

Chapter I

Introduction and Review of Literature

Weed Control in Soybean

Weeds compete with soybean for moisture, light, nutrients and space. Weeds hamper operation of equipment, harbor crop pests such as insects and diseases, and contaminate harvested grain with foreign matter and weed seeds (Lembi and Ross 1999). Some weeds produce and release allelochemicals that adversely affect crop plants. Losses in both yield and quality of crops due to weeds, as well as costs of weed control, constitute an enormous economic problem in all agricultural areas. It has been estimated that Virginia soybean growers lost an average of 1.8 million dollars per year in 1989, 1990 and 1991 due to yield reductions from weed infestation (Anderson and Bridges 1992).

Non-chemical and chemical methods have been used to control weeds in soybean. In the early 1960's, herbicides became more important in weed control programs, although these herbicides performed best when used in addition to good cultural practices rather than as the sole means of control (Wax 1973). After 1965, the use of herbicides in soybean increased markedly (McWhorter and Barrentine 1966; Wax and McWhorter 1968). In the early 1970s, more than 30 herbicides were used on soybean in the United States (Wax 1973). A 1999 survey of herbicide application on soybean in 17 states, which represented 92% of total U. S. acres, indicated that 96% of this soybean acreage was treated with herbicides (USDA-NASS 2000).

Herbicides are integral components of modern full-season and double-crop soybean production systems. Herbicide selection is based on the ability of the product to control important weeds without causing significant injury to the crop. Although the margin of crop safety varies among soybean products on the market, it has generally been accepted that these products will not impact soybean yield potential when used according to label instructions and during favorable environmental conditions. However, increasing numbers of persons are beginning to question the validity of this assumption. Several factors are responsible for these concerns, including changes in herbicide use patterns, the introduction of herbicide resistant

crops that may have the potential to eliminate injury concerns and the growing popularity of yield monitors which provide an easy means to make yield comparisons (Hartzler 1996).

Virginia Soybean Production

Soybean is Virginia's second largest cash crop (approximately \$75-100 million annually) and is produced on approximately 200,000 hectares (Anonymous 2001). Approximately 60% of the crop is planted double-crop behind small grain and the rest of the crop is planted in a full-season system similar to that used in the mid-western United States. The double-crop system has allowed Virginia farmers to be competitive with the rest of the nation and the world, partially due to the continued improvement of intensively managed small grain yields (D. L. Holshouser, personal communication). However, soybean yields have remained relatively fixed. Improvements in the productivity and profitability of the entire cropping systems, not just the small grain crop, should be the consequence of these intensively managed systems. Smith and Circle (1980) found that total soybean seed yield can be increased by applying proper production techniques with respect to environmental factors such as temperature, photoperiod and precipitation patterns.

Double-cropping soybean after small grain offers several advantages for Virginia soybean producers. In this system, a cool-season small grain, such as wheat or barley, is planted from early October to mid-November, often following a corn crop. The small grain crop matures throughout the winter and spring and is harvested in June. Soybean is then no-till planted as soon as possible directly into the small grain residue. A crop growing on the land all year provides control of soil erosion. Spreading annual fixed costs such as land, taxes and machinery over two crops instead of one may increase gross returns per acre with relatively low increases in production costs (Minor and Wiebold 1998). Thus profits per acre may be increased. Keisling et al. (1995) conducted a 4-yr study in Mississippi to determine the profit potential of wheat-soybean double-crop systems. Yields of soybean from all monocrop and double-crop systems were similar with yields ranging from 1625 to 2029 kilograms per hectare. Net returns from the wheat-soybean double-crop system were the largest, ranging from \$287 to \$376 per hectare. Net returns of the continuous no-till and conventional soybean systems averaged \$117 and \$160 per

hectare, respectively. Because soybean yields from these systems were similar, the higher net returns to each double-crop system were attributed to income generated by the wheat crop.

A traditional rotation for Virginia soybean producers is no-till corn, conventional-till small grain and no-till double-crop soybean utilizing three crops in 2 yrs (Holshouser 2001). This rotation has proven to be very sustainable and profitable throughout Virginia. Another rotation often practiced in Virginia consists of no-till corn, no-till full-season soybean, no-till small grain and no-till double-crop soybean utilizing four crops in 3 yrs. In this rotation, soybean is the most important crop and will likely determine long-term profitability. Incorporating cotton into the aforementioned rotations would reduce disease potential in small grain and provide more crop diversification. However, late cotton harvests can delay small grain planting and cotton production in Virginia is currently limited due to growing season requirements. Regardless of the rotation, the importance of double-crop soybean is evident. Double-cropping becomes more important as these systems intensify. A very intense rotation currently being researched consists of no-till barley, no-till double-crop corn, no-till wheat and no-till double-crop soybean utilizing four crops in 2 yrs. This type of rotation has shown potential in some situations; however, difficulties getting all crops planted on time and increased labor and equipment requirements make this system difficult to sustain for growers. In these intensive systems, soybean must mature early and be harvested in a timely manner so small grain yields are not affected by late planting. Therefore, early-maturing soybean may play important roles in the success of these intensified cropping systems.

Soybean Maturity and Development

Soybean plants are sensitive to day length, but not all plants respond the same way (Ritchie et al. 1994). Some cultivars flower under relatively short days while others flower under longer days. Cultivars of soybean are adapted to a narrow band of latitude and this zone of adaptation is identified by number. Maturity groups ranging from 00 to VIII have been established in the United States based upon the adaptability of a soybean variety to effectively utilize the growing season in a given region. The narrow adaptation zone of soybean is due primarily to dependence on day length (photoperiod). Phytochrome, which is a photoreceptor in

soybean, responds to changes in red to far-red light (R:FR ratio) and induces a photoperiod response (Song 1984). Phytochrome exists in two forms, P_r and P_{fr} . The red-absorbing form of the photoreceptor is reversibly activated by light to the far-red absorbing form. This physiologically active far-red-absorbing form triggers flowering in soybean.

Soybean varieties representing maturity group 00 flower under relatively long days and can be grown in the northernmost region of the United States, which consists of northern Minnesota and North Dakota (Ritchie et al. 1994). Soybean varieties representing maturity group VIII flower under short days and can be grown in the southernmost region of the United States, which includes Florida and the southern parts of the Gulf Coast states. During summer, day length increases from south to north. In the north, southern-adapted cultivars mature slowly because of the long days. In the south, northern-adapted cultivars respond to the shorter days and mature earlier than is optimum for obtaining maximum yields.

Most varieties in groups 00 to IV display the indeterminate growth habit, and varieties in groups V to VIII are mostly of the determinate growth habit. Determinate growth habit of soybean is characterized by near cessation of main stem growth at the onset of flowering, a pronounced terminal raceme, and substantially fewer main stem nodes than the indeterminate growth habit (Bernard 1972). Indeterminate growth habit is characterized by continued main stem growth into the reproductive period, producing a longer stem with more internodes than determinate types.

Soybean maturity groups III through VI can be grown successfully in Virginia (Holshouser 2001). When planted in May, group III soybean varieties will mature in September while group VI varieties will mature in early November, which is typical of full-season soybean. Planting an early maturing variety in Virginia, such as group III, can spread economic risk by crop diversification (Burton et al. 1990), increase income because of higher soybean prices prior to traditional harvest dates (Casey et al. 1998), distribute the work load, and result in an early harvest that would allow timely field operations for planting a fall cereal crop. Late season drought stress may also be avoided with early maturing soybean varieties because the grain development period occurs earlier in the season. Any drought stress during the grain

development period can reduce yields (Eck et al. 1987). Planting of early maturing soybean offers several advantages for Virginia producers; however, maturity occurs during the more humid months which often results in decreased seed quality caused by the growth of *Phomopsis* fungi on the pod and seed (Mayhew and Caviness 1994). Maturity group IV and V soybean varieties are the most popular choice for Virginia growers. Maximum long-term yields at most locations in Virginia are usually obtained by growing these varieties. Group IV and V soybean varieties effectively utilize Virginia's entire growing season and seed development coincides with periods of optimum rainfall. Planting maturity group IV and V soybean varieties also allows timely harvest and efficient machinery use.

Double-crop soybean are usually planted later than is optimum for highest yields and selecting a variety of proper maturity is even more critical than it is in full-season plantings. Double-crop soybean encounter a shorter photoperiod than May plantings, resulting in reduced plant height, branch development, days to flowering, seed fill period, and days to maturity (Board and Hall 1984; Board 1985; Dunphy et al. 1979). Yields of determinate soybean are often lowered from late plantings because of reductions in branch number, fertile node number, pod number and seed number per plant (Board 1985; Board and Settini 1986; Boquet 1982). Because the detrimental effects of late planting are often expressed as a reduction in individual plant yield components (Board 1985; Board and Settini 1986), any temporary suppression in plant growth due to additional stresses, such as herbicide injury, insect damage or dry weather, may cause additional yield reductions. An early maturing variety planted late will usually produce very short stalks which will be low yielding and difficult to harvest. Late maturing varieties remain vegetative for a longer period before flowering compared to early maturing varieties and therefore produce more nodes where pods can form. This extended vegetative growth periods results in greater yield potential per plant and longer periods of growth to potentially recover from any crop damage that may occur during early growth stages. Early maturing varieties fill pods earlier in the season compared to full-season varieties. The decreased amount of time between planting and flowering in early maturing varieties limits the opportunity for recovery from stress due to herbicide injury, insect damage or dry weather in these systems.

Soybean Leaf Area Index

Soybean yield is dependent on a large number of variables including weather, soil, fertility, genotype and physiology. Once soybean is planted, several of these variables are set and yield will primarily be the result of the physiology of the crop interacting with the weather. Photosynthesis has long been assumed to be one of the key physiological processes in regards to soybean productivity (Christy and Williamson 1985). Early work by Christy et al. (1976, 1979) reported that soybean grain yield is strongly dependent on seasonal photosynthesis. In these studies, yield was related to the total amount of photosynthesis carried on by the crop during the growing season. Schulze (1978) compared canopy photosynthesis and yield in a number of soybean cultivars from four maturity groups. He reported that yield was a function of canopy photosynthesis during bean fill and that yield increases with longer bean fill duration. This longer bean fill duration may be expected to lead to increased seasonal photosynthesis, and these results would be consistent with the findings of Christy et al. (1976, 1979). Contradicting Schulz's work, Christy and Williamson (1985) reported that the strong relationship between seasonal canopy photosynthesis and yield reported earlier does not hold when comparing cultivars of soybean. The efficiency of converting photosynthate into yield (photosynthetic conversion efficiency (PCE) may be the reason for these different results. PCE, which represents a combination of physiological and biochemical processes that contribute to yield, is both a measure of photosynthate partitioning and an indicator of the efficiency of the crop to convert photosynthesis into yield. It is computed by dividing yield by estimated seasonal photosynthesis. Since the PCE differed for the six cultivars of soybean used, no apparent relationship between photosynthesis and yield was found. Therefore, yield is strongly dependent on seasonal photosynthesis for individual soybean cultivars but when comparing cultivars, differences in their PCE are important in determining the relationship of photosynthesis to their yields.

Christy and Williamson (1985) showed that canopy photosynthetic rates increase as leaf area develops, reach a peak around flowering and early pod fill, and decline during the later stages of pod filling. The maximum rate of canopy photosynthesis occurs when at least 95% of the incoming solar radiation (L_{95}) is intercepted by the canopy (Westgate 1999). At this point, the crop should theoretically achieve canopy closure, maximum canopy photosynthesis for the

developmental stage and maximum yield for the environmental conditions present. Early work by Shibles and Weber (1965) in Iowa found that a leaf area index (LAI), which is the ratio of unit leaf area of the crop to unit land area, of 3.2 was required to achieve L₉₅. It is currently accepted that a LAI of 3.5 to 4.0 correlates with L₉₅ and is also a dependable measure of yield potential (Westgate 1999; Board and Harville 1992).

Row spacing and population studies show that the earlier in the season 'critical' LAI is achieved, the earlier canopy fixation rates attain their maximum values for the given variety and environmental conditions. Christy and Porter (1982) found that soybean canopy formed by equidistant-spacing achieved the highest rates of photosynthesis early in the season and maintained them throughout flowering and pod filling. Two intermediate spacings had lower rates of canopy photosynthesis during most of flowering and pod set. The widest spacing never produced sufficient leaf area to maximize canopy photosynthesis. These studies confirm that rapid canopy development is essential for maximum photosynthetic potential later in the season. When considered over the entire growing season, the advantage of early canopy closure for maximizing canopy photosynthesis is obvious.

In order to approach maximum yield, soybean require a minimum LAI of 3.5 to 4.0. In Louisiana, Board and Harville (1992) found that soybean planted in May invariably reached optimal LAI; however, LAI was always sub-optimum with July planting dates. The effect of late compared with optimal planting was to shorten developmental periods, which resulted in decreased LAI. In Virginia, non-stressed full-season soybean can easily produce a LAI of 4.0 or greater (Holshouser 2001). Because of this extra foliage, it is easy to understand why a minimal loss in leaf area due to herbicide damage or insect defoliation does not affect yield. However, many double-crop systems may not always achieve this minimal soybean leaf area of 3.5. Therefore, any decline in leaf area may result in a direct yield loss.

Soybean Injury Due To Herbicides and The Effect on Yield

An unwanted crop response can result from the application of any chemical. Since herbicides are selected for their ability to kill plants, they typically have a greater potential to

cause damage to soybean than other materials, such as fertilizers or insecticides (Hartzler 2000). Herbicide selectivity is, in many cases, based primarily on the differential ability of plant species to metabolically detoxify the herbicide (Lamoureux et al. 1991; Cole 1994). Any condition that stresses the crop, such as temperature and moisture extremes, can reduce a crop's tolerance to a herbicide (Hartzler 2000). Crops under stress are often more susceptible due to changes in herbicide absorption and metabolism rates. Stressed crops may have less energy reserves available to drive the enzymatic systems that metabolize herbicides and, therefore, the ability to completely detoxify these compounds may be reduced. Photosynthesis creates numerous highly reactive compounds that are injurious to plants, and the production of these compounds increases when the plant is under stress (Alscher and Hess 1993). Plants have several defense mechanisms to limit damage from these phytotoxic compounds. The same defense systems that protect plant cells from toxic chemicals produced by photosynthesis also detoxify many herbicides (Hartzler 2000). Detoxification systems of plants may be overwhelmed by the combination of stress-induced compounds and herbicides resulting in high concentrations of toxins capable of causing crop injury.

Soybean herbicides exhibit several different modes of action that can result in a variety of injury symptoms. 2,4-DB is a phenoxy acid applied postemergence (POST) that derives its herbicidal properties by conversion to the active herbicide 2,4-D by plant enzymes (Ashton et al. 1981). Beta oxidation is the primary mechanism by which this conversion occurs. Injury symptoms often appear as crinkling and/or slight cupping of soybean leaves. Herbicides from the diphenyl ether family, such as fomesafen, acifluorfen and lactofen, interfere with protoporphyrinogen IX oxidase synthesis and cause accumulation of protoporphyrin IX (Duke et al. 1991). Protoporphyrin IX is a potent photosensitizer that generates high levels of singlet oxygen in the presence of molecular oxygen and light, leading to light-induced oxidative breakdown of cell constituents. Diphenyl ethers are usually applied POST and soybean injury is expressed by bronzing and crinkling or spotting of leaves and plant growth is often temporarily reduced when these herbicides are used (Harris et al. 1991). Sulfentrazone, which is a triazolinone, also interferes with protoporphyrinogen IX oxidase; however, it is used mainly as a preemergence (PRE) herbicide (Lembi and Ross 1999). Imidazolinone, sulfonyleurea and triazolopyrimidine sulfonanilide herbicides inhibit acetolactate synthase (ALS) which is essential

for leucine, valine, and isoleucine synthesis (Stidham and Singh 1991). Imidazolinone herbicides, such as imazamox, imazaquin and imazethapyr are applied PRE or POST (Beardmore et al. 1991; Bhalla et al. 1991; Hart et al. 1991). Under adverse growing conditions, such as cool, wet, weather; growth and development can slow or stop, resulting in soybean height reductions. POST applications can cause chlorosis or crinkling of the upper leaves. Injury symptoms of soybean treated with sulfonyleurea herbicides such as chlorimuron and thifensulfuron include chlorosis, necrosis, vein discoloration and terminal bud death in severe cases (Anonymous 1998). Asymmetrical-triazines, such as metribuzin, and benzothiadiazoles, such as bentazon, work by inhibiting photosynthesis in susceptible plants. Metribuzin injury in soybean can result in reduced stands or necrosis to lower leaves and eventual leaf loss (Hagood et al. 1980). Bentazon injury is sometimes reflected as slight discoloration (necrosis or chlorosis) only on soybean leaves contacted by the spray (Ahrens 1994). The potential for and significance of soybean injury from these herbicides is dependent upon many factors including the type and rate of herbicide applied, timing of application and environmental conditions before, during and after application (Hartzler 1996).

The effect of herbicide injury on soybean yield varies greatly. Several studies indicate that soybean completely recover from early season herbicide injury and no yield reductions occur, while other studies show some yield reductions due to herbicide injury. In many instances, weed competition makes it difficult to determine how much of the yield loss can be attributed to herbicide toxicity. Because of this, numerous studies have been conducted under weed-free conditions to eliminate the competitive effects of weeds.

Hagood et al. (1980) evaluated injury and yield effects of several PRE herbicides on soybean in Indiana under weed-free conditions. The recommended rates of these herbicides did not cause soybean yield reductions, however, applications exceeding recommended rates resulted in soybean yield reductions in some years. In situations where soybean yield was reduced, soybean stand reductions and decreased vigor were observed. Because of this, it was determined that yield response is a function of the degree and persistence of crop vigor reduction in reduced stands of soybean plants.

Kapusta et al. (1986) evaluated injury and yield effects of several commonly used POST herbicide treatments, such as bentazon (1.1 kg/ha), acifluorfen (0.6 kg/ha) and bentazon (0.8 kg/ha) plus 2,4-DB (0.01 kg/ha), on indeterminate soybean under weed-free conditions over a four-year period in Illinois. At seven days after treatment (DAT), significant soybean injury resulted from these treatments each year. However, within 14 DAT soybean injury had decreased greatly and new foliage showed no injury symptoms. The rate of recovery varied each year and was largely dependent on the amount of rainfall and resulting soybean vigor. No treatment reduced soybean yield in three out of four years, but reductions in yield occurred in 1980 with bentazon plus 2,4-DB. Drought conditions added stress to the soybean in 1980, and recovery from herbicide injury was not as rapid or complete compared to the other years. Increased susceptibility to herbicide injury was the result of this extra stress. Harris et al. (1991) conducted a similar study in South Carolina to determine the effect of acifluorfen, fomesafen and lactofen on foliar injury and seed yields of determinate soybean when seeded at post-optimal dates. Previous studies indicated that determinate soybean seed yields are lower from late than early plantings because of reductions in individual plant yield components (Board 1985; Board and Settimi 1986; Boquet 1982). Harris et al. (1991) thought that any temporary suppression in plant growth due to herbicides may cause additional yield reductions. They found that visual soybean injury at 9 DAT from the highest application rate were 29, 22, and 9%, respectively, for lactofen, acifluorfen, and fomesafen, which corresponds to responses noted in other studies (Aison et al. 1984, Higgins et al. 1988, Kapusta et al. 1986). However, soybean seed yields were not reduced by any of the herbicide treatments. Similar to what Kapusta et al. (1986) observed with indeterminate full-season grown soybean, determinate soybean seeded at post-optimal dates have the ability to recover from early-season injury and seed yields are not affected under favorable conditions.

It is generally accepted that full season soybean have ample time to recover completely from early-season herbicide injury and no yield losses occur. However, growers continue to show concern regarding the ability of double-cropped soybean to recover. Delayed planting dates in double-crop soybean systems reduce the time for plants to complete vegetative growth before beginning the seed production process. Therefore, double-crop soybean may be limited in their ability to recover from herbicide injury. Grabau et al. (1990) conducted a study in

Kentucky to determine if yields of double-crop soybean are reduced by leaf burn due to the use of acifluorfen. Maturity group IV soybean was planted in 1986, 1987 and 1988 at dates representing full-season and double-crop soybean production systems used in Kentucky. They found that acifluorfen caused significant injury to soybean regardless of rate in both the double-crop and full-season systems. However, yield was only reduced in the 1988 double-crop study when acifluorfen was applied at twice the recommended rate. In 1988, double-crop planting was delayed because of severe drought and, therefore, soybean had even less time to recover from herbicide injury.

Some research has also been conducted to determine the effects of herbicide injury on soybean canopy reduction and its correlation with yield. Barker et al. (1984) indicated that soybean yields were reduced by 2,4-DB at 0.14 and 0.28 kg/ha regardless of planting date and application time. In these tests, measurements of canopy area were a better predictor of yield than visual injury ratings 2 weeks after treatment (WAT). Results indicated a near-perfect correlation between canopy area at bloom and soybean yield. Sherman (1981) found similar results and also indicated that difference in soybean canopy area at bloom was a good predictor of yield. Harvey (1995) conducted a three-year field study in Wisconsin to identify methods to predict soybean yield loss from herbicide injury. Herbicides, such as bentazon, chlorimuron, lactofen, acifluorfen plus bentazon, thifensulfuron, imazethapyr, and fomesafen, were applied at both normal and double rates at the V2 growth stage to insure that some injury occurred. It was assumed that injury from double herbicide rates in a normal year would have similar effects on soybean yield as normal use rates under adverse environmental conditions, which increase soybean susceptibility. Visual injury ratings and soybean canopy reduction measurements were taken throughout the season. The overall level of yield loss differed between the three years of the study due to environmental conditions. Results demonstrated that in two of the three years, injury from POST herbicides caused soybean yield losses. A linear relationship occurred between percent visual herbicide injury or canopy reduction and percent soybean yield loss.

Many stress factors can individually cause sufficient injury to reduce soybean growth and yield; more frequently, however, multiple stresses affect soybean productivity (Browde et al. 1994). In situations where soybean yield reductions result from herbicide treatments, other

factors, such as dry weather or limiting growing seasons, are often present and result in greater soybean susceptibility. Herbicide injury usually appears as stunting, chlorosis, necrosis and/or stand reduction in soybean. Regardless of the injury symptom, reductions in soybean LAI and delays in canopy development can result from herbicide injury. In Virginia, non-stressed full-season soybean can easily produce a LAI of 4.5 or greater. Because of this extra foliage, it is understandable why a minimal loss in leaf area due to herbicide damage does not affect yield. However, many double-crop systems do not achieve this minimal soybean leaf area of 3.5. Therefore, any decline in leaf area may result in a direct yield loss.

Early maturing soybean varieties may also increase the likelihood of yield reductions due to herbicide injury. Early maturing varieties fill pods earlier in the season compared to full-season varieties. The decreased amount of time between planting and flowering in early maturing varieties limits the opportunity to recover from early season herbicide injury in these systems. Late maturing varieties remain vegetative for a longer period before flowering compared to early maturing varieties and therefore produce more nodes where pods can form. This extended vegetative growth period results in greater yield potential per plant and longer periods of growth to potentially recover from any crop damage that may occur during early growth stages.

Glyphosate-tolerant Soybean

The availability of glyphosate-tolerant soybean has made an impact on soybean weed control. A gene encoding a glyphosate insensitive enzyme, 5-enolpyruvyl-shikimate-3-phosphate synthase (EPSPS) was identified and introduced into the soybean crop through genetic engineering (Padgett et al. 1995). Upon glyphosate treatment, the glyphosate-tolerant soybean remains little affected because the continued action of the introduced glyphosate insensitive enzyme, EPSPS, meets the plant's need for the aromatic amino acids (Padgett et al. 1995). Glyphosate used as a postemergence herbicide provides excellent weed control (Delannay et al. 1995; Freed and Nykaza 1995; Gonzini et al. 1995; McNamara et al. 1995) and has not injured soybean significantly (Padgett et al. 1995).

Although glyphosate-tolerant soybean are not totally immune to glyphosate, they generally have a larger margin of safety than typically found with traditional selective herbicides used in soybean and potential risks associated with herbicide injury are reduced (Hartzler 1996). However, the resistance gene in glyphosate-tolerant soybean does not protect the crop from stress of other herbicides used on soybean. Previous research has shown that a single application of glyphosate made to soybean does not control some weed species for the entire growing season (Gonzini et al. 1999). This is due to a lack of soil residual activity with glyphosate, which allows weeds to emerge after herbicide applications have been made. In addition, some weed species, including velvetleaf and ivyleaf morningglory, exhibit some tolerance to glyphosate at larger growth stages (Krausz et al. 1996). For this reason, additional herbicides are sometimes required to provide broad-spectrum weed control in glyphosate-tolerant soybean. Concerns have been expressed about the potential for injury from other POST herbicide treatments to result in yield reduction when applied to glyphosate-tolerant soybean.

Research Objectives

Growers have partially compensated for reduced soybean yields in double-crop systems by narrowing row spacing and increasing plant populations, which in turn, increases LAI, but a more complete understanding of how soybean canopy levels affect yield is needed. As a result, objectives of this research were to:

1. Investigate potential for crop injury by various herbicide-based weed control systems in full-season and double-crop soybean using maturity group III, IV and V varieties
2. Determine if methods of weed management need to be modified so that yield reductions due to reduced soybean leaf area are no longer a problem in Virginia
3. To investigate the relationship between soybean maturity, planting date and herbicide treatment on LAI and soybean yield

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