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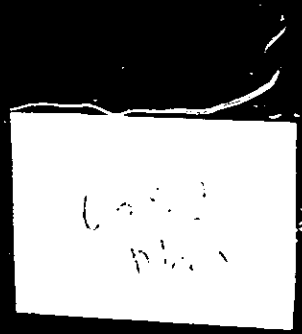

EFFECT OF PLANTING DATE AND CLIMATIC FACTORS ON SOYBEAN SUDDEN DEATH SYNDROME RESPONSE IN CULTIVARS OF DIFFERENT MATURITIES

by

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ABSTRACT

A serious disease affecting soybeans (Glycine max (L.) Merr.) is sudden death syndrome (SDS). SDS is a relatively new disease,which has occurred in several states, causing great concern among farmers growing soybeans. This disease is caused by a soil-borne organism, *Fusarium solani f. sp. phaseoli* strain A, which infects soybean roots. SDS affects mainly fields of high yield potential causing losses up to 80%. Leaf symptoms of SDS usually first appear after flowering as yellow spots between leaf veins, turning into necrosis. As disease progress leaves abscise and pods begin to drop causing yield losses. No effective control has been found for SDS, and varietal choice has been the only relief against it.

Several reports have indicated that SDS is influenced by physical environmental factors. High soil moisture and cool temperatures during the reproductive period appear to encourage greater expression of disease while hot and dry conditions during this period seem to restrict disease development. It has previously been shown that varietal reaction to SDS is influenced by planting date though not in a consistent manner.

The main purpose of this study was to evaluate the effect of planting dates on the expression of SDS in four varieties of different maturity groups. The study was conducted at Ridgway and Villa Ridge, two locations in Southern Illinois chosen based on their previous history of SDS infestation. Four cultivars from maturity group III to VI were used as main plot, and four planting dates spanning from mid May to late June were used as a subplot in a split plot design. Disease scores as well as growth stage were recorded weekly after disease

appearance. Rainfall, minimum-maximum soil temperatures and soil moisture data were collected weekly from the beginning of the season.

First disease appearance occurred as early as the beginning of pod set and more commonly during pod elongation and pod fill stages, with symptoms remaining minor before R4 stage (full length pods). Delayed planting caused reduced ($P<0.001$) disease incidence (DI) in both environments and later maturity groups were affected more than earlier maturity groups ($P<0.05$). However, delayed planting only reduced disease severity (DS) significantly ($P<0.05$) at Ridgway. At both locations maturity groups differed significantly ($P<0.001$) in DS. In some cases, there was also an interaction of planting date and maturity group which affected SDS expression ($P<0.05$). These results from 1994 agree with the overall pattern of results of similar studies conducted from 1987 to 1993, although results from 1990 showed no difference among planting dates. Delay in planting caused reduced yield at Villa Ridge but not at Ridgway. No effect of planting date was observed in seed weight at Villa Ridge, but a slight increase of seed weight at Ridgway with later plantings was observed.

Graphical analysis revealed that the most pronounced periods of disease increase were related to periods of high soil moisture. Overall disease was much higher at Villa Ridge where soil moisture remained high throughout the season than at Ridgway where soil moisture was low between early July and the beginning of September. The effect of soil temperature was not clear but it appeared that periods of rapid increase of disease were related to periods of lower soil temperatures.

According to this and other studies, farmers can reduce the amount of SDS by avoiding planting SDS-prone fields earlier than necessary. However, the yield reduction often associated with delayed planting must be balanced against the benefit of reducing the SDS. Farmers should minimize SDS risk by planting

several varieties which have done best in SDS trials and which encompass a range of maturity.

Further research should examine more critically the effect of environmental factors by improving the assessment of soil and air temperature as well as soil moisture. It would be informative to compare soil moisture and other environmental factors not only to leaf symptoms but also to the time of root infection and progression of root and stem symptoms.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

CHAPTER 1
INTRODUCTION

Production of soybean (*Glycine max (L.) Merr.*), like other crops, faces devastating damage from diseases. A concern among farmers growing soybeans is a relatively new disease named sudden death syndrome (SDS). The name is descriptive in that normal appearing plants turn yellow and die rather quickly in somewhat circular to elongated patches of field after pod set (Scott, 1986).

SDS was first discovered in Arkansas in 1971, but was not very fully described until 1983 (Rupe et al., 1989). By 1989 SDS was found also in Illinois, Indiana, Kentucky, Mississippi, Missouri and Tennessee (Roy et al., 1989). Additional states that have documented reports of SDS include Kansas (Jardine and Rupe, 1993) and Iowa (Yang and Rizvi, 1994), Alabama and Louisiana, and suspected in Texas and Wisconsin (Gibson et al., 1994).

The primary causal agent has been found to be a soil borne fungus, *Fusarium solani* strain A (Roy et al., 1989; and Rupe et al., 1989). In diseased plants, root systems and the number of viable root nodules are reduced, and the vascular tissue is discolored (Rupe et al., 1993).

Above ground visual symptoms of SDS usually first appear after flowering as yellow spots between leaf veins. The spots may become necrotic or may coalesce into chlorotic interveinal streaks which eventually turn necrotic leaving only the major veins green (Rupe et al., 1989; Rupe and Gbur, 1991). Severely affected leaflets abscise leaving petioles attached to the plant (Rupe et al., 1989). Severe foliar symptoms give affected areas in the field a tan to brown cast, and

may be the first evidence of the disease when the field is viewed from a distance (Rupe et al., 1989).

SDS can result in minor or almost total yield losses depending on when it develops. Development of SDS during the early reproductive stages can lead to flower and pod abortion, while later development results in reduced seed size and number (Rupe et al., 1989). Yield losses up to 80% due to SDS have been reported (Hershman et al., 1990).

Environmental conditions associated with the onset and development of the disease are not well understood nor documented (Hirrel, 1986; Gibson et al., 1994). However, Gibson and coworkers (1994), based on their own work and observations of other soybean researchers and growers, reported that SDS is associated with ample soil moisture and that, adequate to more than adequate moisture in the upper rooting zone of the plant during emergence and/or early growth appears important for initial establishment of SDS in the roots, while moderately high levels of soil moisture during pod fill appear to promote the full expression of the disease. Gibson et al. (1994) did not define with soil water measurements the required degree of wetness for SDS development. Cool temperatures as the plant enters its reproductive cycle are suspected to encourage disease as well (Hirrel, 1985). Rupe et al. (1993) reported that soybeans growing in highly productive environments with high soil fertility and irrigation appear to be more susceptible to SDS.

Although several control measures have been examined, no effective chemical or cultural control has been found (Von Qualen et al., 1989; Gibson et al., 1994). However, the most economical and effective method to control SDS is using cultivars which have a history of only mild SDS symptoms (Gibson et al., 1994; Rupe et al., 1989).

Studies have been carried out since 1987 at various locations in Southern Illinois to evaluate the incidence and severity of SDS across planting dates on

cultivars of different maturity groups, and to detect a possible interaction between genotype and environment on the time of onset and progression of the disease (Alghamdi et al., 1992; Gibson et al., 1994). Although some observations indicated that wet and cool conditions preceding initial symptoms of SDS seem to promote the disease ontogeny, the role of soil moisture and air and soil temperature were not clear (Alghamdi et al., 1992).

The objective of this study was to evaluate the effect of planting date and cultivar maturity, in association with climatic factors, on the development, incidence and severity of SDS by monitoring:

1) Rainfall,

2) Soil moisture, and

3) Soil temperature.

CHAPTER 2
THE LITERATURE REVIEW

The Soybean Plant

The soybean belongs to the family Leguminosae, subfamily Papilionoidea and genus *Glycine* Willd. The cultivated form is *Glycine max* (L) Merr., which was never found in the wild (Hymowitz and Singh, 1987).

Apparently domesticated in China (Smith and Huyser, 1987), its adoption in the USA was encouraged by successful use as an oil seed in Europe around 1900. Demand for soybean is derived mainly from the oil and meal, and to only a small extent from whole bean products (Smith and Huyser, 1987). The major producers of soybean are the USA, Brazil, China and Argentina, accounting together for 90 to 95% of the world production (Smith and Huyser, 1987).

Research on soybean has been in proportion to crop production and, as demand for the crop increases and the area planted has expanded, research has also increased (Wilcox, 1987).

Effect of Environment on Phenology

The soybean plant is highly responsive to its environment. The vegetative stage lasts usually six to eight weeks, between emergence and the appearance of the first flower. The ultimate size of the plant depends on the length of the vegetative stage and the environmental conditions prevailing among this period (Scott and Aldrich, 1983).

The ideal temperature for germination and rapid seedling emergence is about 86°F (29°C). Higher or lower temperatures slow the development (Scott

and Aldrich, 1983). Germination and seedling emergence proceed slowly in cold soil and speed as the soil warms. Vegetative growth, flowering and seed set are also affected by temperature. Low temperatures cause slow emergence that increases the probability of injury to seedlings by fungi and insects (Raper and Kramer, 1987).

The soybean plant is photoperiod sensitive, which means that the transition from vegetative to flowering stages occurs in direct response to day length. Most soybeans varieties begin flowering soon after the day length begins to shorten (Scott and Aldrich, 1983).

The soybean plant is very sensitive to changes in the environment, and its total growth is generally in proportion to the availability of water, with the growth of roots as well of the rest of plant affected by soil moisture. High humidity and high temperatures during late stages of seed development may cause poor seed production and quality.

The plant can withstand short periods of drought without serious injury but is very sensitive to drought during germination and seedling growth (Raper and Kramer, 1987).

Soybean Sudden Death Syndrome

General

Records of Tennessee indicate that SDS leaf symptoms may have been seen in fields as early as 1967 (Hines, 1985), but officially sudden death syndrome (SDS) of soybean was first discovered in Arkansas in 1971, yet not very fully described until 1983 (Rupe et al., 1989). Later the disease was noted in Illinois, Indiana, Kentucky, Mississippi and Missouri (Hines, 1985; Sciumbato and Keeling, 1985), where according to Hershman et al. (1990), it is recognized as a major disease of soybean. SDS has also been reported in Kansas (Jardine and

Rupe, 1993), Iowa (Yang and Rizvi, 1994), Alabama and Louisiana, and is suspected in Texas and Wisconsin (Gibson et al., 1994).

Visible symptoms of SDS usually appear after flowering and are often associated with considerable yield losses resulting from pod drop and reduced seed size. Rupe et al. (1993) attributed yield losses in two different years to the effect of SDS on seed size, with an additional yield reduction due to decreased seed number in one of those years. Yield loss has also been reported due to reduction in pod numbers (Von Qualen et al., 1989; Hershman et al., 1990), or due to seed size reduction (Njiti et al., 1993). Yield losses up to 80% due SDS have been reported (Hershman et al., 1990), and according to Gibson (1993), yield losses of 30 bu/ac have been reported in fields expected to produce 55 bu/ac.

Causal Agent

In the early stages of SDS research, some people suspected that nutrient deficiency or herbicide carryover might be the cause of SDS (Brosten and Simmonds, 1989). *Heterodera glycines* Ichinohe, the causal agent of soybean cyst nematode (SCN) was also rumored to be a possible cause of SDS (Hines, 1985). Further research indicated that the primary causal agent of SDS was a soil-borne pathogen, consistent with Diop and Gibson (1988), who were successful in obtaining disease development in the greenhouse using infested soil. *Fusarium solani* (Mart.) Appel & Wollenw. emend. Snyd. & Hans and *Xanthomonas campestris* (Pam.) Dowson were proposed as two possible causal agents, as the two microorganisms caused SDS-like symptoms in greenhouse and growth chambers studies (Rupe et al., 1989). Rupe and Weideman (1986), reported that a soil-borne organism, *Fusarium* sp. was the most frequently isolated pathogen from infested soil, and Sciumbato and Keeling (1985), reported that it was the most frequently isolated from infested roots.

Hirrel (1985) stated that part of the problem in isolating the causal agent was that the infection might occur long before symptom development. His conjecture was proven correct by Killebrew et al. (1988) and Lawrence et al. (1988), who isolated SDS-causing *Fusarium solani* three weeks after planting.

Two morphologically distinct forms of *Fusarium solani,* FS-A and FS-B were isolated from soybean with symptoms of SDS. It was observed that in pathogenicity tests FS-A caused symptoms characteristic of SDS and that it was routinely reisolated from inoculated plants while FS-B caused root rot and no other symptoms characteristic of SDS. These observations led to the conclusion that *Fusarium solani* type A is the primary causal agent of SDS (Roy et al., 1989; Rupe et. al, 1989). O'Donnell and Gray (1995), using molecular data to study phylogenetic relationshipsof several subgroups within the *Fusarium solani* complex, concluded that FS-A strains are members of phylogenetically distinct group that Snyder and Hansen treated as *F. solani* f. sp. *phaseoli* (Burkh.) Snyd. and Hans., and that FS-B strains are an unrelated fungus, *Plectosphaerella cucumerina* (Lindf.) W. Gams. Further molecular investigation by Achenbach (Southern Illinois University, personal communication, 1995) differentiated FS-A from *F. solani f. sp. phaseoli.*

The possible causal involvement of other microorganisms in SDS has also been investigated. Diagnostic techniques for viruses, mycoplasmas and bacteria were employed with negative results (Roy et al., 1989). A *Xanthomonas sp.* was found within xylem vessels of SDS symptomatic plants (Hirrel, 1986). Yopp et al., (1986) reported that *Xanthomonas campestris* is associated with ability to induce SDS symptoms. Hirrel (1983, 1985, 1986), and Sciumbato and Keeling (1985), reported that *Xanthomonas* is often found in high populations in fields where SDS is present, but its role is not well understood. However, it is thought that *Xanthomonas* may be part of a disease complex in which *Fusarium* is the most dominant organism (Rupe et al., 1993).

Indications that SDS is not transmitted by seeds was reported by Scott (1986) and Belmar and Kirby (1990) who in greenhouse studies, found no symptom development when seeds from SDS infested plants were planted in sterilized soil.

The relationship between SCN and SDS has been studied by several researchers. Rupe et al. (1993) and Scott (1986) reported that SCN is often but not always present with SDS and that it was not directly responsible for SDS but had a role that was unclear. Brosten and Simmonds (1984) stated that SCN exacerbates the severity but not the incidence of SDS. Roy et al. (1989) and Melgar and Roy (1994) reported that in greenhouse experiments SCN was not required for infection by *F. solani* but dual inoculation of both organisms caused foliar symptoms to occur earlier and to be more severe than *F. solani* alone. McLean and Lawrence (1993) found that when inoculated with a combination of FS-A and SCN race 3, plants developed symptoms three to four days earlier and that symptoms were more severe. Rupe and Gbur (1995) found that cultivar susceptibility to race 6 of SCN was associated with both earlier appearance and higher severity of SDS. It has been shown that SCN resistant varieties are generally less affected by SDS and that planting SCN resistant cultivars may reduce SDS (Rupe and Gbur, 1995; Rupe et al., 1989; Hershman et al., 1990; Gibson et al. 1994). The role of SCN infestation and its importance regarding SDS will require more study Rupe et al., 1993).

Symptoms

SDS is a disease of soybean roots, lower stems and leaves. Symptoms appear throughout the plant but are most severe on the top leaves (Hershman et al., 1990). The most typical and easily visible disease symptom is the initial yellow

blotching of tissue between the vein in the affected plant leaves. This usually starts to occur during flowering or pod set (Rupe et al., 1989).

Root Symptoms

SDS can also be detected in the roots of affected plants (Brosten and Simmonds, 1989 and Roy et al., 1989). Root symptoms precede foliar symptoms and are characterized by deterioration of taproots, lateral roots and nitrogen-fixing nodules. In SDS-affected plants the roots are reduced in size and crown necrosis is present (Brosten and Simmonds, 1989). The cortex of affected tap roots is light graybrown. The discoloration extends up to the stem several nodes in the vascular tissue but the pith remains white (Rupe et al., 1989). If infected plants are dug up and stems and upper roots split, brown striping of the meaty portion of the lower stem and of the center of the main root can often be seen (Gibson et al., 1994).

Leaf Symptoms

Leaf symptoms usually become evident during flowering or pod fill although symptoms have been seen as early as the four leaf stage (Rupe et al., 1989; Rupe et al., 1993). SDS foliar symptoms include interveinal chlorosis followed by necrosis with midvein and lateral veins remaining green (Rupe et al., 1989; Rupe and Gbur, 1991; Gibson et al., 1994).

Hirrel (1986), described SDS symptoms as interveinal chlorosis developing into interveinal necrosis within 10 days until only tissue near major leaves vein remain green. As the disease becomes more severe leaves abscise at the top of the petiole leaving leafless stems. Later the petioles may also abscise (Von Qualen et al., 1989).

As the causal agent has never been found in the tissue above the crown of any symptomatic plant, the symptoms of vascular discoloration and interveinal

chlorosis may be due to a toxin produced either directly by the pathogen or indirectly through an interaction with the host (Brosten and Simmonds, 1989).

Control

There have been several SDS control measures which have been examined to a greater or lesser extent, such as rotation, tillage, soil fumigation, planting date and use of resistant varieties (Von Qualen et al., 1989; Alghamdi et al., 1992; Gibson et al., 1994). So far, no effective chemical or cultural controls have been found (Gibson et al., 1994). According to Hershman et al. (1990), the development of effective SDS control recommendations has been impeded by lack of or the inconsistency of data on the effect of cultural practices and cultivars on SDS development.

Rotation can be helpful to reduce SCN using non-host crops (Scott, 1986; Gibson et al., 1994) which presumably should reduce the effect of SDS; however, it does not appear to provide much promise of complete relief against SDS. Rotation with some pasture grasses appears to make SDS worse (Hershman, personal communication). According to Howard et al. (1992), soybean fields in rotation with corn have been reported as appearing to increase incidence and severity of SDS. In contrast, Gibson et al.(1994) reported that corn preceding soybeans can increase or decrease SDS symptoms compared to soybeans preceding soybeans, depending on unknown factors.

Apparently depending on the weather, SDS tends to be more severe in early plantings than in later ones (Gibson et al., 1994, Hershman et al., 1990). However, delayed planting is only partially effective and puts the farmer at risk of losing yield from other causes (Gibson, 1993).

Some studies showed that in no-till fields SDS was more severe than in tilled fields, but the data were too limited to draw firm conclusions (Von Qualen et al., 1989; Wrather et al., 1992; Wrather et al., 1995).

Von Qualen et al. (1989) observed that there is not enough gain from chemicals to justify their application, and this was supported by Belmar and Kirby (1990). They reported that fumigation with methyl bromide significantly reduced the incidence of SDS, but is not economically feasible and kills useful soil microorganisms. Brosten and Simmonds (1989) also stated that soil fumigation with methyl bromide-chloropicrin blend is already known to control SDS but is not economical.

Problems in screening cultivars for resistance have led to difficulties in development of reliable lists of SDS resistant cultivars (Hershman et al., 1990). Nevertheless, variety testing has given fairly consistent results and, with accumulation of several years of results in some varieties, it is now possible for the farmer to have some confidence in choosing varieties with less SDS susceptibility (Gibson et al., 1994).

So far the best advice to minimize SDS problems is to avoid planting SDS-prone fields earlier than necessary, to control the SCN problem using a non-host crop in rotation and to choose SCN resistant varieties that have the best record in SDS trials to date (Gibson et al., 1994).

Yield Losses

The effect of SDS on yields depends on the growth stage at the time of initial symptom development (Rupe et al., 1989). SDS can develop prior to bloom, however blooming does tend to accelerate symptoms development (Hirrel, 1985). Severe symptom development in the early reproductive stages may lead to flower and pod abortion as well as pod drop, while severe symptom development during pod fill may result in reduced seed size or quality (Rupe et al., 1989; Von Qualen et al., 1989).

Timing of symptom appearance is an important factor in associating symptoms with yield loss (Stephens et al., 1993). The effect of SDS in the early

stages of pod fill has been reported to be more severe than when it appears in later stages (Scott, 1986, Stephens et al., 1993). Yield loss may be due to reduction in seed size (Rupe et al., 1993, Njiti et al., 1993) or due to reduction in pod numbers (Njiti et al., 1993; Hershman et al., 1990; Von Qualen et al., 1989).

Effect of SDS on Seed Quality

The effect of SDS on seed quality varies from year to year, suggesting that the environment during crop maturation plays a role (Gibson et al., 1994). SDS reduces seed germination (Hartman et al., 1995; Rupe et al., 1993), and this may be attributed to the number of abnormal, dead, and hard seed resulting from seed pathogen attack (Rupe et al., 1993). A greenhouse study evaluating the effect of SDS on seed vigor and germination suggested that the effect of low to moderate SDS levels on vigor and germination was minimal (Leitz et al., 1995).

Diseases with Similar Leaf Symptoms

Brown stem rot (BSR), stem canker and charcoal rot are diseases caused by soil-borne fungi. Symptoms of these diseases are similar to those of SDS (Shurtleff and Hirrel, 1980) and, according to Rupe et al. (1989), this often caused SDS samples prior to SDS identification not to be handled as samples of a new disease.

To clearly differentiate SDS symptoms from those of BSR requires splitting and examining of the lower stem. With SDS, the pith area remains a healthy white or green in contrast to brown stem rot in which the pith appears rotten and distinctly brown or reddish brown (Gibson et al., 1994; Rupe et al., 1989).

Stem canker can often be differentiated from SDS by the presence of a canker lesion which normally forms on the stem at the base of a petiole of one of the lower leaves (Rupe et al., 1989). In the absence of a clearly diagnostic canker, stem canker can still be differentiated from SDS by internal stem symptoms

(Gibson et al., 1994). Stem canker produces discolored and deteriorated pith tissue especially near affected nodes which are also distinctly discolored.

Effect of the Environment on SDS

Environmental conditions associated with the onset and development of the disease are not well understood nor well documented (Gibson et al., 1994; Wrather et al., 1995). Various authors agree that SDS is prevalent during cool, wet growing seasons, and that soil moisture is an important factor in SDS development. McLean and Lawrence (1993) speculated that a growing season that begins with cool temperatures followed by relatively high temperatures and adequate season-long moisture creates optimal conditions for SDS symptoms development. Gibson (1993) reported that conditions such as a period of cooler than normal temperatures during bloom or early period pod set may trigger the start of SDS, and that disease was observed to progress rapidly when the soil was wet and seemed to stop progression when conditions were dry. SDS has been observed to be favored by cool wet weather, soil with high organic matter, and by the presence of cyst nematode (Howard et al., 1992). Rupe et al. (1993) stated that levels of soil moisture, SCN population density and soil fertility are factors that may influence SDS, and the uneven distribution of SDS within a field may reflect differences in soil environment.

Effect of the Environment on Similar Diseases

BSR, charcoal rot, *Fusarium* root rot and *Phytophthora* rot are the most similar diseases to SDS which commonly attack soybeans in Illinois, and which cause varying damage from year to year. All of these diseases cause affected plants to wilt, turn brown and usually die prematurely (Shurtleff and Hirrel, 1980). The diagnosis of these diseases is often difficult, because more than one pathogen may attack the host. Some pathogens are reported to attack both roots and

stems, while others attack only roots or only stems (Athow, 1973). The fungi causing these diseases are basically facultative saprophytes that are often not host specific and may attack other plant species or survive in the soil for some time and this tends to make control through host resistance more difficult (Athow, 1973).

Fusarium Wilt and Root Rot

Symptoms of *Fusarium* root rot are mainly blights of leaves, and vascular discoloration is characteristic at all stages of growth. Infection has been reported to occur at 28° C or above, and wilting due to this disease has been reported to be severe when soil moisture is low (Athow, 1973).

Brown Stem Rot (BSR)

BSR is caused by *Phialophora gregata* (Allington and Chamberlain), (syn *Cephalosporium gregatum*), and has been reported as causing variable yield losses on soybeans. The importance of the physical environment relative to BSR development and its effect on yield is not fully understood. Adequate moisture for normal pathogen growth early in the season and later moisture deficiency were speculated to favor BSR development and subsequent yield reduction (Mengistu et al., 1987).

Schneider et al. (1972) reported that for maximum symptom occurrence in the field, young plants must be exposed to cool temperatures. It was noted that cool weather followed by a warm, dry period at the end of the growing season was prevalent when the most advanced leaf symptoms (withering and browning) were observed, and physiological age of the plant has been implicated as a factor in the development of the disease (Phillips, 1972). Cool weather during the pod fill stage (late July and the first half of August) favors the disease. Hot weather

through August suppresses it. Disease development is optimum at air temperatures ranging from 59 °F to 81 °F (15 to 27° C). Little or no disease develops at 90° F (32° C) or above (Shurtleff and Hirrel, 1980).

Charcoal Rot

Charcoal rot is a disease of soybean roots caused by the fungus *Macrophomina phaseolina* (Tooss) and is most apparent when plants are approaching maturity (Shurtleff and Hirrel, 1980). It attacks the roots and basal portion of the plant, causing black streaks in the xylem of the root and lower stem (Wilcox, 1976). Charcoal rot is mostly found after midsummer and it is favored by hot dry weather especially in combination with unfertile soil or other unfavorable growing conditions (Shurtleff and Hirrel, 1980). Maximum effects in inoculated seedlings were obtained at 30-40° C. The disease development is related to dry conditions rather than wet soil conditions (McGee, 1992).

Phytophthora Rot

Phytopthora rot is caused by the soil-borne organism *Phytophthora megasperma* (Drechs.) var. *sojae* and may attack plants at any stage of growth. It is favored by cool and rainy weather and may kill the seedlings before emergence. *Phythophthora* is found most often in heavy clay soils that are poorly drained and compacted, especially in low areas where surface water has been standing for several days. The optimum temperature for disease development in older plants ranges from 77 to 86° F (20 to 25° C). Seedling death is greatest in the 80-92° F (27-33° C) range (Shurtleff and Hirrel, 1980).

Measurement of Soil Moisture

Soil moisture describes the amount of water contained in soil and can be defined as the mass of water in a unit of mass of soil or as the volume of water in

unit volume of soil (Campbell and Mulla, 1990). Soil water content measurements can be direct or indirect. Direct measurements are done by sampling the soil, weighing, drying and reweighing the samples, while the indirect methods include neutron scattering, gama (¥) attenuation, and electromagnetic interactions (Campbell and Mulla, 1990). Water content can also be inferred from water potential measurements that describe the availability of water to plants and the driving forces that cause water to move in the soil (Warrick, 1990). Water potential can be measured by tensiometers, electrical resistance sensors, thermal conductivity sensors, thermocouple psychometers, and filter paper equilibration methods (Campbell and Mulla, 1990).

There are several methods used to measure soil moisture (Hillel, 1980), but there is no universally recognized standard method and no uniform way to compute and present results of soil moisture measurement. Three commonly used methods are described below.

Gravimetric method

This method involves removing soil samples and determining wet and dry weights. The wet weight is determined by weighing the soil soon after sampling and the dry weight is obtained after drying the soil to a constant weight at 105° C in an oven. A period of up to 48 hours may be required for complete oven drying (Campbell and Mulla, 1990).

This method requires destructive sampling and it is laborious and time consuming. But, as it is accurate and requires little equipment cost, requiring it is the most commonly used for determination of soil water content, even though care must be taken in heterogenous profiles to take representatives samples from each soil layer (Hillel, 1980; Campbell and Mulla, 1990).

The gravimetric percent water content obtained is the ratio of weight of water in the sample (weight lost in drying) to dry weight of the sample (Warrick, 1990).

$$(\_m) = \frac{\text{mass of water in sample}}{\text{dry weight of sample}} \times 100$$

Alternatively, a volumetric water content can be obtained by the ratio of volume of water in sample and the apparent volume of sample (Warrick, 1990).

$$(\_v) = \frac{\text{volume of water in sample}}{\text{apparent volume of sample}} \times 100$$

Where:

(_m) = % water content by weight

(_v) = % water content by volume

The choice between these two alternatives is based on convenience however, the most commonly used is the gravimetric determination (Warrick, 1990).

Electrical Resistance Blocks

This method measures changes in soil moisture by means of changes in electrical resistance. Gypsum blocks are buried in the soil and connected by well-insulated leads to a resistance bridge. The water content of the blocks changes with that of the soil and this produces a measurable change in electrical conductivity of the solution between the electrodes. Different soils can have different wetness versus suction relationships. Because of these soil differences Hillel, (1980) suggests that calibration of these porous blocks against suction (tension) is preferable to calibration against soil wetness.

Inadequate contact between blocks and the soil may prevent the rapid attainment of equilibrium and cause a time lag between the state of water in the soil and the state of the water being measured in the blocks. This effect as well as

the sensitivity of the blocks may not be constant throughout the field. Gypsum blocks also tend to deteriorate rather rapidly especially in acid soils. Hence the relationship between the electrical resistance and suction varies not only from block to block but for each block as a function of time. Because of this and other reasons such as temperature sensitivity the evaluation of soil moisture by means of electrical blocks might be of limited accuracy. However, their use is less destructive to the soil surface than the gravimetric method and they give consistent repeated measurements of the same spot (Campbell and Mulla, 1990).

Tensiometers

The tensiometer consists of a sealed, water filled tube with a porous cup permeable to water on one end, and some means of measuring pressure (a gauge, manometer, or electronic transducer) on the other.

When the soil dries the suction creates a vacuum inside the tensiometer. If the soil is wetted again by irrigation or rain, water is sucked back into the tensiometer thus lowering the reading in the vacuum gauge (Campbell and Mulla, 1990).

Tensiometers are usually installed at two depths in the root zone. They do not need calibration and are more sensitive and reliable than gypsum blocks to measure relatively moist soils, those with tensions from 0 to 80 centibars (Campbell and Mulla, 1990).

CHAPTER 3

MATERIAL AND METHODS

The study was conducted at Ridgway and Villa Ridge in Gallatin and Pulaski County, respectively. The locations were chosen based on their high productivity and their history of SDS infestation in previous years. At Villa Ridge, the soil was a Bonnie silt loam (fine-silty, mixed, acid, mesic Typic Fluvaquents) associated with Belknap silt loam (coarse-silty, mixed, acid, mesic Typic Fluvaquents), while in Ridgway the soil type was Patton silty clay loam (fine-silty, mixed, mesic Typic Haplaquols). At both locations, corn was the previous crop and soil preparation was made by conventional tillage.

Preplant herbicides consisting of a combination of Treflan (trifluralin) and Scepter (imazaquin) were applied at both locations. At Villa Ridge, rates were 0.8 liter of Scepter (imazaquin), 2-[4,5-dihydro-4methyl-4-(methylethyl)-5-oxo-1H-imidazol-2-yl]-2quinoline carboxilic acid, and 1.2 liters of Treflan 10G (trifluralin) (a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine), while in Ridgway the rates were 0.8 l and 1.8 l per hectare of Scepter (imazaquin) and Treflan (trifluralin), respectively. Hand weeding was used as necessary in both locations.

Experimental Material and Design

Cultivars

One susceptible cultivar was chosen from each one of the following four maturity groups:

Maturity Group III–cultivar P3981 (Pioneer 3981); Pioneer Hibred Int'l., Box 85, Johnston, IA 50131).

Maturity Group IV–cultivar CM497 (Callahan Marketing 497); Callahan Marketing 497, Limagrain Genetics Corp., 4640 East State Road 32, Lebanon, IN 46052).

Maturity Group V–cultivar DP105 (Delta Pine 105); Delta Pine Land Co., PO Box 157, Scott, MS 38772).

Maturity Group VI–cultivar Lee 74; (Caviness et al., 1975).

As mid group III, P3981 grows well in Southern Illinois but is earlier than the maturity best suited to this area. DP105 is a very late group V, and Lee 74 (Hartwig et al.,) is an early group VI, both of which exceed the late maturity that is appropriete (mid groupV) for commercial use in Southern Illinois.

Concerning cultivar planting dates, CM497 and DP105 were commercialized in the early 1980s and are competitive in yield with currently grown varieties if no SDS is present. P3981 and Lee 74 were commercialized in the 1970s, and produce reasonable yields, but are no longer competitive with currently grown varieties in their respective area of adaptation.

Planting Dates

Planting dates ranged from mid-May to late-June. Dates were May 13, and June 6, 18 and 24 for Ridgway, and May 17 and 31, and June 15 and 22 for Villa Ridge.

Experimental Design

The experiment was conducted as a split plot design with cultivars as main plots and planting dates as subplots. Main plots were replicated four times in a randomized complete block (RCB) arrangement.

Plot Size

Plots were six rows 75 cm apart by 5 m, end trimmed at approximately the 6th trifoliate stage to 4 m length. Data were collected on the two center rows of each plot.

Soybean Data Collection

The following data were collected on the center two rows of each plot.

Date of Emergence

Date of emergence was recorded as the first day when at least 50% of the seedlings were emerged.

Emergence Score

Emergence score was assessed visually on scale of 1 to 5 where:

1 Very Good - Longest gap within a row no more than 0.46 m
1.5 - Longest gap within a row no more than 0.53 m
2 Good - Longest gap within a row no more than 0.61 m
2.5 - Longest gap within a row no more than 0.76 m
3 Fair - Longest gap within a row no more than 0.91 m
3.5 - Longest gap within a row no more than 1.10 m
4 Poor - Longest gap within a row no more than 1.20 m
4.5 - Longest gap within a row no more than 1.40 m
5 Very poor - Longest gap within a row no more than 1.50 m

Flowering Date

Flowering date was recorded as the first day when at least 50% of the plants had produced at least one open flower.

Reproductive Growth Stages

Growth stages were determined according to Fehr et al. (1971), with R5 to R7 stages further subdivided by Gibson et al. (1994).

i) Description of reproductive stages (Fehr et al., 1971)

Stage No	Abbreviated Stage title	Description
R1	Beginning bloom	One flower at any node on the main stem.
R2	Full bloom	Open flower at one of the two uppermost nodes on the main stem with a fully developed leaf.
R3	Beginning	Pod 5 mm long at one of the four pod uppermost pod nodes on the main stem with a fully developed leaf.
R4	Full pod	Pod 2 cm long at one of the four uppermost nodes on the main stem with a fully developed leaf.
R5	Beginning seed	Beans beginning to develop (can be felt when the pod is squeezed) at one of the four uppermost nodes on the main stem with a fully developed leaf.
R6	Full seed	Pod containing a green seed that fills the pod cavity at one of the of the four uppermost nodes on the main stem with a fully developed leaf.
R7	Beginning maturity	One normal pod on the main stem that has reached its mature pod color.
R8	Full mature	95% of the pods have reached their maturity pod color.

ii) Fractional rating from R 5.0 to R 7.0 (Gibson et al., 1994)

Stages are determined by seed and pod development on the main stem. By R 5.0 the leaf at the terminal node is normally fully developed, so the phrase "with a fully developed leaf" was omitted from the description of the uppermost nodes.

R-Stage	Description
5.0	Pod has reached full length. First stage at which beans can be distinctly felt inside the most mature pod at one of the four uppermost nodes.

5.2	Beans are about 1/4 of full size in the most mature pod at any of the four uppermost nodes.
5.4	Beans are about 1/2 of full size in the most mature pod at any of the four uppermost nodes.
5.6	Beans are about 3/4 of full size in the most mature pod at any of the uppermost nodes.
5.8	Beans are about 7/8 of full size in the most mature pod at any of the four uppermost nodes.
6.0	Beans are full size in at least one pod at any of the four uppermost nodes, but other pods at these nodes are not full, especially in indeterminate varieties.
6.2	Beans are full size in more than 3/4 of the pods in the four uppermost nodes.
6.4	More than 1/4 of the pods in the four uppermost nodes are noticeably YELLOW-GREEN.
6.6	More than 1/4 of the pods in the four uppermost nodes are distinctly YELLOW.
6.8	At least one normal pod, anywhere on the main stem, has almost reached mature pod color.
7.0	At least one normal pod, anywhere in the main stem, has reached mature pod color.

Disease Incidence

Disease incidence (DI) was recorded on a weekly basis as percentage of the plants in each plot with visible SDS leaf symptoms.

Disease Severity

SDS severity (DS) was weekly recorded as an average of plants showing SDS symptoms using a 1-9 scale reflecting increasing chlorosis-necrosis, defoliation, and premature death. Where different symptoms on the same plant (eg. chlorosis and necrosis) would give different ratings the higher rating was assigned:

1= 0-10% total of leaf area chlorotic

2= 10-20% chlorotic or any necrosis up to 10%.

3= 20-40% chlorotic or 10-20% necrotic.

4= 40-60% chlorotic or 20-40% necrotic.

5= Greater than 60% chlorotic or greater than 40% necrotic.

6= premature leaf drop up to 1/3 defoliation.

7= Premature leaf drop from 1/3 to 2/3 defoliation.

8= Premature leaf drop greater than 2/3 defoliation.

9= Premature death.

Yields

Yields were obtained by mechanically harvesting 4m of the two center rows in each plot. All yield were adjusted to 13% moisture.

Seed Weight

Seed weight was obtained by weighing a single random sample of 100 seed from the two harvested rows of each plot.

Interpolation of Disease Scores to the R6 Stage

DI, DS and R-stage were evaluated weekly. For each plot the date of R6 stage was estimated by linear regression of all reproductive stage scores between R5 and R7 against date. Then DI and DS were standardized to the estimated date of R6.2 by linear interpolation of one disease score immediately prior to R6 and to one immediately following R6.

Climatic Data

Rainfall

The amount of accumulated precipitation was recorded weekly with a rain gauge located in the center of the experimental site. To prevent evaporation, a layer of vegetable oil was placed in the rain gauge.

Soil Temperature

Minimum and maximum soil temperatures were recorded weekly by using remote reading thermometers installed 10 cm below the soil surface.

Soil Moisture

Two methods for determining soil moisture were used in this study: Gravimetric, and electrical conductance (gypsum blocks). Soil moisture was sampled between the first and second row of plots containing the first and third planting dates of cultivar CM497, giving eight sampling areas per experiment.

i) Gravimetric method.

Samples of soil were collected weekly using a soil probe 2.5 cm in diameter. Four 20 cm deep cores were taken per plot, and then separated in plastic bags into 0-10 and 10-20 cm depths. The samples were taken to a lab for weighing, and the moisture percentage was determined after drying the sample in oven at 105° C for 48 hours using the following formula as:

$$\text{Soil moisture (\%)} = \frac{\text{wet weight-dry weight}}{\text{dry weight}} \times 100$$

–Warrick (1990).

ii) Electrical Conductance Method.

Gypsum blocks were placed with the bottom at 10, 20, and 30 cm below the soil surface. Meter readings were collected weekly and graphically converted to soil suction using the chart supplied by Soil Moisture Equipment Inc. (CA), with the soil moisture meter (Model 5201). The results were compared to the gravimetric results.

Data Analysis

Analysis of Agronomic Data

To assess the effect of each treatment factor individually and in combination with other factors the following variables were subject to factorial analysis of variance procedure of MSTATC (Freed et al., 1990).

Flowering date

Days from planting to R6

Days from planting to harvest maturity

Disease incidence at R6

Disease severity at R6

Disease index

Yield

100 seed weight

Varieties and planting dates were considered fixed effects and replications were considered random effects. The outline ANOVA is shown below (Little and Hills, 1978):

Sources of variance	df
Variety (MG) (Factor a)	3
Replication (R)	3
Error a (RxMG)	9
Planting Date (PD) (Factor b)	3
PD X MG	9
Error b	36
Total	63

Analysis of Disease Data at Individual Scoring Dates

Since there were unbalanced data due to a wide range of varietal maturity, the means of each scoring date were not analyzed by ANOVA. Instead, a graphical evaluation of disease progress was made.

Analysis of Climatic Data

Rainfall and minimum and maximum soil temperatures were graphically summarized as were the weekly means of gravimetric and electrical conductance soil moisture measurements.

Gravimetric soil moisture was regressed against soil suction readings.

Comparison of Climatic Data to Disease Progress

Disease progress and environmental data were compared graphically to detect any environmental factors related to initial appearance or progression of symptoms.

CHAPTER 4

RESULTS AND DISCUSSION

Although the most important results are the measures of SDS and the effect of environment on their progression, for convenience and continuity, phenological results are discussed first.

A summary of the agronomic performance of the different maturity groups is presented in Appendix Tables 1a and 1b.

Plant Data

Phenology

Days from Planting to Flowering

Delay in planting significantly ($P<0.001$) reduced the number of days required for flowering at both locations (Table 1, App. Table 2a,b). Based on these differences, Villa Ridge means could be separated in to three groups. The number of days required from planting date 1 (PD1) to flowering was significantly ($P<0.001$) longer than all the other planting dates. PD2 and PD4 did not significantly ($P<0.001$) differ in number of days required to flower, but they were significantly shorter than the number of days required by PD3.

At Ridgway, means could be separated in three groups as well. The longest number of days for flowering was required by PD1, while PD4 required significantly less than all other PDs. No significant differences were found between PD2 and PD3 in this location.

Maturity group (MG) means indicated that the later the MG the greater was the number of days required from planting date to flower ($P<0.001$), although

Table 1. Effect of planting date on days from planting to flowering at Villa Ridge and Ridgway.

	Planting Dates				
Cultivar(MG)	May 17	May 31	June 15	June 22	Mean
Villa Ridge					
P3981 (III)	41.0	33.0	40.8	38.5	38.3 C
CM497 (IV)	40.5	35.3	41.5	39.3	39.1 C
DP105 (V)	69.0	64.0	62.8	59.3	63.8 B
Lee74 (VI)	77.8	68.0	65.5	59.1	67.6 A
Mean	57.1 a	50.1 c	52.6 b	49.1 c	52.2
LSD (0.05) PD=2.48		LSD (0.05) MG=2.06			
Ridgway					
	Planting Dates				
	May 13	June 6	June 18	June 24	Mean
P3981 (III)	45.5	41.0	46.5	25.8	39.7 C
CM497 (IV)	52.5	43.5	43.0	29.0	42.0 C
DP105 (V)	71.0	64.3	65.0	53.0	63.3 B
Lee74 (VI)	86.0	70.0	64.0	55.0	68.8 A
Mean	63.8 a	54.6 b	52.6 b	40.7 c	53.4
LSD (0.05) PD=1.83		LSD (0.05) MG=2.73			

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05.

Table 2. Effect of planting date on days from planting to R6.2 at Villa Ridge and Ridgway.

	Planting Dates				
Cultivar(MG)	May 17	May 31	June 15	June 22	Mean
Villa Ridge					
P3981 (III)	105.7	97.0	93.1	94.0	97.4 C
CM497 (IV)	112.7	105.8	102.7	100.6	105.4 B
DP105 (V)	132.4	124.0	114.6	113.1	121.0 A
Lee74 (VI)	134.6	126.4	115.6	111.8	122.1 A
Mean	121.4 a	113.3 b	106.5 c	104.9 c	111.5
LSD (0.05) PD=2.25		LSD (0.05) MG=3.51			
Ridgway					
	Planting Dates				
	May 13	June 6	June 18	June 24	Mean
P3981 (III)	103.9	88.5	93.3	94.1	94.9 C
CM497 (IV)	113.5	99.6	98.4	96.8	102.1 B
DP105 (V)	133.4	114.7	110.6	108.8	116.9.A
Lee74 (VI)	135.8	115.2	108.0	107.4	116.6 A
Mean	121.6 a	104.5 b	102.6 bc	101.8 c	107.6
LSD (0.05) PD= 1.83		LSD (0.05) MG= 2.73			

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD)comparison at α=0.05.

the difference between MG III and MG IV was not significant ($P<0.05$) at either site.

In both locations the interaction PDxMG was significant ($P<0.001$) (App. Tables 2a and 2b), indicating that despite the overall trend, specific cultivar responses to planting dates were observed. The overall effect at Villa Ridge was that flowering required 2 days more in PD3 than in PD2. However, flowering in DP105 and Lee 74 occurred faster in PD3 than in PD2, while in P3981 and CM497 flowering in PD3 required about one week more than in PD2.

At Ridgway, the reduction in number of days to flower from delayed planting in Lee 74 was much more than the reduction in overall means from PD1 to PD2 and from PD2 to PD3. A specific response was also observed in P3981 which at PD4 required 21 days less to flower than in PD3, while the overall mean showed only 14 days reduction.

Days from Planting to R6.2 Stage

The means for number of days required from planting date to R6.2 indicated that in both locations PD1 required significantly ($P<0.001$) longer to reach that stage than did PD2, and that PD3 and PD4 required the least number of days and did not differ from each other (Table 2).

Maturity group means were significantly different ($P<0.001$) at both locations. Overall, earlier maturity groups required significantly fewer days to reach the R6.2 stage than the later ones. At both locations MG III required fewer days to reach R6.2 than any other MG, while MGs V and VI required the greatest number of days to reach the same stage.

Even though overall delay in planting resulted in reduced number of days to R6.2 stage, at both locations cultivars contributed differently to this overall pattern, causing the PDxMG interaction to be significant ($P<0.001$) (Appendix

number of days to R6.2 by 7 days, but this reduction for Lee 74 was about 11 days and compared to 4 for P3981.

At Ridgway, for Lee 74 from PD1 to PD2 and from PD2 to PD3 the reduction in number of days to R6.2 was markedly higher than the overall mean reduction indicating a specific response of this cultivar to planting dates. Another specific response was in P3981, which required five more days to R6.2 in PD3 than in PD2.

Effect of Planting Date on Days from Planting to Harvest Maturity

Delayed planting significantly ($P<0.01$) reduced days to harvest maturity at Villa Ridge (Table 3a, App. Tables 4a). In this location PD1 required significantly more days to reach maturity than the other planting dates. PD2 differed significantly from PD4, but neither PD2 or PD4 differed significantly from PD3. Overall from PD1 to PD2, from PD2 to PD3 and from PD3 to PD4 the number of days to harvest maturity was reduced 12, 6 and 2 days, respectively. However, some cultivar responses did not follow this trend resulting in a significant ($P<0.001$) PDxMG interaction (App. Table 4a). From PD1 to PD2 for DP105 the reduction was considerably lower and for CM497 considerably higher than the overall mean. The reduction for P3981 from PD2 to PD3 was higher than the overall mean, and from PD3 to PD4 the decline in number of days to harvest maturity for CM497 and DP105 was more than the overall mean.

At Ridgway, harvest maturity data for MG V at PD3 and PD4 and MG VI at PD4 were not collected, but overall there was no strong pattern in time to harvest maturity in response to delay in planting (Table 3). However, a complete analysis is presented for MG III and MG IV at all planting dates, and for all MGs at PD1 and PD2 (Tables 3b & 3c). Table 3b indicates that considering only MG III and MG IV no significant ($P<0.05$) difference was found between PD1 and PD2 but they required significantly longer to reach harvest maturity than PD3 and PD4 which in turn did not differ from each other. From Table 3c it can be

observed that MG V and MG VI took significantly (P<0.01) longer to reach harvest maturity than did MG III and MG IV.

Table 3a. Effect of planting date on days from planting to harvest maturity at Villa Ridge and Rdgway.

	Planting Dates				
Cultivar(MG)	May 17	June 6	June 15	June 22	Mean
Villa Ridge					
P3981 (III)	125.5	112.0	103.5	104.0	111.2 D
CM497 (IV)	133.0	117.0	112.5	108.3	117.7 C
DP105 (V)	152.0	146.0	140.0	135.5	143.4 A
Lee 74 (VI)	152.0	137.8	134.0	134.0	139.4 B
Mean	140.6 a	128.2 b	122.5 c	120.4 d	127.9
LSD PD= 1.71		LSD MG=1.88			

*Ridgway

	Planting Dates				
Cultivar(MG)	May 13	June 6	June 18	June 24	Mean
P3981 (III)	122.0	121.5	117.8	117.0	119.6
CM497 (IV)	133.0	132.0	121.3	124.5	127.7
DP105 (V)	151.0	158.5	152.0		
Lee74 (VI)	159.0	156.3	146.0	140.3	
Mean	141.3	142.1	134.2		

Planting date (PD) mean folllowed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD)comparison at α=0.05. *Ridgway means not compared by LSD due to missing values. See Table 3b and 3c for comparison.

Table 3b. Effect of planting date on harvest maturity for MG III and MG IV at all planting dates at Ridgway.

	Planting Dates				
Cultivar(MG)	May 13	June 6	June 18	June 24	Mean
P3981 (III)	122.0	121.5	117.5	117.0	119.5 B
CM497 (IV)	133.0	132.0	121.2	124.5	127.7 A
Mean	127.5 a	126.7 a	119.3 b	120.7 b	123.6
LSD(0.05) PD=2.00			LSD (0.05) MG=2.64		

Table 3c. Effect of planting date on harvest maturity at Ridgway for all MGs at Planting date 1 and 2.

	Planting Dates		
Cultivar (MG)	May 13	June 6	Mean
P3981 (III)	122.0	121.5	121.7 C
CM497 (IV)	133.0	132.0	132.5 B
DP105 (V)	151.0	158.5	154.7 A
Lee74 (VI)	159.0	156.3	157.6 A
Mean (VI)	141.3 a	142.1 a	141.7
LSD (0.05) PD= n.s.	LSD (0.05) MG=3.76		

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05.

The interaction PDxMG was not significant ($P<0.05$) when considering only PD1 and PD2 (App. Table 4c) but it was significant ($P<0.001$) when considering all planting dates (App. Table 4b), suggesting that cultivar behavior did not differ too much from PD1 to PD2, but when considering all PDs some specific cultivar responses could be observed.

Disease Ratings

Effect of Planting Date on R6DI

Table 4 indicates that overall the effects of delaying planting date significantly ($P<0.001$) (App. Tables 5 a, b) reduced disease incidence at the R6.2-stage at both locations. At Villa Ridge, each PD mean was significantly different from all others. At Ridgway, the PD2 mean did not differ significantly from any other PD. PD3 and PD4 did not differ significantly from each other, but their DI was significantly lower than that of PD1.

At Villa Ridge, MG III was significantly lower in DI than the other MGs. At Ridgway, MG means did not differ significantly in DI at the R6.2-stage. Interaction PDxMG was significant ($P<0.001$) at Villa Ridge (App. Table 5a) but not significant ($P<0.05$) at Ridgway (App. Table 5b). At Villa Ridge, DI decreased gradually across PDs. For CM497 and Lee 74 from PD1 to PD2 and from PD3 to PD4 the decrease of DI was very small, but their decrease was much greater than the mean decrease from PD2 to PD3. In contrast the mean decrease in P3981 from PD1 to PD2 was larger than the mean decrease.

Table 4. Effect of Planting Date on R6DI at Villa Ridge and Ridgway.

	Planting Dates				
Cultivar(MG)	May 17	May 31	June 15	june 22	Mean
Villa Ridge					
P3981 (III)	55.3	25.5	4.8	2.2	21.9 B
CM497 (IV)	94.0	85.1	26.5	13.8	54.8 A
DP105 (V)	95.2	78.8	41.6	5.5	55.3 A
Lee74 (VI)	96.3	84.8	18.3	7.8	51.8 A
Mean	85.2 a	68.6 b	22.8 c	7.3 d	45.96
LSD (0.05) PD = 14.38		LSD (0.05) MG = 21.54			
Ridgway					
	Planting Dates				
	May 13	June 6	June 18	June 24	Mean
P3981 (III)	4.0	1.3	1.0	1.0	1.8 A
CM497 (IV)	43.8	29.3	8.8	2.4	21.1 A
DP105 (V)	43.6	17.1	8.1	14.4	20.8 A
Lee74 (VI)	54.1	37.1	6.3	10.9	27.1 A
Mean	36.4 a	21.2 ab	6.0 b	7.2 b	17.7
LSD (0.05) PD = 24.0		LSD (0.05) MG = 31.68			

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05

Effect of Planting Date on Disease Severity at R6-Stage

Disease severity (DS) may have decreased slightly with delayed planting, but there was no statistically significant difference ($P<0.05$) among means in either location (Table 5).

Significant differences ($P<0.05$) were found among maturity group means (Table 5), with disease being more severe in later MGs than in earlier ones in both locations. At Villa Ridge, MGs V and VI were not significantly different from each other but differed significantly from MG III. MG IV did not differ significantly from any other MG.

At Ridgway, disease was significantly more severe in MG VI than in MG III, but it was not significantly different among other MGs, though the trend of higher DS with longer maturity was consistent.

The interaction PDxMG was not significant ($P<0.05$) at either location (App. Tables 6a and 6b), indicating that all cultivar responses followed the overall trend.

Effect of Disease Index (DX) at R6-stage

Overall DX decreased significantly ($P<0.05$) with the delay in planting (Table 6). At Villa Ridge, the first two planting dates did not differ significantly, but both differed significantly from PD3 and PD4. At Ridgway, mean differences among PDs were not significant.

Maturity group means showed that at Villa Ridge, DX in MG III was significantly ($P<0.01$) lower than in all other MG, which in turn did not differ significantly among themselves. On the other hand, at Ridgway, MG means for disease index did not differ significantly ($P<0.05$).

Figure 1 shows the trend of DX across planting dates, and Figure 2 shows maturity group response for DX.

Table 5 Effect of planting date on disease severity (DS) at R6-stage at Villa Ridge and Ridgway.

	Planting Dates				
Cultivar(MG)	June 17	June 31	June 15	June 22	Mean
Villa Ridge					
P3981 (III)	2.5	2.4	2.3	1.5	2.2 B
CM497 (IV)	2.7	2.9	2.6	2.8	2.7 AB
DP105 (V)	3.8	3.3	3.0	3.7	3.4 A
Lee74 (VI)	3.3	3.3	3.0	3.0	3.1 A
Mean	3.1 a	3.0 a	2.7 a	2.7 a	2.9
LSD (0.05) PD=0.69			LSD (0.05) MG=0.87		

Ridgway

	Planting Dates				
	May 13	June 6	June 18	June 24	Mean
P3981 (III)	1.3	1.2	1.0	1.2	1.2 B
CM497 (IV)	2.6	1.8	1.8	1.5	1.9 AB
DP105 (V)	2.7	2.3	2.0	2.1	2.3 AB
Lee74 (VI)	3.3	2.2	2.7	1.7	2.5 A
Mean	2.5 a	1.9 a	1.9 a	1.6 a	1.98
LSD (0.05) PD = 1.22			LSD (0.05) MG =1.28		

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05

Table 6. Effect of Planting Date on Disease Index at R6 Stage at Villa Ridge and Ridgway.

	Planting Dates				
Cultivar(MG)	May 17	May 31	June 15	June 22	Mean
Villa Ridge					
P3981 (III)	15.5	6.9	1.2	0.3	6.0 B
CM497 (IV)	28.4	27.4	8.0	5.2	17.2 A
DP105 (V)	40.3	29.1	14.1	2.2	21.4 A
Lee74 (VI)	34.9	31.1	6.0	2.6	18.7 A
Mean	29.8 a	23.7 a	7.3 b	2.6 b	15.83
LSD (0.05) PD = 7.50		LSD (0.05) MG = 8.47			

Ridgway

	Planting Dates				
Cultivar(MG)	May 13	June 6	June 18	June 24	Mean
P3981 (III)	0.9	0.2	0.1	0.1	0.3 A
CM497 (IV)	15.1	9.2	2.2	0.5	6.7 A
DP105 (V)	13.7	5.2	1.9	4.2	6.3 A
Lee74 (VI)	24.4	11.2	1.8	2.4	9.9 A
Mean	13.5 a	6.5 a	1.5 a	1.8 a	5.85
LSD (0.05) PD = 12.54		LSD (0.05) MG = 13.11			

Planting date(PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05.

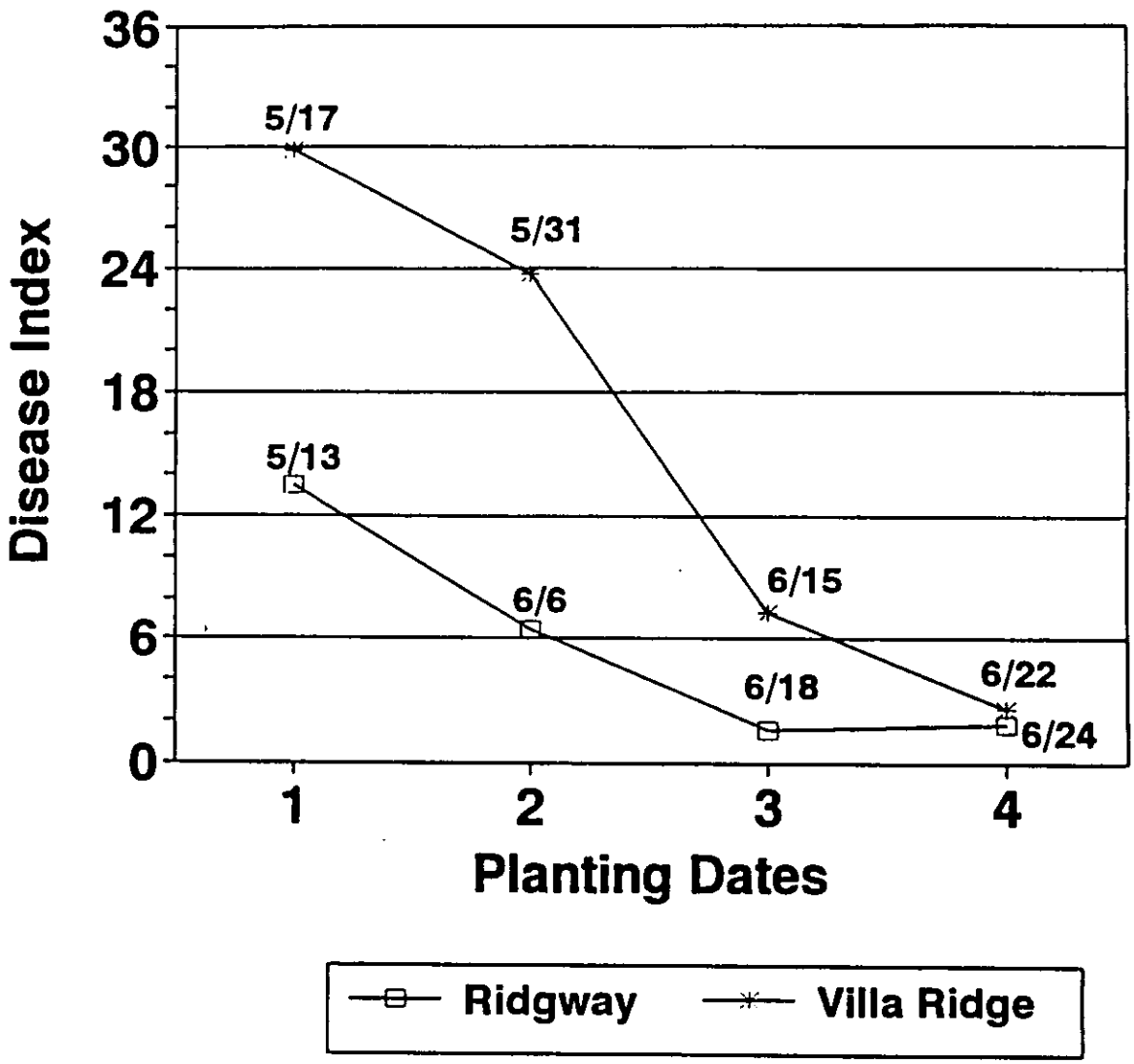

Figure 1. Soybean SDS disease index (DX) at growth stage R6.2 for different planting dates at Villa Ridge and Ridgway, 1994.

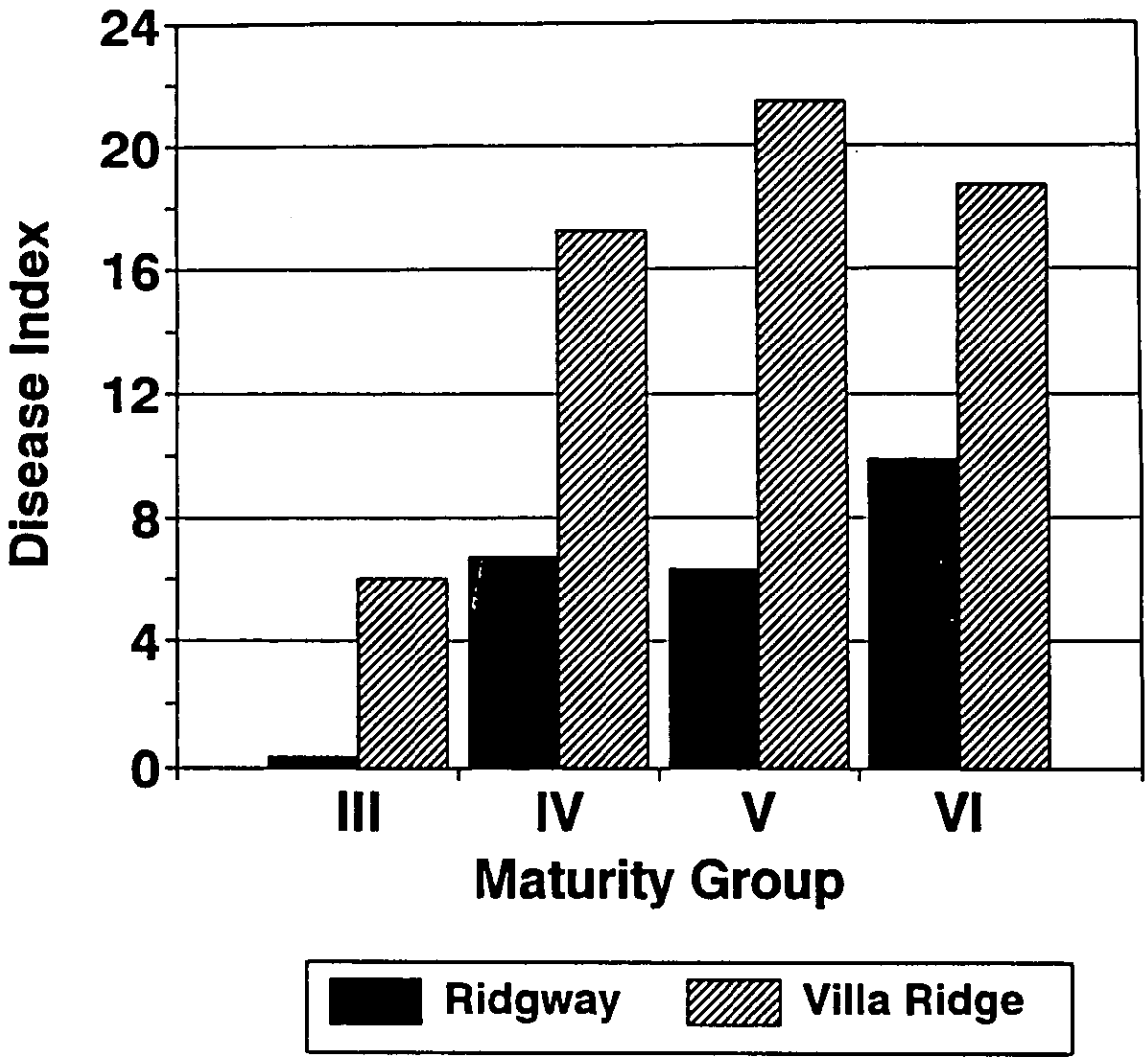

Figure 2. Soybean SDS disease index (DX) at growth stage R6.2 for maturity groups III to VI at Villa Ridge and Ridgway, 1994.

Interaction PDxMG was significant at Villa Ridge ($P<0.01$) but was not significant ($P<0.05$) at Ridgway (App, Tables 7a and 7b), respectively. At Villa Ridge, the overall mean showed greater DX reduction from PD2 to PD3 than any other adjacent PDs. Differently, P3981 showed a gradual DX decrease across PDs. A very little decrease in DX from PD1 to PD2 and from PD3 to PD4 was observed for CM497 and Lee 74, but a greater one was observed from PD2 to PD3.

Effect of Planting Date on Yield

Overall yields were much higher at Villa Ridge than at Ridgway (Table 7a). At Villa Ridge, yield was reduced by delay in planting. The yield reduction across planting dates at Villa Ridge was only statistically significant ($P<0.05$) for the comparison of PD1 and PD4. Maturity group means indicated that at Villa Ridge the yields differed significantly ($P<0.05$) only between MG III and MG VI, with the former having the highest yield.

At Ridgway, PD3 and PD4 for MG V and PD4 for MG VI were not harvested, but overall the yields did not show any distinct trend across planting dates (Table 7b). Due to incomplete data, ANOVA and mean separation at Ridgway were obtained by: i) splitting PD1 and PD2 from the other PDs, and ii) splitting MG III and MG IV from the other two MGs. This approach allowed a complete analysis at all PDs for MGs III and IV (Table 7b), and for all MGs at PD1 and PD2 (Table 7c). Table 7b indicates that yields did not differ significant ($P<0.05$) across planting dates for MG III and MG IV, but MG IV significantly outyielded MG III. Considering only PD1 and PD2, the highest yield was obtained by MG V followed by MG VI and the lowest by the other two MGs (Table 7c).

The interaction PDxMG for yield was not significant ($P<0.05$) at either location (App. Tables 8a-8c).

Table 7a. Effect of Planting Date on yield (T/ha) at Villa Ridge and Ridgway.

	Planting Dates				
Cultivar(MG)	May 17	May 31	June 15	June 22	Mean
Villa Ridge					
P3981 (III)	2.44	2.36	2.48	1.93	2.30 B
CM497 (IV)	3.20	3.24	2.83	2.79	3.02 AB
DP105 (V)	4.27	3.21	3.14	2.66	3.32 A
Lee74 (VI)	2.92	2.72	2.75	2.16	2.64 AB
Mean	3.21 a	2.88 ab	2.80 ab	2.38 b	2.8.2
LSD (0.05) PD=0.80			LSD(0.05) MG=0.76		

*Ridgway

	Planting Dates				
	May 13	June 6	June 18	June 24	Mean
P3981 (III)	1.20	1.17	1.22	1.25	1.21
CM497 (IV)	1.19	1.23	1.17	1.26	1.21
DP105 (V)	1.34	1.53			
Lee74 (VI)	1.22	1.37	1.73		
Mean	1.24	1.37			

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05. *Ridgway means were not compared by LSD due to missing values. See Tables 7b and 7c for comparison.

Table 7b. Yield means (T/ha) for MG III and MG IV at all planting dates.

	Planting Dates				
Cultivar(MG)	May 13	June 6	June 18	June 24	Mean
P3981 (III)	1.22	1.21	1.18	1.17	1.19 B
CM497 (IV)	1.33	1.32	1.21	1.24	1.27 A
Mean	1.27 a	1.26 a	1.19 a	1.20 a	1.23
LSD (0.05) PD= 0.012		LSD (0.05) MG= 0.026			

Table 7c Yield means (T/ha) for all MGs at PD1 and PD2 at Ridgway.

	Planting Dates		
Cultivar (MG)	May 13	June 6	Mean
P3981 (III)	1.20	1.17	1.19 C
CM497 (IV)	1.19	1.22	1.21 BC
DP105 (V)	1.34	1.53	1.43 A
Lee 74 (VI)	1.22	1.37	1.29 B
Mean	1.24 a	1.32 a	1.28
LSD (0.05) PD= n.s.	LSD (0.05) MG= 0.147		

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05.

Effect of Planting Date on g/100 seeds

Delay in planting did not have any significant ($P<0.05$) effect on seed weight at Villa Ridge (Table 8). MG III seeds were significantly ($P<0.05$) larger than all other MGs while those from MG VI were significantly smaller. No significant ($P<0.05$) differences between MGs IV and V were observed. Even though no significant differences were found across planting dates, the interaction PDxMG was significant ($P<0.01$) (App. Table 9a). The decrease in seed weight in DP105 from PD2 to PD3 and from PD3 to PD4 was considerably greater than the decrease in the overall mean. In contrast, CM497 showed some increase in seed weight from PD2 to PD3.

At Ridgway, seed weight was analyzed the same way as yield (Tables 8b and 8c). Considering MG III and MG IV in all PDs, seed weight was only significantly different ($P<0.05$) when comparing PD1 with PD2 or PD3, with the heaviest seed being obtained in the latter PD (Table 8c). Seeds from P3981 were significantly heavier than the seeds of any other MG (Table 8b and 8c), and the lightest seeds were the ones from Lee 74 (Table 8c). Specific cultivar responses to planting date, resulted in a significant ($P<0.05$) PDxMG interaction (App. Tables 9b and 9c). Considering all MGs at PD1 and PD2, CM497 had the greatest increase in seed weight. When considering MG III and IV at all PDs, it could be observed that while from PD2 to PD4, P3981 increased in seed weight, CM497 decreased considerably.

Climatic Factors

Rainfall

Rainfall patterns for Villa Ridge and Ridgway are presented respectively in Appendix Figures 1a and 1b. At Villa Ridge, rainfall was more concentrated towards the end of August through the month of September (117 to 151 days

Table 8a. Effect of Planting Date on 100 seed weight at Villa Ridge and Ridgway.

	Planting Dates				
Cultivar (MG)	May 17	May 31	May 15	May 22	Mean
Villa Ridge					
P3981 (III)	16.5	17.0	17.1	17.2	16.9 A
CM497 (IV)	13.3	13.1	13.9	13.9	13.5 B
DP105 (V)	14.6	14.4	13.2	12.3	13.6 B
Lee74 (VI)	12.7	13.0	12.7	12.6	12.8 C
Mean	14.3 a	14.4 a	14.2 a	14.0 a	
LSD (0.05) PD=1.13			LSD (0.05) MG=0.743		

*Ridgway	Planting Dates				
	May 13	June 6	June 18	June 24	Mean
P3981 (III)	16.6	17.6	18.3	18.4	17.8
CM497 (IV)	13.6	15.6	15.2	14.0	14.5
DP105 (V)	14.9	14.1			
Lee74 (VI)	12.4	13.2	12.4		
Mean	14.6	14.9			

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter, are not significantly different by Least Significant Difference (LSD) comparison at α=0.05.
* Ridgway means were not compared by LSD due to missing values. See Tables 8b and 8c for comparison.

Table 8b. Seed weight means (g) for MG III and MG IV at all planting dates at Ridgway

	Planting Dates				
Cultivar	May 13	June 6	June 18	June 24	Mean
P3981 (III)	16.6	17.6	18.3	18.4	17.7 A
CM497 (IV)	13.6	15.6	15.2	14.0	14.6 B
Mean	15.1 b	16.6 a	16.7 a	16.2 ab	16.1
LSD (0.05) PD= 1.15		LSD (0.05) MG=2.41			

Table 8c. Seed weight means (g) for all MGs at Planting date 1 and planting date 2 at Ridgway

	Planting Dates		
Cultivar (MG)	May 13	May 2	Mean
P3981 (III)	16.6	17.6	16.9 A
CM497 (IV)	13.6	15.6	14.6 B
DP105 (V)	14.9	14.1	14.5 B
Lee74 (VI)	13.3	12.4	12.9 C
Mean	14.5 a	14.9 a	14.7
LSD (0.05) PD=n.s.	LSD (0.05) MG=1.15		

Planting date (PD) means followed by a common lower case letter, or cultivar (MG for maturity group) means followed by a common upper case letter are not significantly different by Least Significant Difference (LSD) comparison at α=0.05. n.s= not significant

after May 1) (App. Figure 1a), while at Ridgway higher amounts of rain were concentrated in June and July (40 to 82 days after May 1) (App. Figure 1b). At Ridgway, rainfall was more frequent even though many times the weekly accumulated amount was less than 15mm. In contrast, at Villa Ridge there were several weeks where no rain was recorded. In the August-September period the highest amount of rain at Ridgway was 23mm recorded on September the 8th (130 days after May 1). All other rain amounts in this period were less than 10mm. The maximum amount recorded in one period at Villa Ridge was 51 mm on August 29 (120 days after May 1), while the maximum amount at Ridgway was recorded at the end of season, about 74 mm on October 6.

Soil moisture

App. Tables 10a and 10b show the soil moisture values obtained by gravimetric and electrical conductance (gypsum block) methods.

App. Figures 2a and 2b indicate the soil moisture correlation between these two methods. The results obtained by the two methods were well correlated, with r^2=0.95 at Villa Ridge and 0.70 at Ridgway. Ridgway generally had lower values of soil moisture (App. Tables 10a and 10b). At low levels of water content the electrical conductance is not a very reliable method, presumably causing the correlation to be lower at Ridgway than at Villa Ridge.

In both locations soil moisture showed fluctuations during the growing season which were clearly related to the rainfall pattern (Figures 3a and 3b).

Soil Temperature

Villa Ridge (Fig.4a) and Ridgway (Fig.4b) maximum and minimum soil temperature showed almost equal patterns, with no great fluctuations across the season. Overall through mid-season (82 days after May 1) maximum temperatures were higher at Ridgway than at Villa Ridge. Minimum temperatures were slightly

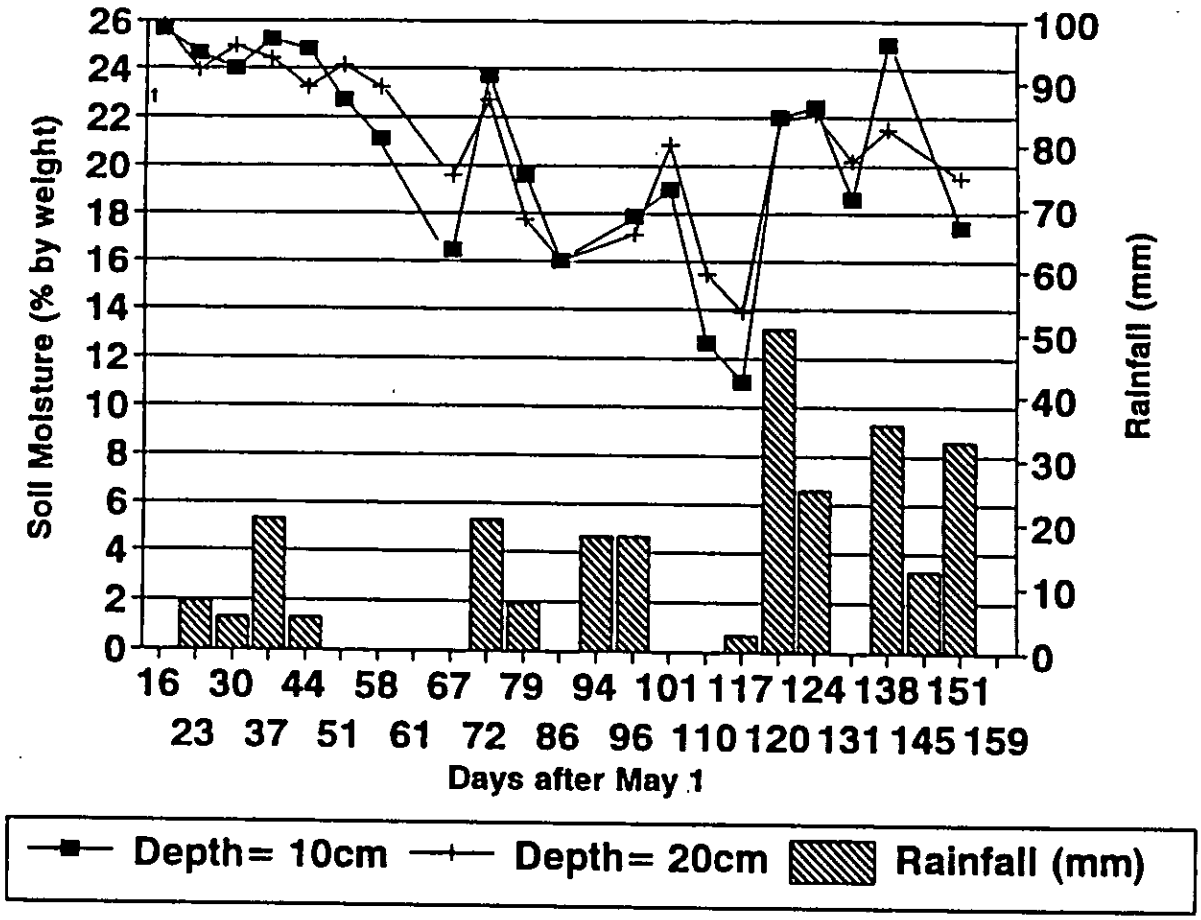

Fig. 3a. Fluctuations of soil moisture (% of dry weight) with rainfall (mm) across the growing season at Villa Ridge, 1994.

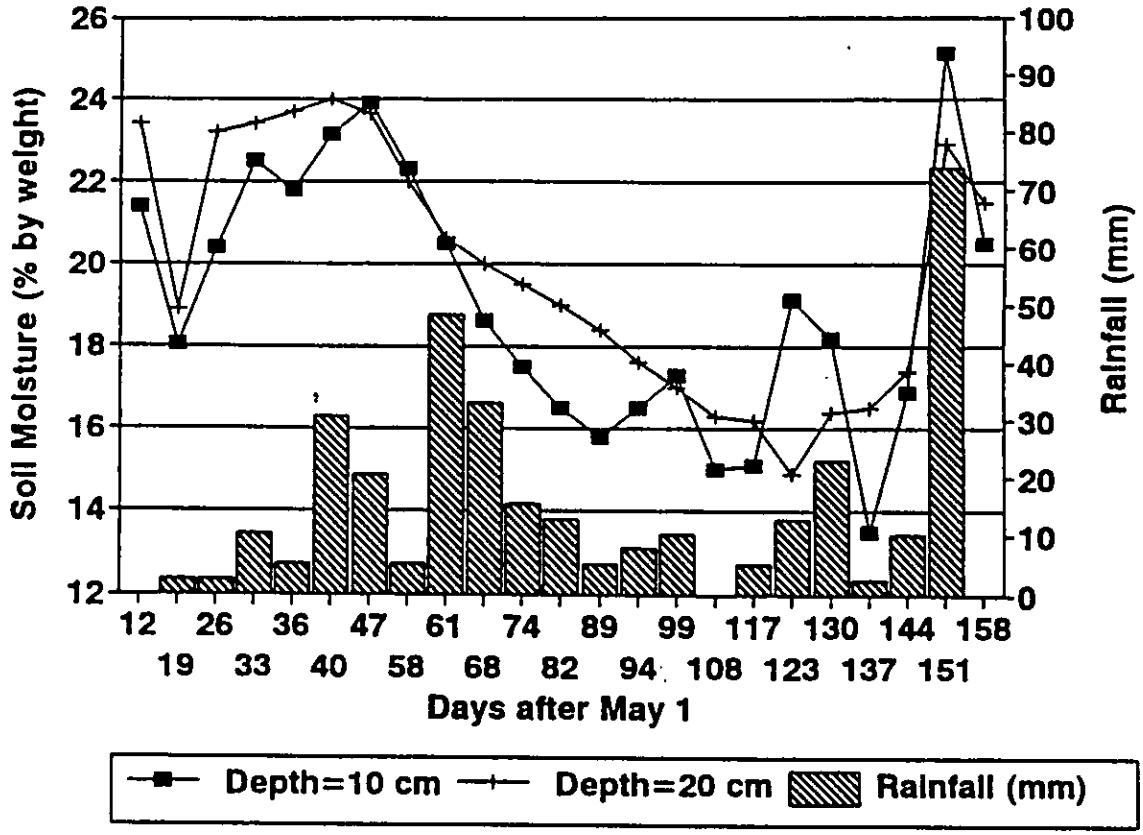

Fig. 3b. Fluctuations of soil moisture (% of dry weight) across the growing season with rainfall at Ridgway, 1994.

lower at Ridgway compared to Villa Ridge in the early season and then higher than Villa Ridge at mid-season. Maximum soil temperatures dropped gradually starting 86 days after May 1 at Villa Ridge with a sharp drop following 117 days after May 1. At Ridgway, one minor decline occurred starting at 74 days after May 1, with a second major decline following 99 days after May 1. It could be observed that at Villa Ridge the period of lower temperatures following 117 days after May 1 corresponded to the period of high rain (App. Fig 1a), but at Ridgway no association with rainfall was clear.

Relationship of Climatic Factors to Patterns of Disease Development

Climatic factors are vital to both plant development and SDS progression. This section will discuss the relationships between climatic data and SDS that were apparent in this study.

Villa Ridge

At Villa Ridge, disease symptoms were first observed at July 22 in CM497 from PD1, with disease scoring starting on July 26 (86 days after May 1). Weekly disease scores are presented in App. Table 11a. Symptoms progressed slowly, beginning to be severe after August 10 (101 days after May 1), whereafter for PD1 all varieties increased rapidly in disease but with the earlier MGs being more affected. At PD1 later MGs increased significantly in symptoms after 124 days (App. Fig. 3a).

For PD2 disease symptoms started to increase after day 101 for CM497 and P3981, while Lee74 and DP105 started slowly, developing symptoms from 110 days and increasing rapidly after 131 days (Appendix Fig. 3b). Even though for PD3 and PD4 the first symptoms appeared at day 96, only at day 131 all varieties were showing noticeable symptoms. There was a substantial increase of symptoms in DP105 and Lee 74 after 131 days for PD3 and 145 days for PD4 (App. Figures 3c & 3d).

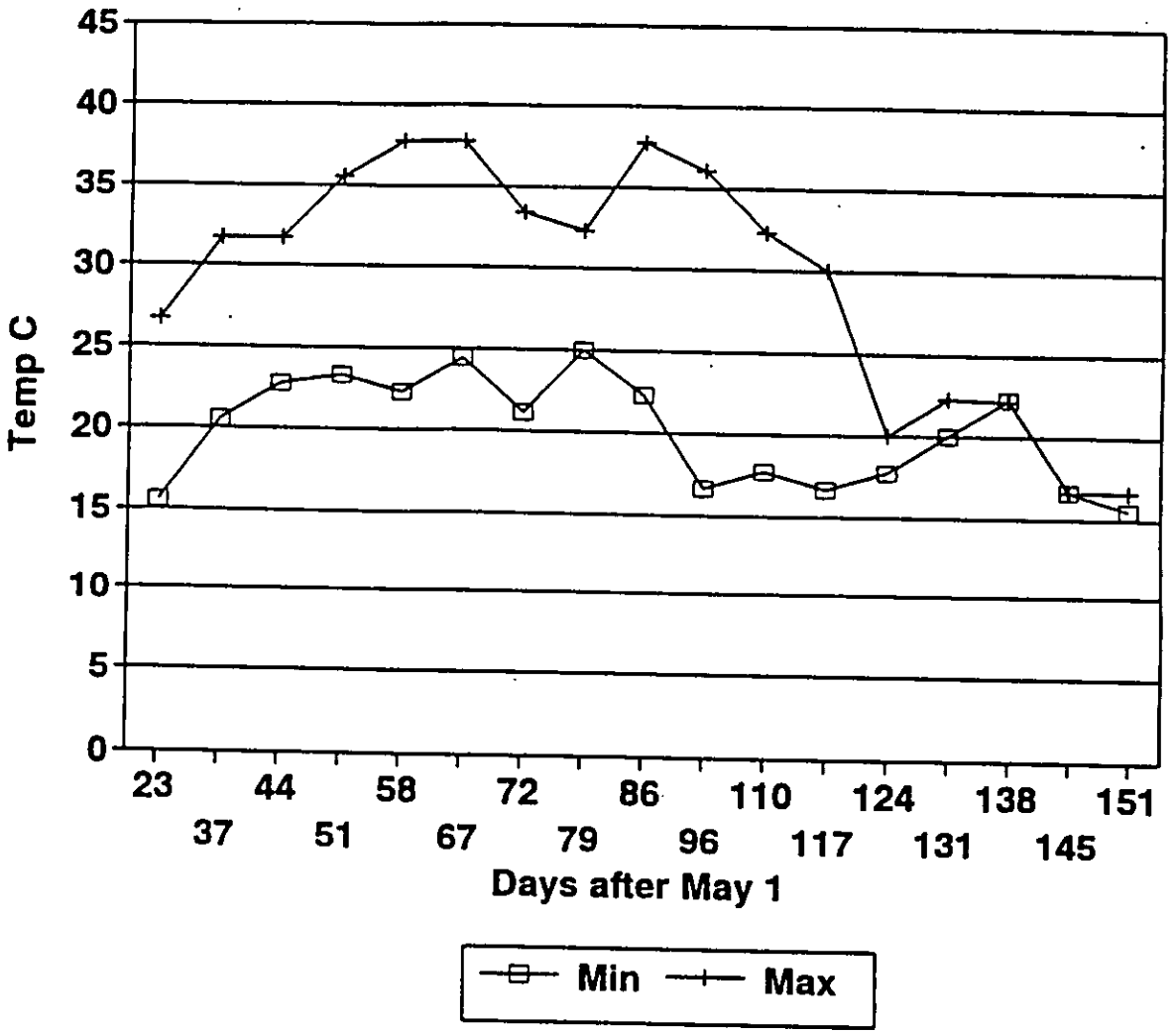

Fig. 4a. Weekly minimum and maximum soil temperatures during the 1994 growing season at Villa Ridge

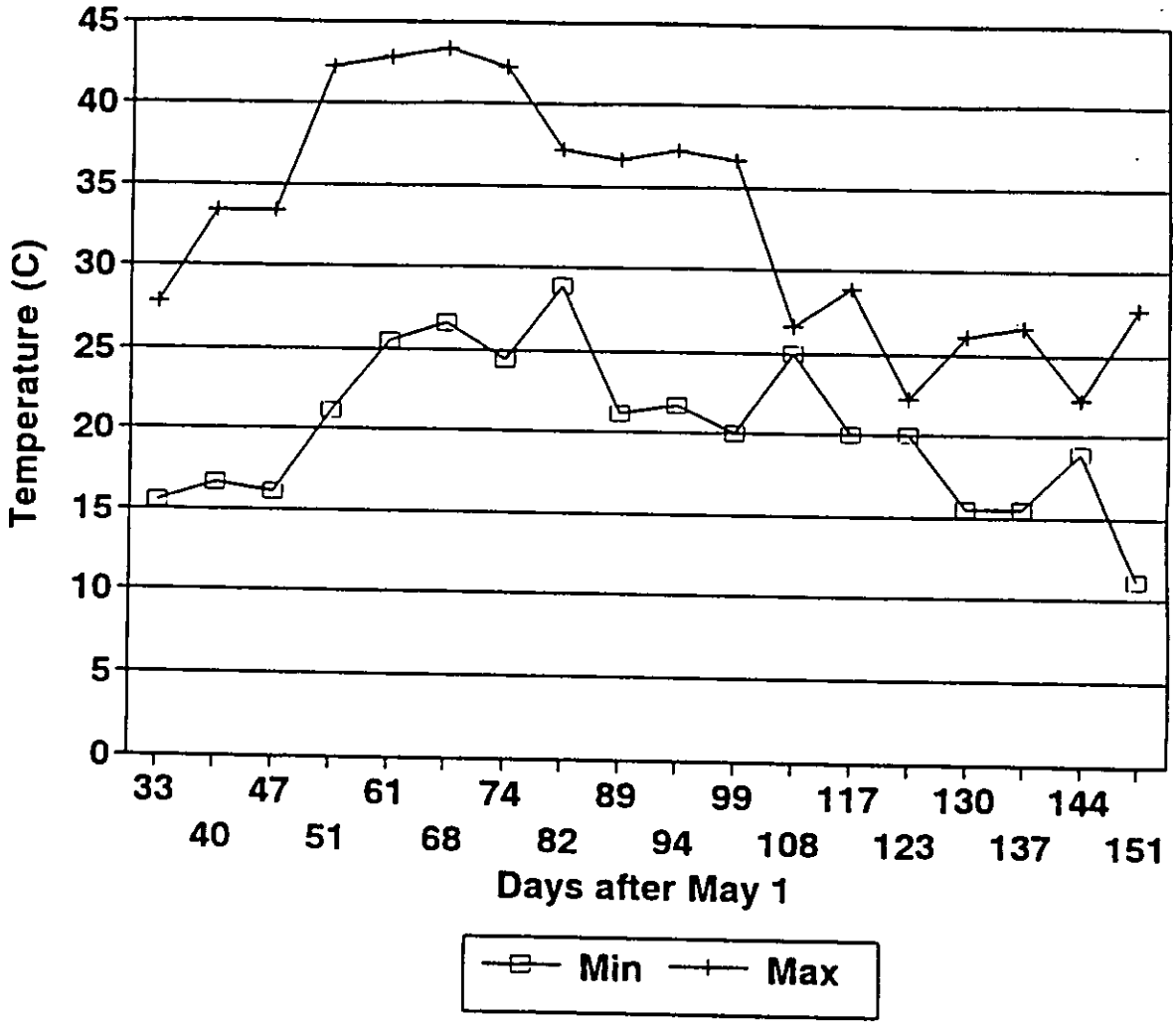

Fig. 4b. Weekly minimum and maximum soil temperatures during the 1994 growing season at Ridgway.

Overall, in the first two planting dates, CM497 and P3981 showed marked increases at day 110, while at PD3 and PD4 they increased at day 131 or 138. The most rapid disease development for DP105 and Lee74 in the first two PDs was observed starting at 124 or 131 days, while for the later PDs it was observed at 145 days (App. Figures 4a-d).

All peak periods of disease symptom increase were associated with rainfall and a major increase in soil moisture one to two weeks prior to the increase in disease. Disease was first observed at 86 days after May 1, following 20 mm and 8 mm rains at 72 and 79 days, respectively (App. Table 10a and Figure 3b). However, disease became severe only after 101 days for the first two PDs, after an 18 mm rain at 96 days. This may suggest that rain caused soil moisture to increase and to trigger leaf symptoms at 86 days which increased even more after the rain at 96 days.

The PD1 and PD2 disease symptom increase for the later MGs at 131 days was preceded by 51 mm and 25 mm rains at 120 and 124 days, respectively. For PD3 and PD4, P3981 and CM497 increased rapidly at 124 or 131 days also. DP105 and Lee 74 showed increase after day 145, following rains at 138 and 145 days.

Ridgway

Disease started to be scored at 108 days after May 1, being most pronounced for CM497 at PD1 (App. Table 10b). For other varieties at PD1 disease started to significantly increase after 130 days (App. Fig. 5a).

For PD2, disease symptoms increased after 117 days for CM497, 130 days for P3981, and 137 days for the other two varieties (App. Fig. 5b). No significant disease was observed at PD3 and PD4 in this location (App. Figures 5c and 5d).

The days preceding the first scoring date (108) showed an increase in shallow soil moisture resulting from 5, 8 and 10 mm of rain at 89, 94 and 99 days, possibly triggering symptom appearance in CM497.

All other days where symptoms showed a marked increase were preceded by rain recorded the previous weekly period and the consequent increase in soil moisture. For example, the symptom increase at 130 days in MG III, MG IV and MG VI cultivars at PD1 were preceded by 13 and 23 mm rains recorded at 123 and 130 days, respectively.

The rain registered at 117 days (5mm) and 123 days (13mm), even though small, may have promoted CM497 symptoms at PD2. The rain at 130 days (23 mm) may also be associated with CM497 and P3981 symptom development at PD2, while the rain at 137 days may be associated with disease symptoms in later MG varieties at PD2 (App. Figure 6b).

The combination of a period of rain, high soil moisture and a drop in soil temperature associated with the pod set to pod development stage corresponded at both locations to a period of disease increase, which is consistent with statements by Howard et al (1992), Rupe et al (1993), and Gibson et al. (1994).

Timing of Symptom Development Relative to Stage of Growth

No disease was observed prior to flowering at either location. At Villa Ridge, DI did not reach 10% before the R4 stage (App.Table 11a). At Ridgway, cultivars were mainly affected after the R5 period (App. Table 11b). The fact that at both locations disease symptoms were stronger after the R4 stage, regardless of planting date and maturity group, suggests that plant development is also associated with the disease progression. It appears that the period of pod elongation and pod fill is the period when the plant develops leaf symptoms more rapidly. The role of developmental stage on time of disease expression can also be suggested by the fact that the increases in soil moisture in later planting dates at Villa Ridge did not cause as much damage to earlier MGs as they did to later MGs.

This may have resulted from the earlier cultivars being past the growth stage when they were most vulnerable to leaf symptom development. The rapidness of symptom increase after R4 appears to be mainly related to environmental conditions regardless of maturity group.

Comparison of Results with Some Previous Studies

Gibson et al. (1994) reported that in a 7 year (1987-1993) study the pattern of response to planting date differed greatly by year, but overall, delays in planting reduced SDS. According to him different varieties responded differently to delays in planting in different years. However, overall, later MGs were more affected than earlier ones.

Included in that 7 year period, a 1988 study by Kiarie (1989) showed that there was a substantial reduction in disease with delay in planting, while a 1990 study by Alghamdi(1991) showed no difference among PDs. Kiarie (1989) found no difference among MGs while Alghamdi 1991) found that later MGs had higher disease incidence and severity.

The results of the present study showed that SDS decreased with delay in planting and that later MGs were more affected than earlier ones.

The 1988 planting dates were May 13, May 27, June 10 and June 23, and 1990 planting dates were May 5, May 12, May 26 and July 10. Even though the first planting dates were earlier in 1990 than in 1988, no disease levels were high in that year, possibly due to hot dry periods observed from late June to early July and between August 27 and September 7. These dry periods may have repressed disease development. On the other hand, in 1988, cool temperature in late July and high soil moisture might have favored disease.

The 1994 planting dates were similar to 1988 planting dates, and conditions at Villa Ridge were similar to the ones of 1988 study, differing only in

that the 1994 disease started earlier. At Ridgway, in 1994, a period of low soil moisture was observed throughout August and may have caused the same effect of the dry and hot periods observed in 1990 in repressing the disease development.

Differences in results among years suggest that conditions other than planting date are also involved in favoring or repressing SDS development. It also demonstrates interaction between maturity group and planting dates as well as between environment and cultivars, since the same cultivar behaves differently at similar planting dates at different locations or years. In addition, cultivars showed specific responses to a particular planting date or environment which contrasted with the general trend of other cultivars.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was conducted during the 1994 growing season at Villa Ridge (Pulaski County) and Ridgway (Gallatin County) in Southern Illinois. These two locations were chosen based on their previous history of SDS infestation.

The study had two objectives: i) To evaluate the effect of different planting dates and varietal maturity groups on SDS incidence and severity, and ii) to examine the association of environmental factors with planting date effects on the time of onset and the progression of disease.

Four susceptible cultivars from Maturity Groups III to VI were planted on four different dates ranging from May 13 to June 24 in a split-plot design with maturity group used as the main plot factor and planting date as the subplot factor.

Disease scores taken as disease incidence (DI) and disease severity (DS) were recorded on a weekly basis once disease symptoms appeared. Reproductive stage (R-stage) and environmental data were recorded weekly as well.

Delaying planting reduced the number of days to flower and to days to harvest maturity at both locations, suggesting sensitivity of cultivars to photoperiod. At Ridgway, however, the delay was not consistent for days to harvest maturity.

Disease was recorded earlier at Villa Ridge and overall the levels of disease were higher than at Ridgway. In both locations the initial symptoms of SDS were observed after flowering.

At Villa Ridge, the first disease score was recorded in all MGs at PD1 with Pioneer 3981 at R4.1 and Lee74 at R1.6. At Ridgway, the first disease score included disease at PD1 for Pioneer 3981, CM497 and Lee74, with Pioneer 3981 at R5.8 and Lee 74 at R3.1.

R6DI decreased significantly ($P<0.05$) with delayed planting at Villa Ridge, while at Ridgway the only significant ($P<0.05$) difference was between PD1 compared to PD3 and PD4. In either location disease severity (DS) was not significantly different across planting dates. At Villa Ridge, DX was significantly less ($P<0.05$) at the two later PDs than at the two earlier ones. At Ridgway, DX decreased with delayed planting as well but that decrease was not statistically significant.

At Villa Ridge, the DI of MG III was significantly ($P<0.05$) lower than all other MGs. At Ridgway, MGs did not differ significantly for DI. DS was significantly higher for MG VI than for MG III in both locations. DX was significantly lower for MG III than for any other MG at Villa Ridge, but no significant differences were found among MGs at Ridgway.

The effect of disease on yield was not clear at either location, probably due to other environmental influences on yield. However, the results indicated that higher disease levels at Villa Ridge did not prevent this location from having higher yield than Ridgway.

At Villa Ridge, MGs did not differ significantly for yield, but at Ridgway later MGs had higher yields despite being slightly more affected by disease than earlier MGs. How 100 seed weight was affected by disease was not clear. At either site, 100 seed weight was not affected by planting date, leaving unclear the connection between disease levels and seed weight. At both locations MG III had significantly ($P<0.05$) heavier seed than any other maturity group, a reflection of the unusually large seed size of the cultivar P3981.

The pattern of rainfall did not differ too much between the two locations. However, between July 12 to September 2 soil moisture was higher at Villa Ridge than at Ridgway, probably contributing to more disease at Villa Ridge.

Conclusions

At both locations disease was significantly reduced with delay in planting, but the pattern of reduction differed with MG. Overall, later MGs exhibited higher SDS severity and incidence resulting in significant differences among MGs.

At Villa Ridge, yields were lower in later planting dates than at earlier ones indicating that higher levels of disease at earlier planting did not offset the yield benefit of earlier planting. The highest yields were obtained in the least SDS affected maturity groups. These two observations suggest that a different analytical approach would be needed to better interpret the effect of the disease on yield.

For all maturity groups at each planting date at both locations, disease became evident starting at the R4 stage indicating that the stage of development is a substantial factor in the progression of the disease.

The precise role of soil moisture and temperature was not clear in this study, but it appeared that high soil moisture between early July and the beginning of September resulted in considerable disease at Villa Ridge. Periods of low soil moisture and higher maximum temperatures between July 22 and August 8 may have contributed to inhibited SDS progression at Ridgway resulting in lower levels of disease than at Villa Ridge.

In both locations, periods where disease increased rapidly were preceeded by substantial rains within the previous two weeks.

At both locations disease appeared in a period where minimum soil temperatures reached lower levels.

Recommendations

Based on this study, some recommendations are suggested for minimizing soybean losses as well as for further research examining SDS.

Production Recommendations

1) Avoid planting soybean earlier than necessary, or when the soil is wetter than necessary, in order to reduce the risk of early establishment of disease.

2) Plant cultivars from different maturity groups.

3) Choose cultivars with the best record against SDS.

Recommendations for Further Research

1) Sample plants and split stems early in the season in order to assess the time of root infection as well as initial appearance and progression of stem symptoms and compare these with the time of appearance of leaf symptoms. By associating this information with environmental conditions, it may be more clear which factors trigger or repress leaf symptom appearance and disease progression.

2) Study more thoroughly the effect of environmental factors on SDS by collecting more accurate environmental measurements. More precise soil and air temperature data will help in understanding the role of those factors on SDS.

3) Examine soil physical characteristics as well as soil fertility effects on SDS.

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APPENDICES

Appendix Table 1a. Summary of agronomic performance of different maturity groups averaged over planting dates at Villa Ridge.

Maturity group/ (cultivar)	Emergence	Vigor	Flower color	Flowering date	Harvest maturity	Plant height (cm)	Yield (T/ha)	100 Seeds (g)
III (P3981)	2.5	2.1	white	38.3	111.3	87.8	2.3	16.9
IV(CM497)	1.7	2.1	purple	39.1	117.7	115.8	3.0	13.5
V (DP105)	1.7	1.9	purple	63.8	143.4	102.6	3.3	13.6
VI (Lee 74)	1.7	1.9	purple	67.6	139.4	99.6	2.6	12.8

Appendix Table 1b. Summary of agronomic performance of different maturity groups averaged over planting dates at Ridgway

Maturity group/ (cultivar)	Emergence	Vigor	Flower color	Flowering date	Harvest maturity	Plant heigh (cm)	Yield (T/ha)	100 Seeds (g)
III (P3981)	1.6	2.2	white	39.7	119.6	80.5	1.2	17.8
IV(CM497)	1.8	2.1	purple	42.0	127.7	113.0	1.2	14.5
V(DP105)	1.9	2.1	purple	63.3	154.4	98.8	1.4	14.3
VI(Lee 74)	1.3	1.8	purple	68.8	150.0	94.7	1.4	12.5

Note: Values for flowering date and harvest maturity refer to days from planting date

Emergence and vigor scored as:

1- Very Good
2- Good
3- Fair
4- Poor
5- VeryPoor

Appendix Table 2a: Analysis of variance for flowering date(days from planting to flowering)at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	4.8	2.88	0.0953
MG (Factor A)	3	3920.8	2369.76	0.0000**
Error a	9	1.7		
PD (Factor B)	3	203.9	67.32	0.0000**
AB (PDxMG)	9	61.0	20.32	0.0000**
Error b	36	3.0		

Appendix Table 2b: Analysis of variance for flowering date (days from plant to flowering)at Ridgway.

Source	df	MS	F	Prob
Rep	3	104.2	5.21	0.0233
MG (Factor A)	3	3476.6	173.95	0.0000**
Error	9	20.0		
PD (Factor B)	3	1450.0	93.03	0.0000**
AB (PDxMG)	9	67.1	4.31	0.0007**
Error	36	15.6		

Appendix Table 3a: Analysis of variance for days from planting to R6.2 stage at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	1.2	0.24	
MG (Factor A)	3	2333.9	484.82	0.0000**
Error a	9	4.8		
PD (Factor B)	3	900.7	365.41	0.0000**
AB (PDxMG)	9	31.7	12.96	0.0000**
Error b	36	2.5		

Rep = Replication
MG = Maturity Group
PD = Planting Date
df = degree of freedom
MS = Mean Square
** = significant at 0.01 probability
F= F Value
P= Probability

Appendix Table 3b: Analysis of variance for days from planting to R6.2 stage at Ridgway.

Source	df	MS	F	Prob
Rep	3	4.1	1.40	0.3047
MG (Factor A)	3	1910.8	655.31	0.0000**
Error	9	2.9		
PD (Factor B)	3	1581.4	969.95	0.0000**
AB (PDxMG)	9	66.6	40.82	0.0000**
Error	36	1.6		

Appendix Table 4a: Analysis of variance for days to harvest maturity at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	0.54	0.39	
MG (Factor A)	3	4021.8	2895.75	0.0000**
Error	9	1.3		
PD (Factor B)	3	1316.5	922.54	0.0000**
AB (PDxMG)	9	24.1	16.90	0.0000**
Error	36	1.4		

Rep = Replication
MG = Maturity Group
PD = Planting Date
df = degree of freedom
MS = Mean Square
F = F Value
Prob= Probability
** significant at 0.01 probability

Appendix Table 4b: Analysis of variance for days to harvest maturity at Ridgway, considering MG III and MG IV at all PDs.

Source	df	MS	F	Prob
Rep	3	4.2	3.09	0.1894
MG (Factor A)	1	528.1	384.09	0.0003**
Error	3	1.4		
PD (Factor B)	3	133.5	73.65	0.0000**
AB (PDxMG)	3	23.8	13.13	0.0001**
Error	18	1.81		

Appendix Table 4c: Analysis of variance for days to harvest maturity at Ridgway, considering all MGs at PD1 and PD2.

Source	df	MS	F	Prob
Rep	3	18.8	1.29	0.3357
MG (Factor A)	3	2420.6	166.33	0.0000**
Error	3	14.6		
PD (Factor B)	1	5.6	0.48	
AB (PDxMG)	3	41.3	3.56	0.0508
Error	11	11.6		

Appendix Table 5a: Analysis of variance for R6DI (Disease incidence at R6-stage) at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	165.5	0.91	
MG (Factor A)	3	4141.0	22.83	0.0002**
Error	9	181.3		
PD (Factor B)	3	21757.2	216.27	0.0000**
AB (PDxMG)	9	607.3	6.04	0.0000**
Error	36	100.6		

Rep = Replication
MG = Maturity Group
PD = Planting Date
df = degree of freedom
MS = Mean Square
** = Significant at 0.01 probability
F = F Value
Prob= Probability

Appendix Table 5b: Analysis of variance for R6DI (Disease incidence at R6-stage)at Ridgway.

Source	df	MS	F	Prob
Rep	3	1717.6	4.38	0.0368
MG (Factor A)	3	1927.6	4.91	0.0273*
Error a	9	392.3		
PD (Factor B)	3	3238.9	11.57	0.0000**
AB (PDxMG)	9	409.4	1.46	0.1994
Error b	36	280.0		

Appendix Table 6a: Analysis of variance for disease severity(DS)at R6-stage at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	0.34	1.18	0.3730
MG (Factor A)	3	4.70	16.04	0.0006**
Error a	9	0.29		
PD (Factor B)	3	0.46	1.98	0.1338
AB (PdxMG)	9	0.38	1.63	0.1430
Error b	36	0.23		

Appendix Table 6b. Analysis of Variance for disease severity(DS)at R6-stage at Ridgway.

Source	df	MS	F	Prob
Rep	3	4.88	7.68	0.0075
MG (Factor A)	3	5.27	8.30	0.0059**
Error a	9	0.64		
PD (Factor B)	3	2.28	3.16	0.0364*
AB (PDxMG)	9	0.39	0.54	
Error b	36	0.72		

Rep = Replication
MG = Maturity Group
PD = Planting Date
df = degree of freedom
MS = Mean Square
** = Significant at 0.01 probability
* = Significant at 0.05 probability
F = F Value
Prob = Probability

Appendix Table 7a. Analysis of variance for disease index (DX)at R6-stage at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	40.7	1.45	0.2919
MG (Factor A)	3	740.1	26.40	0.0001**
Error a	9	28.0		
PD (Factor B)	3	2689.2	98.40	0.0000**
AB (PDxMG)	9	118.0	4.32	0.0007**
Error b	36	27.3		

Table 7b. Analysis of variance for disease index (DX)at R6-stage at Ridgway.

Source	df	MS	F	Prob
Rep	3	385.4	5.74	0.0179
MG (Factor A)	3	255.5	3.80	0.0519
Error a	9	67.2		
PD (Factor B)	3	504.8	5.98	0.0020**
AB (PDxMG)	9	76.4	0.91	
Error b	36	84.4		

Appendix Table 8a. Analysis of variance for yield (T/ha) at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	1.042	4.5643	0.0331
MG (Factor A)	3	3.144	13.7712	0.0010**
Error	9	0.228		
PD (Factor B)	3	1.843	8.6208	0.0002**
AB (PDxMG)	9	0.309	1.4471	0.2053
Error	36	0.214		

Rep = Replication
MG = Maturity Group
PD = Planting Date
df = degree of freedom
MS = Mean Square
** = Significant at 0.01 probability
F= F Value
Prob = Probability

Appendix Table 8b. Analysis of variance for yield (T/ha) for MGIII and MG IV at all PDs at Ridgway.

Source	df	MS	F	Prob
Rep	3	0.0150	6.79	0.0749
MG (Factor A)	1	0.0003	0.01	
Error a	3	0.0220		
PD (Factor B)	3	0.0063	2.04	0.1494
AB (PDxMG)	3	0.0035	1.12	0.3704
Error b	16	0.0031		

Table 8c. Analysis of variance for yield (T/ha) for all MGs at PD1 and PD2 at Ridgway.

Source	df	MS	F	Prob
Rep	3	0.0070	0.17	
MG (Factor A)	3	0.1109	24.03	0.0001**
Error a	9	0.0042		
PD (Factor B)	1	0.0064	5.24	0.0428*
AB (PDxMG)	3	0.0020	1.66	0.2330
Error b	11	0.0122		

Appendix Table 9a. Analysis of variance for 100 seed weight(g) at Villa Ridge.

Source	df	MS	F	Prob
Rep	3	2.039	9.41	0.0039
MG (Factor A)	3	55.28	256.38	0.0000**
Error a	9	0.22		
PD (Factor B)	3	0.42	0.67	
AB (PDxMG)	9	1.83	2.96	0.0098**
Error b	36	0.62		

Rep = Replication
MG = Maturity Group
PD = Planting Date
df = degree of freedom
MS = Mean Square
F= F Value
Prob = Probability
** = Significant at 0.01 propbability
* = Significant at 0.05 probability

Appendix Table 9b. Analysis of variance for 100 seed weight at Ridgway, considering MG III and MG IV at all PDs.

Source	df	MS	F	Prob
Rep	3	0.16	0.14	
MG (Factor A)	1	79.04	68.77	0.0037**
Error a	3	1.15		
PD (Factor B)	3	4.28	7.39	0.0025**
AB (PDxMG)	3	1.91	3.30	0.0473*
Error b	16	0.58		

Appendix Table 9c. Analysis of variance for 100 seed weight at Ridgway, considering all MGs at PD1 and PD2.

Source	df	MS	F	Prob
Rep	3	1.09	2.12	0.1681
MG (Factor A)	3	22.16	42.88	0.0000**
Error a	3	0.52		
PD (Factor B)	1	1.36	2.37	0.1624
AB (PDxMG)	3	4.50	7.86	0.0091**
Error b	8	0.57		

Rep = Replication
MG = Maturity Group
PD = Planting Date
df = degree of freedom
MS = Mean Square
F= F Value
Prob = Probability
** = Significant at 0.01 probability

Appendix Table 10a. Summary of Climatic and Soil Moisture Data at Villa Ridge.

Date	Days After May1	Weekly accumulated Rain (mm)	Weekly Soil Temperature °C		Soil Moisture as (%) of Dry Weight		Gypsum Block Readings		
			Min	Max	0-10 cm	10-20 cm	8 cm	15 cm	30 cm
5/17	16	0.0			25.6	25.8			
5/24	23	7.6	15.6	26.7	24.6	23.9	85.6	88.9	91.4
5/31	30	5.1			24.0	24.9	85.6	88.7	91.4
6/7	37	20.3	20.6	31.7	25.2	24.3	88.6	88.6	91.7
6/14	44	5.1	22.8	31 7	24.8	23.2	90.9	91.0	93.5
6/21	51	0.0	23.3	35.6	22.7	24.1	79.6	88.9	87.7
6/28	58	0.0	22.2	37.8	21.13	23.2	90.2	90.2	92.2
7/7	67	0.0	24.4	37.8	16.5	19.6	57.0	71.1	88.7
7/12	72	20.3	21.1	33.3	23.7	22.7	70.6	81.7	89.0
7/19	79	7.6	25.0	32.2	19.6	17.8			
7/26	86	0.0	22.2	37.8	16.0	16.0	55.0	76.1	77.1
8/5	96	17.8	16.7	36.1	17.9	17.1	86.9	71.2	71.5
8/11	101	0.0			19.0	20.9	79.2	73.2	71.5
8/19	110	0.0	17.8	32.2	12.6	15.5	49.2	70.5	68.0
8/26	117	2.5	16.7	30.0	11.0	13.9			
8/29	120	50.8			22.0	21.8			
9/2	124	25.4	17.8	20.0	22.4	22.1			
9/9	131	0.0	20.0	22.2	18.6	20.2	90.5	81.4	62.9
9/16	138	35.6	22.2	22.2	12.4	10.0	89.4	87.6	62.4
9/23	145	12.7	16.7	16.7	25.0	21.5	60.7	74.1	59.9
9/29	151	33.0	15.6	16.7	17.4	19.5	87.2	876.9	76.0

Appendix Table 10b. Summary of Climatic and Soil Moisture Data at Ridgway.

Date	Days After May 1	Weekly Accumulated Rain (mm)	Weekly Soil Temperature °C		Soil moisture as % of dry weight		Gypsum Blocks Readings		
			Min	Max	0-10cm	10-20cm	8 cm	15cm	30cm
5/13	12				21.4	23.4			
5/20	19	2.5			18.1	18.9	72.1	90.7	90.4
5/27	26	2.5			20.4	23.2	63.7	89.7	90.5
6/3	33	10.2	15.6	27.8	22.5	23.4	65.9	89.6	91.2
6/6	36	5.1			21.8	23.7	75.7	90.2	91.9
6/10	40	30.5	16.7	33.3	23.1	24.0	93.7	91.7	92.6
6/17	47	20.3	16.1	33.3	23.9	23.6	96.1	95.0	95.4
6/21	51		21.1	42.2			60.5	64.2	85.5
6/28	58	5.1			22.3	22.0	67.2	75.9	83.0
7/1	61	48.3	25.6	42.8	20.5	20.6	36.1	52.6	67.2
7/8	68	33.0	26.7	43.3	18.6	20.0			
7/14	74	15.2	24.4	42.2	17.5	19.5	42.5	33.9	62.0
7/22	82	12.7	28.9	37.2	16.5	18.2			
7/29	89	5.1	21.1	36.7	15.8	18.4	15.2	11.4	13.4
8/3	94	7.6	21.7	37.2	16.5	17.6	10.1	9.9	10.1
8/8	99	10.2	20.0	36.7	17.3	17.0	10.9	8.9	8.2
8/17	108	0.0	25.0	26.7	15.0	16.3			
8/26	117	5.1	20.0	28.9	15.1	16.2	16.7	8.9	7.4
9/1	123	12.7	20.0	22.2	19.1	14.9	69.7	56.2	27.9
9/8	130	22.9	15.6	26.1	18.2	16.4	28.2	28.7	19.0
9/15	137	2.5	15.6	26.7	13.5	16.5			
9/22	144	10.1	18.9	22.2	16.9	17.4	90.7	91.9	90.7
9/29	151	73.7	11.1	27.8	25.1	22.9			

Appendix Table 11a. Disease Progression at Villa Ridge.

MG	PD	7/26 (86)*			8/5 (96)*			8/10 (101)*			8/19 (110)*		
		R	DI	DS	R	DI	DS	R	DI	DS	R	DI	DS
III	1	4.1	1.7	0.7	4.4	2.3	1.0	5.2	3.8	1.0	6.0	27.3	2.5
	2	3.5	0.0	0.0	3.7	0.0	0.0	4.6	0.0	0.0	5.8	7.0	2.1
	3				3.2	0.3	0.3	3.8	0.3	0.3	5.2	0.5	0.3
	4							2.8	0.0	0.0	3.9	0.0	0.0
IV	1	3.5	14.3	1.0	3.9	20.8	2.1	4.3	25.3	2.1	5.5	41.8	2.6
	2	3.1	0.8	0.3	3.3	0.8	0.3	3.8	3.3	0.6	5.3	33.8	2.1
	3				2.7	0.0	0.0	3.3	0.0	0.0	4.3	0.5	0.5
	4				1.8	0.0	0.0	2.6	0.0	0.0	3.5	0.0	0.0
V	1	2.6	0.3	0.3	3.0	1.0	0.5	3.6	2.3	0.9	4.1	19.8	1.7
	2				1.8	0.0	0.0	2.3	0.0	0.0	3.5	2.5	1.0
	3							1.6	0.0	0.0	2.3	0.0	0.0
	4										1.7	0.0	0.0
VI	1	1.6	2.8	0.8	2.0	3.3	1.0	2.7	5.3	1.0	3.8	7.5	1.6
	2							1.8	0.8	0.3	3.1	3.3	0.7
	3							1.1	0.7	0.3	2.3	0.5	0.3
	4										1.8	0.0	0.0

MG = Maturity Group
MG III= Pioneer P3981
MG IV= CM497
MG V= DP105
MG VI= Lee 74
* = Days after May 1

PD = Planting Date
PD1 = 5/17
PD2 = 5/31
PD3= 6/15
PD4 =6/22

R= Rstage
DI= Disease incidence
DS= Disease severity

Appendix Table 11a. (Cont.). Disease Progression at Villa Ridge.

MG	PD	8/26 (117)*			9/2 (124)*			9/9 (131)*			9/16 (138)*		
		R	DI	DS	R	DI	DS	R	DI	DS	R	DI	DS
III	1	6.2	60.5	2.5	6.6	69.5	2.6	7.0					
	2	6.0	20.8	2.4	6.2	35.5	2.3	6.7			7.0		
	3	5.4	1.3	1.0	5.8	2.5	1.6	6.2	5.5	2.1	6.6	12.3	2.8
	4	4.4	0.0	0.0	5.2	0.0	0.0	5.6	0.3	0.3	6.2	3.8	1.4
IV	1	5.9	89.5	2.6	6.3	100.0	2.8	6.6	100.0	3.8	6.9		
	2	5.6	56.8	2.3	6.0	80.0	2.4	6.3	87.8	3.0	6.6	100.0	3.6
	3	4.6	3.5	1.3	5.1	6.5	1.5	5.6	14.0	2.0	6.1	25.0	2.5
	4	4.1	0.8	0.3	4.7	0.8	0.3	5.2	3.0	0.8	5.9	13.8	2.2
V	1	4.8	28.3	1.8	5.2	37.8	2.2	5.7	68.3	3.3	6.1	89.0	3.6
	2	4.1	8.3	1.6	4.8	14.0	2.2	5.3	27.0	2.8	5.8	63.8	3.2
	3	2.8	1.5	0.8	3.5	3.8	1.0	4.2	7.8	1.9	5.0	25.3	2.8
	4	2.2	0.0	0.0	2.9	0.0	0.0	3.6	0.3	0.5	4.4	3.3	2.3
VI	1	4.2	14.8	1.5	4.8	19.5	1.8	5.4	33.0	3.1	6.0	89.8	3.1
	2	3.6	8.3	1.2	4.2	11.3	1.5	4.7	17.5	2.0	5.5	54.0	3.3
	3	2.9	1.3	0.5	3.5	1.3	0.5	4.3	2.8	0.8	5.0	12.0	2.5
	4	2.4	0.0	0.0	3.2	0.0	0.0	3.9	0.8	0.3	4.6	5.5	1.5

MG = Maturity Group
MG III= Pioneer P3981
MG IV= CM497
MG V= DP105
MG VI= Lee 74
* = Days after May 1

PD = Planting Date
PD1 = 5/17
PD2 = 5/31
PD3= 6/15
PD4 =6/22

R = R stage
DI = Disease Incidence
DS= Disease severity

Appendix Table 11a. (Cont). Disease Progression at Villa Ridge.

MG	PD	9/23 (145)*			9/30 (152)*			10/7 (159)*		
		R	DI	DS	R	DI	DS	R	DI	DS
III	1									
	2									
	3									
	4	6.5	4.0	1.3	7.0					
IV	1									
	2									
	3	6.5	29.3	2.8	6.7			7.0		
	4	6.3	14.8	2.1	6.5			6.7		
V	1	6.4	100.	4.0	6.7	100.0	3.1	7.0		
	2	6.2		3.3	6.4	95.0	3.3	6.7	100.0	3.5
	3	5.8		2.8	6.2	35.3	2.5	6.4	78.8	2.6
	4	5.2		2.0	5.8	17.8	1.5	6.3	45.0	2.4
VI	1	6.4	96.3	3.4	6.6	100.0	3.4	6.8		
	2	6.0	79.0	3.1	6.4	90.5	3.1	6.6	100.0	3.8
	3	5.7	13.8	2.3	6.1	28.0	2.3	6.4	53.0	2.9
	4	5.3	7.8	2.3	5.9	13.3	2.3	6.3	31.3	2.6

MG = Maturity Group
MG III= Pioneer P3981
MG IV= CM497
MG V= DP105
MG VI= Lee 74
* = Days after May 1

PD = Planting Date
PD1 = 5/17
PD2 = 5/31
PD3= 6/15
PD4 =6/22

R= R stage
DI= Disease Incidence
DS= Disease severity

Appendix Table 11b. Disease Progression at Ridgway.

MG	PD	8/17 (108)*			8/26 (117)*			9/1 (123)*			9/8 (130)*		
		R	DI	DS	R	DI	DS	R	DI	DS	R	DI	DS
III	1	5.8	1.5	0.4	6.2	3.8	0.8	6.4	4.0	1.0	6.7	6.3	2.3
	2	5.5	0.0	0.0	5.8	0.3	0.3	6.1	0.3	0.3	6.4	2.3	1.1
	3	4.0	0.0	0.0	4.5	0.0	0.0	5.0	0.0	0.0	5.3	0.0	0.0
	4	3.0	0.0	0.0	3.6	0.0	0.0	4.0	0.0	0.0	4.5	0.3	0.3
IV	1	5.4	25.5	1.9	5.6	27.3	1.4	6.0	36.8	2.3	6.3	44.8	2.9
	2	5.0	0.8	0.5	5.2	1.0	0.6	5.5	6.3	1.1	5.9	15.3	1.5
	3	3.4	0.0	0.0	3.8	0.0	0.0	4.2	2.3	0.8	5.0	4.5	4.4
	4	2.8	0.0	0.0	3.2	0.0	0.0	3.6	0.5	0.3	4.3	1.0	0.6
V	1	3.7	0.0	0.0	4.1	1.0	0.5	4.6	3.0	0.7	5.2	5.3	1.4
	2	2.7	0.3	0.3	3.2	0.8	0.4	3.6	0.8	0.3	4.3	2.8	0.5
	3				2.4	0.0	0.0	3.0	0.0	0.0	3.5	0.5	0.3
	4							2.3	0.0	0.0	3.0	0.0	0.0
VI	1	3.1	1.5	0.3	3.5	1.8	0.4	4.0	3.0	0.4	4.7	5.5	0.8
	2	2.7	0.0	0.0	3.1	0.0	0.0	3.5	0.0	0.0	4.1	2.3	1.3
	3				2.1	0.0	0.0	2.6	0.0	0.0	3.6	0.0	0.0
	4							1.5	0.0	0.0	2.6	0.0	0.0

MG = Maturity Group
MG III= Pioneer P3981
MG IV= CM497
MG V= DP105
MG VI= Lee 74
* = Days after May 1

PD = Planting Date
PD1 = 5/13
PD2 = 6/6
PD3= 6/18
PD4 = 6/24

R= Rstage
DI = Disease incidence
DS = Disease severity

Appendix Table 11b. (Cont.) Disease Progression at Ridgway.

MG	PD	9/15 (137)*			9/22 (144)*			9/24 (151)*			10/6 (158)*		
		R	DI	DS	R	DI	DS	R	DI	DS	R	DI	DS
III	1	7.0											
	2	6.6	18.0	1.6									
	3	5.9	0.5	0.3	6.4	1.3	0.3	6.6					
	4	4.8	0.3	0.3	6.0	1.0	0.5	6.3	5.7	0.7	6.6		
IV	1	6.6	76.0	3.2									
	2	6.3	31.3	1.6	6.5	32.5	1.8	6.8					
	3	5.6	5.8	1.2	6.1	6.5	1.5	6.4	10.3	1.9	6.0	5.0	1.0
	4	5.1	1.0	0.7	5.9	1.5	3.4	6.1	6.3	1.2	6.4	3.8	1.3
V	1	5.6	13.5	2.1	6.2	34.8	2.7	6.4	41.3	2.6	6.6		
	2	5.1	5.3	1.1	5.9	9.0	1.7	6.2	15.8	2.0	6.4	23.5	2.4
	3	4.2	0.8	1.2	5.0	1.8	0.8	5.6	5.0	1.5	6.1	8.8	1.7
	4	3.6	0.0	0.0	4.4	0.3	0.8	5.1	4.8	1.5	5.8	7.7	1.4
VI	1	5.4	19.8	2.5	6.0	43.0	3.2	6.3	56.0	3.1	6.6	100.0	6.0
	2	5.0	6.0	1.6	5.8	24.5	2.0	6.1	34.0	2.2	6.5	42.5	2.5
	3	4.4	0.3	2.5	5.3	2.3	0.9	5.9	6.3	1.7	6.3	12.0	1.7
	4	3.6	0.0	0.0	4.3	0.0	0.0	5.2	1.8	0.5	5.9	4.8	4.3

MG = Maturity Group
MG III= Pioneer P3981
MG IV= CM497
MG V= DP105
MG VI= Lee 74
* = Days after May 1

PD = Planting Date
PD1 = 5/13
PD2 = 6/6
PD3= 6/18
PD4 = 6/24

R= R stage
DI = Disease incidence
DS = Disease severity

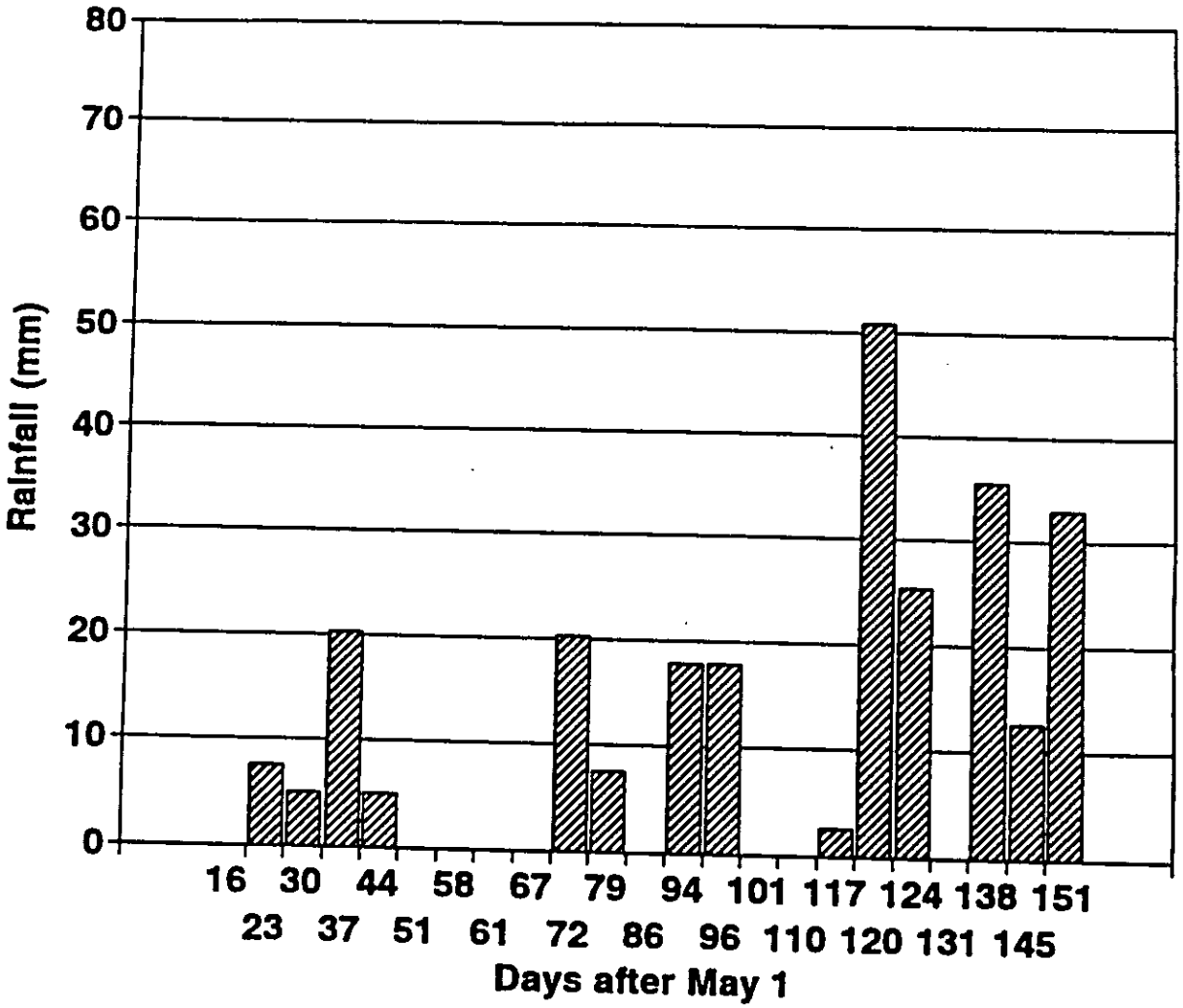
Appendix Table 12a. Summary of days after planting to R6 stage (R6date) and R6stage disease data at Villa Ridge.

Maturity Group (cultivar)	Planting Date		R6Date	R6DI	R6DS	R6DX
III (P3981)	1	5/17	105.7	55.3	2.5	15.5
	2	5/31	97.0	25.5	2.4	6.9
	3	6/15	93.1	4.8	2.3	1.2
	4	6/22	94.0	2.2	1.5	0.3
IV (CM497)	1	5/17	112.7	94.0	2.7	28.4
	2	5/31	105.8	85.1	2.9	27.4
	3	6/15	102.7	26.5	2.6	8.0
	4	6/22	100.6	13.8	2.8	5.2
V (DP105)	1	5/17	132.4	95.2	3.8	40.3
	2	5/31	124.0	78.8	3.3	29.1
	3	6/15	114.6	41.6	3.0	14.1
	4	6/22	113.1	5.5	3.7	2.2
VI (Lee 74)	1	5/17	134.6	96.3	3.3	34.9
	2	5/31	126.4	84.8	3.3	31.1
	3	6/15	115.6	18.3	3.0	6.0
	4	6/22	111.8	7.8	3.0	2.6

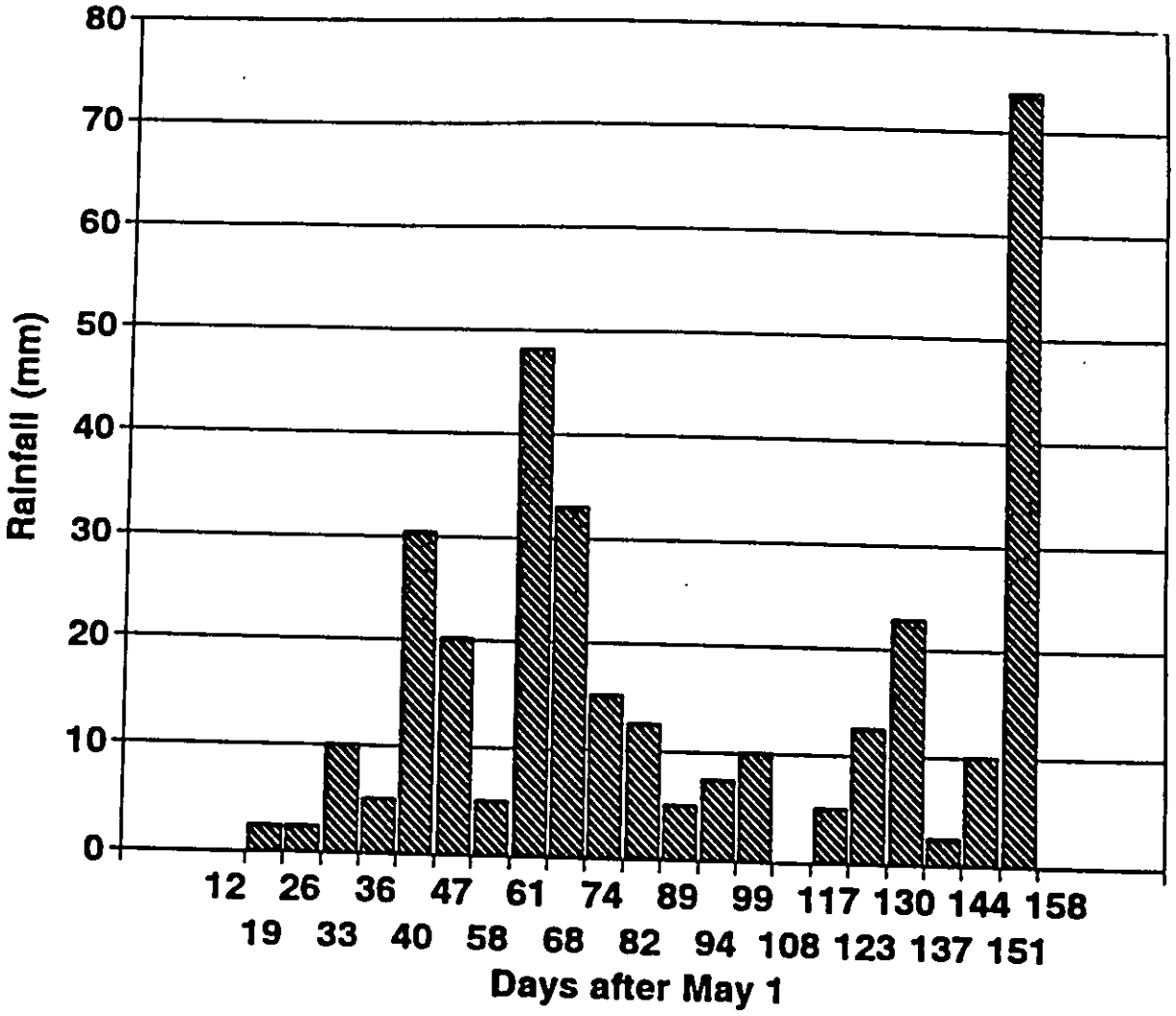
Appendix table 12b. Summary of days after planting to R6 stage (R6date) and R6stage disease data at Ridgway.

Maturity Group (cultivar)	Planting	Date	R6Date	R6DI	R6DS	R6DX
III (P3981)	1	5/13	103.9	4.0	1.3	0.9
	2	6/6	88.5	1.3	2.0	0.2
	3	6/18	93.3	1.0	1.0	0.1
	4	6/24	94.1	1.0	1.2	0.1
IV (CM497)	1	5/13	113.5	43.8	2.6	15.1
	2	6/6	99.6	29.3	1.8	9.2
	3	6/18	98.4	8.7	1.8	2.2
	4	6/24	96.8	2.4	1.5	0.5
V (DP105)	1	5/13	133.4	43.6	2.7	13.7
	2	6/6	114.7	17.1	2.3	5.2
	3	6/18	110.6	8.1	2.0	1.9
	4	6/22	108.8	14.4	2.1	4.2
VI (Lee 74)	1	5/13	135.8	54.1	3.3	24.4
	2	6/6	115.2	37.1	2.2	11.2
	3	6/18	108.0	6.3	2.7	1.8
	4	6/24	107.4	10.9	1.7	2.4

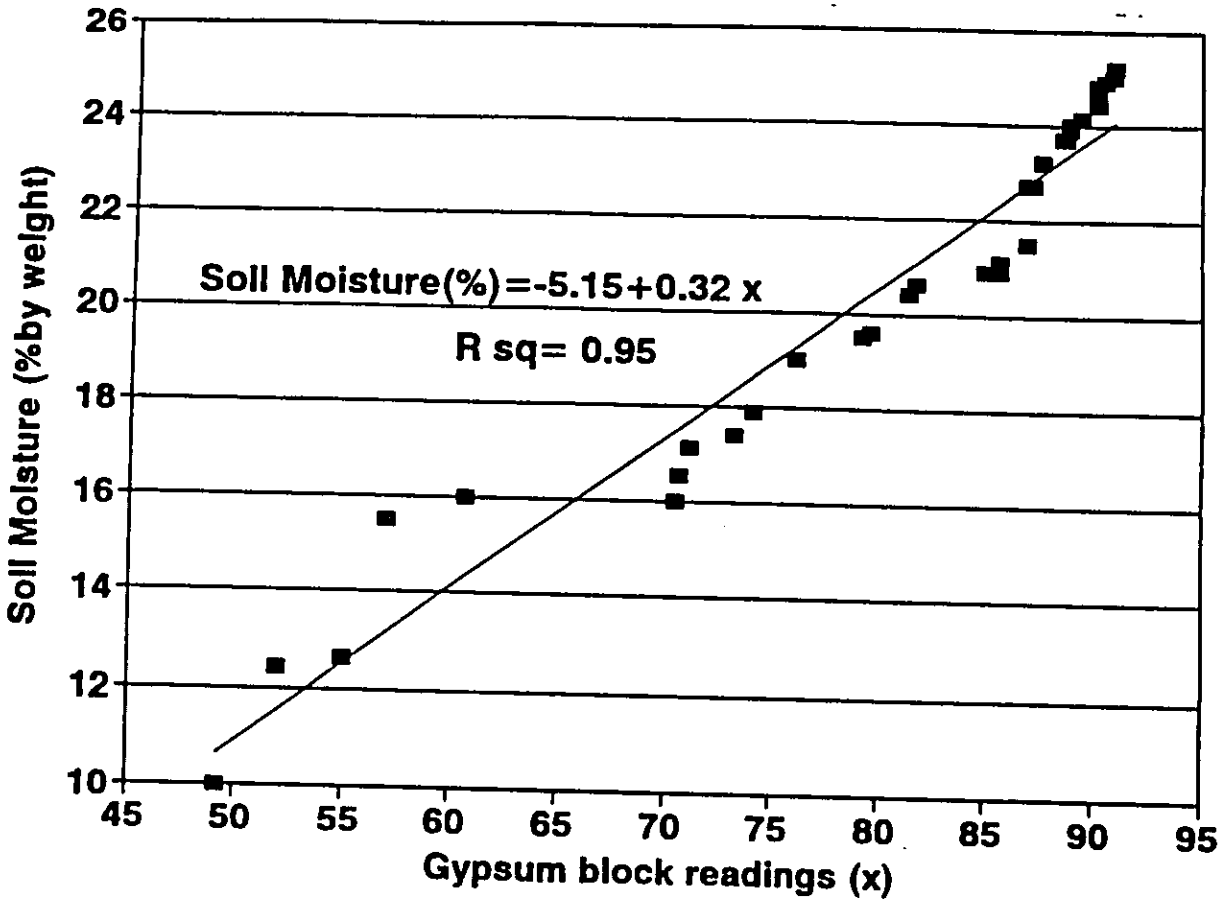
Appendix Fig. 1a. Rainfall (mm) from 1st planting to September 30 at Villa Ridge 1994.



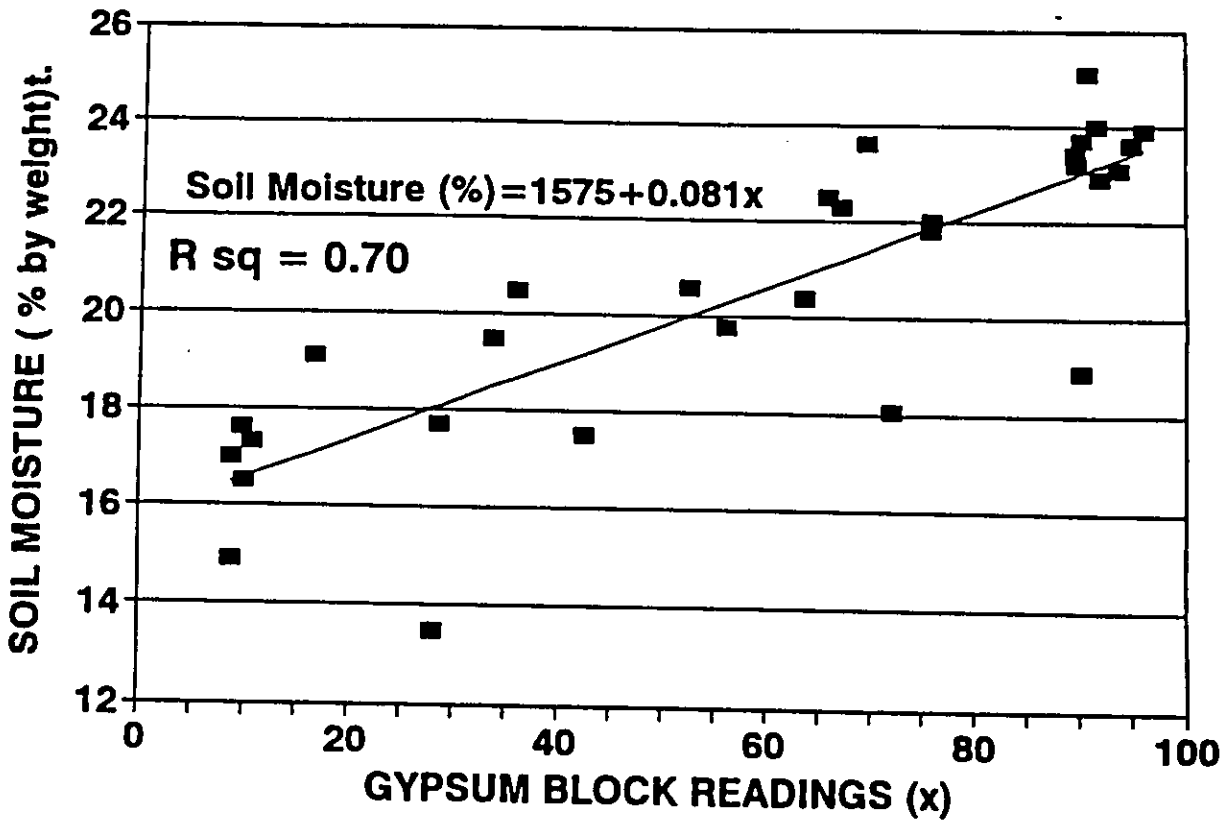
Appendix Fig. 1b. Rainfall(mm) from 1st planting to September 30 at Ridgway 1994.



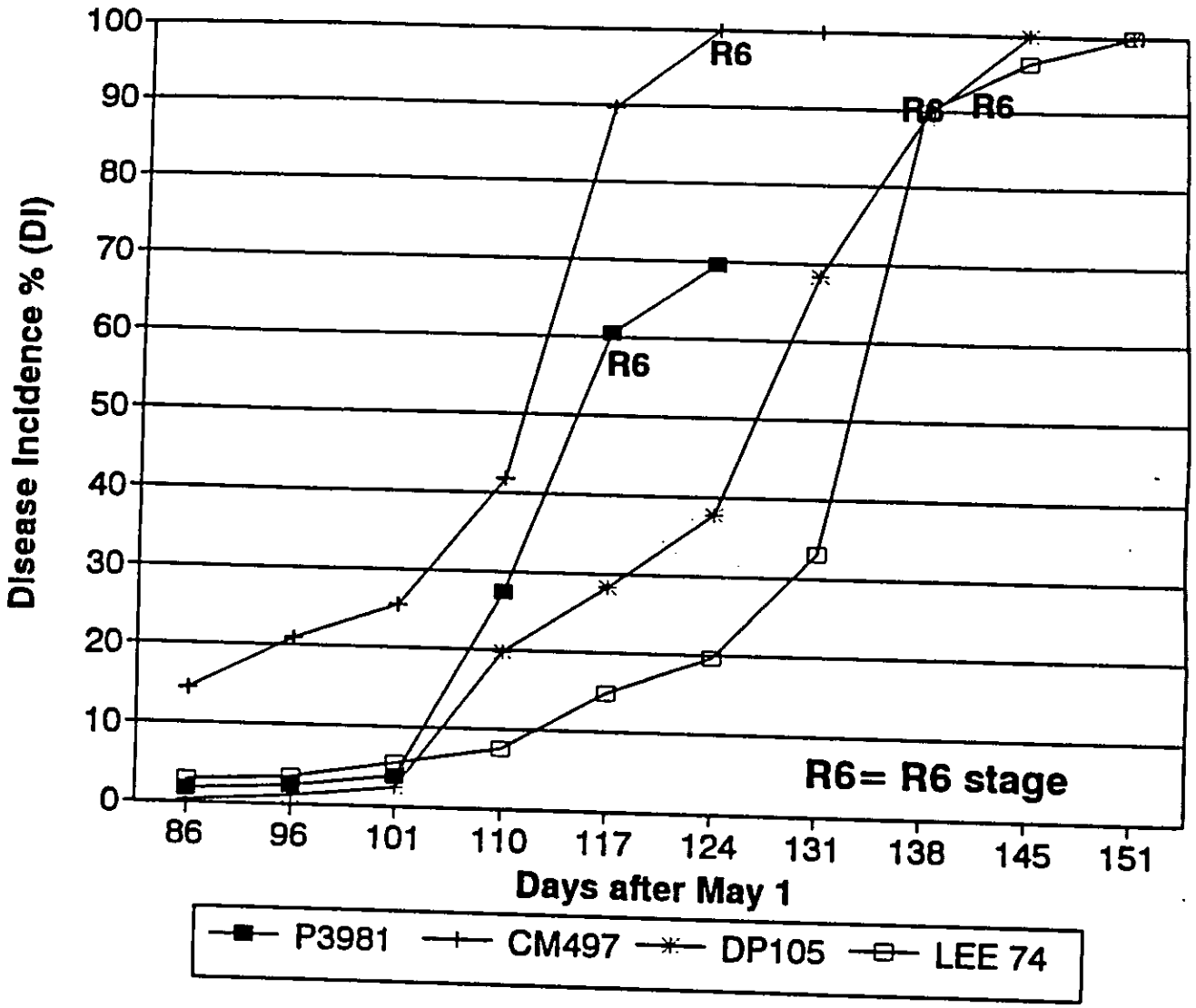
Appendix Fig 2a. Regression of weekly gravimetric soil moisture and gypsum block readings, during 1994 growing season at Villa Ridge.



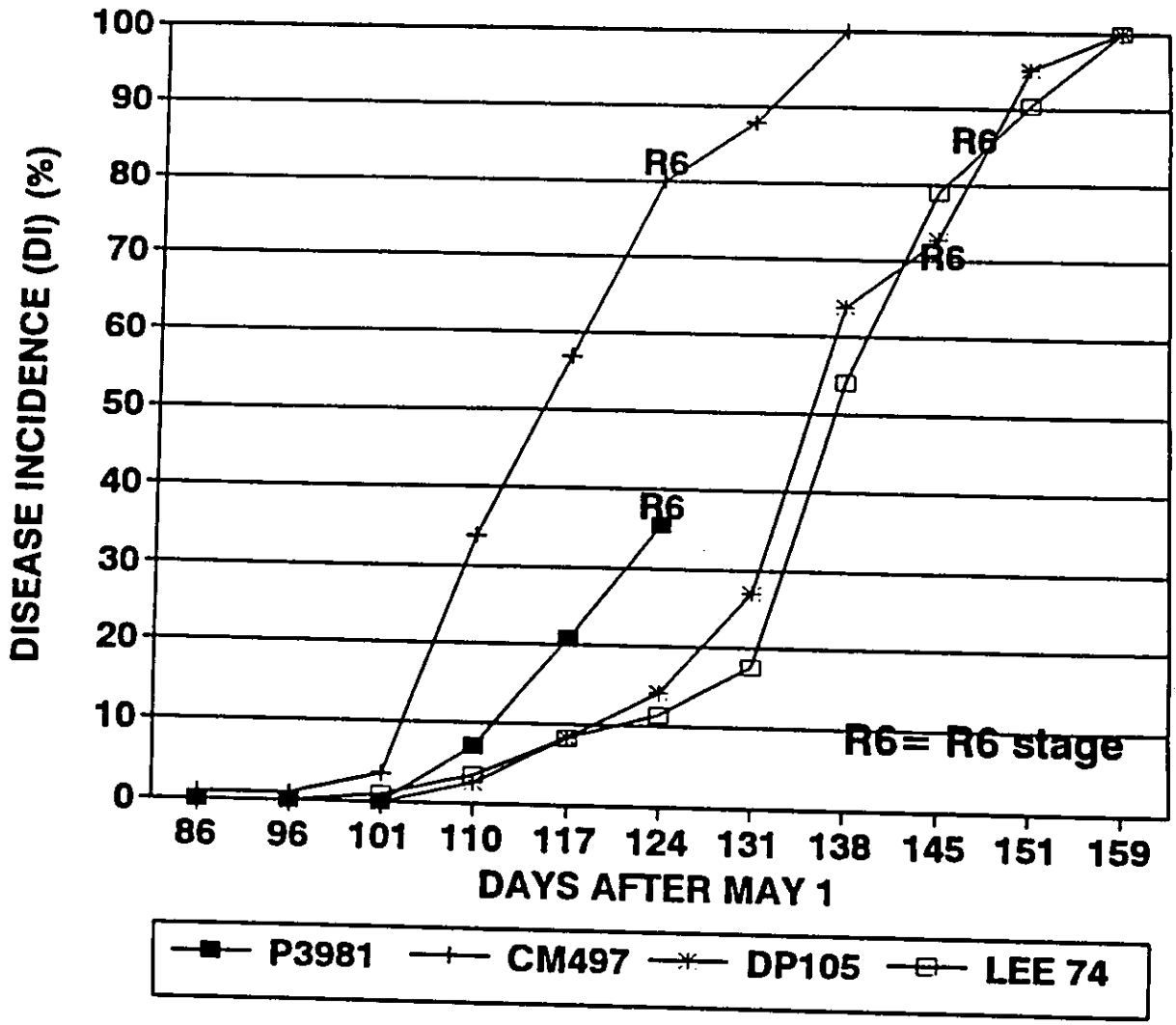
Appendix Fig 2b. Regression of weekly gravimetric soil moisture and gypsum block readings during 1994 growing season at Ridgway.



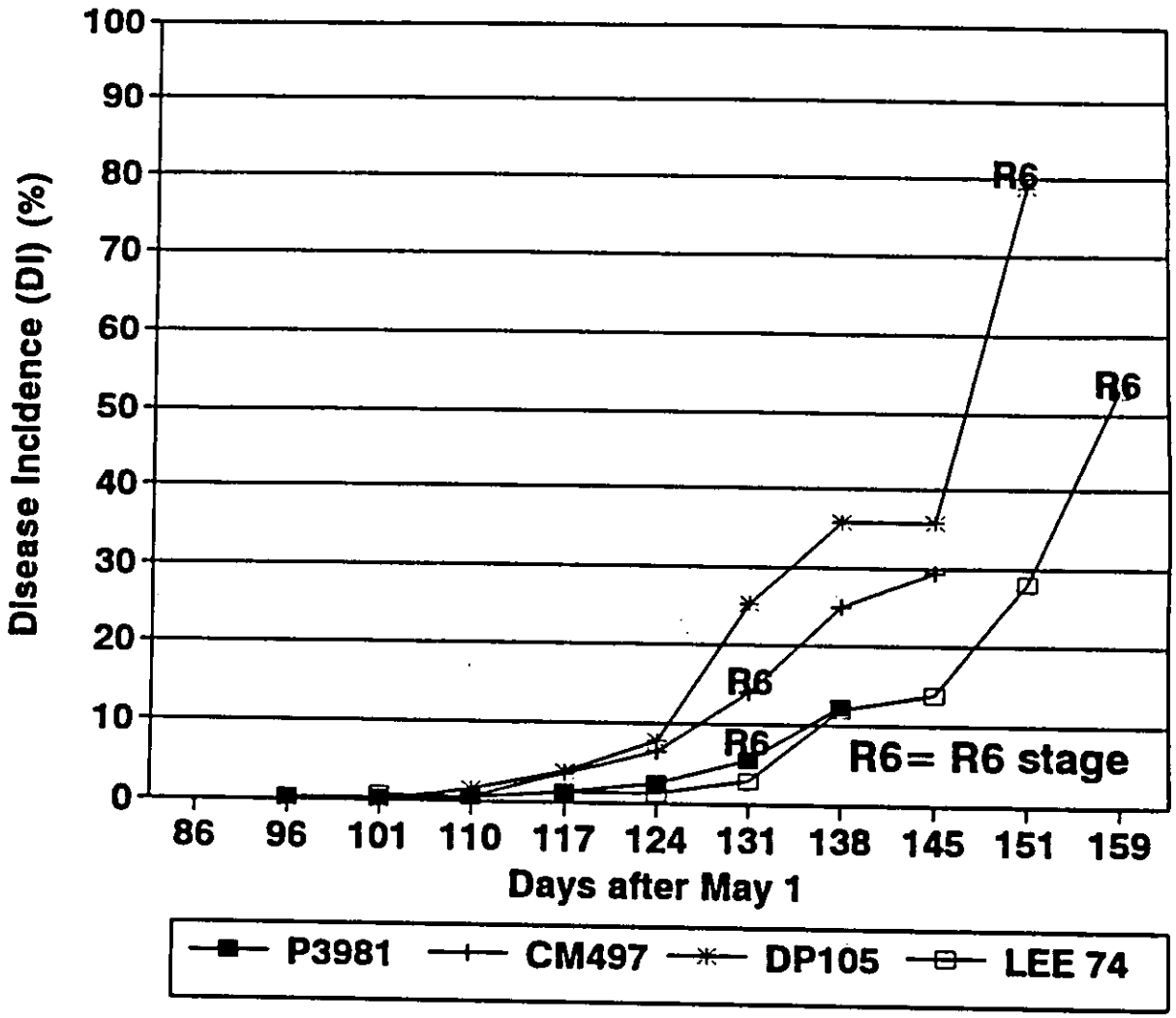
Appendix Fig 3a. PD1 vs Disease Incidence (DI) at Villa Ridge 1994.



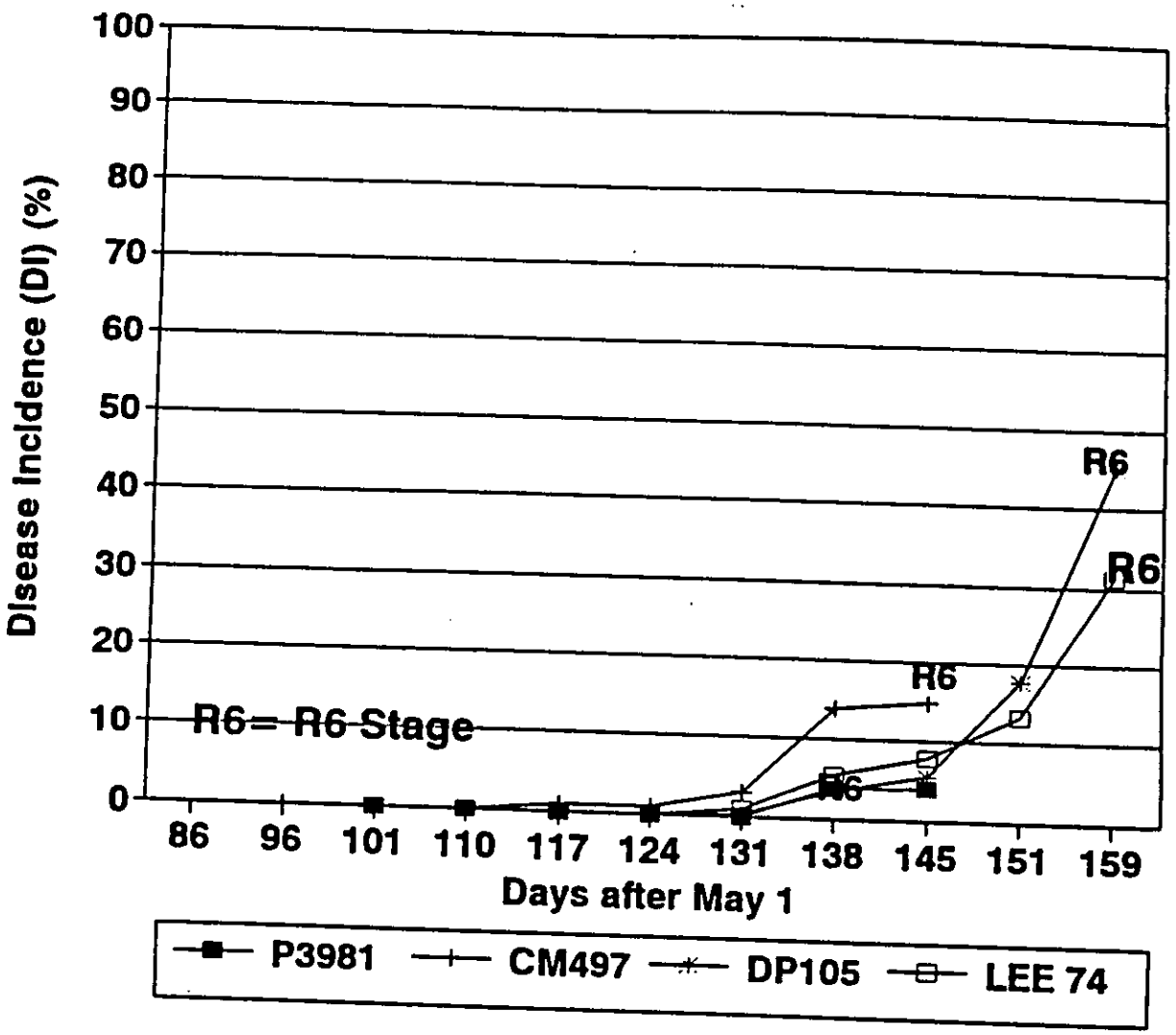
Appendix Fig 3b. PD2 vs Disease Incidence (DI) at Villa Ridge 1994.



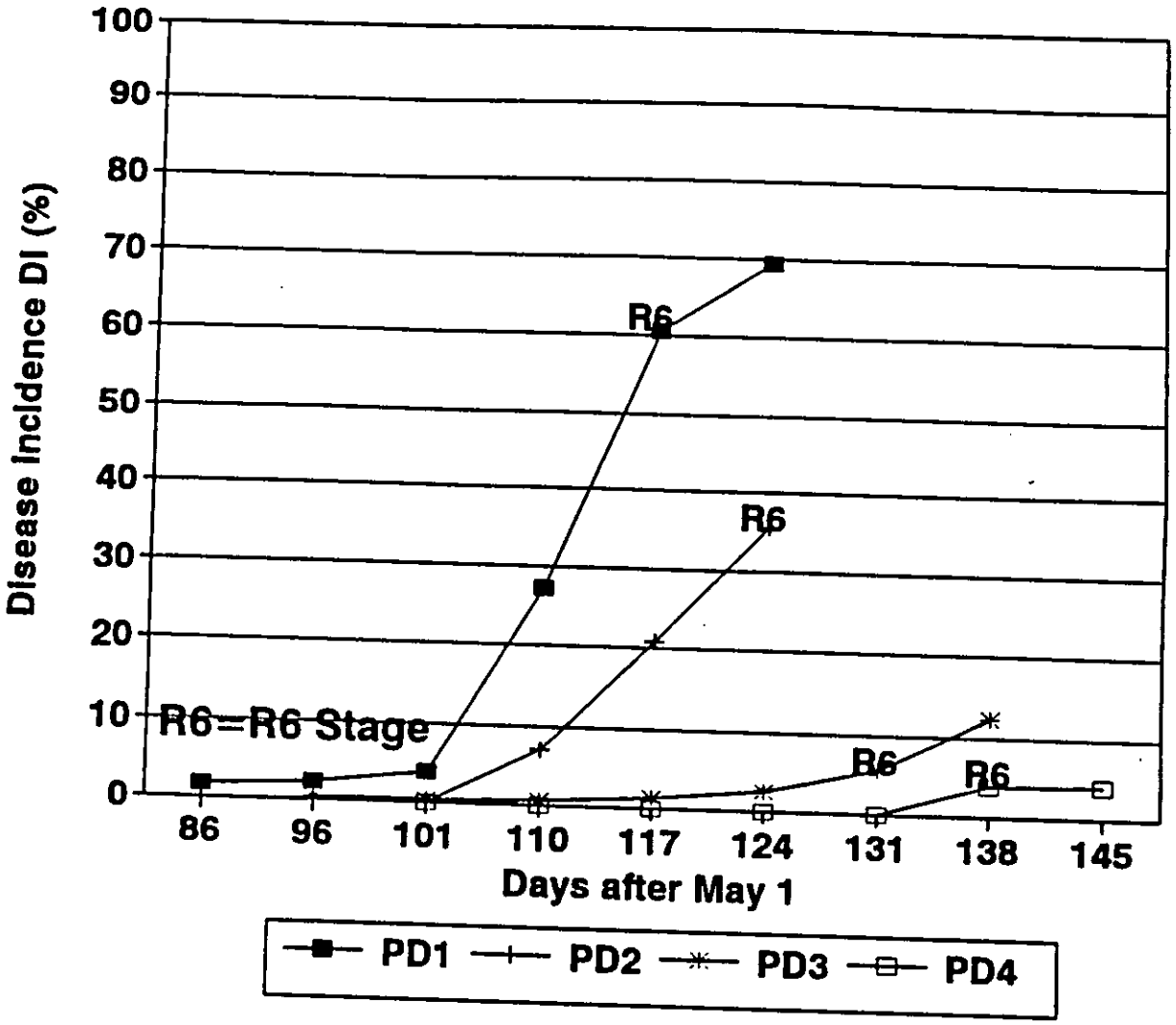
Appendix Fig 3c. PD3 vs Disease Incidence (DI) at Villa Ridge 1994.



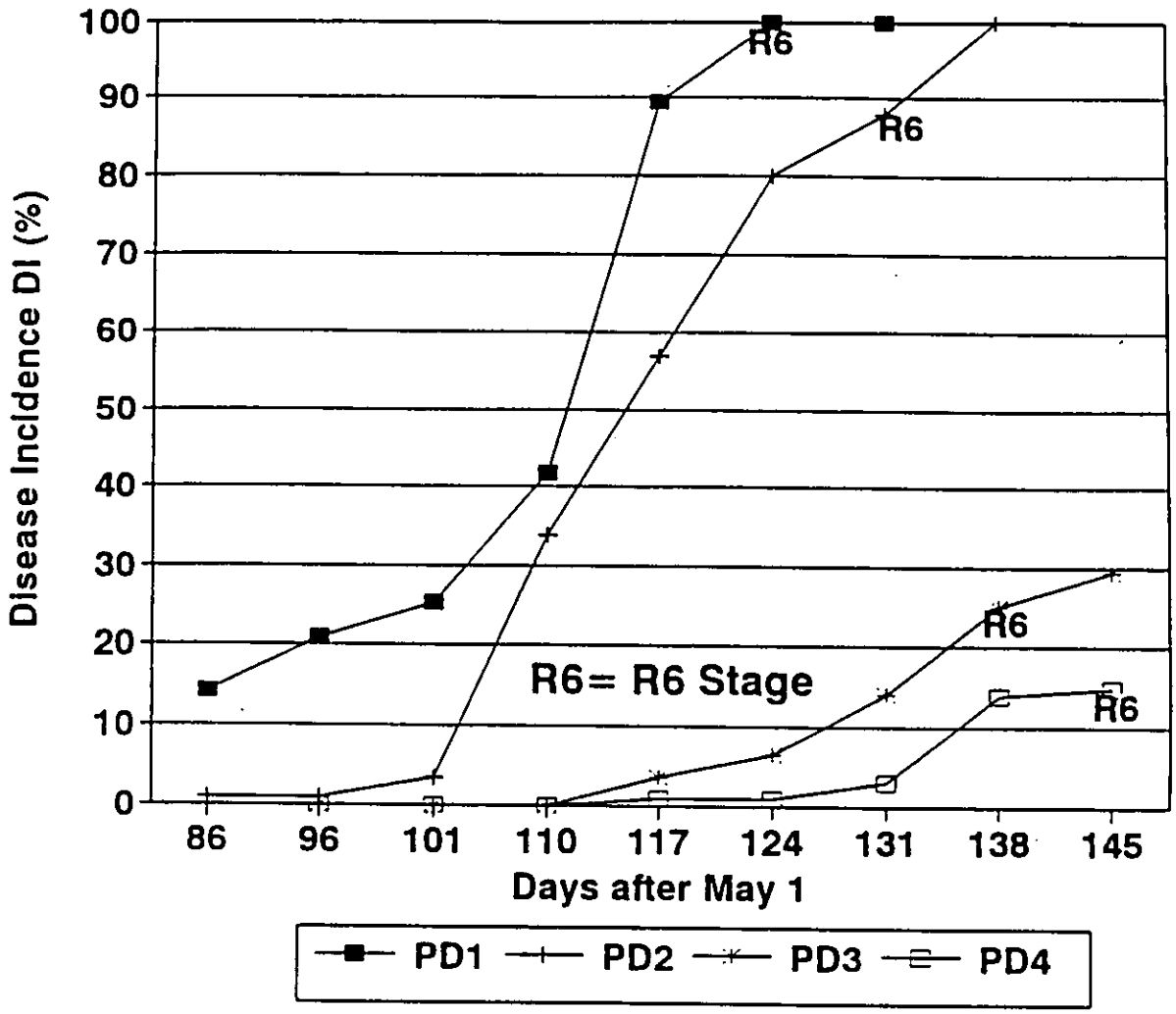
Appendix Fig 3d. PD4 vs Disease Incidence (DI) at Villa Ridge 1994.



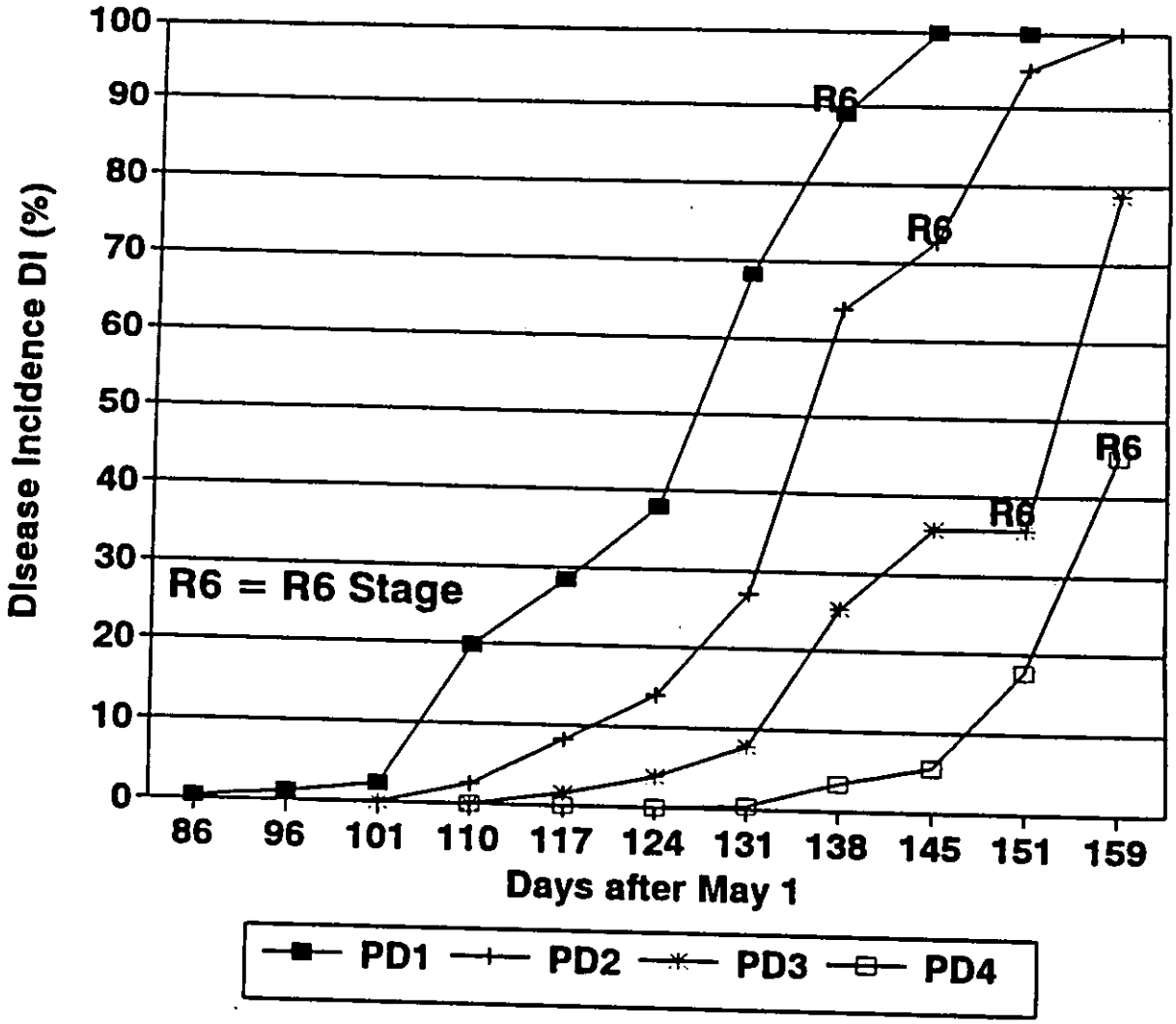
Appendix Fig 4a. P3981 vs Disease Incidence (DI) at Villa Ridge.



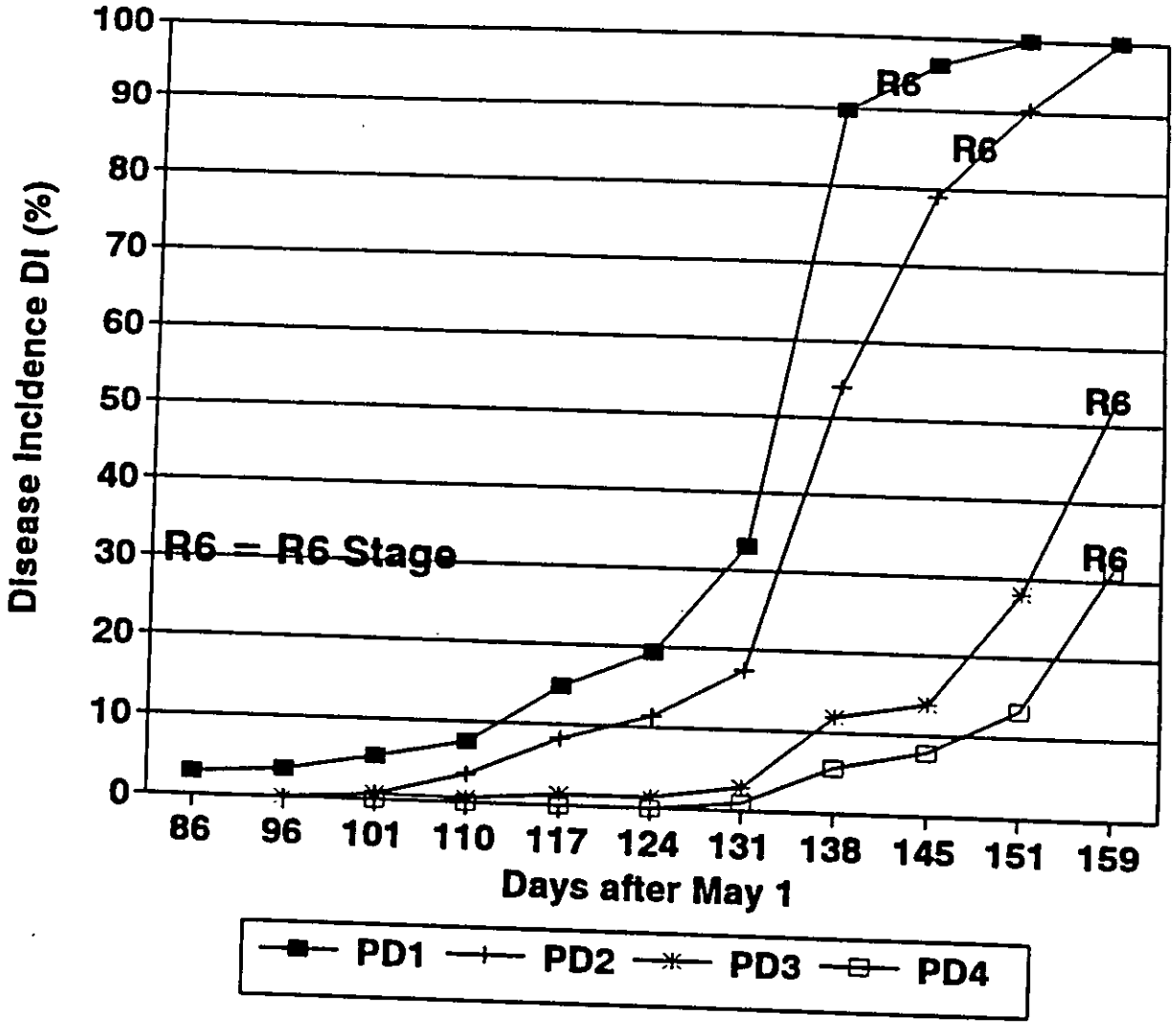
Appendix Fig 4b. CM497 vs Disease Incidence (DI) at Villa Ridge 1994.



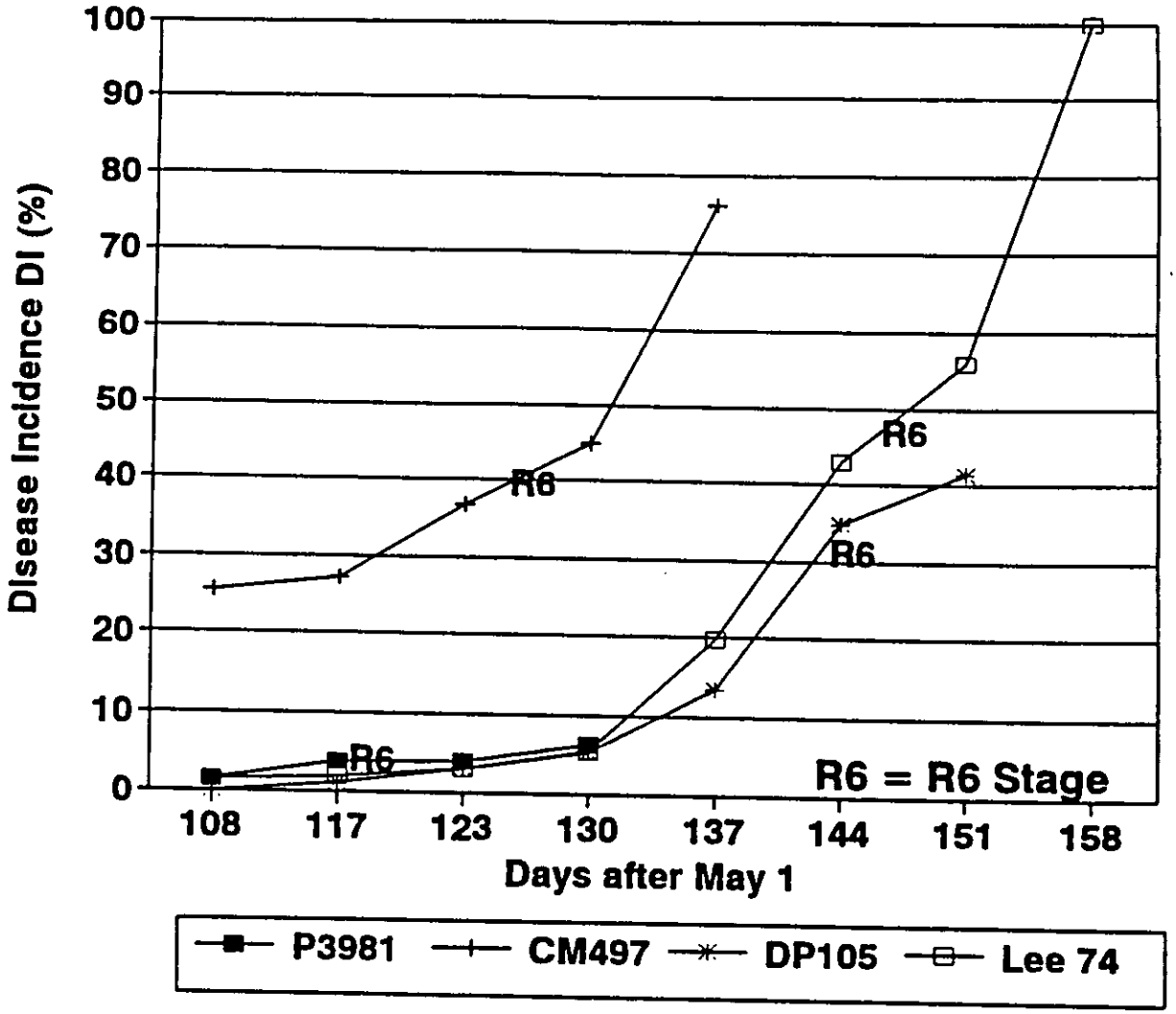
Appendix Fig 4c. DP105 vs Disease Incidence (DI) at Villa Ridge 1994.



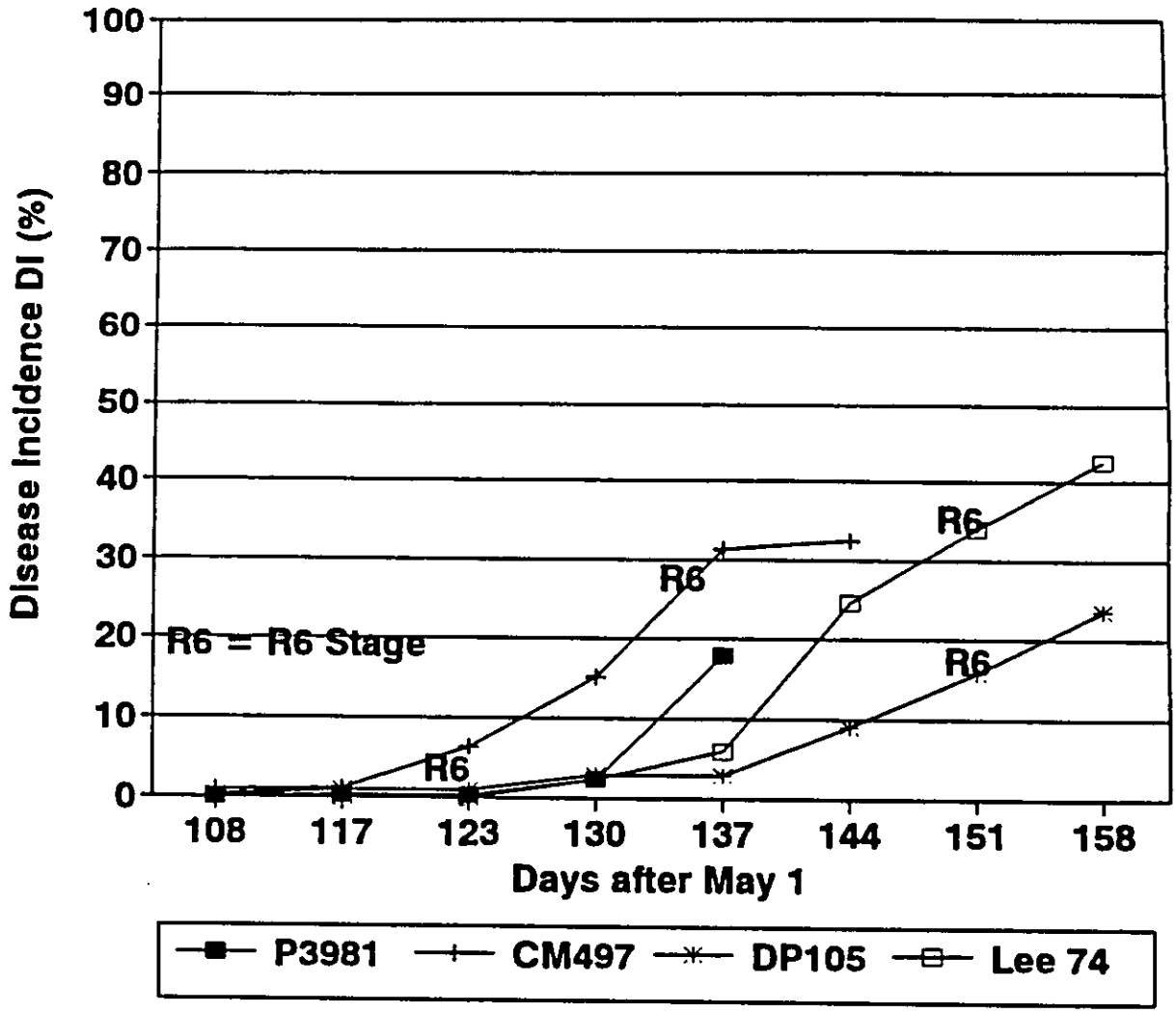
Appendix 4d. Lee 74 vs Disease Incidence (DI) at Villa Ridge 1994.



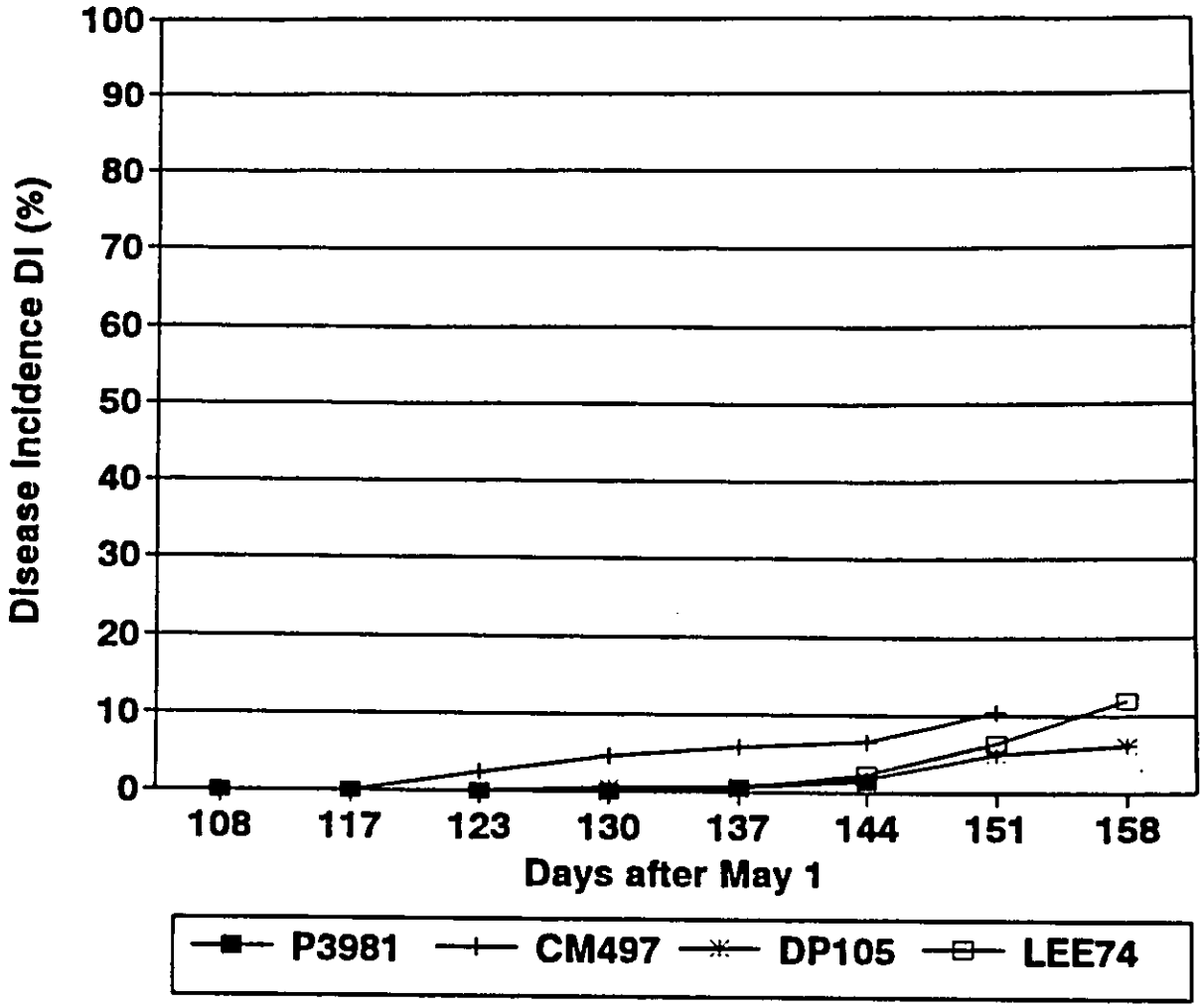
Appendix 5a. PD1 vs Disease Incidence (DI) at Ridgway 1994.



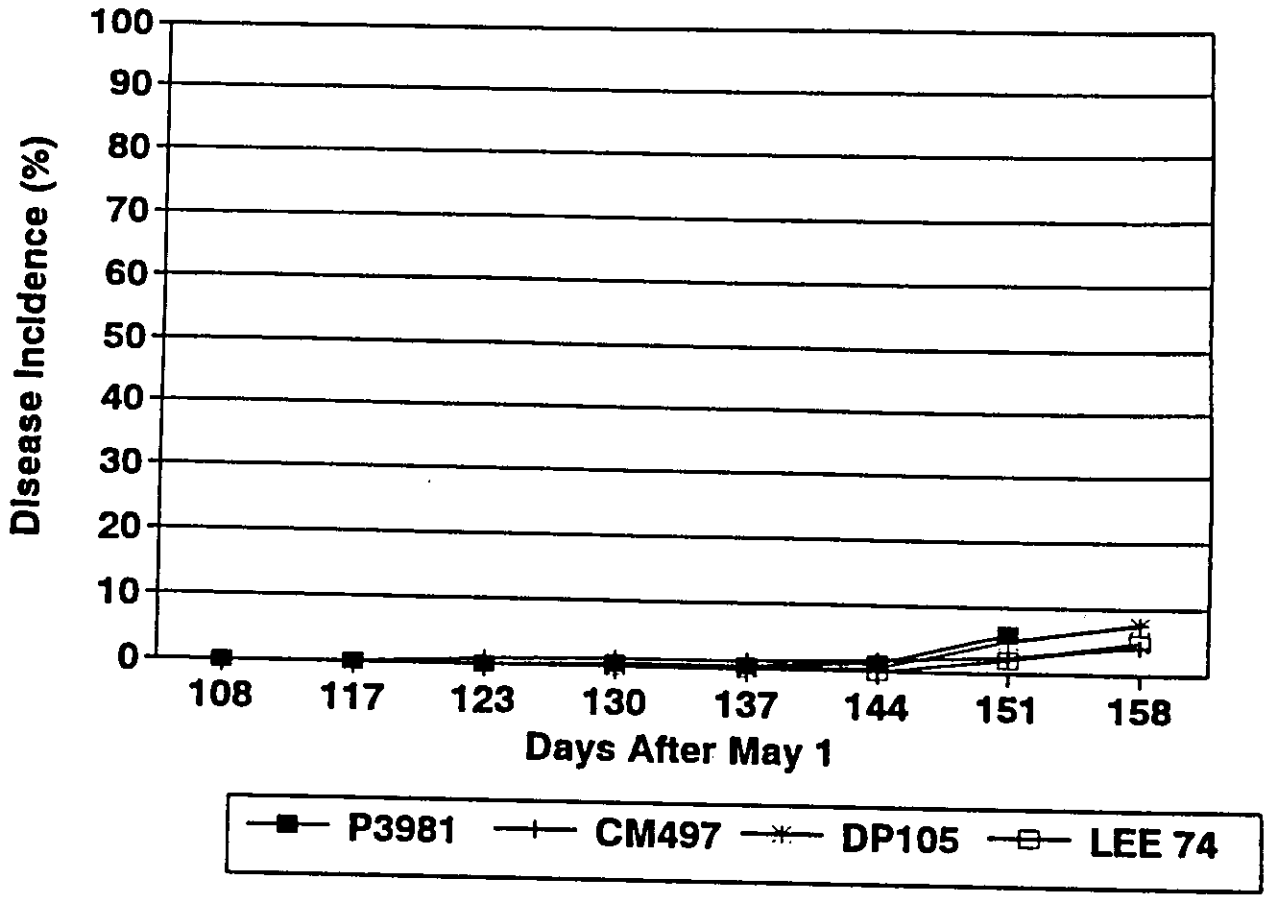
Appendix Fig 5b. PD2 vs Disease Incidence (DI) at Ridgway 1994.



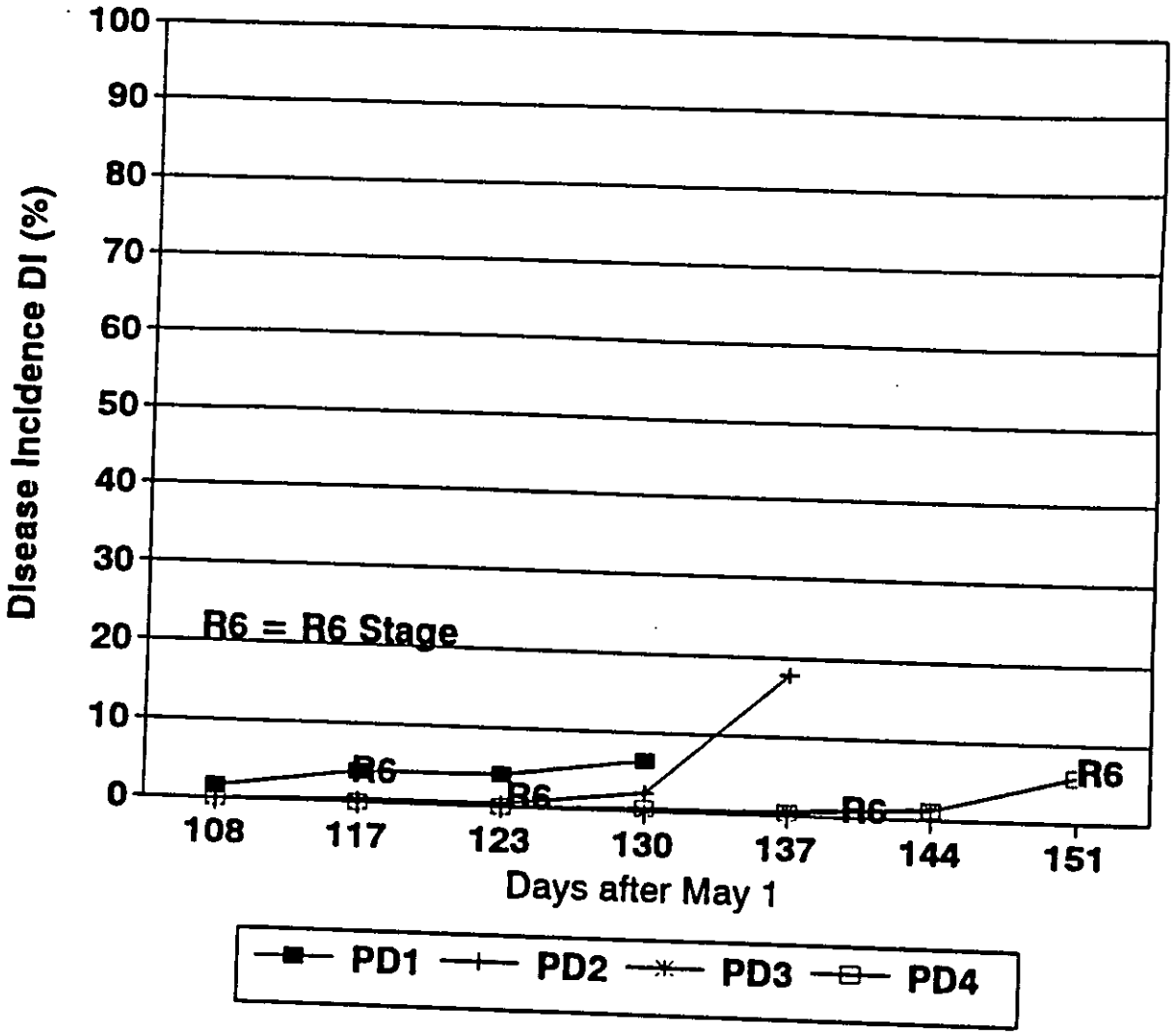
Appendix Fig 5c. PD3 vs Disease Incidence (DI) at Ridgway 1994.



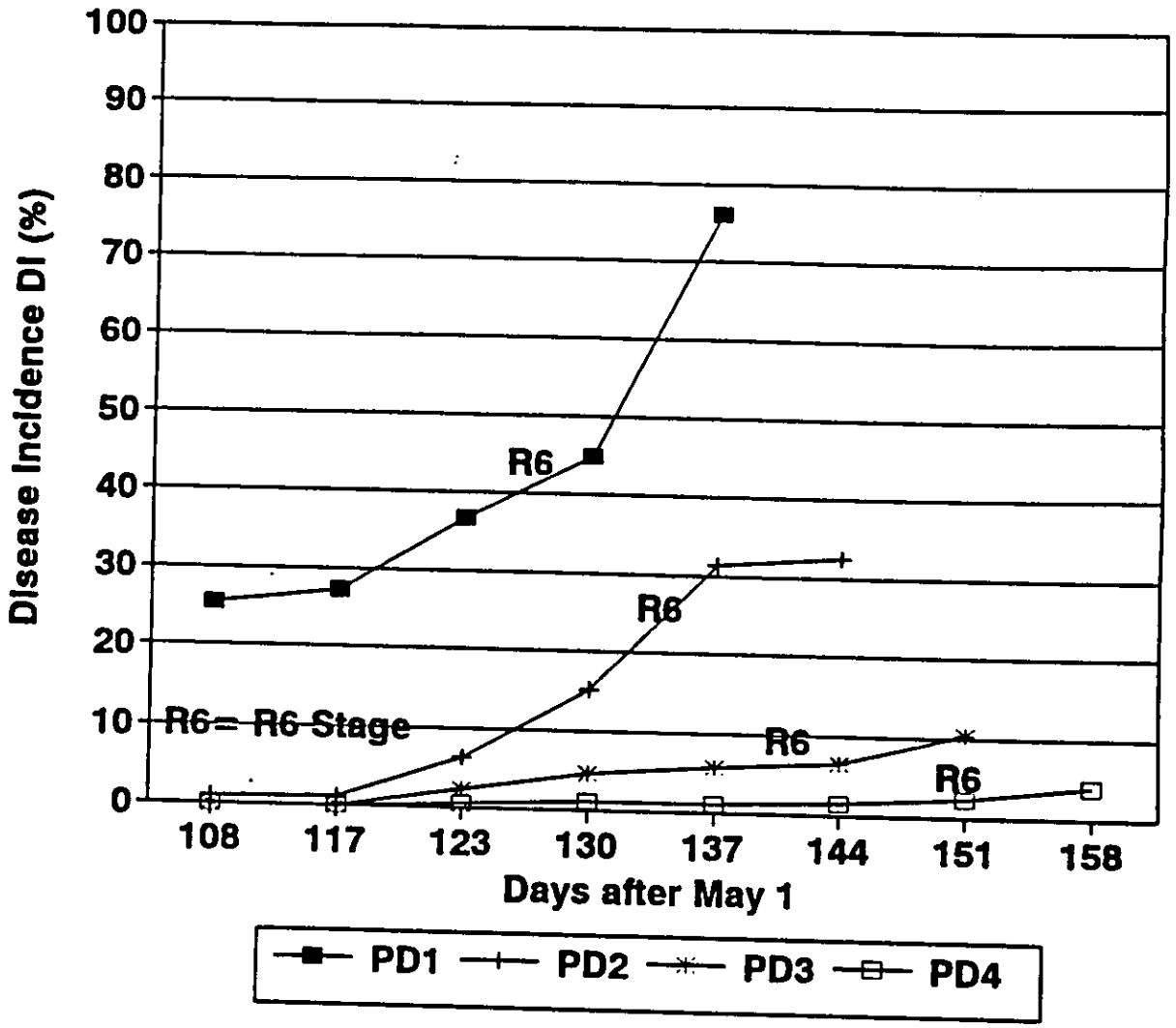
Appendix Fig 5d. PD4 vs Disease Incidence (DI) at Ridgway 1994.



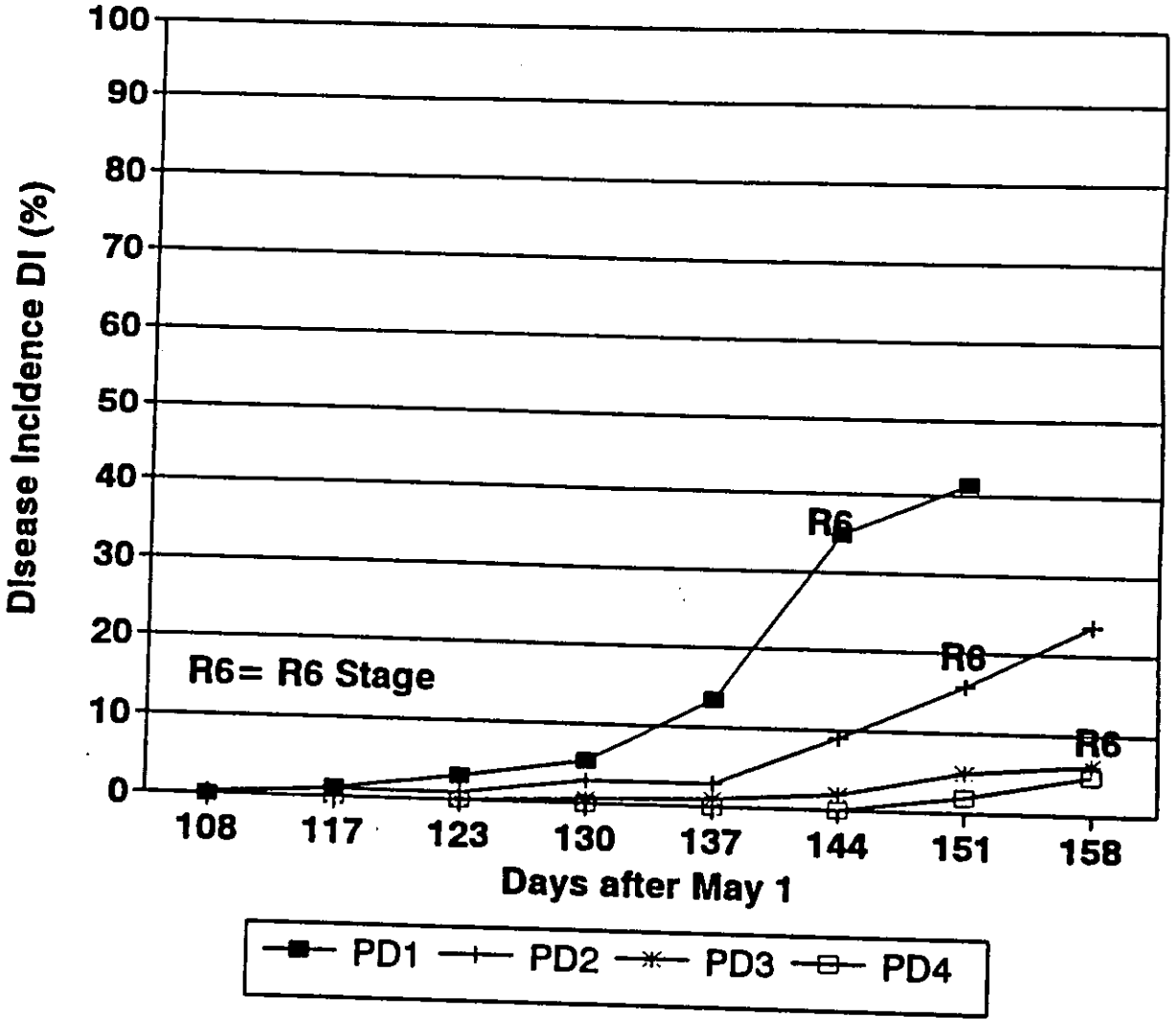
Appendix Fig 6a. P3981 vs Disease Incidence (DI) at Ridgway 1994.



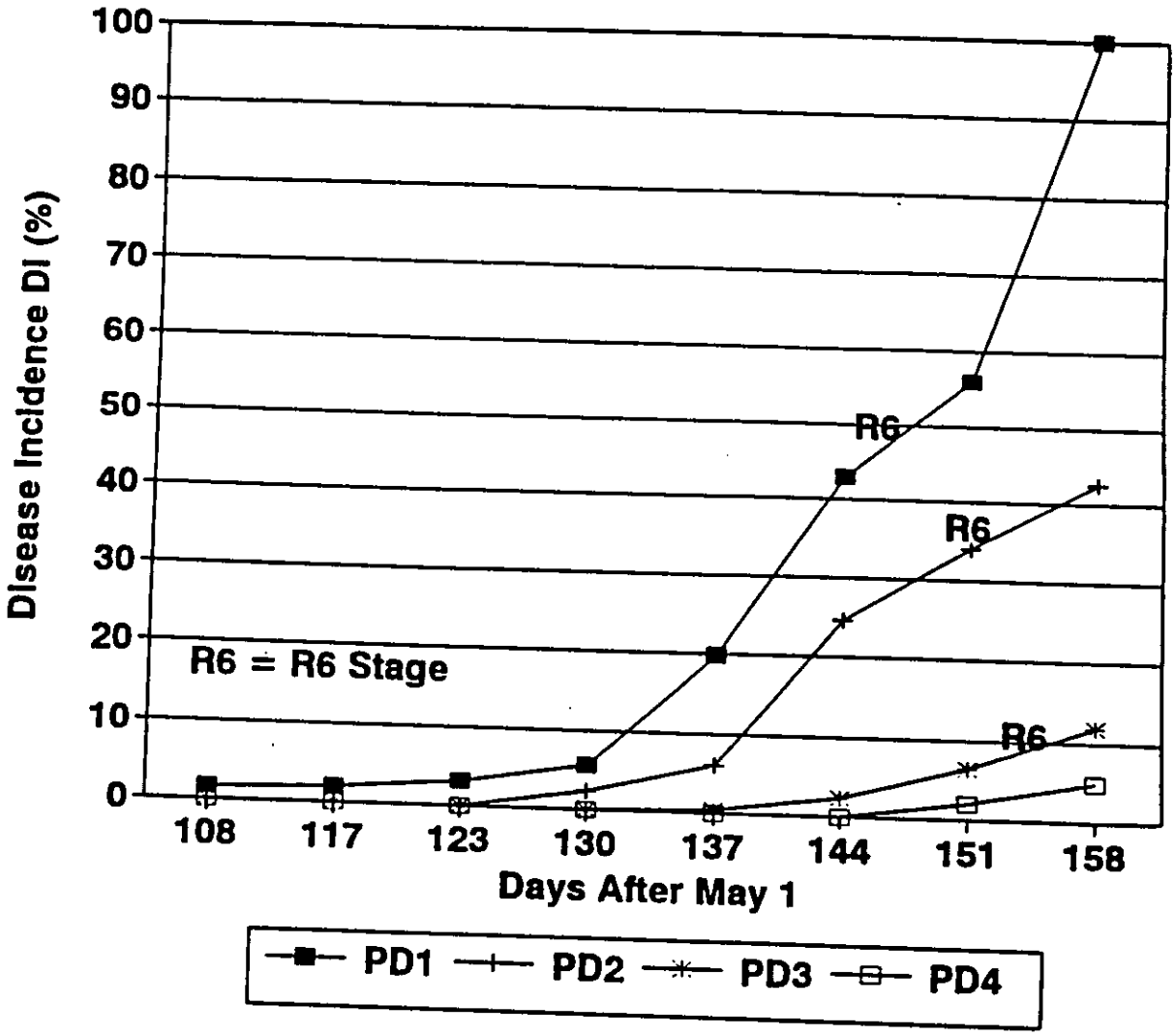
Appendix Fig 6b. CM497 vs Disease Incidence (DI) at Ridgway 1994.



Appendix Fig 6c. DP105 vs Disease Incidence (DI) at Ridgway 1994.



Appendix 6d. Lee 74 vs Disease Incidence (DI) at Ridgway 1994.



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Thesis Title:

Effect of Planting Date and Climatic Factors on Soybean Sudden Death Syndrome Response in Cultivars of Different Maturities

Publications:

Abstracts:

Massinga, R.A., P.T. Gibson, R.J. Suttner, M.A. Shenaut, and V.N. Njiti. 1995. Soybean SDS response to planting date, 1987-1994. Agronomy Abst. p. 92.

Massinga, R.A., P.T. Gibson, R.J. Suttner, M.A. Shenaut, and V.N. Njiti. 1993. Effect of planting date on soybean SDS. Agronomy Abst. p. 145.

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