	*Sept. 1*	*Sept. 10*	*Sept. 20*	*Sept. 30*
			Bushels per acre		
1961	26.2	23.3	24.3	18.0	14.0
1964	21.7	27.1	28.6	29.8	29.9
1965	4.4	8.0	8.8	7.0	4.8
1966	26.9	22.6	30.1	39.8	33.6
1967	21.2	24.5	28.0	31.1	29.3
1968	29.7	29.8	31.1	27.9	25.7
Avg.	21.7*a	22.6 a	25.2 b	25.6 b	22.9 a

*Figures with the same letter are not significantly different at the .05 level.

Kimball County
Elevation — 5100 feet above sea level

Year harvested	Date of planting				
	Aug. 20	*Sept. 1*	*Sept. 10*	*Sept. 20*	*Sept. 30*
			Bushels per acre		
1955	28.0	25.5	23.1	20.9	12.6
1956	16.6	16.9	15.4	14.4	9.8
1957	37.7	37.7	37.8	29.7	16.5
1958	46.8	48.6	45.2	44.7	40.4
1959	20.1	23.0	23.1	20.7	15.0
1960	29.2	29.7	27.0	17.1	11.2
1961	28.6	23.0	20.2	15.6	11.7
1964	10.1	15.5	20.0	14.5	8.6
Avg.	27.1* c	28.7 c	26.5 bc	22.2 b	15.7 a

*Figures with the same letters are not significantly different at the .05 level.

Chase County, 1953-1957[2]

The location in southwest Nebraska was at the Imperial airport. The elevation was 3,270 feet and the average rainfall recorded was 22.07 inches per year. Length of growing season was 151 days per year. Soils at the experimental site were Dawes loam soil.

The highest yields (36.1 bu/A) were obtained on land planted to wheat Sept. 25. Lowest yields were from wheat planted Aug. 25, followed by Sept. 5, Oct. 5 and Sept. 15. In no year did Aug. 25 or Sept. 5 produce the highest yield of wheat. No significant difference was observed on test weight or protein content of wheat produced from various dates of seeding. Based on these studies, Sept. 15 to 25 is the best planting time for winter wheat.

Banner County, 1958-1968

The site was in the Horseshoe Bend area in northeast Banner County. The elevation was 3,800 feet, average rainfall was 14.78 inches per year and length of growing season was 139 days. Soils at the site were a Bridgeport fine sandy loam.

The highest average yields were 37.6 bu/A produced from wheat seeded Sept. 20. The next best dates were Sept. 10 and Sept. 30, averaging 35.3 and 34.5 bu/A respectively. In no year during the 10-year period of the experiment were the highest yields of wheat produced from the Aug. 20 or Sept. 1 date of seeding.

[2]Acknowledgment is given to J. W. Schmidt, Nebraska Agricultural Experiment Station, and V. A. Johnson, ARS-USDA, who conducted these studies.

No significant difference was observed in test weight or protein content of grain. However, Sept. 30 average was the highest and Sept. 1 was the lowest.

Based on the studies, with consideration of fine sandy soil with aggregate stability of soil, optimum date of seeding would be from Sept. 10 to Sept. 20.

Box Butte County, 1958-1968

The Box Butte County location was at the Northwest Agricultural Laboratory five miles northwest of Alliance, Nebr. Elevation at the laboratory is 4,020 feet. The average rainfall was 15.03 inches per year and growing season was 138 days. Soils at the experimental site were a Keith very fine sandy loam.

Highest yields of wheat were obtained from wheat seeded on Sept. 10 followed closely by Sept. 20. Lowest yields of wheat were consistently produced from wheat seeded Aug. 20.

The test weight of the wheat was significantly less from wheat seeded Sept. 20 and Sept. 30. There was a trend for protein content of wheat to be slightly higher from wheat produced on later dates of planting.

These studies indicate that Sept. 10 is the optimum date for planting wheat.

Cheyenne County, 1961-1967

Elevation of the plots in Cheyenne County was about 4,085 feet above sea level. The average rainfall was 15.65 inches, and length of growing season 148 days per year. Soils were a Keith silt loam. Two locations were used during the date of seeding experiments on winter wheat. Tests in 1961, 1964 and 1968 were north of Sidney; in 1965 and 1967 they were north of Lodgepole.

The best yields of wheat were obtained from plots seeded Sept. 10 and Sept. 20. Yields per acre were 25.2 and 25.6 respectively. Heavy rains after seeding of wheat in 1961 affected wheat stands from plots seeded Sept. 1 and Sept. 10, probably reducing wheat yields. Test weight of the wheat was relatively low due to black stem rust in 1965 and a late spring freeze followed by black stem rust in 1967. The black stem rust materially reduced the test weight of grain, especially on later seeding dates. Protein was not materially affected by seeding dates.

Kimball County, 1955-1964

Elevation of the plots in Kimball County was 5,100 feet, average rainfall 16.97 inches and length of growing season 137 days. Best yields from this location were obtained from Aug. 20 and Sept. 1 seeding dates. Each succeeding date produced less grain. Wheat harvest at the Kimball location was about 10 days later than the other locations in the Panhandle. Test weight was lower in the later dates of seeding.

Test Weight of Grains

Test weight of grain was affected only in the latter dates of seeding of winter wheat (Table 2). In wheat planted later than Sept. 20 and at an elevation of 4,000 feet or more, black stem rust was a factor *causing shrivelling of grain and* delayed maturity. The wheat in the latter seeding dates matured seven to 10 days later than that in the early seeding dates.

Protein Content of Grain

When data from all locations were statistically analyzed, there was no significant difference in protein content between wheat produced at various dates of seeding (Table 3). However, in Chase, Banner and Box Butte Counties, the later dates of seeding produced higher protein level.

Moisture Use

Moisture determinations were calculated by the gravimetrical method. Three core samples were taken in each plot every Dec. 1 after planting of the wheat and again the following April 1 (Table 4). In the first foot of soil, moisture was significantly less on the Aug. 20 to Sept. 10 seeding dates than the Sept. 20 and 30 dates. The moisture depletion carried into the second foot of soil, being significantly less on Aug. 20 planting date. Sept. 20 and 30 had significantly more moisture in the second foot of soil. The same pattern existed in April for the various dates of seeding.

Winter Barley Yields

Dates of seeding of winter barley *(Hordeum vulgare* L.) were conducted during various years at North Platte Station[3] and Box Butte and Banner Counties. The results are summarized in Table 5. Lack of winter hardiness

Table 2. The effect of date-of-planting and elevation on winter wheat test weight in western Nebraska.

County	*Elevation*	*Year trial conducted*	*Average test weight lb/bu Planting date*				
			8/25	9/5	9/15	9/25	10/5
Chase	3270	1953-57	59.2*a	60.0a	59.9a	59.5a	58.7a
			8/20	9/1	9/10	9/20	9/30
Banner	3800	1956-68	59.9a	60.5a	60.7a	60.6a	60.6a
Box Butte	4020	1958-68	58.0a	58.0a	57.9a	55.7b	55.2c
Cheyenne	4085	1961-68	55.8a	55.4a	55.9a	55.1a	53.4b
Kimball	5100	1955-64	58.0a	58.1a	58.2a	56.4b	54.6c

*Figures with the same letters in the same line are not significantly different at the .05 level.

[3]Acknowledgment is given to Robert Ramig, former agronomist at North Platte Station, who conducted these studies.

Table 3. Average protein level of winter wheat produced at various locations and dates-of-planting in western Nebraska expressed in percent at 13.5% moisture.

County	*Elevation*	*Year trial conducted*	*Percent protein[a] planting dates*				
			8/25	9/5	9/15	9/25	10/5
Chase	3270	1953-57	10.1	10.9	10.8	11.2	12.3
			8/20	9/1	9/10	9/20	9/30
Banner	3800	1956-68	11.0	10.8	11.1	11.3	12.1
Box Butte	4020	1958-68	10.8	10.2	10.4	11.3	11.5
Cheyenne	4085	1961-67	11.0	10.5	10.0	11.4	11.5
Kimball	5100	1955-64	12.7	13.2	13.2	13.6	12.9

[a]Statistically there were no significant differences.

Table 4. Average inches of available soil moisture in the date-of-planting plots in Box Butte County, 1961-64.

Date-of-planting	*Sampling dates and depths*			
	December 1		*April 1*	
	0-1 ft.	1-2 ft.	0-1 ft.	1-2 ft.
Aug. 20	.40[a]*	.54[a]	.67[a]	.78[a]
Sept. 1	.38[a]	.73[b]	.74[ab]	.79[a]
Sept. 10	.43[a]	.80[b]	.74[ab]	.97[ab]
Sept. 20	.76[b]	1.02[c]	.82[b]	1.02[b]
Sept. 30	.84[c]	1.10[c]	.81[b]	1.09[b]
Average	.56	.84	.75	.93

*Data having same letters in the same column are not significantly different at the .05 level.

caused a great variation in winter survival and effect on yield.

In Banner and Box Butte Counties, the best average yields were obtained on the Sept. 10 date of seeding followed closely by Sept. 20. In Box Butte County, the highest yields were obtained from the Sept. 20 seeding four years out of the six years studied. However, in 1960 and 1961, Sept. 1 and Sept. 10 produced better yields than Sept. 20.

Table 5. Yield of winter barley (bu/A) in Box Butte and Banner Counties and North Platte Station during various years.

Year	Date of seeding				
	8/20	9/1	9/10	9/20	9/30
			North Platte Station		
1955	14.5	19.4	35.7	41.9	43.5
1956	33.6	33.2	26.6	32.2	20.0
1959	34.8	41.1	46.8	45.7	34.6
1960	34.0	54.0	57.0	64.0	47.0
Average	29.2	37.0	41.5	46.0	38.8
			Banner County		
1959	21.2	30.1	32.1	28.0	28.9
			Box Butte County		
1959	5.2	12.1	18.1	21.0	20.3
1960	39.3	48.2	47.8	20.6	20.6
1961	16.0	23.9	26.1	23.0	12.7
1962	4.3	6.6	14.5	15.8	14.2
1963	0	3.3	8.3	18.1	17.1
1964	0	8.3	15.0	22.2	25.7
Average	10.8	17.1	21.6	20.1	18.4

At North Platte, the highest yields were obtained from plots seeded Sept. 20, followed by Sept. 10 date of seeding.

Suggested dates of seeding of winter barley for the Box Butte area, 4,000 feet elevation, is Sept. 10. This date produces better ground cover for erosion control than does Sept. 20. Suggested date of seeding for the North Platte area, 2,900 feet elevation, is Sept. 20.

Amount of Growth of Wheat and Barley During Fall and Winter

Farmers frequently plant winter annual crops early in the fall so that plant growth will help prevent wind erosion. A fall seeded crop may be severely damaged or completely lost by wind erosion plus having much valuable top soil eroded. Several factors such as soil condition at planting time, amount of moisture received, length of growing season, temperature and snow cover influence plant growth in fall and winter.

Wheat and barley plant samples were taken each Dec. 1 and again the following April 1. Fig. 7 shows the effects of planting dates on pounds of

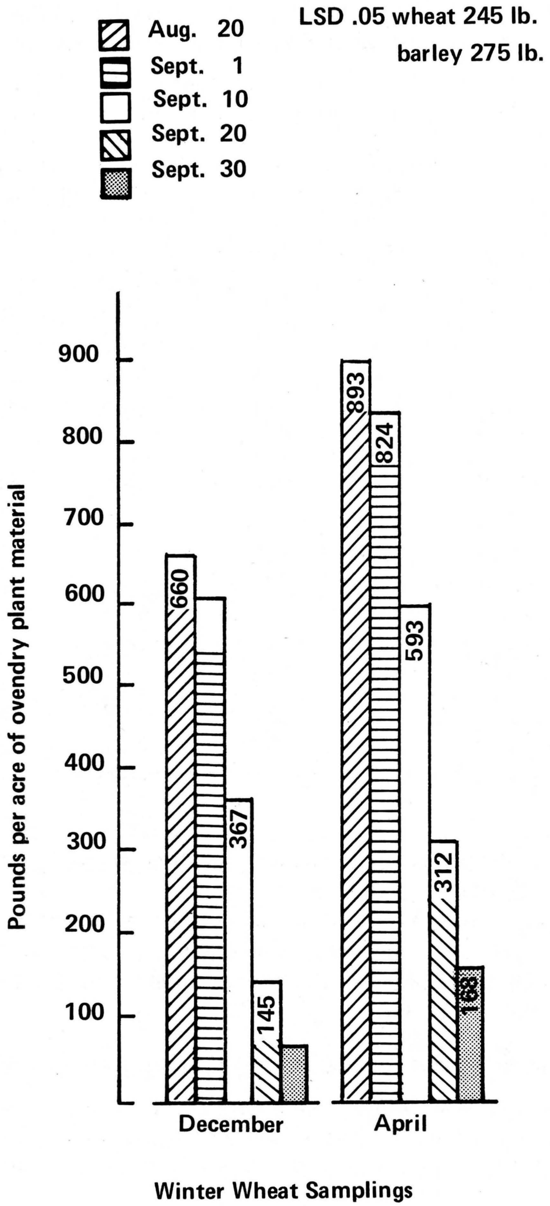


Fig. 7. Effects of planting dates on pounds of ovendry ground cover produced by winter wheat sampled Dec. 1 and April 1. Average of ovendry weights at five locations over a four-year period.

ovendry ground cover produced by winter wheat and barley on Dec. 1 and April 1 at the five locations over a four-year period. Aug. 20 planting produced the most dry matter and each succeeding later planting date had progressively less. The amount of dry matter on Dec. 1 was slightly less than on April 1.

The amount of dry matter produced in the fall and winter on even the earliest seeded plots was not sufficient to protect soils from wind erosion. Using the equation for measuring wind erosion (11) of a highly erodible soil free of residues with a relatively low surface roughness factor and assuming that growing winter wheat or barley plants are equal to mature plant residues, erodibilities for the various dates of planting were determined. Natural wind erodibility varied from 3.6 tons per acre for the Aug. 20 date of seeding to eight tons per acre for the Sept. 30 date of seeding. According to Chepil and Woodruff, less than .25 tons per acre is insignificant erosion.

For losses of .25 to five tons per acre, the soil is only partially protected. For greater than five tons per acre, soil is considered highly erodible and its surface is virtually unprotected from wind erosion. The early date of planting does help to produce vegetative cover which increases soil protection, but it is not sufficient.

Black Fallow vs Stubble Mulch Fallow

Dates of winter wheat planting were compared on both black fallow and stubble mulch fallowed land, Table 6. Dates of planting seem more critical for optimum yield than the fallow method. However, later dates of seeding favored stubble mulch. Optimum yields and test weights on stubble mulch fallow wheat were obtained between Sept. 1 to Sept. 20 and on black fallow wheat between Aug. 20 to Sept. 10. Protein on black fallow wheat was higher than on stubble mulch for all dates of seeding.

Table 6. Average yields of winter wheat planted at various dates on black fallow and stubble mulch fallowed soil in Box Butte County during 1958-1966.

Date of seeding	*Stubble mulch*			*Black fallow*		
	Bu/A	*Test wt.*	*Protein*	*Bu/A*	*Test wt.*	*Protein*
Aug. 20	25.8	58.0	10.0	27.1	57.2	12.2
Sept. 1	28.3	58.0	10.0	28.5	57.6	12.1
Sept. 10	28.3	58.2	10.1	29.8	57.5	12.0
Sept. 20	27.1	57.1	10.8	25.1	56.0	12.8
Sept. 30	23.2	55.1	11.2	18.9	53.7	12.6
Average	26.7	57.3	10.5	25.9	56.4	12.3

MINIMIZING ROOT AND CROWN ROT THROUGH DATE OF PLANTING

Cultural practices greatly affect the incidence and severity of root diseases. Cultural practices influence the environment which may affect the susceptibility of the plant and the viability and virulence of the pathogen.

The seeding date of wheat and barley in western Nebraska influences the incidence of root and crown rot. The highest amount of disease generally occurs on wheat and barley planted too early for a given locality (Table 7). Wheat and barley planted in late August had a much higher incidence of root and crown rot and yielded considerably less than crops planted Sept. 1–20 (Table 1).

Several theories based on the results of these and other studies may be postulated to explain the severe development of the disease on the early planted crops. It is believed that when the combined influence of soil temperature and moisture are unfavorable to the crop, fungus attack follows, due probably to the disturbance of the normal metabolism of the host (17, 18). Little is known, however, about the biochemical aspects of the diseases in relation to high soil temperature and low soil moisture. Another theory relates to the fact that the early seeded crop makes considerable growth in the fall. Such lush growth in a dry fall could put a tremendous water stress on the plant and increase its vulnerability to root and crown rot.

There are seasons when the recommended dates of seeding wheat and barley will not markedly reduce the incidence of root and crown rot. A case in point was in 1965. The unusually long fall that season meant soil temperatures remained high until winter began. Another factor contributing to the high incidence of the disease in 1965 related to the luxuriant growth of the crop in the fall and to the very high incidence of leaf rust which resulted in weakened plants going into winter.

Furthermore, the declining, struggling plants were dealt yet another sharp blow by drought and frost in the spring. Consequently, the recommended seeding dates for southwestern Nebraska did not reduce substantially root and crown rot.

Unfortunately, there is no positive way of predicting these extremely unfavorable seasons in order to accordingly adjust the seeding date. More accurate and specific seeding dates cannot be recommended for the Panhandle area of the state until such time as accurate, long-range weather forecasts are forthcoming. With this in mind, then, it is a good policy to plant wheat at the recommended date.

Based on five-year tests in various areas of western Nebraska, a rule of thumb has been developed for determining the best seeding date for winter wheat. For specific areas in western Nebraska with 4,000 feet as the base elevation and Sept. 10 as the base date each 100 feet of difference in elevation means one day difference in planting time. The higher the elevation, the earlier the best planting date. The lower the elevation, the later the best planting date. These seeding dates relate to soil temperatures at different elevations at a specific time.

Table 7. The effect of date of seeding and the type of fallow on root and crown rot development of Cheyenne winter wheat grown at the Box Butte Experiment Station, 1962.[a]

Seeding date	*Plant organ*	*Month, type of fallow and disease index[c]*											
		Nov.		*Dec.*		*Jan.*		*Feb.*		*March*		*April*	
		SM[b]	*BF*	*SM*	*BF*	*SM*	*BF*	*SM*	*BF*	*SM*	*BF*	*SM*	*BF*
Aug. 20	Crown												
	roots	L	L	L	L	L-M	M	L-M	M	L-M	M	L-M	H
	Crowns	N	N	N	N	N	L	L	L-M	L	M	L	H
Sept. 1	Crown												
	roots	L	L	L	L	L	L	L-M	L-M	L-M	L-M	L-M	M
	Crowns	L	L	L	L	L	L	L	L-M	L	M	L	M
Sept. 10	Crown												
	roots	L	L	L	L	L	L	L-M	M	—	—	L-M	M
	Crowns	N	N	N	N	N	N	N	N	L	L	L	L
Sept. 20	Crown												
	roots	L	L	L	L	L	L	L	N	—	—	L-M	M
	Crowns	N	N	N	N	N	N	N	N	N	N	N	N
Sept. 30	Crown												
	roots[d]	—	—	—	—	—	—	—	—	—	—	—	—
	Crowns	N	N	N	N	N	N	N	N	N	N	N	N

[a]Essentially the same results were obtained with winter barley.

[b]SM=Stubble Mulch and BF=Black Fallow.

[c]Disease Index Rating:

N = No disease symptoms (lesions) on the crown roots, no discoloration of crown.

L = 5-20% of crown roots show lesions, less than 50% of crown tissue is discolored but sound.

M = 21-40% of crown roots show lesions, 50% or more of the crown is discolored but sound.

H = 41-100% of crown roots show lesions, all of the crown tissue is discolored and is partially or completely deteriorated.

[d]Insufficient number of crown roots to make reading.

Based on this formula, the following seeding dates are recommended for counties in western Nebraska with these elevations:

COUNTY	ELEVATION	BEST PLANTING DATE
Chase	3,268	Sept. 25
Banner	3,800	Sept. 15
Box Butte & Cheyenne	4,000	Sept. 10
Kimball	5,100	Sept. 1

By following these recommended dates for seeding wheat, growers of western Nebraska have reduced markedly losses from root and crown rot. It is estimated this cultural practice of seeding wheat at the proper date has increased yields of wheat five bushels per acre annually for the past five years. This represents an annual yield increase of wheat in western Nebraska of five million bushels which amounts to about $6,250,000.

This substantial increase in wheat yield resulted from research on a cultural practice in ascertaining the appropriate seeding dates of wheat and barley for specific areas of western Nebraska in providing an environment favorable to young plants and unfavorable to root and crown rot.

The firmness of seedbed also may affect the incidence of root and crown rot of wheat and barley. Results from preliminary studies indicate that wheat planted in a firm seedbed will have less root and crown rot than wheat planted in a loose seed bed.

The effect of leaf rust on the incidence of root and crown rot of wheat was investigated in western Nebraska for several years. In this study one plot of wheat was treated with Maneb in the fall of the year to control leaf rust. Leaf rust infection resulted from natural inoculum. Yield of grain was 1.7 bu/A better on the Maneb treated plots. The amount of root and crown rot was slightly higher on plants infected with leaf rust. However, leaf rust infection was light in the three fall seasons the tests were made. This may account for the lack of a greater differential of root and crown rot between the rusted and the non-rusted plants.

CONTROL

The following recommendations are offered for the control of root and crown rot and for the maximum yields of wheat and barley in southwestern Nebraska.

1. In western Nebraska plant wheat and barley at the recommended date in relation to elevation.
2. Plant the recommended varieties for your area.
3. Plant in a firm, mellow seedbed.
4. Control weeds in summer fallow land because they deplete soil moisture which would hasten drought stress which in turn predisposes the plants to root and crown rot.
5. All seed should be treated with an appropriate fungicide before planting.

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