A Comparison of Determinate and Indeterminate Soybean Lines for Double Cropping in Virginia

by

Marjorie Elizabeth Pyle

Dissertation submitted to the Graduate Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Agronomy

APPROVED:

G. R. Buss, Chairman

T. M. Starling

P. H. Reid

E. W. Carson, Jr.

A. Esen

May, 1982
Blacksburg, Virginia

ACKNOWLEDGEMENTS

The author extends her sincere appreciation to G. R. Buss for his guidance throughout this study. His advice has been invaluable. Gratitude is also extended to T. M. Starling, P. H. Reid, E. W. Carson, Jr., and A. Esen for serving on the advisory committee.

Appreciation is also extended to and his staff at the Eastern Virginia Research Station, Warsaw, VA and and staff at the Piedmont Research Station, Orange, VA for maintaining the research plots. Gratitude for statistical advice is also extended to . In addition the author wishes to thank for typing part of the manuscript.

Finally, the author wishes to thank all of the people who provided friendship and encouragement throughout her graduate studies including , , et al., and her parents, and .

CONTENTS

INTRODUCTION

Soybeans (*Glycine max* L. Merrill) may be classified into two morphologically different plant types: determinate and indeterminate. Determinate plants essentially halt vegetative growth once reproductive growth (flowering) begins while indeterminate plants continue to grow after flowering has begun. In the United States, indeterminate cultivars are grown primarily in the northern latitudes while determinates predominate in the South. Determinate soybean cultivars predominate in Virginia.

Double cropping soybeans after a small grain such as barley (*Hordeum vulgare* L.) or wheat (*Triticum aestivum* L.) has become an increasingly popular cropping system in Virginia. Farmers are growing the same cultivars in the double cropping system as were selected for culture under full-season cropping systems. Double cropped soybeans flower during the latter half of August, a time when the weather is often dry, which dramatically reduces the yields of these soybeans as compared to their full-season counterparts which flower the first week in August. Determinate cultivars flower for only a short period of time while indeterminates may flower two to three weeks longer, corresponding to their longer vegetative period. By incorporating the indeterminate (Dt_1) gene into adapted germplasm, soybeans may be better able to recover after a dry period and produce good yields when double cropped. Also, in a year with adequate summer rainfall, indeterminates would grow taller than comparable determinates and thus increase the likelihood of better yields.

The objectives of this study were 1) to compare the potential of determinate and indeterminate lines for double cropping and 2) to compare the performance of the best lines of both types to standard cultivars.

LITERATURE REVIEW

Planting Date

Virginia farmers have been double cropping soybeans using cultivars that were selected under full-season conditions. Smith et al. (1961) evaluated six cultivars at four locations and five planting dates from early May through early July to examine soybean performance under different environments. Maximum yields were generally obtained from either the 29 May or 5 June plantings, though some cultivars yielded best at the 5 May planting, depending on the location. The 20 June and 5 July plantings were generally lower yielding. All plantings were on plowed soil with adequate moisture. The period for planting double cropped soybeans in Virginia is about 20 June to 5 July. Moisture is often the limiting factor when double cropping. Unless there is rapid vegetative growth prior to flowering, yield will be low because fewer flower nodes will be produced. Because of these adverse environmental conditions, Camper et al. (1972) suggested that cultivars specifically adapted to double cropping be developed.

Carter and Boerma (1979) further substantiated the need for development of soybean cultivars for double cropping. They noted that late planted soybeans are usually planted in narrow rows. The data showed significant genotype x planting date, genotype x row spacing, and genotype x planting date x row spacing interactions for yield. Different rankings of the tested cultivars were observed when grown under both full-season and late planted conditions at wide and narrow row spacings, respectively. Different factors within a genotype may be expressed under different environmental conditions as are encountered at different planting dates. Therefore, selection under double cropping conditions should favor those factors expressed under such conditions.

Increased soil temperature in late June as compared to May is one possible environmental factor contributing to poor seed germination in June (Fehr et al., 1973). Iowa data showed that the mean soil temperatures at a 10 cm depth for 15 days after planting on 1 May 1970 ranged from 12 to 20 C while in the 26 May planting they ranged from 18 to 25 C and after 18 June they ranged from 20 to 30 C. Similar ranges were observed for the periods after 1 May, 9 June, and 25 June 1971, respectively. The soil temperatures fluctuated up to 5 C during any one day at 10 cm while a 10

C change was observed for seed planted at 5 cm. Even with the fluctuations, the mean temperature at both depths was similar. In 1970, 77% of the seed planted emerged on 1 May at 5 and 10 cm. Emergence was 95% for both 26 May and 18 June at 5 cm and 52% and 26%, respectively, at 10 cm. In 1971, 62% and 30% germinated at 5 and 10 cm, respectively, for the 1 May planting while 64% and 43%, respectively, germinated for 9 June and 47% and 35%, respectively, for 25 June. When averaged over dates and years, 73% of the seed germinated at 5 cm and 43% at 10 cm. Although the percent emergence at the later plantings varied between the years, temperature apparently influenced emergence.

A study in Arkansas found that the optimum planting date was in May (Caviness and Smith, 1959). Arkansas is at a slightly lower latitude than Virginia with soybeans from groups V and VI being grown there. Yields were generally reduced for plantings made in late June, although the data suggested that planting up to 20 June produced adequate yields. Adapted mid-season cultivars gave higher yields than early cultivars.

Rogers et al. (1971) in Alabama noted that high soybean yields were observed for double cropped plots when rainfall was adequate. However, full-season plantings generally produced the best yields because of good soil moisture and better weed control. Low rainfall inhibited germination and vegetative growth.

Williams and Marshall (1976) also found that for the 20 June plantings, the yields were reduced as compared to 20 May in Louisiana. Height was reduced but lodging increased with late planting. Yield decreased by 33.6 kg/ha each day planting was delayed after 30 May up until July 25.

In Texas, yields of soybeans decreased when planted after 1 June, though late plantings were higher yielding than the very early planting of 14 April on the gulf coast (Sij and Dornhoff, 1973). This supported the findings of Harvey and Brigham (1971) for the southern high plains of Texas where yields were reduced after 1 June. Plant height and height of the lowest pod were also reduced so that many of pods were missed by the combine.

Data from Tennessee also supported the Texas findings for yield reductions after 1 June (Peters et al., 1971; Graves et al., 1976; Graves et al., 1978). In addition, maturity was delayed less than one day for each day that planting was delayed after 1 June (Peters et al., 1971). The length of the flowering period was reduced with delayed planting (Graves et al., 1972).

Double cropped soybeans following small grains are often planted as a no-till crop. One disadvantage of the no-till system is that the soil tends to crust if there is a heavy rainfall as compared to plowed soil, thus reducing plant stands and yields (Sanford et al., 1973). Weeds may also be a problem in that they compete for space as well as moisture. Therefore, herbicide applications are generally recommended for no-till double cropping systems (McKibben and Oldham, 1973).

A study in Oklahoma (Crabtree and Rupp, 1980) examined yields of soybeans planted as a late planted conventionally-tilled monocrop (CTMC), conventionally-tilled double crop (CTDC), and no-till double crop (NTDC) after wheat. In 1976, there was no significant difference in yield among the three systems when soybeans were planted in 50 cm rows although the CTDC yield was highest. In 75 cm rows, the CTDC yield was significantly higher than the others. In 1977, CTMC yields were significantly greater than the other treatments at both row spacings. When considering the yields of both soybeans and wheat, NTDC and CTDC were more efficient in production of grain with the available moisture than CTMC systems; however, in a dry year, the opposite might be true.

All of these studies indicated that there is a need for selecting a cultivar specifically adapted to double cropping. In addition to obtaining a cultivar that is tolerant of environmental stress, proper management is a key to successful double cropped soybeans. Reduced row widths increase pod height, thereby reducing harvesting losses. Proper depth of planting is also critical since soil temperature and moisture affect germination.

Plant Type

Soybean cultivars currently grown in the southern part of the country are predominantly determinate cultivars. Bernard (1972) has defined determinate growth as stem growth terminating abruptly at the onset of flowering. Other characteristics include a short, thick stem with few internodes and a long inflorescence at the terminal node. Many cultivars classified as maturity group V and later fall into this category. In contrast to this are the northern cultivars (group IV and earlier) which are primarily indeterminate. Bernard characterized indeterminate growth as a continuation of stem growth and node and leaf production for several weeks after flowering has begun. This type can be distinguished from determinate types by the slender top internode and the progressively smaller stem and leaves toward the top. The terminal node generally has no more than three pods.

Stem termination is controlled by a gene pair designated Dt_1-dt_1. Determinate plants have the homozygous recessive genotype (Bernard, 1972). The heterozygous genotype is semi-determinate while the homozygous dominant is indeterminate. Plant height was reduced by 61% with dt_1 in a 'Harosoy' background and 45% in 'Clark'. Both cultivars are indeterminate.

Indeterminate plants have a tendency to lodge in high-yielding environments. Cooper (1981) developed several determinate cultivars adapted to Illinois environments that were lodging resistant and higher yielding than the checks. These new cultivars, 'Elf', 'Pixie', 'Sprite', and 'Gnome', did well in high yielding environments but if there was an early season drought, then the indeterminate cultivars did better.

Indeterminate plants are being evaluated for use in double cropping systems because it is believed that the plants will recover better from a period of water stress during flowering than will determinate plants (Coffman, 1978). Indeterminate plants have not completed their vegetative growth by the time reproductive growth has started and therefore will continue to initiate new flower buds. Determinate plants flower over a short period of time (three weeks) and yields can be sharply reduced if this period coincides with a period of water stress.

Egli and Leggett (1973) determined how much dry matter accumulated before, during, and after flowering and where it was distributed in the plant. 'Kent' and 'D66-5566' represented the indeterminate and determinate plant types, respectively. Plant samples were taken two to four times per week from the four-five trifoliolate leaf stage until maturity. Each sample was separated into leaf blades, petioles, stems, and reproductive material, and was dried. The data showed that D66-5566 had reached 80-87% of its maximum height at flowering while Kent was only 40-52% of its maximum height. Stem dry weights followed the same trend as the heights. At initial flowering, 30 and 67% of the final stem weight of Kent and D66-5566, respectively, had been accumulated. Also at this time, Kent had produced 57.8% of its vegetative material while D66-5566 had produced 78.4% during the same time. Most of the total vegetative material had been accumulated by initial pod development, with 87.4% for Kent and 91.6% for D66-5566. If the rate for photosynthate production was equal for both lines, then the competition for photosynthates in Kent between the reproductive and vegetative sinks was greater than in D66-5566. Kent flowered 14 days earlier and had a six to eight day longer flowering period than did D66-5566. There was little difference between the cultivars for yield in either year, though the determinate cultivar was consistently higher.

Beaver and Cooper (1977) found contrasting results concerning rate of vegetative growth. They found similar rates of vegetative dry weight production while Egli and Leggett (1973) observed that determinates grew faster than indeterminates. Beaver and Cooper used two indeterminate cultivars, 'Williams' and 'Corsoy', and a determinate cultivar, Elf, as well as a determinate isoline of Clark, L63-3279. Varietal difference may account for some of the discrepancy between the two studies.

Bernard (1972) noticed that determinate isolines (dt_1) flowered one or two days earlier than Clark or Harosoy and stopped two to three weeks sooner than the indeterminate cultivars. The length of flowering in this study was similar to that observed by Egli and Leggett (1973). Indeterminate plants had more nodes than the determinates. Determinate plants were slightly earlier maturing. This may be due to the absence of late-setting pods and reduced plant height, resulting in faster drying during ripening.

A recent study in Iowa suggested that semi-determinate (Dt_2) lines may be better than indeterminate lines for production in that area (Green et al., 1977). Lodging was significantly higher ($p=0.01$) for indeterminate plant types, averaging 2.9 (1=erect, 5=prostrate) as compared to 2.6 for semi-determinates. Yields for indeterminate lines were significantly higher than for semi-determinates when combined for the two crosses ('Amsoy' x Harosoy and 'Hark' x Harosoy). Most of the difference was found in Amsoy x Harosoy. Semi-determinate lines were suggested for use where excessive plant growth results in high lodging because the difference in lodging, and consequently yield, would be greatest in those situations.

Lodging was the major reason for lower yields in a previous comparison of indeterminate vs. determinate cultivars (Hartwig and Edwards, 1970). A line similar to 'Lee', D49-2491, was the recurrent determinate parent in a backcross with PI 174,862. The mean height of a composite of indeterminate F_4 lines selected after the fifth backcross was 142 cm while the determinate parent averaged 86 cm. The determinate line yielded 2660 kg/ha while the indeterminate lines produced only 2128 kg/ha, a 20% reduction. Seed size did not differ between the two types.

Height of the lowest pod differed between the plant types in a study from Illinois (Hicks et al., 1969). Determinate plants (dt_1) averaged 8.2 cm while indeterminates averaged 19.2 cm. Semi-determinate plants (Dt_2) had a similar value to the indeterminates, 19.0 cm. Approximately 25-30% of the indeterminate and semi-determinate stands were lodged while there was essentially no lodging in the determinate stands. Yield data, averaged over two years, were not significantly different for plant types.

Lodging and pod distribution, as affected by stem termination, maturity, and furrow irrigation, were investigated using Clark and Harosoy isolines and Williams, 'Will', and Elf (Hartung et al., 1981). Delaying maturity in indeterminates resulted in fewer pods lower than 15 cm on the stem but increased lodging which increased harvesting loss because more stems were closer to the ground. The determinates didn't lodge but there were more pods on the lower 15 cm. The data indicated that because determinate cultivars didn't lodge, they would be better suited to furrow irrigation systems if the seeding rate were higher so that there would be fewer seed at the lower nodes. Similar results were found under a sprinkler irrigation system (Hartung et al., 1980).

Wilcox (1980) examined semi-determinate and indeterminate isolines of Harosoy at two row spacings (1.0 and 0.5 m) to see if plant type had a major effect on yield or any other agronomic characteristics in the Mid-west. Row spacing x plant type interactions were not significant. Of the two examined, the indeterminate lines were significantly higher yielding (p=0.05), later maturing (by one day), and taller by an average of 12 cm. Higher yields were observed in narrow rows, regardless of plant type. Overall, Wilcox concluded that the differences between plant types were not great enough to give either type an advantage and either plant type could be used successfully in a soybean improvement program.

Damage due to hail, insects, and other environmental factors during reproductive development often results in yield loss. Fehr et al. (1971, 1977) examined the recoverability of determinate and indeterminate cultivars to 100% defoliation and half-plant cut-off at stages R2 through R7. Within a plant type, cultivars did not differ significantly in percentage yield loss due to injury but differed significantly across plant type. Determinate plants were able to produce new leaf tissue after flowering had begun but the total area produced was less than for indeterminate plants. Determinates then flowered and produced seed uniformly after recovery. Fehr noted that "By having different phases of flower, pod, and seed development on the bottom and top of the plant, a smaller percentage of the indeterminate plant would be severely influenced by stress at a given stage of development." Yield reductions due to 100% defoliation were much less with indeterminate than determinate cultivars (38% vs. 59%) while percent reduction due to half-plant cut-off was similar.

Fehr et al. (1981) also looked at yield response to 100% defoliation when determinate and indeterminate lines were defoliated at stages R4 through R6 as described by Fehr and Caviness (1977) and Fehr et al. (1971). The indeterminate type was reduced by 59% while the determinate was reduced by 80% across all stages. The greatest loss occurred at the R5 stage for both types.

Disease is another factor reducing soybean yields. Lantican (1977) noted that determinate types susceptible to rust (<u>Phakopsora pachyrhizi</u> Sydow) were more severely affected than indeterminate types. He suggested that this was because the terminal leaves of the indeterminates were younger and less susceptible to rust than were the predominantly older leaves of the determinates.

Tseng and Lee (1976) studied plant type vs. yield potential. The data indicated that determinate cultivars had reached 74-96% mature plant height at flowering while indeterminates were only 46-65% as tall as mature plants. The percent of total vegetative material present at early pod development was 69-78% and 43-60% for determinate and indeterminate type, respectively. These percentages were slightly lower than those found by Egli and Leggett (1973).

Growth was described as vigorous early in the season for the determinates and evenly distributed throughout the growing season for the indeterminates.

Poor seed quality, due to non-uniformity of seed maturation, was evident on indeterminate cultivars (Tseng and Hosokawa, 1972). Flowering and seed set of indeterminate plants were over a longer period of time, as compared to determinates. This may lower seed quality but if adverse environmental conditions are encountered, this prolonged flowering may minimize yield loss.

Part of an Iowa study (Sumarno and Fehr, 1980) examined the yields of one determinate (Elf) and two indeterminate (Williams and 'Cumberland') cultivars when grown by themselves, in alternate rows, or as blends. Yields in pure stands averaged 2844 kg/ha while in blends and alternate rows the means were 2820 and 2927 kg/ha, respectively. Elf decreased in yield by 35% and 20% with Williams and Cumberland, respectively, when in either blends or alternate rows while Williams and Cumberland increased by 37% and 27%, respectively, when planted with Elf. In this study the determinates did not compete well with indeterminates.

Determinate and indeterminate isolines differ in their response to row spacing. Shannon et al. (1971) compared indeterminate, semi-determinate, and determinate isolines of Clark and Harosoy in hill plots spaced from 30 to 122 cm apart. The determinates were earlier maturing at close spacings while the indeterminates were earliest at intermediate spacings. Yields increased as spacing increased for all genotypes although the determinates tended to plateau at spacings of 89 cm for Harosoy dt_1 and 104 cm for Clark dt_1. Within each cultivar, the indeterminate and semi-determinate isolines had similar yields within hill spacings.

Singh and Whitson (1976) examined the evapotranspiration and water use efficiency of indeterminate and determinate isolines (unreleased) to see if there was a relationship between water use, canopy morphology, and yield. Evapotranspiration was calculated as the total soil water at the beginning of a measurement period plus precipitation minus the total water in the soil at the end of the measurement period. Water use efficiency was determined as kilograms of grain produced per hectare-centimeter of water used. The data showed that 0.244 and 0.205 cm of water was used for vegetative growth of the determinate and indeterminate line, respectively. The water use increased to 0.455 and 0.422 cm, respectively, during the early reproductive stage and then decreased to 0.336 and 0.361 cm, respectively, for the remaining reproductive growth. The greater water use of the indeterminate line during the late reproductive stage corresponds with the continued vegetative growth as compared with the determinate line which had essentially halted vegetative growth. During the entire growing season, the evapotranspiration for the determinate and indeterminate lines was 41.2 and 39.0 cm, respectively. This 5.6% difference in water use was statistically significant. The determinate line had a higher water use efficiency of 66.5 kg/ha-cm as compared to 56.3 kg/ha-cm for the indeterminate line. Therefore, even though the determinate line used more water than the indeterminate line, it was much more efficient in producing seed.

A study conducted to evaluate the leaf photosynthetic characteristics of determinate soybean cultivars in comparison with indeterminate lines showed that apparent photosynthesis (AP) was similar for both plant types when conducted under high light conditions but not when grown under low light (Bhagsari et al., 1977). Under low light, determinate cultivars had higher AP rates. Photorespiration was similar for both plant types. It appears that there is little difference in photosynthetic capacity between plant types under normal field conditions.

The various studies described above have indicated that indeterminate soybeans have a tendency to be taller, flower longer, and have a higher pod height than indeterminate plants. Lodging is also higher in a high yielding environment. Indeterminates have been shown to recover after a period of stress such as hail or drought better than determinates. The non-uniform seed maturity of the indeterminates may result in some loss in quality.

Plant Type Differences Under Double Cropping

Lodging is frequently cited as a major problem with indeterminate plants. Most of the studies have been conducted in Iowa and Illinois under full-season conditions. Under double cropping conditions, less vegetative material would be produced because of the shorter season. Therefore, there may be a reduction in the amount of lodging. Because of the longer flowering and vegetative growth periods, in conjunction with reduced lodging, indeterminate cultivars might be higher yielding under double cropping conditions because of their ability to recover from a period of water stress that often accompanies flowering of late plantings.

A planting date study using both determinate and indeterminate cultivars in the Namoi Valley, New South Wales, Australia, showed that the indeterminate cultivars

('Wayne', 'Delmar', and 'Ruse') were lower yielding if planted early in the growing season (early November) than they were if planted at the normal time (December) or double cropped (January) (Constable, 1977). This held for the 1973-74 season while in 1974-75, the yield of double cropped plants was similar to the early planting. On the other hand, the determinate cultivars, 'Dare', Lee, and 'Bragg', showed no consistent reaction to planting date for either year. Although plant type was confounded with maturity, the author concluded that all planting date and cultivar combinations yielded well.

In the US, research on the potential use of indeterminate cultivars for double cropping in the South has been centered in Georgia. Flack (1976) evaluated the F_2 and F_4 generations of six crosses between determinate and indeterminate plants. The F_2 material was evaluated in hill plots while the F_4 was planted in rows. The mean yield of all the indeterminate plants was 98 g/plant as compared to 63 g/plant for all determinates from the F_2 populations. This represents a 56% increase in yield of indeterminates over determinates. Height of the lowest pod, flowering date, number of nodes, height at flowering and maturity, and lodging score were significantly higher for indeterminate plants than determinates. Determinate plants had a greater seed size. The indeterminates also flowered and matured later than the determinates by four and seven days, respectively. Plant height almost doubled from flowering to maturity for indeterminates while it only increased by 1 cm for determinates. In the F_4 generation, indeterminates were significantly higher yielding than the determinates, with the yield being 1939 and 1844 kg/ha, respectively. Seed size was greater for the indeterminate lines as compared to the determinate lines. Height of the lowest pod, maturity date, number of nodes, height at maturity, and lodging were higher for indeterminate plants, though the data were similar to the determinate lines. Plant height at flowering for the determinate and indeterminate lines were 42 and 41 cm, respectively. Data from both the F_2 and F_4 generations indicated that indeterminate lines may be higher yielding under double cropping conditions than determinates.

Boerma (1979) suggested that indeterminate cultivars would be desirable for double cropping because of their ability to recover from water stress if late season conditions were good because they grow simultaneously for both vegetative and reproductive traits. Determinate cultivars might be at a disadvantage in double cropping schemes because not enough vegetative growth is produced before reproductive growth begins. These observations are based on data from Flack (1976). Genotypes tested included only those from groups VI, VII, and VIII.

Double cropping soybeans after small grains north of southern Illinois is not feasible due to the length of the growing season and lack of moisture. Chan et al. (1980) studied the effect of relay intercropping soybeans into spring oats (Avena sativa L.). Both a determinate (Elf) and indeterminate (Williams) cultivar were seeded with a cone planter into 41, 61, and 81 cm wide oat rows. The soybeans were planted between all rows. Both cultivars yielded highest in the 81 cm rows and progressively decreased in yield as row width narrowed. The decrease was more pronounced in Elf. Oat yield was not affected by the soybeans but the intercropped soybeans yielded less than monocropped soybeans at all spacings. Soybean height at oat harvest was similar for both cultivars so there was no advantage to either plant type for mechanical harvesting of small grains but the indeterminate type was higher yielding because it was able to overcome early season drought conditions.

Environmental stability of determinate and indeterminate soybeans was compared over five planting dates ranging from early April to mid-July in Georgia (Shilling, 1979). A genotype was considered stable if the deviation from regression did not significantly differ from zero. The indeterminates were more stable over the entire planting range than the determinates. The determinates were more responsive to high yielding environments while the indeterminates were adapted to both high and low yielding environments. The author suggested that indeterminate lines that branch and have early vegetative vigor be developed for double cropping.

The literature indicates that indeterminate soybean cultivars may have an advantage over determinate cultivars under double cropping situations due to their stability over a wider range of conditions. These conditions include such factors as planting date, moisture, and fertility. The indeterminates were higher yielding than determinates when either double cropped or relay intercropped in the southern and northern parts of the US, respectively. In the South, it appears that double cropped soybean yields may be increased by planting indeterminate cultivars. The indeterminates have a higher pod height which reduces yield loss. The ability of indeterminates to simultaneously produce both vegetative and reproductive growth decreases the chance of crop failure during a dry year. The longer flowering period of indeterminates provides a greater chance of seed set if moisture conditions should become favorable during the latter part of flowering.

MATERIALS AND METHODS

Single plant selections were made in the F_4 generation from five crosses planted 26 June 1979 at the Eastern Virginia Research Station, Warsaw, VA. Lines were selected from the bulk F_4 generation of Essex x S63-5328S and Essex x SRF400. In Essex x V73-23, V68-1034 x SRF400, and V71-656 x V73-23, selections were taken from the F_4 generation of F_2-derived lines. Herein, the two F_4 populations and F_4 lines are referred to as families. Plant material from the last three crosses had been used in a previous study (Pyle, 1979). V73-23 is a selection from ('Samson' x 'Hill') x Clark while V68-1034 is a selection from 'York' x P.I. 71506. Delmar and V66-318 are the parents of V71-656. V66-318 is a selection from J22 x D53-184 with J22 being a selection from 'Arksoy' 2913 x 'Dunfield' and D53-184 being a selection from D49-2525 x L6-5679. D49-2525, a sister of Lee, was selected from S-100 x CNS. L6-5679 is a selection from 'Lincoln' x 'Richland'. In each cross the female parent was determinate (dt_1) while the male parent was indeterminate. These families were grown on plowed soil (Kempsville loam: Typic Hapludult; fine-sandy, silicious, thermic) that had been previously fertilized with 448 kg/ha of 0-10-20 fertilizer.

Approximately 40 plants, 20 of each type, were selected from the nine families and threshed individually. Ten plants of each growth type were selected from families for a seed increase in a winter nursery in Belize, Central America. The criteria for selection for increase included a high number of seed, seed quality, and freedom from purple seed stain (Cercospora kikuchii) and seed coat mottling due to viruses.

In 1980, lines selected from the four families of Essex x V73-23, two families of V71-656 x V73-23, and one each from the remaining crosses were planted at Warsaw on 1 July. Fourteen lines, five determinate and nine indeterminate, from each family, were replicated twice in a split-plot design with the families as main plots. More indeterminate than determinate lines were evaluated to take into account those lines that were segregating for plant type. Heterozygous (Dt_1dt_1) plants are difficult to distinguish from homozygous dominant plants and since some of the selected plants were only two generations removed from the heterozygous F_2 plants, several heterozygous plants would be expected in the selections. Selection of lines for evaluation was based on number of seed from the winter nursery increase. In two families, only 12 or 13 lines with enough seed were available so check cultivars were substituted. These checks included Essex, Crawford, and Williams. The three row, 6.1 m long plots were seeded with a two row planter on plowed soil at a rate of 180 seed per row. The rows were 0.61 m apart. Disulfoton was incorporated into the soil at planting at a rate of 7.5 kg/ha. Fertilizer (0-10-20) had been previously applied to the soil at a rate of 448 kg/ha. All plots were sprayed with carbaryl on 23 August to control insects. Cultivation and hand weeding were provided as necessary.

Data were collected on flowering date (approximately one third of the plants in bloom), flower color, mid-season height (14 August), mature height, days to maturity (after 31 August), pubescence color, leaf type, seed yield, seed size (g/100 seed), percent purple stained seed, percent seed coat mottling, and seed quality score. Plant type was also recorded to see if those plants selected as indeterminate in 1979 were homozygous or heterozygous for plant type. Those rows segregating for plant type or misclassified in 1979 were discarded. The center row of each plot (5.03 m) was harvested in mid-November. V68-1034 x SRF400 and one family of V71-656 x V73-23, were not harvested due to poor stands. Data from lines of the remaining seven families advanced to the 1981 test were summarized using the Statistical Analysis System (SAS User's Guide, 1979).

Lines from the above test and those from two other tests containing the remainder of the original selections and grown adjacent to the main test were considered for evaluation in 1981. The primary criteria for selection were maturity and uniformity of plant type. Determinate and indeterminate lines within families were matched as closely as possible to avoid confounding the plant type comparisons with maturity differences. Lines from the two additional tests were used only when needed to make good maturity matches. Other characters were given little consideration. Most of the lines chosen for the 1981 test were higher yielding than the average of the entire 1980 test largely because extremely late and consequently poorer yielding lines were not selected. While care was taken to match lines for maturity, there was a wide range of maturity within and among families. Forty lines were chosen with 16 from Essex x V73-23 and eight each from Essex x SRF400, Essex x S63-5328S, and V71-656 x V73-23. In all cases, half of the lines from each cross were determinate and half were indeterminate. Five check cultivars, Essex, Bay, Will, Williams, and Crawford, were also included.

Three plantings were made in 1981, two at Warsaw on 11 June and 8 July and one at the Piedmont Research Station, Orange, VA (Davidson clay loam: Rhodic Paleudult; clayey, oxidic, thermic) on 12 June. All plantings were on plowed soil. Entries for each planting were replicated twice in a randomized complete block design. Plots consisted of three 6.1 m rows 0.91 m apart at Warsaw and 0.76 m apart at Orange. Seeding rate was increased from 180 seed per row to 200 seed per row to compensate for the poor seed quality caused by drought conditions in 1980. Disulfoton was applied at a rate of 7.5 kg/ha during planting at Warsaw. Trifluralin was applied the first week of May at a rate of 1.2 l/ha. The land was not fertilized at Warsaw. Fertilizer (3-18-18) was applied at Orange on 27 May at a rate of 450 kg/ha. Additionally, metolachlor herbicide was sprayed at a rate of 2.3 l/ha on 27 May and 11 June at Orange. Cultivation and hand weeding were provided as necessary.

Data were collected on flowering date (approximately one third bloom), flower color, mid-season height (about flowering), pubescence color, leaf type, plant type, days after 31 August to maturity (11 June Warsaw), mature height, and seed yield. The lines of the 8 July Warsaw planting were not mature when a killing frost occurred 12 October so the plots were given a score of 1-5 with one being the most mature and five the least mature. Data obtained from the seed included seed size (g/100 seed), quality score, percent purple stain, and percent mottling. All data were analyzed using the Statistical Analysis System (SAS User's Guide, 1979).

Significant differences between the two plant types were calculated by orthogonal contrasts using the error mean square of the randomized complete block design for the denominator of an F-test for all characteristics. Maturity of the 11 June planting was analyzed in a completely randomized design because data had not been collected on all entries in the second replication due to a killing frost on 12 October. At that time, maturity estimates were given to the later lines in the first replication. Data were not combined over years because different experimental designs were used. A significant difference refers to the 0.05 level of probability unless otherwise noted.

RESULTS AND DISCUSSION

1980 Planting at Warsaw

Low yields were characteristic of the 1980 season. Poor stands were apparently caused by a combination of dry soil and low seed vigor. Some of the stands were so poor that the plots were not harvested. Lack of precipitation during the growing season resulted in erratic data. Approximately 12.5 cm of rain fell between planting and flowering (11 August) with only 6.2 cm falling between flowering and maturity. A summary of the data by cross for lines chosen for evaluation in 1981 is presented in Table 1. Essex x S63-5328S and Essex x V73-23 include lines from two similar tests. Because of this mixture of lines from different tests, no statistics, other than means, were computed.

A theoretical advantage of using indeterminate lines for double cropping is that they flower longer and therefore can take advantage of better growing conditions later in the season than can determinates (Coffman, 1978). However, when moisture is severely limited, it appears that neither plant type has any advantage. In the Essex crosses, the

Table 1. Mean yield, maturity, and seed size of determinate and indeterminate† types from four crosses and three check cultivars planted July 1, 1980, at Warsaw.

Cross§	Yield Det	Yield Indet	Maturity¶ Det	Maturity¶ Indet	Seed size Det	Seed size Indet
	---q/ha----				g/100 seed	
Essex x SRF400	10.8	10.6	54.9	53.8	14.0	12.9
Essex x S63-5328S	11.4	10.9	59.6	54.0	13.9	14.3
Essex x V73-23	10.7	9.8	60.0	57.1	14.6	14.4
V71-656 x V73-23	7.5	8.1	51.3	50.6	14.8	14.8
Average	10.1	9.9	56.5	53.9	14.3	14.1
Essex	10.0		69.0		14.0	
Crawford		9.7		54.5		16.8
Williams		6.4		48.0		15.7

†Det = determinate, Indet = indeterminate.
§Data combined over families. Only those lines advanced to 1981 were summarized.
¶After 31 August

determinates were slightly higher yielding than the indeterminates. Only in V71-656 x V73-23 were the indeterminates higher yielding. With the check cultivars, the determinate Essex was higher yielding than the two indeterminate cultivars. Although it is doubtful that any of the differences are significant, the determinates may have been higher yielding than the indeterminates due to the relationships between the reproductive and vegetative stages. The indeterminates support both reproductive and vegetative growth simultaneously while determinates nearly halt vegetative growth once reproductive growth begins. The extreme drought conditions may have given the determinates a yield advantage because following flowering all of the photosynthate was used primarily for seed fill and not for both seed fill and vegetative growth as in the indeterminates. This is not contrary to theory, since it assumes the indeterminates will be able to resume growth if moisture becomes available before all vegetative growth has ceased (Coffman, 1978; Boerma, 1979). However, in 1980 the drought was not broken until very late in the season.

The determinate lines were later maturing than the indeterminates in all four crosses. The difference averaged from one to greater than three days. Bernard (1972) found determinate lines to be earlier maturing than indeterminates because of the lack of late pod development, as found on the indeterminates. In this study, accurate maturity notes were difficult to take because of the droughty conditions so the observed differences between plant types are probably not significant. Both plant types of V71-656 x V73-23 were earlier than in the other crosses and these had the lower yields. Although there was some shattering evident in the field, all crosses were affected and there did not appear to be enough shattering to reduce yields materially.

Seed size was greater for the determinates in Essex x SRF400 and Essex x V73-23 while it was greater for the indeterminates in Essex x S63-5328S. However, it does not appear that any relationship between seed size and plant type or yield is present.

Summaries for the other data collected could not be made since data were not available for some of the selected lines.

1981 Planting at Orange

Only one planting was made at Orange and it was considered a full-season crop. Therefore, no conclusions can be made regarding plant types in relationship to planting dates at this location. It did, however, provide a different environment in which to evaluate these lines. A summary of the data is found in Table 2.

The determinate lines were higher yielding than the indeterminate lines for Essex x SRF400, Essex x S63-5328S, and V71-656 x V73-23 but the difference was significant only for V71-656 x V73-23. The indeterminates were significantly higher yielding for Essex x V73-23. In all crosses, the indeterminates were taller than the determinates at maturity but this was not the case at mid-season. The determinate lines of Essex x SRF400 were significantly taller than the indeterminates at mid-season. In this same cross, the determinates were not significantly different from the indeterminates at maturity. Mid-season height was measured on all lines on 13 August. This was approximately mid-way through flowering for the entire test. In other words, some entries had finished flowering by that time while others were just beginning. The change in height from flowering to maturity was calculated for each plot. The indeterminates had a significantly greater increase in growth than the

Table 2. Summary of performance of determinate and indeterminate† lines of four crosses planted June 12, 1981, at Orange.

	Essex x SRF400			Essex x S63-5328S			Essex x V73-23			V71-656 x V73-23		
Characteristic	Det		Indet	Det		Indet	Det		Indet	Det		Indet
Yield (q/ha)	28.1		26.7	26.0		25.6	25.3	**	27.7	26.9	**	24.1
Mature height (cm)	90.1		92.5	87.6	**	109.5	84.7	**	112.7	67.0	**	107.2
Mid-season (8-13) height (cm)	67.3	**	60.5	70.9		72.0	68.6	**	73.2	63.6	**	75.0
Change in height (cm)§	22.9	**	32.0	16.7	**	37.5	16.1	**	39.5	3.4	**	32.3
Plot rating¶	2.6		2.8	2.9		2.7	3.0	**	3.4	1.9	**	4.1
Lodging#	3.1	**	2.5	3.2	**	2.5	3.2		3.3	1.1	**	3.3
Seed size (g/100 seed)	14.1	**	11.8	13.2	**	14.2	12.2	**	14.1	15.1		14.9
Purple stain (%)	0.1		0.3	0.1		0.0	0.1	*	0.2	0.0		0.0
Mottling (%)	1.9	**	24.1	21.9		21.5	6.7	**	12.4	13.4	**	28.6
Seed quality¶	1.6	*	1.8	1.5		1.7	1.6		1.6	1.5	**	1.9

*,**Means of determinate and indeterminate within each cross were significantly different at the 0.05 and 0.01 levels of probability, respectively.
†Det = determinate, Indet = indeterminate
§Change in height = mature height - mid-season height.
¶Plot rating and seed quality based on a 1-5 scale; 1=very good, 5=very poor.
#Lodging based on a 1-5 scale; 1=all plants erect, 5=all plants lodged.

determinates. This has been observed in other studies (Egli and Leggett, 1973; Flack, 1976).

High yield is not the only factor to consider in cultivar development. Ease of mechanical harvesting is very important since low pods or lodged plants result in the harvester leaving seed in the field (Sij and Dornhoff, 1973; Harvey and Brigham, 1971; Hartung et al., 1981). Height of the lowest pod was not measured but a lodging score was given to each plot. These estimates were based on a visual evaluation of the percentage of plants lodged. A score of five indicates that most of the plants were lodged while a score of one means that most of the plants were erect. A taller plant is more likely to lodge than a shorter one. Thus an indeterminate plant is expected to lodge more than a determinate plant (Cooper, 1981; Hartwig and Edwards, 1970; Hicks et al., 1969). This was true for Essex x V73-23 and V71-656 x V73-23 although it was only significant for the latter cross. In the other two crosses, the determinates were significantly more lodged. The determinates in all of the Essex crosses were of a similar height and received similar scores. The relationship between plant height and lodging appears to hold within plant types, but not across plant types.

Each plot was visually evaluated for overall general appearance. This includes such things as height, branching, and number of pods. In Essex x V73-23 and V71-656 x V73-23, the indeterminates had a significantly worse rating (5=worst, 1=best). They also had a fairly high lodging score. In the other two crosses there was no difference between the two types. There does not appear to be any relationship between yield and plot appearance or lodging. The poorer looking plots were not always the most lodged or lowest yielding.

Seed size was significantly different between the types in the three Essex crosses with the determinates being larger for Essex x SRF400 while the indeterminates were larger for the other two crosses. There was no difference in size for V71-656 x V73-23. Seed size did not appear to be correlated with yield at this location because the higher yielding type did not always have the larger seed. None of the crosses had much purple stain but there was quite a bit of mottling. The indeterminates of Essex x SRF400, Essex x V73-23, and V71-656 x V73-23 had significantly more mottling than the determinates while there was no difference for Essex x S63-5328S. The longer vegetative period of the indeterminates may have made them more vulnerable to the spread of virus by aphids. Essex x S63-5328S is a later maturing cross and the high incidence of mottling in both plant types may indicate that the virus infection took place late in the summer. The indeterminates were of a similar or slightly lower quality than the determinates with the difference being significant only in Essex x SRF400 and V71-656 x V73-23.

<u>11 June 1981 Planting at Warsaw</u>

All of the entries planted at Warsaw on 11 June showed good germination and growth. The data are summarized in Table 3.

All four crosses showed significant differences between plant types. The determinates were significantly higher yielding for Essex x SRF400 and V71-656 x V73-23 while the indeterminates had a significantly greater yield in the other two crosses. These yields were higher than at Orange (Table 2) and followed the same trend for all crosses except one. In Essex x S63-5328S, there was no difference between types at Orange even though the determinates were slightly higher yielding. At Warsaw, the indeterminates were significantly higher yielding.

Maturity differences were significant for Essex x SRF400 and V71-656 x V73-23. The determinates were 0.9 days later in the first cross and 1.5 days later in the second one.

Table 3. Summary of performance of determinate and indeterminate† lines of four crosses planted June 11, 1981, Warsaw.

	Essex x SRF400			Essex x S63-5328S			Essex x V73-23			V71-656 x V73-23		
Characteristic	Det		Indet	Det		Indet	Det		Indet	Det		Indet
Yield (q/ha)	30.5	**	27.6	29.6	*	31.6	27.0	*	27.8	28.5	**	26.1
Maturity (days after 8-31)	48.6	*	47.5	53.6		55.0	46.1		45.1	41.0	*	42.6
Mature height (cm)	100.0	**	113.0	94.5	**	120.2	88.0	**	126.6	75.3	**	124.8
Mid-season (8-11) height (cm)	87.1	**	76.3	79.8	**	87.7	80.4	**	90.2	73.0	**	94.3
Change in height (cm)§	12.9	**	36.8	14.7	**	32.6	7.6	**	36.3	2.3	**	30.5
Plot rating¶	1.9		1.8	2.4		2.8	2.6	**	3.1	2.4		2.9
Lodging#	3.5	**	3.3	2.8	**	3.7	3.8	**	4.0	1.1	**	2.7
Seed size (g/100 seed)	15.3	**	12.6	14.1	**	15.5	12.8	**	15.4	15.9		15.8
Purple stain (%)	0.0	**	0.3	0.0	**	0.3	0.0	*	0.1	0.2		0.2
Mottling (%)	0.8	**	2.8	3.5		2.5	0.4	**	3.4	4.8	*	3.6
Seed quality¶	1.4	**	1.7	1.4		1.4	1.4	**	1.6	1.4		1.4

*,**Means of determinate and indeterminate within each cross were significantly different at the 0.05 and 0.01 levels of probability, respectively.

†Det = determinate, Indet = indeterminate

§Change in height = mature height - mid-season height.

¶Plot rating and seed quality based on a 1-5 scale; 1=very good, 5=very poor.

#Lodging based on a 1-5 scale; 1=all plants erect, 5=all plants lodged.

There was no difference at the 5% level in maturity between types in Essex x S63-5328S and Essex x V73-23. Even though the maturity difference between plant types was significant in two crosses, the difference does not appear large enough to affect performance. The Orange planting appeared to be later maturing than at Warsaw. Although no maturity data were collected at Orange, a difference in flowering was observed when the mid-season height was taken. At that time (11 August at Warsaw and 13 August at Orange), only about half of the lines at Orange had flowered while all had flowered at Warsaw.

All four crosses showed the indeterminates to be significantly taller at maturity and to attain significantly more growth between flowering and maturity. All plots had reached at least one third flowering when mid-season height was taken on 11 August. The indeterminates were significantly taller than the determinates at mid-season in three of the crosses with the exception being Essex x SRF400 in which the determinates averaged more than 10 cm taller than the indeterminates. At maturity, Essex x SRF400 also had the tallest determinates and shortest indeterminates of the four crosses studied.

Only the plots in the first replication were given a visual rating. Three of the crosses had indeterminate lines with a poorer rating than the determinate lines, the exception being Essex x SRF400. This may be related to the fact that determinates of this cross were very tall at maturity and lodged quite a bit. The plant type of all four crosses that had the poorer plot rating also had more lodging. Lodging was significant among plant types for each cross.

In all four crosses, the plant type with the larger seed size had the higher yield. The size difference for V71-656 x V73-23 was not significant but the differences were significant in the other three crosses. As at Orange, there was little purple stain in any of the lines at Warsaw and differences between plant types were very small. The indeterminate lines had significantly more mottling than the determinates for Essex x SRF400 and Essex x V73-23, while the opposite was true for V71-656 x V73-23. There was no significant difference between types in Essex x S63-5328S although the determinate lines had more mottling. The two plant types had similar seed quality scores for Essex x S63-5328S and V71-656 x V73-23. In the other two crosses, the indeterminates had a poorer seed quality although, despite the significant differences, the types were not that dissimilar. In view of the lack of any consistent differences between plant types for seed factors, it appears that plant type has little effect on seed quality.

Overall, the 11 June Warsaw test had high yields in spite of the lodging. The excessive growth contributed to the high degree of lodging. It would be desirable to select lines that are not as tall when grown as a full-season crop to avoid severe lodging problems.

8 July 1981 Planting at Warsaw

All of the lines were evaluated under conditions similar to double cropping at Warsaw. Double cropped soybeans are normally planted immediately after a small grain crop is harvested, frequently with minimum or no tillage. However, this planting was planted on plowed soil. There was no previous small grain crop. The data are summarized in Table 4.

Boerma (1979) has suggested that indeterminate lines might be advantageous under double cropping conditions because of their ability to overcome stress conditions. Precipitation in 1981 was fairly evenly distributed throughout the growing season and therefore, water stress was probably not a factor in soybean performance. In the three Essex crosses, the indeterminates were higher yielding than the determinates and this difference was significant for Essex x S63-5328S and Essex x V73-23. At the earlier planting (Table 3), the indeterminate lines of these two

Table 4. Summary of determinate and indeterminate† lines of four crosses planted July 8, 1981, at Warsaw.

	Essex x SRF400			Essex x S63-5328S			Essex x V73-23			V71-656 x V73-23		
Characteristic	Det		Indet	Det		Indet	Det		Indet	Det		Indet
Yield (q/ha)	22.2		22.3	19.8	**	21.7	20.1	**	20.6	21.8		21.2
Maturity§	4.0		3.6	4.3		4.0	3.7	*	3.4	2.3		2.3
Mature height (cm)	89.9		84.5	80.8	**	91.4	82.6	**	94.7	64.1	**	93.7
Mid-season (9-1) height (cm)	87.3	*	78.4	85.3		78.3	85.5		84.8	75.9	*	85.1
Change in height (cm)¶	2.5	**	8.0	-4.6	**	13.1	-2.9	**	9.9	-11.8	**	8.6
Plot rating#	2.3		2.6	2.3		2.7	3.1		3.2	3.0		3.1
Lodging††	2.8	**	1.3	3.1	**	1.3	3.4	**	2.7	1.0	*	1.3
Seed size (g/100 seed)	12.8	**	11.0	12.7		12.9	12.0	**	13.6	15.7	*	15.4
Purple stain (%)	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0
Mottling (%)	0.8	**	3.8	2.2		2.3	0.9	**	3.6	6.5		7.5
Seed quality#	1.6	**	1.3	1.4		1.3	1.4		1.4	1.4	**	1.8

*,**Means within each cross were significantly different at the 0.05 and 0.01 levels of probability, respectively.

†Det = determinate, Indet = indeterminate.

§Maturity scored on a 1-5 scale; 1=most mature, 5=least mature.

¶Change in height = mature height - midseason height.

#Plot rating and seed quality scored on a 1-5 scale; 1=very good, 5=very poor.

††Lodging scored on a 1-5 scale; 1 = all plants erect, 5 = all plants lodged.

crosses were also significantly higher yielding than the determinates. With the remaining two crosses, there was no statistical difference in yield between the types, while at the earlier planting the determinates were higher yielding. This indicates a shift to better double crop performance of the indeterminate lines in the latter two crosses. There was less change in the relative performance in the other two crosses, implying a possible interaction of plant types with crosses.

The determinates were generally later maturing, but the differences between plant types were small and generally consistent with the earlier planting. V71-656 x V73-23 had the earliest lines which was consistent with the earlier planting (Table 3).

The lines were not as tall as they were in the 11 June planting, due to the shortened growing season. At maturity, the indeterminate lines were significantly taller than the determinate lines in all crosses but Essex x SRF400 in which the determinate lines were taller but not significantly so. Mature height was measured from the soil surface to the end of the stem or growing point. Mid-season height was measured on 1 September from the soil surface to the top of the canopy in contrast to the other plantings in which mid-season height was measured from the soil surface to the tip of the main stem. This resulted in apparent negative changes in height for many of the determinate lines in this test. Flowering was completed at the time of the measurements. The determinates of Essex x SRF400 were significantly taller than the indeterminates at mid-season and were taller in the other two Essex crosses but not significantly so. In V71-656 x V73-23, the indeterminates were significantly taller. The mid-season heights of the indeterminate lines are probably more accurate than the determinate lines because the canopy of a determinate extends further above the growing point than it does on an indeterminate. As in the other plantings, the indeterminates increased more in height from flowering to maturity than did the determinates.

There was no difference between types for visual rating although the indeterminates in each cross had slightly poorer scores than the determinates. The determinates of the three Essex crosses lodged much more than the indeterminates while in V71-656 x V73-23 the opposite was true. In all four crosses, the type that was more lodged had the lower yield. The yields of some lodged plots may have been even lower if they had been machine harvested rather than hand harvested.

The greatest differences in seed size were among crosses. V71-656 x V73-23 had the largest seed with the determinates being the larger of the two types, as they also were in Essex x SRF400. Seed from the indeterminate plants of the other crosses were larger but only significantly so in Essex x V73-23. None of the seed samples had any purple stain. Percent mottling was fairly low although it tended to be highest in the indeterminate lines. Seed quality was good overall but the determinates of Essex x SRF400 and indeterminates of V71-656 x V73-23 received somewhat poorer scores as compared to their respective counterparts.

Overall, the crosses yielded well at this late planting in spite of the early frost. The quality of the seed did not seem to be affected by the frost. The amount of lodging was higher than might be expected for a late planting but good growing conditions contributed to the taller than normal growth.

All 1981 Plantings

Table 5 summarizes all of the crosses combined for the three plantings. At Orange, the plant types had a similar average yield while at the 11 June planting at Warsaw the determinates were significantly higher yielding and at the 8 July planting the indeterminates were higher yielding. In all cases, the higher yielding type had less lodging.

Table 5. Summary of the performance of determinate and indeterminate† lines from all crosses (excluding checks) for three plantings in 1981.

	Orange, 12 June			Warsaw, 11 June			Warsaw, 8 July		
Characteristic	Det		Indet	Det		Indet	Det		Indet
Yield (q/ha)	26.4		26.5	28.6	**	28.0	20.8	**	21.2
Maturity§	--		--	46.5	*	46.0	3.6	**	3.3
Mature height (cm)	83.0	**	107.1	89.5	**	122.6	79.9	**	92.0
Mid-season height (cm)	67.9	**	70.8	80.1	**	87.9	83.9		82.6
Change in height (cm)¶	15.1	**	36.3	8.9	**	34.7	-4.0	**	9.7
Plot rating#	2.7	**	3.3	2.4	**	2.8	2.7	**	3.0
Lodging††	2.8	**	3.0	2.9	**	3.5	2.7	**	1.9
Seed size (g/100 seed)	13.4	**	13.8	14.3	**	14.9	13.1	**	13.3
Purple stain (%)	0.1		0.1	0.0	**	0.2	0.0		0.0
Mottling (%)	10.9	**	19.4	2.1	**	3.2	2.3	**	4.2
Seed quality#	1.5	**	1.7	1.4	**	1.5	1.5		1.4

*,**Means of determinate and indeterminate within each planting are significantly different at the 0.05 and 0.01 levels of probability, respectively.
†Det = determinate, Indet = indeterminate
§Maturity for Warsaw 11 June is days after 31 August. Maturity for Warsaw 8 July based on a 1-5 scale; 1=most mature, 5=least mature.
¶Change in height = mature height - mid-season height.
#Plot rating and seed quality scored on a 1-5 scale; 1=very good, 5=very poor.
††Lodging based on a 1-5 scale; 1=all plants erect, 5=all plants lodged.

The indeterminates were taller in the earlier plantings for both the mid-season and mature heights. Additionally, they had the greatest growth between the two stages for the Orange planting and the 11 June planting at Warsaw. At the later planting, the indeterminates were taller at maturity and showed a greater growth from flowering to maturity. The increase in growth of the two Warsaw plantings cannot be compared because of the different measuring methods for the mid-season heights. The tallness of the indeterminates was probably a factor in their higher lodging and general appearance scores.

Seed size was greater for the indeterminates in all three plantings. They had more mottling and purple stain where this condition was present. In the two earlier plantings, the indeterminates had an overall poorer seed quality while the opposite was true for the later planting though it was not a significant difference.

A comparison of planting dates with plant types can be made using the two Warsaw plantings. As expected, yields and plant heights were lower at the second planting as compared to the first one. In addition, seed size was smaller. Yields of the indeterminate lines were greater than the determinate lines at the second planting. The opposite was true for the first planting. This agrees with

Boerma's (1979) study in Georgia where yields of indeterminate plants were higher than yields of determinate plants.

Indeterminate plants have been shown to lodge more than determinate plants (Cooper, 1981) and the degree of lodging is generally reduced at a later planting (Green et al., 1977). In this study there was a reduction in lodging in both types from the 11 June to the 8 July planting. The determinates had an average reduction of 9% for the four crosses while the indeterminates had an average lodging reduction of 46%. It should be noted that lodging was scored on the first planting on 19 October while the second planting was scored on 12 November. The change in lodging may be related to the change in height from the first to the second planting. The determinates had an average decrease in height of 11% while the indeterminates had an average height reduction of 25%. One of the problems with growing indeterminates in the South as a full-season crop is the excessive growth and resultant lodging. The data show that this would not be a problem under double cropping conditions because the shorter growing season results in less growth and less lodging. In this study (Table 4) the indeterminates lodged less than the determinates. The lack of lodging coupled with the higher yields would indicate that indeterminates would be suitable for double cropping.

A study comparing determinate and indeterminate lines under double cropping conditions in Georgia (Flack, 1976) showed that the indeterminate lines were higher yielding than the determinate lines by 5%. In the present study the difference was 2%. Other similarities between the two studies were that the indeterminates had a larger seed size and were taller at maturity than the determinates. Dissimilarities between the studies were for maturity and lodging in which Flack found the indeterminates to be later maturing and more lodged than the determinates. The present study found the indeterminates to be earlier and to have less lodging. The differences observed may be due to the different location and genotypes of the crosses examined and to the method of selecting experimental lines.

Another way of examining the plant type with planting date relationship is to look at the correlations among the different characteristics for each type in the two Warsaw plantings. Table 6 has the correlations for both the determinate and indeterminate lines of both plantings at Warsaw. Correlation coefficients were calculated using plot values. If correlations are of similar magnitude and direction for both plantings, then planting date does not affect the relationship of the correlated characteristics. For example, the determinate yield had a significant

Table 6. Correlation coefficients among eleven characteristics for determinate (above diagonal) and indeterminate (below diagonal) lines planted June 11 (D1) and July 8 (D2), Warsaw.

		Yield	Maturity	Mature height	Mid season height	Change in height	Plot rating	Lodging score	Seed size	Percent purple stain	Percent Mottling	Seed Quality Score
Yield	D1		.44*	.42**	.41**	.11	-.31*	-.04	-.42**	-.03	-.08	-.15
	D2		-.33*	-.23	-.26	-.14	-.54**	-.52**	.37*	.00	.15	-.15
Maturity	D1	-.23		.85**	.62**	.56**	.18	.65**	-.29	.01	.05	-.26
	D2	-.20		.83**	.74**	.67**	.04	.60**	-.73**	.00	-.45**	.16
Mature height	D1	-.11	.69**		.76**	.54**	-.20	.62**	-.16	-.15	-.10	-.28
	D2	-.42**	.64**		.79**	.88**	.11	.64**	-.73**	.00	-.38*	.32*
Mid-season height	D1	.06	.20	.60**		-.13	-.27	-.39*	-.04	-.18	-.13	-.07
	D2	-.35*	.30	.65**		.40*	.06	.64**	-.62**	.00	-.38*	.36*
Change in height	D1	-.19	.66**	.70**	-.15		.05	.44**	-.19	.01	.01	-.34*
	D2	-.27	.60**	.79**	.05		.13	.46**	-.60**	.00	-.27	.21
Plot rating	D1	-.07	.38*	-.13	.17	-.13		.15	-.43**	.00	.27	.53**
	D2	-.48**	.05	.42**	.22	.34*		.39*	-.04	.00	-.01	.27
Lodging	D1	-.11	.78**	.64**	.24	.57**	.44**		-.54**	-.21	-.50**	-.18
	D2	-.53**	.56**	.75**	.62**	.48**	.35*		-.72**	.00	-.41**	.42**
Seed size	D1	.23	-.45*	-.01	.30	-.28	.34*	-.21		.18	.21	.15
	D2	.04	-.84**	-.37*	-.09	-.41**	.12	-.31*		.00	.56**	-.22
Purple stain	D1	.30	-.07	-.21	-.08	-.19	.06	-.23	.10		.12	-.23
	D2	.00	.00	.00	.00	.00	.00	.00	.00		.00	.00
Mottling	D1	.25	-.27	-.19	.05	-.28	-.20	-.12	.22	-.00		-.00
	D2	.10	-.71**	-.44**	-.33*	-.31	-.10	-.38*	.54**	.00		.09
Seed quality	D1	.07	.17	-.06	-.25	.15	-.10	.12	-.20	.16	.02	
	D2	-.18	-.15	.17	-.21	.06	.34*	.01	.21	.00	.07	

*,**Correlation coefficients are significant at the 0.05 and 0.01 levels of probability, respectively.

positive correlation with mature height (r=0.42) in the first planting and a negative, non-significant correlation (r=-0.23) in the later planting. This indicates that taller determinates tended to be higher yielding in the first planting while there was no significant relationship between the two variables at the second planting. It therefore seems that planting date did interact with height to affect yield.

There are some differences in correlations among different characteristics for plant types. Plot rating was negatively correlated with seed size at the first planting of the determinate lines but at the same planting was positively correlated for the indeterminate lines. Both the determinate and indeterminate lines had high correlations between mature height and maturity at both plantings but it was higher for the determinates. The determinates had a highly significant correlation between mid-season height and maturity while there was a non-significant correlation for the indeterminates. The determinates had completed most of their growth by mid-season. The lack of relationship between mid-season height and maturity of the indeterminates may be related to the increase in vegetative growth that occurs between flowering and maturity. Maturity and mottling of the determinates were negatively correlated (r=-0.45) at the second planting but were not related at the first planting (r=0.05). The values for the indeterminates were more negative. This means that at the second planting, later maturing lines had less seed coat mottling.

Lodging and seed size had a highly significant negative correlation for the determinates and a low correlation for the indeterminates. This indicates that the determinate plants that lodged more had smaller seed. Lodging and yield correlations differed between plantings for both plant types. At the first planting there was no relationship between yield and lodging, while there was a significant negative correlation at the second planting, indicating that lodging of double cropped soybeans resulted in lower yields. There were high correlations of lodging with both maturity and mature height for all plantings and plant types, which was expected since taller plants have a greater tendency to lodge. Lodging had an adverse effect on seed quality of the determinate lines in the second planting but not in the first planting or on the indeterminate lines.

The correlation coefficients showed that not all of the characteristics expressed themselves in the same way under full-season and double cropping conditions or for the two plant types. The determinates showed a higher negative correlation between lodging and seed size than did the indeterminates. The yield-lodging correlations show that the plant types act similarly but there is a planting date response. High correlations were observed for both plant types and planting dates between maturity, mature height, and lodging. Differences could be seen between types for the correlation between maturity and mid-season height and between lodging and seed size but the response was similar at both planting dates.

Comparison of Best Lines with Check Cultivars

One of the objectives of this study was to compare the best lines of each type with check cultivars. Table 7 includes the two highest yielding determinate and indeterminate lines in each of the Warsaw plantings and the check cultivars. In each planting, the entries, including experimental lines and checks, were ranked from highest to lowest with the highest yielding entry receiving a rank of one. Spearman's rank correlation test was run on entries in the two Warsaw plantings. A correlation coefficient of 0.23 was obtained indicating that high yielding lines of one planting are not necessarily high yielding in the other planting.

The best two indeterminates from the 11 June planting were both from Essex x S63-5328S. They were ranked fourth

Table 7. Comparison of check varieties with the highest yielding determinate and indeterminate lines from the June 11 and July 8 plantings, at Warsaw.

			June 11		July 8		Change¶	
Entry	Cross	Type†	Yield	Rank§	Yield	Rank	Yield	Rank
			q/ha		q/ha		-%-	
Best lines from early planting								
21	Essex x SRF400	D	33.2	2	19.2	39	-42	-37
10	Essex x S63-5328S	D	31.8	8	18.6	41	-42	-33
20	Essex x S63-5328S	I	32.4	4	22.2	15	-32	-11
2	Essex x S63-5328S	I	31.8	7	21.8	17	-31	-10
Best lines from late planting								
41	Essex x SRF400	D	31.6	10	24.9	1	-21	+9
16	V71-656 x V73-23	D	27.1	33	23.2	4	-14	+29
22	Essex x SRF400	I	28.1	28	23.9	2	-15	+26
13	Essex x V73-23	I	31.1	13	22.9	6	-26	+7
	All lines	D	28.6		20.8		-27	
		I	28.0		21.2		-24	
	Essex	D	34.0	1	23.2	5	-32	-4
	Bay	D	32.1	6	19.5	38	-39	-32
	Will	SD	32.4	3	20.4	29	-37	-27
	Williams	I	32.2	5	23.5	3	-27	+2
	Crawford	I	28.6	24	22.8	7	-20	+17
	LSD (.05)		6.7		2.6			

†D = determinate, I = indeterminate, SD = semi-determinate.
§Rank based on a 45 entry test; 1=highest yielding, 45=lowest yielding.
¶Change in yield is the percent reduction from June 11 to July 8. Change in rank determined by subtracting the July 8 rank from the June 11 rank.

and seventh in the first planting and fifteenth and seventeenth, respectively, in the second planting. The indeterminates also were ranked lower in the late planting but there was much less of a reduction than for the determinates. Entry 21 dropped in rank by 37 places while entry 10 dropped 33 places. The indeterminate lines dropped only 11 and 10 places. In comparing the yields of the four top lines of the first planting with the check cultivars, it can be seen that the lines yield less than Essex but not significantly so, based on an LSD of 6.2 q/ha. They were all higher yielding than the lowest check, Crawford. The two indeterminates had higher yields than the two determinates at the later planting. Using an LSD of 2.6 q/ha, one determinate line, entry 10, was significantly lower yielding than either of the indeterminates.

The top lines from the second planting were not significantly different from each other. The change in rank of these lines, when compared to their full-season ranks, exhibited a positive change. This indicates that those lines that are highest yielding at a late planting were not the best yielding at the first planting. The two indeterminate checks, Williams and Crawford, exhibited a positive change in rank from the first to the second planting while the determinates all decreased in rank. This implies that of the check cultivars evaluated, the indeterminates do better under double cropping conditions than under full-season conditions. All four lines were significantly better (LSD=2.6) than Bay while three lines, entries 41, 16, and 22 were significantly better than both Bay and Will. Two of these lines, entries 41 and 22, were higher yielding than the top two check cultivars, Essex and Williams, though not significantly higher. There was less percent reduction in yield of the lines that ranked high in the later planting as compared to those that ranked high in the first planting. This indicates that lines can be selected for adaptation to late planting and that these lines might not necessarily be adapted to full-season production, as indicated by Spearman's rank correlation of 0.23.

Other plant characteristics for the eight lines discussed above as well as the check cultivars can be found in Table 8. A comparison of entries 41 and 22 to Essex and Williams shows that these lines have a similar maturity and seed size to Essex. These two lines are taller than Essex and Williams, in addition to having a better plot rating and low lodging scores at late planting. In the early planting, however, they had poorer lodging scores than most of the check cultivars. The seed quality was similar among the two

Table 8. Summary of top determinate and indeterminate lines and check cultivars for eleven characteristics from June 11 (D1) and July 8 (D2) planting at Warsaw.

Entry and Pedigree†	Date	Yield	Mat	Ht	Midht	Htdif	Rating	Lodg	Size	PS	Mot	Qual
2(a)	D1	31.8	57.0	116.8	35.2	27.3	3.0	3.5	14.1	0.0	6.5	1.3
	D2	21.8	5.0	92.7	31.5	12.7	2.0	1.5	11.5	0.0	2.0	1.0
10(a)	D1	31.8	60.0	97.8	33.9	11.8	2.5	2.0	14.6	0.0	6.5	1.5
	D2	18.6	4.8	87.6	35.0	-1.3	1.8	1.8	12.5	0.0	5.0	1.5
13(b)	D1	31.1	57.0	151.5	37.0	57.1	2.5	5.0	14.6	0.0	1.0	1.5
	D2	22.9	4.0	104.1	34.5	12.7	2.5	3.3	11.8	0.0	1.0	1.8
16(c)	D1	27.1	46.0	76.2	26.3	9.7	3.5	1.0	15.4	0.5	5.0	1.5
	D2	23.2	2.5	58.4	28.5	-14.0	2.8	1.0	15.4	0.0	3.5	1.3
20(a)	D1	32.4	53.0	114.3	34.8	25.8	2.5	3.0	15.2	1.0	0.5	1.5
	D2	22.2	3.0	87.6	30.0	11.4	2.3	1.0	13.7	0.0	3.0	1.3
21(d)	D1	33.2	55.0	102.9	37.8	5.9	1.5	4.3	15.7	0.0	0.0	1.3
	D2	19.2	5.0	100.3	37.0	6.4	3.8	4.0	13.3	0.0	0.5	1.8
22(d)	D1	28.1	48.0	114.3	37.0	40.3	2.5	3.0	12.9	1.0	4.0	1.8
	D2	23.9	3.3	78.7	31.0	0.0	2.0	1.0	11.7	0.0	4.5	1.0
41(d)	D1	31.6	47.0	106.7	34.1	20.2	2.0	3.5	15.8	0.0	0.5	1.5
	D2	24.9	3.8	88.9	33.0	5.1	1.5	1.3	13.6	0.0	0.5	1.5
AVE	D1	30.9	52.9	110.0	34.5	24.8	2.5	3.2	14.8	0.3	3.6	1.5
	D2	22.1	3.9	87.4	32.6	4.1	2.3	1.9	12.9	0.0	3.1	1.4
Will	D1	32.4	19.0	74.9	30.5	-2.6	1.5	1.0	18.0	1.5	1.0	1.0
	D2	20.4	1.0	55.9	29.0	-17.8	2.3	1.0	16.8	0.0	3.5	1.5
Williams	D1	32.2	26.0	95.3	38.8	-3.3	2.0	1.0	18.8	0.5	11.5	1.3
	D2	23.5	1.0	71.1	29.0	-2.5	2.3	1.0	19.9	0.0	3.0	1.3
Bay	D1	32.1	47.0	114.3	39.8	13.3	3.0	3.5	16.9	0.0	3.0	1.3
	D2	19.5	4.8	97.8	37.0	3.8	3.8	5.0	15.3	0.0	14.0	1.3
Essex	D1	34.0	48.0	85.1	33.1	1.1	1.5	1.8	13.7	0.0	0.5	1.5
	D2	23.2	3.3	69.9	30.5	-7.6	3.0	1.0	13.1	0.0	1.5	1.5
Crawford	D1	28.6	38.5	123.2	36.6	30.2	2.0	2.5	18.2	1.0	7.5	1.3
	D2	22.8	1.8	80.0	30.0	3.8	2.3	1.0	18.1	0.0	3.0	1.0

† a = Essex x S63-5328S, b = Essex x V73-23, c = V71-656 x V73-23, d = Essex x SRF400.

checks and two lines. Therefore, in addition to having slightly higher yields, these lines appear to be as good as the highest yielding check cultivars for other plant and seed characteristics.

There was less lodging evident in the later planting as compared to the earlier one, an attribute desirable for double cropping. These top lines from the 8 July planting were also earlier maturing when planted late as compared to those of 11 June. Although the overall test indicated that indeterminate lines were significantly higher yielding than determinate lines when double cropped, an evaluation of the top lines indicates that either type could be selected for adaptation to double cropping.

SUMMARY AND CONCLUSIONS

Ten determinate and ten indeterminate single plant selections from each of five crosses (Essex x SRF400, Essex x S63-5328S, Essex x V73-23, V71-656 x V73-23, and V68-1034 x SRF400) were made in 1979 from nine families and increased in a winter nursery. In 1980, five determinate and nine indeterminate lines from these families were planted in three replicated experiments at the Eastern Virginia Research Station, Warsaw, VA on 1 July. The lines of two families were not harvested due to poor stands. Forty lines, 20 determinate and 20 indeterminate, from the remaining crosses were selected and matched for maturity. They were planted with five check cultivars in 1981 on 11 June and 8 July at Warsaw and 12 June at the Piedmont Research Station, Orange, VA in randomized complete block (RCB) experiments with two replications. Significance of differences between plant types was calculated by orthogonal contrasts using the error mean square of the RCB design as the denominator of the F-test.

Lack of rainfall resulted in poor stands and low yields in 1980. The determinate lines averaged 10.1 q/ha while the indeterminates averaged 9.9 q/ha. Only the data from those lines selected for evaluation in 1981 were summarized. Although indeterminates were expected to withstand periods of adverse growing conditions better than determinates, it appears that neither plant type did well under the extreme drought conditions.

Good yields were obtained in all 1981 experiments. A summary of all three plantings shows that there were no differences between types for yield at Orange but the determinates were significantly higher in yield for the 8 July planting at Warsaw. The determinates were slightly later maturing for both Warsaw plantings. The indeterminates in all three plantings were significantly taller than the determinates and had a poorer plot rating. More lodging was observed for the indeterminates in the full-season plantings as compared to the determinates, while the opposite was true for the double crop planting. The increased height and lack of lodging, as well as the greater yield associated with the indeterminates when double cropped, supports the theoretical advantage of indeterminates over determinates for double cropping.

A comparison of correlation coefficients showed that the determinate and indeterminate lines acted differently when planted either full-season or double cropped. The determinates in the 11 June planting at Warsaw showed yield to have a significant positive correlation with maturity (r=0.44), mature height (r=0.42), and mid-season height (r=0.41) and a negative correlation with plot rating (r=-0.31) and seed size (r=-0.42). This differs from the indeterminates in the same planting which showed no significant correlations among these traits. At the double crop planting, the determinate yields had a significant positive correlation only with seed size (r=0.37) and negative correlations with maturity (r=-0.33), plot rating (r=-0.54), and lodging (r=-0.52). Indeterminate yields were negatively correlated with mature (r=-0.42) and mid-season height (r=-0.35), plot rating (r=-0.48), and lodging (r=-0.53). These correlations, although significant, are not very high.

Spearman's rank correlation coefficient of 0.23 for yield at the early vs. late plantings at Warsaw indicates that high yielding lines in the early planting may not be the best yielding ones in the later planting. There was less of a change in rank of the best yielding indeterminate vs. determinate lines when comparing the two plantings. This was also true for the indeterminate checks, Williams and Crawford. Both determinate and indeterminate lines were among the top lines of the 8 July planting at Warsaw indicating that good lines of either plant type can be selected for adaptation to double cropping and that environmental adaptation might be a greater determinant of double crop performance than is plant type.

The data also indicated that the higher yielding plant type was a function of the genetic background of each cross. In 1981, the indeterminates of both Essex x S63-5328S and Essex x V73-23 were significantly higher yielding than the determinates at both Warsaw plantings. However in the other two crosses, the determinates were significantly higher in the first planting with no difference in type evident in the second planting. Selection of adapted indeterminate or determinate lines for double cropping appears feasible and the data indicate that indeterminates may be more adaptable to double cropping due to their reduced lodging with greater height as compared to the determinate lines. Further evaluation of these lines will help to determine the effect of other environments on the observed effects.

LITERATURE CITED

Beaver, J. S. and R. L. Cooper. 1977. Comparison of morphological and physiological traits of two determinate and two indeterminate strains of soybeans (Glycine max (L.) Merr.). Agron. Abstr. p.49.

Bernard, R. L. 1972. Two genes affecting stem termination in soybeans. Crop Sci. 12:235-239.

Bhagsari, A. S., D. A. Ashley, R. H. Brown, and H. R. Boerma. 1977. Leaf photosynthetic characteristic of determinate soybean cultivars. Crop Sci. 17:929-932.

Boerma, H. R. 1979. Breeding soybeans for double cropping. p. 57-62. In Proc. Eighth Soybean Seed Res. Conf. 1978. Amer. Seed Trade Assoc. No. 8.

Camper, H. M., Jr., C. F. Genter, and K. E. Loope. 1972. Double cropping following winter barley harvest in eastern Virginia. Agron. J. 64:1-3.

Carter, T. E. and H. R. Boerma. 1979. Implications of genotype x planting date and row spacing interactions in double-cropped soybean cultivar developed. Crop Sci. 19:607-610.

Caviness, C. E. and P. E. Smith. 1959. Effect of different dates and rates of planting soybeans. Ark. AES Report Series 88.

Chan, L. M., R. R. Johnson, and C. M. Brown. 1980. Relay intercropping soybeans into winter wheat and spring oats. Agron. J. 72:35-39.

Coffman, B. 1978. New double crop varieties show promise. Soybean Digest 390:25S.

Constable, G. A. 1977. Effect of planting date on soybeans in the Namoi Valley, New South Wales. Aust. J. Expt. Agric. An. Husb. 17:148-155.

Cooper, R. L. 1981. Development of short-statured soybean cultivars. Crop Sci. 21:127-131.

Crabtree R. L. and R. N. Rupp. 1980. Double and monocropped wheat and soybeans under different tillage and row spacings. Agron. J. 80:445-448.

Egli, D. B. and J. E. Leggett. 1973. Dry matter accumulation patterns in determinate and indeterminate soybeans. Crop Sci. 13:220-222.

Fehr, W. R. and C. E. Caviness. 1977. Stages of soybean development. Iowa State University Special Report 80.

Fehr, W. R., J. S. Burris, and D. F. Gilman. 1973. Soybean emergence under field conditions. Agron. J. 65:740-742.

Fehr, W. R., C. E. Caviness, D. T Burwood, and J. S. Pennington. 1971. Stage of development descriptions for soybeans, Glycine max (L.) Merrill. Crop Sci. 11:929-931.

Fehr, W. R., C. E. Caviness, and J. J. Vorst. 1977. Response of indeterminate and determinate soybean cultivars to defoliation and half-plant cut-off. Crop Sci. 17:913-917.

Fehr, W. R., B. K. Lawrence, and T. A. Thompson. 1981. Critical stages of development for defoliation of soybean. Crop Sci. 21:259-262.

Flack, E. A. 1976. Evaluation of characteristics for the development of late-planted soybean cultivar. M. S. Thesis. Univ. GA., Athens, GA.

Graves, C. R., J. R. Overton, and H. Morgan. 1976. Effect of date of planting on soybean varieties in 1974. Tenn. Farm Home Sci. Prog. Rept. 97:32-34.

Graves, C. R., J. R. Overton, and H. Morgan. 1978. Soybean - variety - date of planting study from 1974-76. Tenn. AES Bull. 582.

Graves, C. R., J. R. Overton, H. Morgan, and L. N. Skold. 1972. Soybean variety date of planting study. Tenn. AES Bull. 496.

Green, D. E., P. F. Burlamaqui, and R. Shibles. 1977. Performance of randomly selected soybean lines with semideterminate and indeterminate growth habits. Crop Sci. 17:335-339.

Hartung, R. C., J. E. Specht, and J. H. Williams. 1980. Agronomic performance of selected soybean morphological variants in irrigation culture with two row spacings. Crop Sci. 20:604-609.

Hartung, R. C., J. E. Specht, and J. H. Williams. 1981. Modification of soybean plant architecture by genes for stem growth habit and maturity. Crop Sci. 21:51-56.

Hartwig, E. E. and C. J. Edwards, Jr. 1970. Effects of morphological characteristics upon seed yield in soybeans. Agron. J. 62:64-65.

Harvey, C. and R. D. Brigham. 1971. Response of soybeans to planting date - Southern high plains of Texas. Publ., Texas AES No. MP994.

Hicks, D. R., J. W. Pendleton, R. L. Bernard. and T. J. Johnson. 1969. Response of soybean plant types to planting patterns. Agron. J. 61:290-293.

Lantican, R. M. 1977. Observations and theories on cultivar resistance of soybeans to rust. p.54-57. In R. E. Ford and J. B Sinclair (eds.) Rust of soybean - The problem and research needs. Report of workshop held in Manila, the Philippines, Feb. 28 - March 4, 1977. INTSOY Series No. 12.

McKibben, G. E. and M. G. Oldham. 1973. Double cropping soybeans in small grain stubble. Ill. Res. 15:10-11.

Peters, L. N., C. O. Qualset, and F. F. Bell. 1971. Soybean varieties for double cropping. Tenn. Farm Home Sci. Prog. Rept. 78:12-15.

Pyle, M. E. 1979. Methods of selecting and evaluating soybeans for adaptation to double cropping in Virginia. M. S. Thesis, VPI&SU, Blacksburg, VA.

Rogers, H. T., D. L. Thurlow, and G. A Buchanan. 1971. Cropping systems and other cultural practices. AES Auburn Univ. Bull. 413:31-38.

Sanford, J. O., D. L. Myhre, and N. C. Merwine, 1973. Double cropping systems involving no-tillage and conventional tillage. Agron. J. 65:978-982.

SAS User's Guide. 1979. SAS Institute Inc., Raleigh, NC.

Shannon, J. G., J. R. Wilcox, and A. H. Probst. 1971. Response of soybean genotypes to spacing in hill-plots. Crop Sci. 11:38-40.

Shilling, T. T. 1979. A comparison of determinate and indeterminate soybeans at five planting dates. M. S. Thesis. Univ. of GA.

Sij, J. W. and G. M. Dornhoff. 1973. Response of soybeans to planting dates and seeding rate in the Texas gulf coast. Texas AES PR-3247.

Singh, B. P. and E. N. Whitson. 1976. Evapotranspiration and water use efficiency by soybean lines differing in growth habit. Agron. J. 68:834-835.

Smith, T. J., H. M. Camper, M. T. Carter, G. D. Jones, and M. W. Alexander. 1961. Soybean performance in Virginia as affected by variety and planting date. VA AES Bull. 526.

Sumarno and W. R. Fehr. 1980. Intergenotypic competition between determinate and indeterminate soybean cultivars in blends and alternate rows. Crop Sci. 20:251-254.

Thseng, F.-S. (Tseng, F. S.) and Sadaji Hosokawa. 1972. Significance of growth habit in soybean breeding. I. Varietal differences in characteristics of growth habit. Ikushugaku Zasshi 22:261-268.

Thseng, F.-S. and M.-S. Lee. 1976. Significance of growth habit in soyabean breeding. 7. Determinate vs. indeterminate types in growth and their bearing on yield potential. (a) Autumn crop season. J. Agric. Assoc. China 94:37-46. Field Crop Abstr. 30, 7623.

Wilcox, J. R. 1980. Comparative performance of semideterminate and indeterminate soybean lines. Crop Sci. 20:277-280.

Williams, C. and J. G. Marshall. 1976. Planting dates for soybeans in central Louisiana. LA AES Bull. 692.

The vita has been removed from the scanned document

A COMPARISON OF DETERMINATE AND INDETERMINATE SOYBEAN LINES FOR DOUBLE CROPPING IN VIRGINIA

by

Marjorie Elizabeth Pyle

(ABSTRACT)

Forty lines, 20 determinate and 20 indeterminate, from four soybean (Glycine max L. Merrill) crosses were evaluated under full-season and double cropping conditions to compare the performance of the two plant types under both cropping systems. The parents and selected lines were in the range of Maturity Groups IV and V. In 1980, the lines were planted 1 July in a replicated test at Warsaw, VA while in 1981 these lines were planted in three replicated tests on 11 June and 8 July at Warsaw and on 12 June at Orange, VA. Both June plantings were considered full-season. Standard cultivars in 1980 included 'Essex', 'Williams', and 'Crawford'. 'Bay' and 'Will' were added in 1981.

Yields were similar in 1980 for both plant types with the determinates yielding 10.1 q/ha and the indeterminates yielding 9.9 q/ha. In 1981, the yields were similar for both types at Orange with the determinates and

indeterminates yielding 26.4 and 26.5 q/ha, respectively. The types were significantly different in the 11 June planting at Warsaw, with yields of 28.6 and 28.0 q/ha for the determinate and indeterminate lines, respectively. The opposite was observed for the 8 July planting in which the indeterminates yielded 21.2 q/ha and the determinates yielded 20.8 q/ha.

A comparison of the two determinate and indeterminate lines with the highest yields in both 1981 Warsaw plantings showed that indeterminates were more adaptable to double cropping, though high yielding lines of both types were present. The high yielding indeterminates of the 8 July planting had a tendency to be taller and more erect than the determinates, an attribute desirable for double cropping. Lines that were highest yielding in the 11 June planting were ranked lower in the 8 July planting and vice versa. Spearman's rank correlation for yield in the two Warsaw plantings had a coefficient of 0.23, indicating a high degree of specific adaptation to the two environments.

Selection of better adapted lines for double cropping appears feasible. The indeterminate trait appears to make some contributions to this adaptation.