Agronomic and Economic Comparison of Full-Season and Double-Cropped Small Grain and Soybean Systems in the Mid-Atlantic USA

by

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ABSTRACT

Increased demand for barley has changed the proportion of crops grown in Virginia and the Mid-Atlantic USA. Winter wheat is the predominant small grain crop, but barley can be a direct substitute, although much less of it is grown. Soybean is grown full-season and double-cropped after both small grains. Historically, wheat was the primary small grain in the soybean double-crop rotation because of its greater profitability. The barley-soybean cropping system is not a new concept in the region, but the literature is outdated. New agronomic and economic data that directly compares full-season soybean, barley-soybean, and wheat-soybean systems using modern cultivars and management practices is needed. The objectives of this research were to: i) determine soybean yield and compare cropping system profitability of the three cropping systems; ii) perform a breakeven sensitivity analysis of the three cropping systems; and iii) determine the effect of planting date and previous winter crop on soybean yield and yield components. Soybean grown after barley yielded more than full-season soybean in two of six locations and more than soybean double-cropped after wheat in three of six locations. Net returns for the barley-soybean system were the greatest. These data indicate that soybean double-cropped after barley has the potential to yield equal to or greater than full-season soybean or double-cropped soybean following wheat, but its relative yield is very dependent on growing conditions. The profitability comparison indicated that the barley-soybean cropping system was generally more profitable than the full-season soybean and double-cropped wheat-soybean systems. This conclusion was supported by the breakeven sensitivity analysis, but remains dependent on prices that have been extremely volatile in recent years. In another study, soybean

yields declined with planting date at two of four locations in 2009, a year that late-season rainfall enabled later-planted soybean to yield more than expected. In 2010, soybean yield decline was affected by the delay in planting date at both locations. Winter grain did not affect soybean yield in either year. Yield component data reinforced these results and indicated that the lower seed yield in the later planting dates was due primarily to a decrease in the number of pods.

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Sine quibus non.

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Chapter 1 – Introduction and Justification

Appomattox Bio Energy, owned by Osage Bio Energy, built a barley-based ethanol plant in eastern Virginia, near Hopewell. The company purchases barley (*Hordeum vulgare* L.) grown regionally for use at this plant. Anecdotal evidence suggests barley hectarage has increased due to the ethanol plant, substituting for land allocated for wheat (*Triticum aestivum* L.) or replacing land allocated for full-season soybean [*Glycine max* (L.) Merr.]. Winter wheat is the predominant small grain crop grown in the Mid-Atlantic USA (, Delaware, Maryland, New Jersey, North Carolina, and Pennsylvania, Virginia). Barley can be a direct substitute for wheat, but much less of it is grown. Soybean is grown full-season (May-planted) and double-cropped after both small grains (Table 1.1) (National Agricultural Statistics Service, 2011). The Commonwealth of Virginia follows similar trends, with much more wheat grown than barley, but grows proportionally more double-cropped soybean than the rest of the Mid-Atlantic. Historically, wheat was the primary small grain in the soybean double-crop rotation because of its greater profitability. That is, net returns over costs were greater for the wheat-soybean rotation than for the barley-soybean rotation. Little current information is available comparing the profitability of barley-soybean, wheat-soybean, and full-season soybean cropping systems.

The literature is replete with evidence that wheat-soybean double-cropped systems can generate higher net returns than full-season soybean (Crabtree and Rupp, 1980; Farno et al., 2002; Kelley, 2003; Kyei-Boahen and Zhang, 2006; Sanford, 1982; Sanford et al., 1986; Wesley, 1999; Wesley and Cooke, 1988; Wesley et al., 1994, Wesley et al., 1991; Wesley et al., 1995). There are fewer reports of the opposite. In certain situations, irrigated full-season soybean brought greater returns than non-irrigated double-cropped soybean in the mid-South (Wesley and

Cooke, 1988; Wesley et al., 1994; Wesley et al., 1995). In higher latitudes with shorter growing seasons, full-season systems provided greater returns than double-cropped systems (Moomaw and Powell, 1990). These scenarios should be reanalyzed using updated prices and input costs.

Other double-crop systems aside from wheat-soybean have been studied as well. In Oklahoma and Iowa, sorghum [*Sorghum bicolor* (L.) Moench] was successfully double-cropped after wheat and triticale, respectively (Crabtree et al., 1990, Goff et al., 2010). In Mississippi, grain sorghum as well as sunflower (*Helianthus annuus* L.) planted after wheat was successfully grown, but were not as profitable as wheat-soybean in an irrigated environment (Sanford et al., 1973; Sanford et al., 1986, Wesley et al., 1994). In a non-irrigated environment, a rotation that included grain sorghum had returns greater than \$60 ha^{-1} more than traditional cropping systems (Wesley et al., 1995).

Less research is available regarding double-cropping soybean with barley. Double-crop soybean has been successful when harvested after barley and oats (*Avena sativa* L.) grown as spring forage in the upper Midwest (Kaplan and Brinkman, 1984; LeMahieu and Brinkman, 1990). Research conducted from 1972 to 1975 in Kentucky found that soybean following barley yielded similarly to full-season soybean (Herbek and Bitzer, 1998). In Virginia, soybean, grain sorghum, and corn (*Zea mays* L.) were all profitable when double-cropped after barley harvested for grain (Camper et al., 1972). Groover et al. (1989) concluded that a grain farm in eastern Virginia should include a barley-soybean rotation to maximize income at varying levels of risk. However, these conclusions need to be reanalyzed using today's prices and input costs.

While a wheat-soybean double-crop system may generate more net returns than full-season soybean, the seed yield of full-season soybean is typically greater relative to the soybean double-cropped after wheat (Caviness and Collins, 1985; Kelley, 2003; Kyei-Boahen and Zhang, 2006; Sanford et al., 1986; Wesley, 1999; Wesley and Cooke, 1988; Wesley et al., 1988; Wesley et al., 1991; Wesley et al., 1994). Soybean planting date influences yield significantly. In general, the agronomic yield potential is lowered as planting date is delayed (Bastidas et al., 2008; Beatty et al., 1982; Chen and Wiatrak, 2010; De Bruin and Pedersen, 2008; Oplinger and Philbrook, 1992). Egli and Cornelius (2009) summarized fifty years of planting date research and concluded that the yield remains fairly constant in May, but declined 1 to 1.2% daily after June 7th in the Upper South, and 1.1 to 1.3% daily after May 27th in the Deep South. Other research in Ohio indicated that soybean planted after wheat harvest may lose up to 470 kg ha^{-1} per week after June 15th (Beuerlein, 2001; Jeffers et al., 1973).

Full-season soybean is usually planted in May and double-cropped soybean in late June to early July after wheat harvest. Barley is harvested in early June, two to three weeks before wheat. For growers with large hectarage, wheat harvest and soybean planting may extend well into July. If a farmer substitutes barley for only the portion of the wheat crop that may be harvested in early July, soybean normally planted during this time would now be planted a full month earlier. The aforementioned Kentucky research indicated that wheat-soybean yielded nearly nine bushels per acre less than full-season soybean, while the barley-soybean had less than one-bushel difference (Herbek and Bitzer, 1998). In eastern Virginia, farm-level data used by Groover et al. (1989) found that soybean following wheat yielded about the same up to 336 kg ha^{-1} more than full-season soybean, while the barley-soybean yielded 269 to 806 kg ha^{-1} more than full-season soybean.

The goal of this research was to develop new information about the agronomic and economic benefits of a barley-soybean double-cropping system using field experiments and updated enterprise budgets. Three cropping systems were compared: full-season soybean, double-cropped wheat-soybean, and double-cropped barley-soybean. The objectives of this study were to:

(1) Determine soybean yield and compare cropping system profitability of the three cropping systems.

(2) Perform a breakeven sensitivity analysis of the three cropping systems.

(3) Determine the effect of planting date and previous winter crop on soybean yield and yield components.

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Table 1.1. Hectarage comparisons† of small grain and soybean in Virginia and the Mid-Atlantic‡.

	Virginia		Mid-Atlantic	
Crop	2009	2010	2009	2010
	Planted all purposes (1,000 ha)			
Barley	27	30	94	89
Wheat	101	73	597	447
Soybean	235	227	1453	1368

† SOURCE: National Agricultural Statistics Service, 2011.

‡ Mid-Atlantic states include: Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, and Virginia.

Chapter 2 – Yield and Profitability Comparisons of Full-Season Soybean, Double-Cropped Wheat-Soybean, and Double-Cropped Barley-Soybean Systems

ABSTRACT

Full-season soybean and double-cropped soybean [*Glycine max* (L.) Merr.] after wheat (*Triticum aestivum* L.) are the predominant soybean cropping systems in the Mid-Atlantic USA. Double-cropping soybean after barley (*Hordeum vulgare* L.) presents an additional option, but new agronomic and economic data directly comparing barley-soybean with wheat-soybean and full-season soybean systems using updated prices, costs, and management practices are needed. Field studies were conducted to compare yield and net returns from a double-cropped barley-soybean system with double-cropped wheat-soybean and full-season soybean systems. Soybean grown after barley yielded 629 and 1458 kg ha^{-1} more than full-season soybean grown after a rye cover crop in two of six locations and 462, 680, and 955 kg ha^{-1} more than soybean double-cropped after wheat in three of six locations. Wheat yields ranged from 1448 to 4463 kg ha^{-1} across all locations and years, and contributed 37-56% of the total gross returns for the double-cropped wheat-soybean system. Barley yields ranged from 3820 to 6766 kg ha^{-1} across all locations and years, and contributed 30-52% or 26-47% of the total gross returns for the double-cropped barley-soybean system, depending on the barley price estimation method. Two barley pricing strategies were used in the profitability comparison. Using the first strategy, net returns for the barley-soybean system were greater than full-season soybean at three of four locations in 2009, averaging \$234 to 620 ha^{-1}, and greater than double-cropped wheat-soybean at three of four locations, averaging \$234 to 506 ha^{-1}. The barley-soybean cropping system at the second barley pricing strategy had net returns greater than the full-season soybean grown after rye at

every location, averaging \$95 to 757 ha^{-1}, and greater than the double-cropped wheat-soybean system in three of four locations, averaging \$364 to 634 ha^{-1}. In 2010, the double-cropped barley-soybean system net returns using the first barley pricing strategy were not different from the full-season soybean or double-cropped wheat-soybean systems averaged across locations. At the second barley pricing strategy, the double-cropped barley-soybean system net returns were \$108 and 130 ha^{-1} greater than the full-season rye-soybean and double-cropped wheat-soybean systems, respectively. These data indicate that soybean double-cropped after barley has the potential to yield equal to or greater than full-season soybean or double-cropped soybean following wheat, but performance is dependent on rainfall amount and distribution. The profitability analysis indicated that the barley-soybean cropping system could be more profitable than either the full-season soybean or double-cropped wheat-soybean systems.

INTRODUCTION

Full-season and double-cropped small grain-soybean are common soybean cropping systems in the Mid-Atlantic USA (National Agricultural Statistics Service, 2011). Full-season soybean is usually planted in May and is the only crop grown during that calendar year. The wheat-soybean double-cropping system includes planting winter wheat in October through November, harvesting that crop at the end of June, and planting soybean immediately following wheat harvest. A barley-soybean double-cropping system includes planting barley in October, followed by barley harvest and soybean planting in early June. Barley harvest occurs two to three weeks before wheat. The longer soybean growing season after barley has the potential to increase soybean yield and system profitability.

It is well documented that full-season soybean yields more than double-cropped soybean after wheat (LeMahieu and Brinkman, 1990; Sanford et al., 1986; Wesley et al., 1994; Wesley et al., 1995). At the same time, the double-crop wheat-soybean rotation as a whole is more profitable than full-season soybean alone, shown most recently in Kansas (Kelley, 2003) and Mississippi (Kyei-Boahen and Zhang, 2006; Wesley, 1999). Little research has been conducted with soybean grown after barley.

LeMahieu and Brinkman (1990) conducted a study where full-season soybean was compared with several double-crop soybean rotations grown after small grain in the Upper Midwest, including winter wheat and spring barley grown as forage crops. Full-season soybean had the greatest yield, but the double-cropped barley-soybean and wheat-soybean rotations were more profitable. The wheat-soybean double-cropped system was more profitable than the barley-soybean double-cropped system, but soybean following barley yielded equally to soybean following wheat. In a 1972-75 research project conducted in Kentucky, Herbek and Bitzer

(1998) found that soybean grown after barley did not yield significantly less than full-season soybean. Double-cropped wheat-soybean was not included in that study. In Virginia, Camper et al. (1972) found that a barley-soybean double-crop system was viable and profitable, but it was not compared to either full-season soybean or double-crop wheat-soybean. Groover et al. (1989) compared the risk of several crop rotations, and concluded that an eastern Virginia grain farm should include a double-crop barley-soybean rotation. This 1989 Virginia study used historical yield records, but did not include any yield trials. New agronomic and economic data directly comparing barley-soybean with wheat-soybean and full-season soybean systems are needed.

We hypothesize soybean double-cropped after barley yields less than full-season soybean but greater than soybean double-cropped after wheat, and that a barley-soybean cropping system can be more profitable than either full-season soybean or double-cropped wheat-soybean, depending on yields and prices. We assumed that barley planted in October would be harvested two to three weeks earlier than wheat planted in November, thereby lengthening the double-crop soybean growing season and providing for greater soybean yield, which would contribute to the total system profitability. The objectives of this study were to (i) compare the yields of double-crop barley-soybean with yields of full-season soybean and double-crop wheat-soybean, and (ii) compare the net returns from all the cropping systems.

MATERIALS AND METHODS

Experiments were conducted from fall 2008 through fall 2009 at the Eastern Virginia Agricultural Research and Extension Center (EVAREC) near Warsaw on a Kempsville loam (fine-loamy, siliceous, subactive, thermic typic hapludults), the Southern Piedmont Agricultural Research and Extension Center (SPAREC) near Blackstone on an Appling fine sandy loam (fine, kaolinitic, thermic typic kanhapludults), and two sites at the Tidewater Agricultural Research and Extension Center (TAREC1 and TAREC2) near Suffolk, Virginia. A Eunola loamy fine sand (fine-loamy, siliceous, semiactive, thermic aquic hapludults) and a Rains fine sandy loam (fine-loamy, siliceous, semiactive, thermic, typic paleaquults) (tile-drained) represented the soils at TAREC1 and TAREC2, respectively. Experiments were repeated from fall 2009 through fall 2010, but drought and poor emergence and growth during the 2010 growing season prevented accurate data collection at EVAREC and SPAREC. A Nansemond loamy fine sand (coarse-loamy, siliceous, subactive, thermic aquic hapludults) and a Dragston fine sandy loam (coarse-loamy, mixed, semiactive, thermic aeric endoaquults) (tile-drained) represented the soils at TAREC3 and TAREC4, respectively. The soil yield potentials for all sites are shown in Table 2.1.

Experimental design for both growing seasons was a randomized complete block with four replications. In 2008-2009, plots were the small grain crops rye (as a cover crop), barley, and wheat (Table 2.2). Soybean was grown full-season after killed rye and double-cropped after harvested barley and wheat. In 2009-2010, plots were the same, but an additional full-season fallow-soybean plot was added due to grower interest. The initial planting dates for full-season soybean were in May, while the initial planting dates for double-cropped soybean followed small grain harvest (Table 2.3).

The barley and wheat cultivars at all locations were Thoroughbred (Virginia Crop Improvement Association, Richmond, VA) and SS520 (Southern States Cooperative, Richmond, VA), respectively. Thoroughbred is a late-maturing winter barley cultivar, while SS520 is an early-maturing, soft red winter wheat cultivar. Although SS520 yields less than later-maturing wheat cultivars, it was used so that soybean following wheat could be planted as early as possible, a practice that Virginia farmers follow to minimize the effect of late planting date. Soybean cultivars and planting dates are shown in Table 2.3. Soybean cultivar 95Y70 (Pioneer Hi-Bred, Int'l, Johnson, IA) is a maturity group V and contains resistance to root knot nematode (*Melooidogyne* spp.), which was known to be present in low numbers at TAREC1 in 2009. AG4907 (Monsanto Co., St. Louis, MO) is a maturity group IV cultivar, and was used to facilitate earlier harvest on TAREC2 and TAREC4, fields that can become wet during November and inhibit timely harvest. Otherwise, AG4907 and AG5605 are both considered standard high-yielding cultivars at their respective locations.

Fields were fertilized with phosphate and potash according to soil tests. Nitrogen needs for small grains varied and were met with 25-35 kg ha^{-1} at planting followed by split applications based on tiller counts and tissue analysis (Alley et al., 2009a; Alley et al., 2009b). Soybean was no-till planted within three days of small grain harvest using a five-row plot planter in 2009 and a thirteen-row drill in 2010. Row spacing was 38 and 19 cm for the planter and drill, respectively. Soybean seeding rates gradually increased with planting date, based on the standard guidelines recommended by Virginia Cooperative Extension (Holshouser, 2010). In 2009, individual plots were 7.3 m long by 4.6, 5.5, 3.6, and 3.6 m wide at EVAREC, SPAREC, TAREC1, and TAREC2, respectively. In 2010, individual plots were 7.3 m long by 4.9 m wide. The land was disked and land-conditioned before small grain planting and soybean was planted no-till. In 2009, TAREC2 received 1.4 and 0.67 kg ha^{-1} of manganese and sulfur, respectively, in mid-July to correct visual manganese deficiency. In 2010, TAREC3 and TAREC4 received 0.13 and .054 kg ha^{-1} of manganese and sulfur, respectively, in mid-July. Standard pesticides were applied to control weeds, insects, and diseases for all crops, per Virginia Cooperative Extension recommendations (Herbert and Hagood, 2011). TAREC1 was irrigated once in 2009

(15 July) with 50 mm and TAREC3 was irrigated twice in 2010 (1 and 20 July), with 25 mm on each occasion. Small grain and soybean were harvested with a plot combine equipped with a weigh bucket and moisture sensor. Yields were adjusted to 130 g kg^{-1} moisture content.

Profitability was calculated to determine the net returns over variable and fixed production costs for all cropping systems using the Virginia Enterprise Budget System Generator (Eberly, 2010). Variable costs included seed, fertilizer, pesticides, applications, equipment maintenance and repair, labor, crop insurance, operating loan interest, and hauling; fixed costs included general overhead and yearly equipment ownership costs (Appendix A). Total costs did not include storage, drying, scouting, or land costs. Five-year average (2006-2010) Virginia commodity prices were used for soybean, barley, and wheat in the budgets (National Agricultural Statistics Service, 2011). An additional barley price was calculated as 80% of five-year average Chicago Mercantile Exchange July corn future prices for January 2006-December 2010 (*FutureSource*, 2011). The second barley price was based on the pricing mechanism of Osage Bio Energy, a relatively new company that is purchasing barley for ethanol production in eastern Virginia. Prices used to calculate gross income were \$0.354, \$0.176, \$0.122, and \$0.153 kg^{-1} for soybean, wheat, barley (Virginia price), and barley (Osage price), respectively (Appendix B). Gross income was calculated by multiplying yield by the five-year average price. Net returns over total costs were calculated by subtracting total costs from the gross income.

Yield and net returns were subjected to analysis of variance using PROC GLM (SAS Institute, 2008). Years were analyzed separately because of the additional full-season fallow-soybean plots in 2010. Location and cropping system were considered fixed factors, while blocks were considered random. Least square means of the fixed effects were calculated and separated using the PDIFF statement at $P = 0.05$.

RESULTS AND DISCUSSION

Yield Comparison

In 2009, only brief periods without rainfall were experienced and precipitation generally increased as the season progressed, resulting in better than average growth for the double-crop soybean systems (Fig. 2.1). In 2010, soybean experienced one of the hottest and driest growing seasons of the last century. TAREC3 was irrigated (25 mm) twice during the worst of the drought. These were emergency irrigations to salvage the experiment, without which there may have been no appreciable soybean yield. TAREC4 could not be irrigated, but the Dragston soil at this site had greater water holding capacity. At TAREC, rainfall during the summer months of June, July, and August totaled 295 mm in 2009 compared to 99 mm in 2010. Temperatures were also much hotter in 2010 than 2009, frequently reaching or exceeding 40°C. At the end of the 2010 growing season, soybean plots received 324 mm of rainfall in one week from the end of September to the start of October.

There were cropping system and location differences and a cropping system by location interaction for small grain yield in 2009 (Table 2.4). In 2010, cropping system and location differences remained, but there was no interaction. Barley yielded more than wheat at all locations except for TAREC1 and TAREC2 (Table 2.5). Barley yields ranged from 3820 to 6766 kg ha^{-1} across all locations and years (Table 2.5). This is generally in keeping with Virginia's 2006-2010 average yield of 4021 kg ha^{-1}, although in all cases except EVAREC yields were below the corresponding soil yield potential (Table 2.1) (National Agricultural Statistics Service, 2011). Wheat yields ranged from 1448 to 4463 kg ha^{-1} across all locations and years (Table 2.5). All but two locations were less than Virginia's 2006-2010 average yield of 4193 kg ha^{-1} (National Agricultural Statistics Service, 2011). At all locations the yields were less than the soil yield potential (Table 2.1). Wheat at SPAREC yielded far below anticipated yield, but could be attributed to very poor stands. Other yield differences could be due to variations in rainfall and/or soil types between the different locations.

In 2009, barley was harvested during the first week of June at all TAREC locations and the second week of June at EVAREC and SPAREC. Wheat at TAREC1 and TAREC2 matured during the first and second weeks of June, respectively, which is unusually early, due to warm and dry weather. Wheat was harvested during the fourth week of June at EVAREC and SPAREC. In 2010, barley was harvested during the first week of June at TAREC3 and TAREC4. Wheat matured in mid-June and was harvested during the third week of June at both TAREC locations. All double-cropped soybean was planted the same day as small grain harvest, except for soybean planted after wheat at TAREC1 in 2009, which was planted later to represent a more typical double-crop soybean growing season (Table 2.3). Full-season soybean matured in mid-October followed soon after by harvest. Double-crop soybean matured in late-October and was harvested by late-November.

Analysis of variance of 2009 soybean data revealed cropping system, location, and cropping system by location interactions (Table 2.4). Therefore, yield data for 2009 are separated by location and cropping system. Analysis of variance of 2010 soybean data revealed location differences, but no cropping system or cropping system by location interaction (Table 2.4).

In 2009, double-crop soybean following barley yielded equal to full-season soybean at EVAREC and SPAREC, but 1629 and 1458 kg ha^{-1} greater at TAREC1 and TAREC2, respectively. Soybean planted after barley yielded 462 to 955 kg ha^{-1} greater than soybean planted after wheat at three of four locations (Table 2.5). Soybean following wheat yielded 826 and 326 kg ha^{-1} less than full-season soybean at SPAREC and TAREC1, respectively, and 1218 kg ha^{-1} greater at TAREC2. As previously stated, soybean yield did not differ between cropping systems in 2010 (Table 2.5).

These data appear to validate the Kentucky study where soybean yielded as much following barley as full-season soybean (Herbek and Bitzer, 1998). In our study, soybean planted after barley never yielded less than full-season soybean, but soybean yields following wheat need to be taken into account. Soybean double-cropped after wheat yielded less than full-season soybean only twice in these experiments, and yielded greater than full-season soybean once. Usually, soybean grown after wheat yields far less than full-season soybean (LeMaheiu and Brinkman, 1990; Sanford et al., 1986; Wesley, 1999).

The unexpected yields can be explained primarily by the weather patterns experienced during both growing seasons (Fig. 2.1). Long-term average rainfall is approximately 100 mm per month at all locations, but varies greatly between years. If rainfall was evenly dispersed through the growing season, differences in yield due to planting date would be solely a result of shortening of the vegetative growth period, which leads to less leaf area and to a lesser extent a shortening of the reproductive growth period, which in turn translates into less pods, seed, or seed weight. However, greater rainfall during the vegetative stages, even when the length of those stages is shortened, could lead to similar or even greater amounts of leaf area for later plantings. Furthermore, greater late-season rainfall during pod and seed filling may overcome differences in vegetative growth; therefore yield could potentially, although not usually, be greater with later planting dates. For example, at EVAREC in 2009, full-season soybean received 88, 140, 78, 220, and 74 mm of rainfall 30 days before, and 0 to 30, 30 to 60, 60 to 90, and 90 to 120 days after planting, respectively (Fig. 2.1). The first 60 days after planting represented vegetative development stages, the next 30 days represented development stages R1 (beginning flower) through R5 (beginning seed fill), and the last 30 days represented R5 though R7 (physiological maturity). Compared to soybean following barley, 108, 66, 142, 138, and 115 mm of rainfall were received during those stages. While both full-season soybean and double-crop soybean following barley received similar and adequate rainfall during the season, more rainfall was distributed during seed filling for the double-crop soybean. Therefore, yield was greater with soybean following barley. As planting date was delayed until late June, the first 60 days represented the vegetative stages through R4 (late pod development), the next 30 days represented R4 through early R6 (full seed), and the next 30 days represented R6 through R8 (full maturity). For soybean following wheat, rainfall was 138, 25, 236, 111, and 111 mm in the 30 days before, and 0 to 30, 30 to 60, 60 to 90, and 90 to 120 days after planting, respectively. Although rainfall was greater during pod and seed fill for the double-crop soybean following wheat, less vegetative growth due to a shortened vegetative growth period likely resulted in less yield than soybean following barley. On the other hand, this greater amount of rainfall during pod and seed fill resulted in a yield equal to full-season soybean.

At SPAREC, 260 mm of rainfall fell in the first two months after full-season soybean planting, and 198 and 136 mm of rain fell in the first two months after planting soybean following barley or wheat, respectively (Fig. 2.1). The timing of the rainfall at SPAREC clearly favored early plantings. Vegetative growth was greater with full-season soybean than soybean planted after barley, which was greater than soybean planted after wheat. It was also relatively dry during August and much of September until just over 25 mm fell later in the month. During much of this time the soybean was in the R4-R6 stages, when the yield is most susceptible to drought; hence the lower yields at this location.

Rainfall in 2009 at Suffolk favored later-planted soybean. At TAREC1 and TAREC2, full-season soybean received only two rain events greater than 10 mm in the first 69 days after planting (Fig. 2.1). This lack of rainfall stunted growth at both locations. TAREC1 was irrigated 55 days after planting, relieving visible stress occurring at that time. In contrast, 55 mm of rainfall was received within two days after barley-soybean planting and another 64 mm was received approximately 45 days after planting, resulting in better growth than the full-season planting. By the time soybean was planted after wheat, consistent rainfall resumed through maturity of all planting dates. The timely rainfall during pod and seed development resulted in very good soybean yields in all cropping systems except for the full-season planting at TAREC2, which did not benefit from the irrigation that TAREC1 received. Although rainfall was adequate during the most critical development times, lack of vegetative growth likely caused the lower yields at that location.

In 2010, full-season soybean, double-crop soybean following barley, and double-crop soybean following wheat received only 121, 55, and 70 mm of rainfall, respectively, in the first two months after soybean was planted (Fig. 2.1). Even so, soybean yield did not differ among cropping systems. Most of the rainfall that fell on the full-season soybean came early in the year. What little rainfall was received over the summer fell in August. The irrigation in July for TAREC3 allowed those later plantings to emerge and likely contributed to greater yields. Still, yields at TAREC3 were less than TAREC4, which was a more productive soil. There was little visible difference in growth between plantings by mid-August at either location. Late September rain may have helped the double-crop soybean, but the full-season soybean had already matured.

Future research should repeat these comparisons to establish long-term yield trends. The data presented in this paper would be greatly influenced by a different growing season. Our data shows soybean following barley has the potential to out-yield either full-season soybean or soybean following wheat, but is very dependent on growing conditions. Although the weather in both years was atypical, it can be concluded that soybean double-cropped after barley is agronomically competitive with established Mid-Atlantic soybean cropping systems.

Profitability Comparison

The least squares mean production costs of the double-cropped barley-soybean (\$1200 ha^{-1}) and wheat-soybean (\$1261 ha^{-1}) systems were greater than both the full-season rye-soybean (\$703 ha^{-1}) and fallow-soybean (\$596 ha^{-1}) systems (Appendix A). This was expected because of the additional seed, fertilizer, and pesticide expenses incurred by the barley and wheat crops. The rye-soybean system expenses were greater than the fallow-soybean system due to the costs of planting and killing the rye cover crop. Production costs for the wheat-soybean system were greater than the barley-soybean system primarily because of higher wheat seed cost. Production cost differences between locations varied slightly according to differences in site-specific fertilizer and herbicide applications. Analysis of variance of 2009 data revealed cropping system, location, and cropping system by location interaction effects (Table 2.6). Therefore, net returns data for 2009 are separated by location and cropping system (Table 2.7). Analysis of variance of 2010 data also revealed location and cropping system differences, and a marginally significant cropping system by location interaction ($p = 0.0752$) (Table 2.6). Therefore, 2010 net returns data are also presented separately for each location and cropping system, but discussed as cropping system and location least squares means (Table 2.7).

The net returns for the double-cropped barley-soybean system at average Virginia prices ranged from \$(72) to 976 ha^{-1}, with an average return of \$440 ha^{-1} (Table 2.7). The net returns for the double-cropped barley-soybean system at Osage Bio Energy prices ranged from \$23 to 1181 ha^{-1} (Table 2.7), with an average return of \$579 ha^{-1}. The double-cropped wheat-soybean system net returns ranged from \$(525) to 674 ha^{-1} (Table 2.7), with an average return of \$255 ha^{-1}. The full-season rye-soybean system net returns ranged from \$(15) to 525 ha^{-1} (Table 2.7) with an average return of \$207 ha^{-1}, while the full-season fallow-soybean system had an average return of \$176 ha^{-1} on the two TAREC locations in 2010.

In both years, the barley-soybean system at Osage Bio Energy prices had the greatest net returns at every location, although returns were not always significantly different (Table 2.7). In 2009, the barley-soybean system net returns at average Virginia prices were less than the barley-soybean system net returns at Osage Bio Energy prices at three of four locations, but greater than or equal to the net returns from the full-season rye-soybean and double-crop wheat-soybean systems at every location. The full-season rye-soybean had lower net returns than the Osage Bio Energy barley-soybean system at every location, and the double-crop wheat-soybean system was lower than the Osage Bio Energy barley-soybean system at three of four locations. In 2010, TAREC4 had greater net returns than TAREC3 across cropping systems. The Osage Bio Energy barley-soybean system net returns were greater than every other cropping system except full-season fallow-soybean across locations (Table 2.7).

Our data indicate that an average of 43% of the wheat-soybean system total returns was due to wheat: 39, 43, 37, and 39% at EVAREC, SPAREC, TAREC1, and TAREC2, respectively in 2009, and 56 and 41% at TAREC3 and TAREC4, respectively in 2010. In a Mississippi study, Kyei-Boahen and Zhang (2006) reported an average of 68% of the returns of a wheat-soybean double-crop system were due to wheat in 2001, 2002, and 2004. The average wheat yield reported by the authors was 5170 kg ha^{-1} compared to our average yield of 3386 kg ha^{-1}. In addition, the percentage of net returns contributed by wheat in a wheat-soybean double-crop system has been less over the last several years due to greater soybean prices. In the Mississippi study, soybean prices averaged \$.192 kg^{-1} over the three years compared to Virginia's 2006-2010 average price of \$.354 kg^{-1}. At statewide Virginia barley prices, an average of 37% of the barley-soybean system total net returns was due to barley: 37, 47, 26, and 29% at EVAREC, SPAREC, TAREC1, and TAREC2, respectively in 2009, and 45 and 36% at TAREC3 and TAREC4, respectively in 2010. Our data show that at Osage Bio Energy barley prices, an average of 42% of the barley-soybean system total net returns was due to barley: 42, 52, 30, and 34% at EVAREC, SPAREC, TAREC1, and TAREC2, respectively in 2009, and 50 and 45% at TAREC3 and TAREC4, respectively in 2010.

Future research should repeat these comparisons to further establish yield trends. The net returns data presented might change significantly with different yields, and therefore a different growing season. Our data shows the barley-soybean double-cropped system as being generally more profitable than either the full-season soybean or wheat-soybean double-cropped systems. These conclusions need to be taken in context with the volatile weather and commodity markets present during the time of this experiment. It is important to keep in mind that the prices used are long-term averages, and short-term management decisions might use spot prices that differ significantly. It will be interesting to see how additional research will compare with the results presented here.

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Table 2.1. Soil series and yield potential† for 2009 and 2010 experimental locations.

			Yield potential†			
Year	Location‡	Soil series	Corn	Barley	Wheat	Soybean (early / late)§
			-----------------kg ha ^{1}-----------------			
2009	EVAREC	Kempsville	8780	4730	4700	2690 / 2280
	SPAREC	Appling	7525	4730	4700	2350 / 1680
	TAREC1	Eunola	8150	4730	4700	2690 / 2280
	TAREC2	Rains (drained)	10660	4730	4700	3020 / 2280
2010	TAREC3	Nansemond¶	10030	6180	5375	2690 / 2280
	TAREC4	Dragston	10030	6180	5375	2690 / 2280

† All yield potentials based on VALUES, Virginia Agronomic Land Use Evaluation System (Simpson, 1993; Virginia Soil and Water Conservation, 2005).
‡ Location: Tidewater (TAREC), Eastern Virginia (EVAREC), and Southern Piedmont (SPAREC) Agricultural Research and Extension Centers.
§ Late season soybean assumed planted on or after 21 June.
¶ Yield potentials do not correspond to those experienced at the TAREC in numerous experiments. The Nansemond is a loamy find sand whose subsoil consists of sandy loam from 20 to 74 cm then becomes a loamy fine sand to 168 cm, where it changes to a sand. Yields in the City of Suffolk Soil Survey lists the soil as yielding 672 and 336 kg ha^{-1} less than a Dragston and similar to the Eunola. We think that this soil has less yield potential than any soil listed except for the Appling.

Table 2.2. Locations and small grain cultivars used at various planting dates for the 2008-2009 and 2009-2010 growing seasons.

		Planting date	
Year	Location†	Thoroughbred barley	SS520 wheat
2008-2009	EVAREC	15 Oct. 2008	12 Nov. 2008
	SPAREC	16 Oct. 2008	6 Nov. 2008
	TAREC1	14 Oct. 2008	3 Nov. 2008
	TAREC2	10 Oct. 2008	3 Nov. 2008
2009-2010	TAREC3	20 Nov. 2009	20 Nov. 2009
	TAREC4	23 Oct. 2009	23 Oct. 2009

† Location: Tidewater (TAREC), Eastern Virginia (EVAREC), and Southern Piedmont (SPAREC) Agricultural Research and Extension Centers.

Table 2.3. Locations, soybean cultivars, and planting dates for full-season and double-crop systems in 2009 and 2010.

			Planting date			
Year	Location†	Cultivars	FS-F‡	FS-R	DC-B	DC-W
2009	EVAREC	Asgrow AG4907	----	27 May	8 June	23 June
	SPAREC	Asgrow AG5605	----	21 May	9 June	22 June
	TAREC1	Pioneer 95Y70	----	21 May	4 June	17 June
	TAREC2	Asgrow AG4907	----	21 May	2 June	11 June
2010	TAREC3	Asgrow AG5605	21 May	21 May	3 June	17 June
	TAREC4	Asgrow AG4907	22 May	22 May	3 June	17 June

† Location: Tidewater (TAREC), Eastern Virginia (EVAREC), and Southern Piedmont (SPAREC) Agricultural Research and Extension Centers.
‡ FS-F, full season fallow-soybean (2010 only); FS-R, full season rye-soybean; DC-B, double-crop barley-soybean; DC-W, double-crop wheat-soybean.

Table 2.4. Analysis of variance for small grain and soybean yields in full-season and double-crop systems in 2009 and 2010.

	2009		2010	
Effect	Small grain	Soybean	Small grain	Soybean
		P value		
CS†	<0.0001	<0.0001	0.0012	0.6459
Location	<0.0001	<0.0001	0.0138	<0.0001
CS x Location	<0.0001	0.0001	0.1370	0.4575

† Cropping System.

Table 2.5. Barley, wheat, and soybean yields in four cropping systems in 2009 and 2010.

	Year						
	2009				2010		
Crop†	EVAREC‡	SPAREC	TAREC1	TAREC2	TAREC3	TAREC4	LS means
	------------------------kg ha^{-1}--------------------				---------------kg ha^{-1}-----------		
Small Grain							
Barley	6766a§	4220a	3987a	4515a	3820	4918	4369a
Wheat	4463b	1448b	3492a	4359a	3109	3442	3276b
LS means	----	----	----	----	3465b¶	4180a	
Soybean							
FS-F	NA††	NA	NA	NA	1648	2710	----
FS-R	3613ab	1822a	3536b	2158b	1818	2316	----
DC-B	3984a	1676a	4165a	3616a	1690	2630	----
DC-W	3522b	996b	3210c	3376a	1589	2467	----
LS means	----	----	----	----	1686‡‡	2593	

† FS-F, full season fallow-soybean (2010 only); FS-R, full season rye-soybean; DC-B, double-crop barley-soybean; DC-W, double-crop wheat-soybean.
‡ Location: Tidewater (TAREC), Eastern Virginia (EVAREC), and Southern Piedmont (SPAREC) Agricultural Research and Extension Centers.
§ Means within a column for a given location followed by the same letter are not significantly different at the 0.05 probability level using Fisher's protected least significant difference.
¶ Small grain yielded less at TAREC3 than at TAREC2 across cropping systems.
†† NA, not applicable.
‡‡ Soybean yielded less at TAREC1 than at TAREC2 across cropping systems.

Table 2.6. Analysis of variance for barley, wheat, and soybean net returns in full-season and double-crop systems in 2009 and 2010.

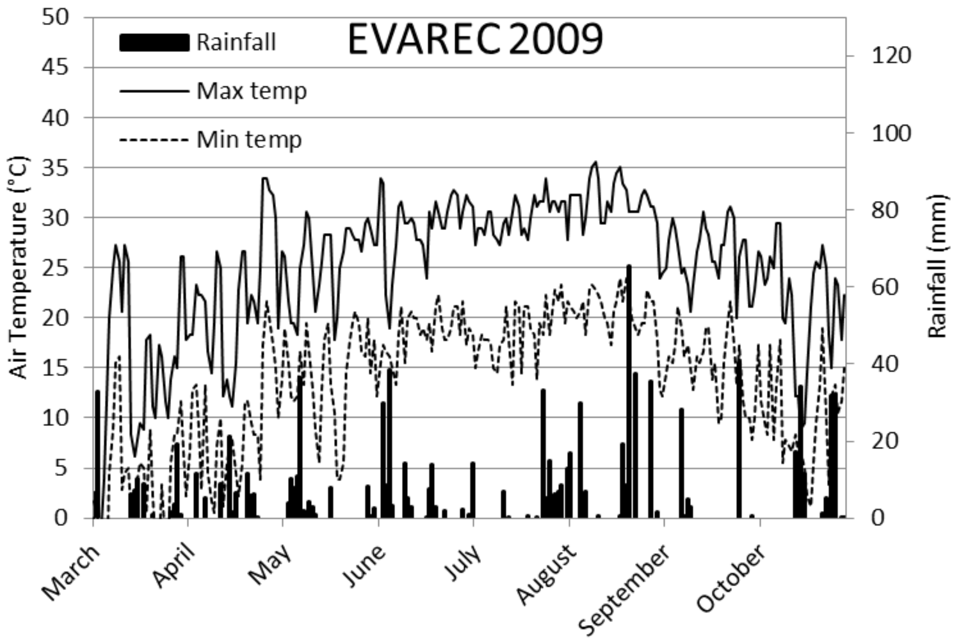
Effect	2009	2010
	P value	
Cropping System	<0.0001	0.0254
Location	<0.0001	<0.0001
Cropping System x Location	<0.0001	0.0752

Table 2.7. Net returns above production costs† in four cropping systems in 2009 and 2010.

Crop‡	Year						
	2009				2010		
	------------------------$ ha^{-1}--------------------				------------$ ha^{-1}-----------		
	EVAREC§	SPAREC	TAREC1¶	TAREC2	TAREC3	TAREC4	LS means
FS-F	NA#	NA	NA	NA	17	335	195ab
FS-R	523d††	14b	500c	87b	(15)	134	78c
B1 + DC	976b	(19)b	734b	707a	(72)	312	121bc
B2 + DC	1181a	109a	855a	844a	23	461	242a
W + DC	664c	(525)c	491c	674a	12	212	112bc
LS means	----	----	----	----	(7)‡‡	306	

† Net returns above production costs were calculated as the difference between gross income and variable and fixed costs (source: Eberly, 2010). Production costs did not include costs associated with land, scouting, storage, and drying. Gross income was calculated as the product of yield and five-year (2006-2010) average commodity prices: \$.354 kg^{-1} soybean, \$.176 kg^{-1} wheat, and two barley prices, \$.122 and .153 kg^{-1}. Soybean, wheat, and the first barley price were based on average Virginia prices, and the second barley price was based on 80% of Chicago Mercantile Exchange July corn futures prices (sources: National Agricultural Statistics Service, 2011; *FutureSource*, 2011).
‡ FS-F, full season fallow-soybean (2010 only); FS-R, full season rye-soybean;
B1 + DC, double-crop barley-soybean at average Virginia barley prices; B2 + DC, double-crop barley-soybean at average Osage Bio Energy barley prices; DC, double-crop wheat-soybean.
§ Location: Tidewater (TAREC), Eastern Virginia (EVAREC), and Southern Piedmont (SPAREC) Agricultural Research and Extension Centers.
¶ TAREC1 and TAREC3 production costs do not include irrigation expenses.
# NA, not applicable.
†† Means within a column for a given location followed by the same letter are not significantly different at the 0.05 probability level using Fisher's protected least significant difference.
‡‡ Net returns were less at TAREC3 than at TAREC4 across cropping systems.

Figure 2.1. Maximum and minimum temperatures and rainfall† at EVAREC, SPAREC, and TAREC in 2009, and TAREC in 2010.



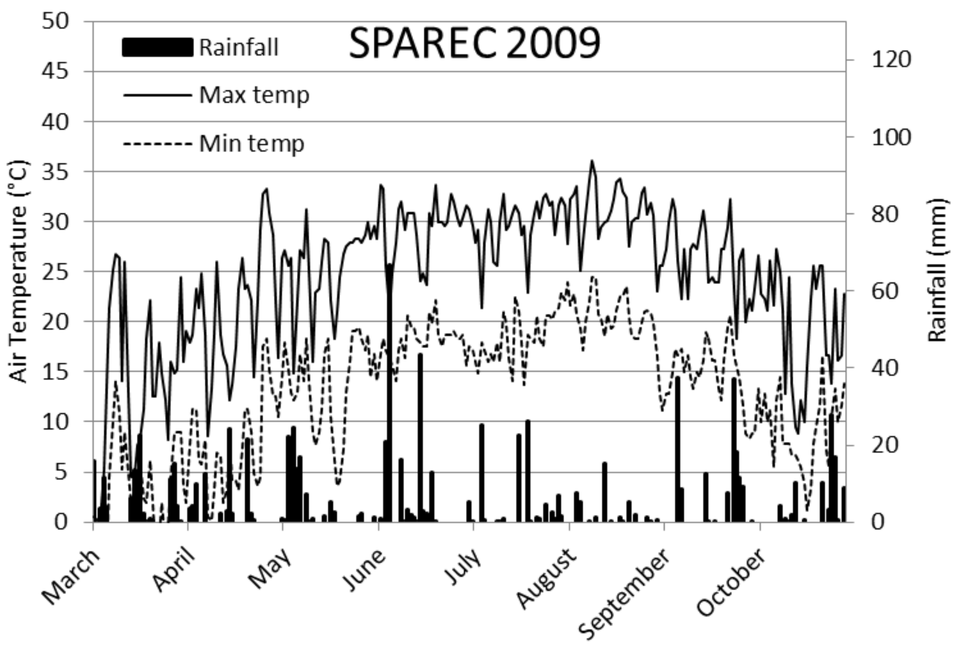
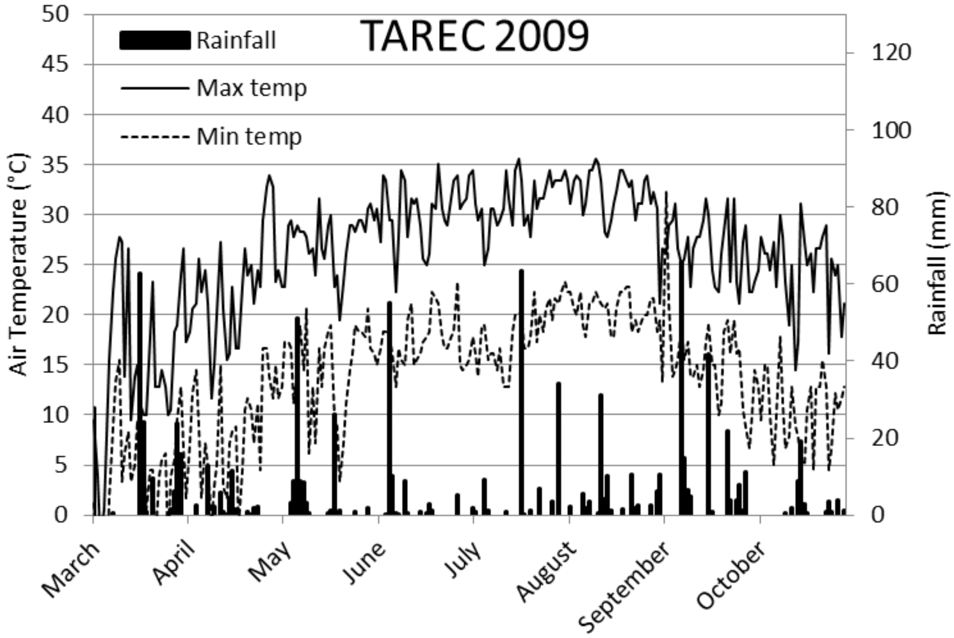
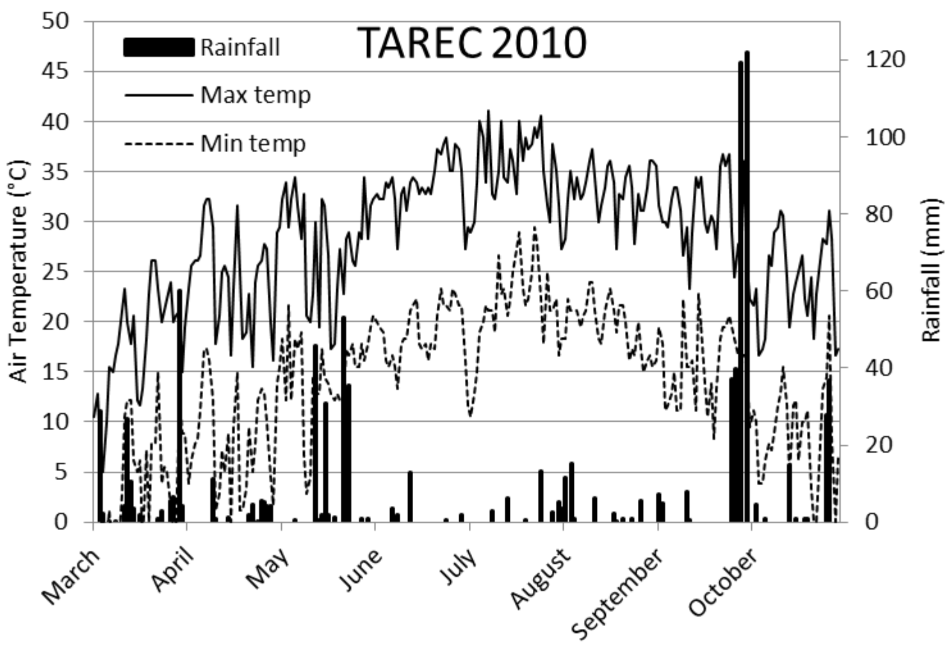


Fig. 4.3. Continued.





†TAREC rainfall does not include 50 mm of irrigation on 15 July 2009 and 25 mm on two occasions on 1 and 20 July 2010.

Chapter 3 – Breakeven Sensitivity Analysis of Full-Season and Double-Cropped Soybean Systems

Introduction

Full-season soybean and soybean grown after wheat are the predominant soybean cropping systems in the Mid-Atlantic. A barley-based ethanol plant recently built in Virginia is increasing demand for locally grown barley. Very little information is available comparing a barley-soybean system to either full-season soybean or wheat-soybean cropping systems. Virginia studies are outdated and new data is needed. This paper describes a model that can be used to determine breakeven prices among these different cropping systems. Double-cropped systems are generally more efficient than mono-cropped systems because some costs, such as lime, land rent, or machinery depreciation, which remain independent of cropping system, will be more spread out because of the increased crop production per acre. Production practices between the double-cropped wheat-soybean and double-cropped barley-soybean systems are assumed to be virtually the same and will require no additional equipment.

What does a breakeven number represent?

The breakeven number is the sales value at which one enterprise has net returns equal to another enterprise. This principle is universal across financial and business fields, and is applicable to many areas aside from agriculture. The specific comparisons addressed in this paper are all soybean rotations. First, it is assumed that the price is held constant for soybean double-cropped after barley or wheat. Once this assumption is made, a breakeven price can be calculated for wheat and barley. That is, the breakeven price per bushel needed for wheat so that the net returns from a wheat-soybean double-cropped system is equal to the net returns from a barley-soybean double-cropped system. Conversely, the price per bushel for barley can be calculated in the same manner. Breakeven prices can also be calculated for wheat or barley in a double-cropped system versus full-season soybean. If a farmer currently only grows full-season soybean, a comparison with either double-cropped system would be helpful when making a rotation decision.

Furthermore, the model can be used at any time of the year. This aspect would be useful when making management decisions in response to major changes in prices or yield during the growing season. For example, if the prices for a small grain decrease near harvest, a grower could determine if the net returns would be worth the cost of harvesting the small grain. Breakeven prices for corn (or any other crop) can also be calculated and compared to these or any other rotation using the principles outlined here. It is assumed that while there may be marginal acreage differences between crops planted on an annual basis, farmers will not plant all of their land with one crop; therefore, only soybean cropping systems are included in this model. Breakeven values can be calculated for any other factor as well, such as yield or a specific variable cost. For example, if yields for wheat or barley were anticipated to be poor, breakeven yields could be compared with the net returns from the full-season soybean to justify harvesting the small grain crop; however, only breakeven prices are included in this model.

How is this useful?

Breakeven prices are useful as a management tool. Making sound production decisions is one of the most important responsibilities of a farm manager. Profitability is one of the primary goal of any business, so it makes sense that growers will select crop rotation to support a more profitable business. Breakeven tables allow the user to compare the prices needed for an alternative enterprise to be as profitable as the status quo. By using this model, the user will understand what is required for a crop rotation to be more profitable.

What values are needed?

The formula used in this model to calculate net returns for double-cropped systems is as follows:

Eq. 1: $(P_B)*(Y_B) + (P_{SB})*(Y_{SB}) – (VC_B + VC_{SB}) = (P_W)*(Y_W) + (P_{SB})*(Y_{SB}) – (VC_W + VC_{SB})$

Where P_B , P_W , P_{SB} = Price of Barley, Wheat, and Soybean
Y_B , Y_W , Y_{SB} = Yield of Barley, Wheat, and Soybean
VC_B , VC_W , VC_{SB} = Variable Costs of Barley, Wheat, and Soybean

The left-hand side of equation 1 is the net returns of the barley-soybean system:

$$(P_B)*(Y_B) + (P_{SB})*(Y_{SB}) – (VC_B + VC_{SB})$$

Gross income for barley is defined by $(P_B)*(Y_B)$, and gross income of soybean following barley is defined as $(P_{SB})*(Y_{SB})$. The sum is the total gross income of the double-cropped barley-soybean system. Next, $(VC_B + VC_{SB})$ is equal to the variable costs of growing both the barley and the soybean. Subtracting the variable cost from the gross income equals net returns over variable cost, defined as net returns for the remainder of this discussion.

The right-hand side of equation 1 is the net returns of the wheat-soybean system:

$$(P_W)*(Y_W) + (P_{SB})*(Y_{SB}) – (VC_W + VC_{SB})$$

Gross income for wheat is defined by $(P_W)*(Y_W)$, and gross income of soybean following wheat is defined as $(P_{SB})*(Y_{SB})$. The sum is the total gross income of the double-cropped barley-soybean system. Finally, $(VC_W + VC_{SB})$ is the variable cost of the entire system. The full-season soybean net returns are calculated in a similar manner, except net returns are determined for only the soybean crop. Once the net returns are known, the full-season soybean can be compared with either double-cropped system.

Variable Costs vs. Fixed Costs

The idea of using variable costs only is an important assumption, and needs to be discussed in more detail. Production expenses are usually split into two categories: variable costs and fixed costs. Fixed costs are incurred no matter the enterprise. These include, but are not limited to, expenses such as depreciation, management, operator labor, and equity capital. Variable costs, on the other hand, include expenses specific to the enterprise. These include such things as fertilizer, fuel, seed, chemicals, and hired labor.

When comparing a wheat-soybean rotation with a barley-soybean rotation, it is assumed that fixed costs will be the same for both enterprises. For example, the farmer's machinery depreciation (a fixed cost) is going to be the same whether barley or wheat is grown. On the other hand, seed cost (a variable cost) will be different for the two crops. Land rental rates and other costs that are not dependent on cropping system are not included. These costs need to be taken into account when making long-term cropping decisions, but are beyond the scope of this model. Individual growers can plug in their own fixed cost numbers to consider returns to all costs.

Example Calculation

This section goes over an example breakeven calculation using values taken from the example enterprise budgets in Appendix C. Prices are the median commodity values available at Petersburg and Hopewell from 2006 to 2010 (Appendix B). Yield estimates are based on Virginia yield trials and unpublished experimental data (D.L. Holshouser, Personal Communication, 2011). Assumptions used are as follows:

Barley-Soybean Rotation
P_B = \$3.19; Y_B = 90 bu/ac

P_{SB} = \$9.19; Y_{SB} = 33 bu/ac

$VC_B + VC_{SB}$ = \$377.26 /ac

Return over Variable Costs = (3.19 x 90) + (9.19 x 32) – (375.46) = **\$213.11**

Wheat-Soybean Rotation
P_W = \$4.08; Y_W = 70 bu/ac

P_{SB} = \$9.19; Y_{SB} = 26 bu/ac

$VC_W + VC_{SB}$ = \$408.75

Return over Variable Costs = (4.08 x 70) + (9.19 x 26) – 408.75 = **\$115.79**

The breakeven price of wheat is solved as follows:

$$(P_W \text{ x } 70) + (9.19 \text{ x } 26) - 408.75 = 213.11$$

$$(P_W \text{ x } 70) + 238.94 - 408.75 = 213.11$$

$$(P_W \text{ x } 70) = 213.11 + 408.75 - 238.94$$

$$P_W \text{ x } 70 = 382.92$$

$$\mathbf{P_W} = 375.53 / 70 = \mathbf{\$5.47}$$

Therefore, \$5.47 is the price needed for wheat to breakeven with barley when barley is \$3.19.

Likewise, the breakeven price of barley:

$$(P_B \text{ x } 90) + (9.19 \text{ x } 33) - 377.26 = 115.79$$

$$(P_B \text{ x } 90) + 303.27 - 377.26 = 115.79$$

$$(P_B \text{ x } 90) = 115.79 + 377.26 - 303.27$$

$$(P_B \text{ x } 90) = 189.78$$

$$\mathbf{P_B} = 189.78 / 90 = \mathbf{\$2.11}$$

Here, \$2.11 is the price needed for barley to breakeven with wheat when wheat is \$4.08. In addition to breakeven prices, barley, wheat, and soybean breakeven yields or variable costs can also be calculated in the same manner, although they are not included in this model.

Explanation of the Excel Model

The breakeven calculations are estimates based on historical values and growers should incorporate personal knowledge into their individual analysis. When the spreadsheet is opened the first tab is labelled ‘Table of Contents’. This sheet serves as a navigation tool for the rest of the model. To calculate breakeven prices follow the individual steps listed on this sheet. If any tabs are mentioned that are not listed they can be accessed by clicking on the ‘Index’ link at the bottom of this first sheet. This will take you to an index of all tabs used in the model with links to each. However, only the steps listed in the ‘Table of Contents’ tab are absolutely necessary to use the program.

The first step asks for verification of the production costs as listed in the individual budgets. Clicking on the ‘Corn Budget’ link will take you to the enterprise budget used specifically for the corn crop. Here any changes in prices of seed, fertilizer, labor, etc. can be made. Note that prices and yields at the top of the budget are not changed here; this will be done later. The corn budgets are not used in the breakeven calculations for the soybean systems, but will be listed in the ‘Summary Table’ to provide context for the overall rotation. Once finished, click on ‘Return to Table of Contents’ and you will be redirected to the first page. Follow the same process for the ‘Full-Season Soybean Budget’, ‘Barley-Soybean Double-Crop Budget’, and ‘Wheat-Soybean Double-Crop Budget’ links.

All of these budgets are derived from Virginia Cooperative Extension’s Enterprise Budget System Generator (Budsys) (Eberly, 2010). All of the costs used in the budgets are based on average 2010 operating expenses, as estimated by the Budsys computer program and Virginia Tech Extension faculty. The user can adjust the enterprise budgets to reflect values deemed most accurate for their farm. Estimated costs (both variable and fixed) are provided in the tabs ‘Chemicals’, ‘Machinery’, ‘Seed’, and ‘Rates’. *Note*: Only costs should be changed in the individual budgets. Prices and yields should be changed in the tab ‘Summary Table’ as will explained later. If costs are changed in the individual budgets, the total variable costs and returns over variable costs columns in the “Summary Table” will adjust automatically. It might be noticed there are tabs labeled “Full-Season Avg. Budget”, “Barley DC Avg. Budget”, and “Wheat DC Avg. Budget”. These budgets should *not* be adjusted, as they automatically use the average prices described above to provide a reference point for the individual breakeven tables. This will be explained later in more detail.

Excel Spreadsheet: Summary Table

The second step is to enter anticipated prices and yields. Click on the ‘Summary Table’ link. This takes you to a sheet that shows the prices, yields, variable costs, and returns over variable costs for each enterprise. The breakeven analysis looks only at the full-season soybean, barley-soybean, and wheat-soybean systems, but in this chart corn is also summarized to provide context.

This is the only sheet in the model where the user must enter data. First, an elevator is chosen. Obviously, a farmer might do business with any number of elevators. Here, Petersburg and Tappahannock simply represent the two different barley pricing mechanisms. We assume Osage Bio Energy will offer 80% of Chicago July corn prices for barley delivered to their ethanol plant in Hopewell. The prices “local” to Hopewell for wheat, soybeans, and corn are represented by the Petersburg prices. Presumably, if a grower has the means to ship barley to Hopewell, the other crops can be shipped nearby to Petersburg. The other pricing mechanism is barley delivered to one of several buy-in stations in Virginia and Maryland, including

Tappahannock. Osage Bio Energy will offer 80% of Chicago July corn futures less a $.25 per bushel basis for barley delivered to a buy-in station. Presumably, if a grower will ship barley to Tappahannock, the other crops can be shipped to Tappahannock as well. These two delivery stations serve as reference points in this model.

Next, the summary table lists the enterprises being evaluated. In the second column, the commodity prices need to be manually entered. The prices listed when the spreadsheet is first opened reflect the 50th percentile of commodity prices at Petersburg for corn, wheat, and soybeans from January 2006-December 2010 (*Virginia Market News: Virginia Grain Prices and Statistics*, 2011). The barley price is the average barley price that would have been available if Osage Bio Energy had been offering 80% of Chicago corn from January 2006-December 2010 (*FutureSource*, 2011). Regardless, at this point the user should enter the commodity prices deemed to be most accurate for the individual operation. Once the full-season soybean price is entered the two double-cropped soybean prices are automatically filled in for all soybean regardless of the cropping system.

Once commodity prices are entered, the third column will automatically "look up" the percentile of historical prices from either the tab 'Petersburg Prices' (January 2006-December 2010), or the tab 'Tappahannock Prices', which contains the monthly prices available at Tappahannock from January 2006-December 2010. If the percentile is 50%, this is the value where half the prices over the last five years have been higher and half have been lower. If the percentile is 75%, prices have been greater 25% of the time over the last five years, but have been less 75% of the time. This is where the elevator choice comes into play; the percentiles will be slightly different at the two locations. This idea of a "percentile" price merely serves as a reference point.

The fourth column is yield for each of the four cropping systems. These values need to be manually entered. Keep in mind all three soybean yields should be different, as planting dates will vary across the rotations. For instance, if barley is harvested in the first week of June, soybean planted immediately after will have several weeks more growing time than soybean planted after wheat in late June or early July. This is another key difference in the rotations: how will planting date affect soybean yield?

The fifth column shows variable costs. These values do not need to be manually entered. The variable costs are taken automatically from the individual enterprise budgets for each cropping system, and, if necessary, should have been adjusted in the first step. The sixth and final column in the 'Summary Table' tab shows the returns over variable costs. This is calculated as shown above: price times yield less variable costs. This information is calculated automatically given the numbers manually entered in the earlier columns. All of the values needed are now available so the model can calculate breakeven prices. Click on 'Return to Table of Contents'.

Excel Spreadsheet: Breakeven Tables

The third step is interpreting the breakeven prices. Click on the link titled 'Breakeven Tables'. These breakeven tables are calculated using the data entered in the 'Summary Table' according to the breakeven equation. The first section in the 'Breakeven Tables' compares "barley vs. wheat breakevens". The upper table is discussed first. This breakeven table uses the average prices and average enterprise budgets mentioned earlier. When price and yield data are entered, the lower table will change to reflect the individual farm data, but this "average" table will not. It serves as a standard against which to compare the second table.

The median price of $4.08 for wheat was shown earlier to equal $2.11 for barley according to the previous assumptions, including $9.19 for soybeans. Of course, the median price is almost never going to be the price offered, so a sensitivity analysis is needed. A sensitivity analysis looks at how deviations in price away from the median will affect the breakeven price. At less 25% of the median price wheat is $3.06, which in turn is reflected in a lower barley breakeven price. At plus 25% of the median price wheat is $5.10, which is also reflected in a higher barley breakeven price. "Less 25%" does not mean the 25th percentile; it just means 75% of the median price ($4.08 x .75 = $3.06). Likewise, "Plus 25%" does not mean the 75th percentile; it means 125% of the median price ($4.08 x 1.25 = $5.10). The lower part of this table is read in a similar manner: the breakeven prices of wheat given the prices of barley shown. The explanation of the table is also found beside it in the Excel spreadsheet.

The second table is what shows the breakeven numbers that reflect the prices and yields manually entered in the 'Summary Table'. It is calculated in the same way as the median values, but is specific to the values the user has entered. All of these values are automatically calculated; the 'Summary Table' is the only tab where values are required to be entered. When the spreadsheet is first opened, the upper and lower breakeven tables are identical. This is because the average values used in the sample calculation are the default values when the program is first opened. Once the prices and yields are changed the lower table will change automatically, but the upper table will keep using the median values.

The second step in the 'Breakeven Tables' compares "wheat vs. full-season soybean breakevens". The upper table uses the median prices and average enterprise budgets in the same manner as the barley vs. wheat breakevens, except the average full-season soybean numbers are used instead of the double-cropped barley-soybean numbers. The median price of $4.08 for wheat is equal to $8.36 full-season soybean (when double-cropped soybean is $9.19), given the calculation. Again, the median price is almost never going to be the price offered, so a sensitivity analysis is needed. The lower part of this table is read in a similar manner: the breakeven prices of wheat given the prices of full-season soybean shown. The explanation of the table is also found beside it in the Excel spreadsheet. The lower table in this section shows the breakeven numbers that reflect the prices and yields manually entered in the 'Summary Table'.

The third step in the 'Breakeven Tables' compares "barley vs. full-season soybean breakevens". The upper table uses the median prices and average enterprise budgets in the same manner as the wheat vs. full-season soybean breakevens, except the average double-cropped barley-soybean numbers are used instead of the double-cropped wheat-soybean numbers. The median price of $3.19 for barley is equal to $11.14 for full-season soybean (when double-cropped soybean is $9.19), given the calculation. The lower part of this table is read in a similar manner: the breakeven prices of wheat given the prices of full-season soybean shown. The explanation of the table is also found beside it in the Excel spreadsheet. The lower table in this section shows the breakeven numbers that reflect the prices and yields manually entered in the 'Summary Table'.

Excel Spreadsheet: Summary Graph

The fourth and final part of the model is a visual representation of total cropping system profitability. Click on the 'Summary Graph' link. Here, a bar graph reflects the returns over variable costs as shown in the 'Summary Table'. This is automatically created with the numbers that are manually entered. Again, when the spreadsheet is first opened, the graph will reflect the average default numbers. This tab is a visual representation of income flow.

Excel Spreadsheet: Index of Tabs

All of the tabs in the model are accessed by clicking on the 'Index' link on the 'Table of Contents' sheet. An index of the spreadsheet tab links will be shown as below, in the order in which they appear in the Excel file.

1) Table of Contents
2) Summary Table
3) Breakeven Tables
4) Summary Graph
5) Petersburg Prices
6) Tappahannock Prices
7) Corn Budget
8) Full-Season Budget
9) Full-Season Avg. Budget
10) Barley DC Budget
11) Barley DC Avg. Budget
12) Wheat DC Budget
13) Wheat DC AVg. Budget
14) Chemicals
15) Machinery
16) Seeds
17) Rates

Interpretations

The breakeven tables can provide support on selecting a profitable cropping system. For instance, look at the first section of the breakeven tables that compares barley versus wheat. Here, the breakeven prices for barley ($1.32, $2.11, and $2.90) are all less than the 50th percentile barley price of $3.19. This implies that the barley-soybean system as a whole is generally more profitable than the wheat-soybean system (assuming the yields entered in the summary table and $9.19 for soybean). Likewise, the wheat breakeven prices ($4.45, $5.47, and $6.50) are all higher than the 50th percentile wheat price of $4.08. This implies that the wheat-soybean system is generally less profitable than the barley-soybean system.

Fig. 3.1. Wheat vs. Barley Breakeven Prices

Wheat		Barley
Less 25%	$3.06	$1.32
Price	$4.08	$2.11
Plus 25%	$5.10	$2.90
Barley		**Wheat**
Less 25%	$2.39	$4.45
Price	$3.19	$5.47
Plus 25%	$3.99	$6.50

Next, look at the wheat versus full-season soybean breakevens (Fig. 3.2). When wheat is $4.08 or $3.06, the breakeven soybean prices ($6.32 and $8.36) are below the 50th percentile soybean price of $9.19. When wheat prices go up, in this example to $5.10, the breakeven soybean price increases to $10.40, which is greater than $9.19. This indicates that at lower wheat prices full-season soybean is more lucrative, but as wheat prices increase (into the range where they are trading today) the double-cropped wheat-soybean system is more profitable. Again, please bear in mind the assumptions that are being used, and that these interpretations might change with different prices and yields.

Fig. 3.2. Wheat vs. Full-Season Soybean Breakeven Prices

Wheat		Soybean
Less 25%	$3.06	$6.32
Price	$4.08	$8.36
Plus 25%	$5.10	$10.40
Soybean		**Wheat**
Less 25%	$6.89	$3.35
Price	$9.19	$4.50
Plus 25%	$11.49	$5.65

Finally, the third part of the breakeven tables examines barley versus full-season soybean breakevens (Fig. 3.3). At the lower barley price of $2.39, the soybean breakeven price is $9.09, which is below the $9.19 50th percentile price. As the barley prices increase to $3.19 then to $3.99, the soybean prices are higher than the $9.19. This indicates that at very low barley prices the full-season soybean system is more profitable. Incidentally, this is the range where barley prices have been in Virginia for a long time. When the barley prices increase into the range where they exist today, the double-cropped barley-soybean system is more profitable. Again on the lower chart, a barley-soybean system appears to be more profitable except at very high full-season soybean prices.

Fig. 3.3. Barley vs. Full-Season Soybean Breakeven Prices

Barley		Soybean
Less 25%	2.39	9.09
Price	3.19	11.14
Plus 25%	3.99	13.19
Soybean		**Barley**
Less 25%	6.89	1.54
Price	9.19	2.43
Plus 25%	11.49	3.33

Profitability Scenarios

This model can be used in other ways aside from the breakeven sensitivity analysis as well. The summary table can be used to compare the initial profitability over variable costs of the different systems. This is particularly helpful when making short-term management decisions that compare prices that are available to the individual using the program. The breakeven tables use five-year prices, so that aspect provides interpretations for more long-term decisions. A comparison is easily done by comparing the returns over variable costs as listed in the summary table. Going forward with the idea of percentile prices, commodities can be compared at different levels of sales value. The prices used in this scenario are taken from Petersburg soybean and wheat and Hopewell barley as listed in Table 3.1. The crop yield assumptions are 90 and 70 bushels per acre for barley and wheat, respectively. The full-season soybean yield is a base yield, with soybean after barley as 90% of full-season yield and soybean after wheat as 75% of full-season yield. Once all these assumptions are made, total system profitability can be compared as seen in Table 3.2 on the next page.

Table 3.1. Five-year soybean, barley, and wheat prices at various percentiles.

	Price percentiles				
Crop	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}
			$ / bushel		
Soybean	5.65	7.13	9.19	10.90	12.87
Barley	2.02	2.84	3.19	3.59	4.80
Wheat	3.11	3.72	4.08	6.02	7.44

Table 3.2. Full-season soybean, double-cropped barley-soybean, and double-cropped wheat-soybean system profitability at various yields and prices.

		Full-season soybean yields (bu/ac)				
Percentile Price	Cropping System	30	40	50	60	70
		---------------------$ / acre----------------------				
10th	Full-Season Soybean	(0.27)	42.36	84.99	127.62	170.24
	Barley-Soybean	(25.97)	12.31	54.44	92.17	134.30
	Wheat-Soybean	(57.26)	(27.74)	6.19	35.21	69.64
25th	Full-Season Soybean	44.13	101.56	158.99	216.42	273.84
	Barley-Soybean	90.75	142.35	199.28	250.33	307.26
	Wheat-Soybean	19.48	59.36	105.13	144.51	190.78
50th	Full-Season Soybean	105.93	183.96	261.99	340.02	418.04
	Barley-Soybean	181.99	252.13	329.66	399.25	476.78
	Wheat-Soybean	92.06	146.36	208.61	262.41	325.16
75th	Full-Season Soybean	157.23	252.36	347.49	442.62	537.74
	Barley-Soybean	267.58	353.11	447.74	532.72	627.35
	Wheat-Soybean	267.19	333.46	409.39	475.16	551.59
90th	Full-Season Soybean	216.33	331.16	445.99	560.82	675.64
	Barley-Soybean	433.61	536.87	651.20	753.91	868.24
	Wheat-Soybean	411.90	491.96	583.65	663.21	755.40

Table 3.2 provides some interesting food for thought. At the lowest prices and lowest yields none of the systems are profitable (keeping in mind that crop insurance revenue is not included in the budgets). At the lowest prices and highest soybean yields, full-season soybean is the most profitable. This is because the full-season soybean has a lower variable cost to overcome to be profitable. As the prices increase this quickly changes to the barley-soybean system as the additional income from the barley crop begins to show. At median prices and median soybean yields, the barley-soybean system is still the most profitable, but the differences between full-season soybean and wheat-soybean are interesting. At the 50^{th} percentile full-season soybean is more profitable than the wheat-soybean system because the wheat-soybean system has a high variable cost, but as prices go up the wheat-soybean system replaces the full-season soybean. Here, the barley-soybean system is more profitable, but if farmers spread out their risk with another cropping system, which should they choose? A small variation in prices or yields could make one appear better than the other. There is no clear answer here. Obviously, all farmers (and farms) have different yield potentials and market their crops in different ways, so the trend of barley acreage over the next couple of years should be a clear indicator of how growers are responding to the changing dynamics of Virginia commodity markets.

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Chapter 4 – Soybean Planting Date and Small Grain Residue Effects on Soybean Yield and Yield Components

ABSTRACT

Full-season soybean [*Glycine max* (L.) Merr.] and double-cropped soybean following wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.) are three soybean cropping systems used in the Mid-Atlantic USA. Research comparing these systems is limited; therefore, field studies were conducted to determine the effect of planting date and winter grain on soybean yield and yield components. Soybean yields declined with planting date at two of four locations in 2009, a year that late-season rainfall enabled later-planted soybean to yield more than is expected. Across these two locations, yield ranged from 1676 to 3887 kg ha^{-1} for the May and early June planting dates, and declined to 905 to 3166 kg ha^{-1} by the mid-July planting date. Soybean yield declined with planting date at 74 or 12 kg ha^{-1} less per week at the two locations. Winter grain did not affect soybean yield in either year. These data indicate that planting date has a greater effect on yield than the small grain residue. The yield component data reinforced these results and indicated that the seed yield decline with later planting dates is due largely to a decrease in the number of pods, which decreased an average of 29 or 56 pods m^{-2} per week at each location in 2010.

INTRODUCTION

Soybean planting date is one of the most important factors related to agronomic yield. Research methodology of soybean crop rotation and planting date has varied greatly across the United States, but scientists have generally concluded that critical planting dates exist after which soybean yields begin to decline. In the Mid-Atlantic USA, soybean is usually planted in May as a full-season crop or in late-June to early-July as a double-crop after winter wheat. A recent increase in the demand for barley presents double-crop soybean planted in early-June as a third cropping system.

It is well documented that the later soybean is planted, the lower the seed yield. This has been demonstrated most recently in Nebraska by Bastidas et al. (2008), in South Carolina by Chen and Wiatrak (2010), and in Iowa by De Bruin and Pedersen (2008). Egli and Cornelius (2009) summarized fifty years of planting date research in the Midwest, Upper South, and Deep South regions of the United States, but did not include any Virginia studies. Their analysis concluded that soybean yield is constant in early May, but begins to decline after May 30th in the Midwest, June 7th in the Upper South, and May 27th in the Deep South. New agronomic data describing soybean yield decline over time is needed in the Mid-Atlantic and Virginia in particular.

In Nebraska, Bastidas et al. (2008) looked at soybean yield decline over four planting dates from late-April to mid-June. In their experiment, soybean yield declined linearly from the earliest planting dates. In Iowa, De Bruin and Pedersen (2008) also examined soybean yield decline over four planting dates from late April to Mid-June and concluded that soybean yield begins declining at an increasing rate after the earliest planting dates. In South Carolina, Chen and Wiatrak (2010) studied soybean yield decline over seven planting dates from late-April to mid-July. They found that soybean yield generally begins to decline by mid-June regardless of maturity group, but is very dependent on growing conditions. In all of these studies soybean was mono-cropped; none was planted after small grain. Other research has shown that the yield decline with later planting dates is primarily due to decreased pods m^{-2}, as shown most recently by Pedersen and Lauer (2004) in Wisconsin and Robinson et al. (2009) in Indiana.

In addition to planting date, the effect of small grain residue may be partially responsible for lower soybean yields following small grain. Yields may be lower due to the removal of soil moisture by the small grain crop, leaving an inadequate supply for the succeeding soybean crop. Or, other factors such as allelopathy may be involved. Allelopathy originally encompassed all types of biochemical interactions between plants, both positive and negative (Molisch, 1937). More recently it has come to be associated primarily with the negative effects one plant has on another (Rice, 1984). This has long been associated with residue left on the soil surface from a previous crop (Collison and Conn, 1925). Little is known about the variation in soybean yield decline after different small grains.

Information describing the decline of soybean yield with planting date is well documented, but less research of this nature has been conducted in Virginia. Even less data is available comparing the soybean yield decline with delayed planting following different small grain crops. The objectives of this study were to (i) describe the rate of yield decline for full-season soybean, double-cropped barley-soybean, and double-cropped wheat-soybean systems as planting date is delayed, and (ii) describe differences in soybean yield components as planting is delayed in these cropping systems, and (iii) determine the effect of small grain residue on soybean yield response to planting date.

MATERIALS AND METHODS

Experiments were conducted at four locations from fall 2008 through fall 2010: the Eastern Virginia Agricultural Research and Extension Center (EVAREC) near Warsaw on a Kempsville loam (fine-loamy, siliceous, subactive, thermic typic hapludults), the Southern Piedmont Agricultural Research and Extension Center (SPAREC) near Blackstone on an Appling fine sandy loam (fine, kaolinitic, thermic typic kanhapludults), and four experiments at the Tidewater Agricultural Research and Extension Center (TAREC1-TAREC4) near Suffolk, Virginia. A Eunola loamy fine sand (fine-loamy, siliceous, semiactive, thermic aquic hapludults) and Rains fine sandy loam (fine-loamy, siliceous, semiactive, thermic, typic paleaquults) (tile-drained) represented the soils at TAREC1 and TAREC2 during the 2008-2009 growing season, respectively. In the 2009-2010 growing season, Nansemond loamy fine sand (coarse-loamy, siliceous, subactive, thermic aquic hapludults) and Dragston fine sandy loam (coarse-loamy, mixed, semiactive, thermic aeric endoaquults) (tile-drained) represented the soils at TAREC3 and TAREC4, respectively. The soil yield potentials for all sites are shown in Table 4.1. Drought, poor emergence, and poor growth during the 2010 growing season prevented accurate data collection at EVAREC and SPAREC; therefore, results from these experiments are not included.

The experimental design for the first growing season was a randomized complete block with four replications and arranged as a split-plot. Main plots were the winter small grains rye, barley, or wheat. Rye was treated as a cover crop and killed with herbicide in early May. Barley and wheat were harvested for grain. Subplots were planting date, with the initial planting date for soybean following rye in May, or immediately following wheat or barley harvest (Table 4.2). In 2009-2010, the experimental design was a randomized complete block arranged as a strip-plot and replicated four times. Horizontal plots were the same winter small grains rye, barley, or wheat plus an additional treatment with no small grain crop. Vertical plots were planting date, with the initial planting dates for all plots in May and progressing weekly, resulting in a total of nine planting dates (Table 4.3). Winter grain plots planted to soybean before wheat or barley harvest were treated as cover crops and sprayed with herbicide one to two weeks before the expected soybean planting date. Previous crop residue was corn at all sites except TAREC3, where cotton was grown the previous year.

The barley and wheat cultivars at all locations in both years were Thoroughbred (Virginia Crop Improvement Association, Richmond, VA) and SS520 (Southern States Cooperative, Richmond, VA), respectively. Soybean cultivars for each location in both years are shown in Tables 4.2 and 4.3. Soybean cultivar 95Y70 (Pioneer Hi-Bred, Int'l, Johnston, IA) is a maturity group V and contains resistance to root knot nematode (*Melooidogyne* spp.), which was known to be present in low numbers at TAREC1 in 2009. AG4907 (Monsanto Co., St. Louis, MO) is a maturity group IV cultivar, and was used to facilitate earlier harvest on TAREC2 and TAREC4, fields that can become wet during November and inhibit timely harvest. Otherwise, AG4907 and AG5605 are both considered high-yielding cultivars of the most adapted maturity group at their respective locations.

Fields were limed and fertilized with phosphate and potash according to soil tests. Nitrogen needs for small grains varied and were met with 25-35 kg ha^{-1} at planting followed by split applications based on tiller counts and tissue analysis (Alley et al., 2009a; Alley et al., 2009b). Soybean was planted using a five-row plot planter in 2009 and a thirteen-row no-till drill in 2010. Row spacing was 38 and 19 cm for the planter and drill, respectively. Seeding rates were gradually increased with planting date, following the standard guidelines recommended by Virginia Tech Extension faculty (Holshouser, 2010). In 2009, individual plots were 7.3 m long by 4.6, 5.5, 3.6, and 3.6 m wide at EVAREC, SPAREC, TAREC1, and TAREC2, respectively. In 2010, individual plots were all 7.3 m long by 4.9 m wide. The land was disked and land-conditioned before small grain planting and soybean was planted no-till. In 2009, TAREC2 received 1.4 and .67 kg ha^{-1} of manganese and sulfur, respectively, in mid-July to correct visual manganese deficiency. In 2010, both TAREC3 and TAREC4 received .13 and .054 kg ha^{-1} of manganese and sulfur, respectively, in mid-July. Standard pesticides were applied to control weeds, insects, and diseases for all crops per Virginia Cooperative Extension recommendations (Herbert and Hagood, 2011). TAREC1 was irrigated once in 2009 (15 July) with 50 mm and TAREC3 was irrigated twice in 2010 (1 and 20 July), at the rate of 25 mm on each occasion. Small grain and soybean were harvested with a plot combine equipped with a weigh bucket and moisture sensor. Yields were adjusted to 130 g kg^{-1} moisture content. One meter (.381 m^{-2}) of one or two rows were hand-cut at ground level from each plot in 2009 and 2010, respectively. From this sample, seed yield (g m^{-2}), biomass (g m^{-2}), height $plant^{-1}$, plants m^{-2}, pods m^{-2}, pods $plant^{-1}$, seed m^{-1}, seed pod^{-1}, and seed weight (g 100 $seed^{-1}$) were measured.

The Shapiro-Wilk statistic in the PROC UNIVARIATE: NORMAL TEST showed non-normality for the yield and yield component data; therefore the analysis of variance test was conducted using PROC GLIMMIX (SAS Institute, 2008). Years were analyzed separately because of different experimental design and the additional fallow-soybean plots in 2010. In 2009, treatments were considered fixed factors, while blocks were considered random factors. In 2010, cropping system and planting date were considered fixed factors, while blocks were considered random factors. Least square means were calculated and separated at $p = 0.05$ using Fisher's Protected LSD. In 2010, standard orthogonal polynomial coefficients were used to test for linear, quadratic, and cubic trends of soybean yield with planting data. The CONTRAST option of the PROC GLIMMIX procedure was used to perform this analysis.

RESULTS AND DISCUSSION

Analysis of variance of 2009 soybean yield data revealed location differences; therefore, yield data are separated by location. Further analysis revealed treatment differences at EVAREC, SPAREC, and TAREC2, but not at TAREC1. Soybean yields at TAREC1 averaged 3548 kg ha^{-1} for full-season soybean, 3534 kg ha^{-1} for soybean grown after barley, and 3407 kg ha^{-1} for soybean grown after wheat. Least square means of all 2009 locations are presented in Fig. 4.1. With the exception of the last two planting dates at EVAREC, there were no soybean yield differences between winter grain crop treatments within a planting date. There were yield differences due to winter grain crop at only one planting date at SPAREC. Although large differences in yield appeared to be present at TAREC2 at several planting dates, variability within that experiment prevented significant differences at $p = 0.05$. Within winter crop treatments, there was a gradual yield decline with planting date at EVAREC, with the last two planting dates being significantly different from the first three. At SPAREC, a rather abrupt decline in yield occurred at the 22 June planting date, with no further yield loss afterwards. At TAREC2, there were few differences between planting dates and no differences when planting dates were compared within a small grain crop treatment.

In 2010, there were planting date differences at both TAREC3 and TAREC4, but no cropping system or cropping system by planting date interaction at either location. Yield decreased as a cubic function of planting date at each location, with a strong correlation at TAREC4 (R^2 = .92) and a weaker one at TAREC3 (R^2 = .46) (Fig. 4.4 and 4.5).

Plants m^{-2} and pods $plant^{-1}$ differed at all locations in 2009. Seed yield, height $plant^{-1}$, pods m^{-2}, seed m^{-2}, and seed weight (g 100 $seed^{-1}$) differed at every location except TAREC2, and biomass differences were present at two of three locations (Table 4.4). Biomass measurements were lost at TAREC1.

At EVAREC, seed yield decreased with planting date, with significantly lower yield after the 23 June planting date (Table 4.6). Additionally, a corresponding drop in biomass, pods m^{-2}, and seed m^{-2} occurred. These measurements correspond well with the plot yield data (Fig. 4.1). Plants m^{-2} increased with planting date due to the intentional increase in seeding rate. Due to this increase in plants m^{-2}, pods $plant^{-1}$ decreased with planting date. Seed pod^{-1} did not differ between planting date, indicating seed pod^{-1} as having little to no impact on seed yield. At EVAREC, rainfall was near or above long-term averages, but not evenly distributed with 131, 98, 235, and 77 mm in June, July, August, and September, respectively (Fig. 4.3). August rainfall was more than twice that normally received during this month, and minimized stress during the critical pod and seed filling stages. From these data, it seems that a growth reduction, as indicated by biomass and height measurements, was the primary cause for a yield decrease with planting date at this location.

At SPAREC, soybean planted after a rye cover crop yielded more than if planted after barley at the 9 June planting date (Table 4.7). This cannot be fully explained. However, it is possible that barley extracted more moisture from the soil than the rye cover crop that was killed with herbicide during the first week of May. Soil water storage becomes of greater importance on Piedmont soils where the plant-available water-holding capacity is low. Rainfall at SPAREC totaled 174, 100, 40, and 142 mm in June, July, August, and September, respectively (Fig. 4.3). In addition, there was a period from 8 May to 4 June with no rainfall over 7 mm. Two rainfall events occurred before and after planting (88 and 43 mm on 4-5 June and 15 June, respectively), but this did not likely store enough water for the ensuing dry August. As a result, seed yield declined sharply after the 9 June planting, with an accompanying loss in biomass, height, pods m^{-2}, and seed m^{-2}. Again, the increased plants m^{-2} somewhat compensated for the loss in pods $plant^{-2}$, and seed pod^{-1}did not have a great impact on seed yield. It is worth noting that seed weight declined with planting date, further demonstrating the drought's effect during the seed fill (R5-R6) phase of development that occurred during August through late September. The seed yield decline can be primarily traced with a corresponding drop in precipitation.

At TAREC1, there were no differences in seed yield between the winter crop treatments (Table 4.8). However, seed yield and seed m^{-2} gradually declined after the 17 June planting date. This is in contrast to the plot yield data, which showed no significant yield differences between any winter crop – planting date combination. This may be explained by the smaller harvested area used for the yield component measurements. Plants m^{-2} increased with planting date delay as the seeding rates were increased, explaining why pods $plant^{-1}$ were less after the 4 June planting date. The yield decline was large reflected by a decline in pods m^{-2} and seed m^{-2}. Contributing to the decline in seed m^{-2} was a reduction in the number of seed pod^{-1} at the 7 and 14 July planting dates. There appears to be no reason for this decline in seed pod^{-1} as rainfall was generally adequate during August, when seed number was being established. Seed weight differences contributed minimally to the seed yield decline, although there was a gradual decline in seed weight with planted date if averaged over winter crop. Although biomass was not measured at this location, the height data may reflect less growth from later planting dates. Since rainfall was enough for good yields at this location, the decline in later planting dates were likely due to vegetative growth differences.

At TAREC2, there were no yield or yield component treatment differences except for increased plants m^{-2} and decreased pods $plant^{-1}$ with planting date, which increased due to the greater target plant population (Table 4.9). This contrasts somewhat with the plot yield data (Fig. 4.1). Some of the yield component measurements correspond well with the plot yield data, but little can be gleaned from these data to explain any plot yield differences. Still, as stated earlier when discussing the plot data, few differences between planting dates existed and planting dates did not differ when compared within a small grain treatment.

The lack of and discrepancies in yield and yield component differences at TAREC in 2009 may be explained by adequate rainfall, relatively cool temperatures, and the more productive soil type. Only brief periods without rainfall were experienced and this was generally earlier in the growing season during late-May and June, before the crop entered reproductive stages. Furthermore, both soil types at this location are relatively productive (Table 4.1). The Rains soil at TAREC2 is a poorly drained soil without tile drainage (the water table is closer to the surface) and it contains greater silt and clay content than most soils in the region, and therefore has better soil-water relations. Although moderately well-drained with a sandy topsoil, the Eunola contains a higher water-holding capacity sandy clay loam B horizon, which appears 25 to 38 centimeters below the surface. Therefore any temporary halt in rainfall did not likely affect growth to a great extent. Precipitation increased and was evenly distributed as the season progressed, resulting in better than average growth for the double-crop soybean systems. Rainfall totaled 86, 123, 86, and 195 mm in June, July, August, and September, respectively (Fig. 4.3), which were close to or above the average of approximately 100 mm per month.

Analysis of the 2010 soybean yield component data revealed no treatment interaction differences at either location (Table 4.5). At TAREC3, only height $plant^{-1}$ was affected by the winter grain, with taller plants following wheat than the fallow plots (Table 4.10). Taller plants were observed for the 3 June through 1 July planting dates, which reflects the two irrigations in June. Seed weight was significant for planting date only, generally increasing with planting date delays. This may reflect rainfall occurring during late September during the seed filling phase of the later planted soybean. Plants m^{-2} was significant for the planting date effect, but this was expected because seeding rates were gradually increased over time as in 2009. The uniform treatment responses are most likely due to the dry weather experienced during the summer; only 19, 26, and 52 mm of rainfall occurred during June, July, and August.

At TAREC4, all measurements were significant for the planting date effect, and all yield component data was significant for the winter grain effect except height $plant^{-1}$ and seed pod^{-1} (Table 4.11). There was no planting date by winter grain interaction. Seed yield decreased significantly after the 17 June planting date, along with lower biomass and less height $plant^{-1}$, pods m^{-2}, and seed m^{-2}. Seed pod^{-1} again did not appear to be a major determinate of total seed yield. The number of plants m^{-2} fell steeply after the 17 June planting, and then increased again in the middle of July. This was due to dry soil conditions that inhibited emergence for the late-June and early-July planting dates, followed by rainfall during the end of the summer that ensured better emergence for the later planting dates. Pods $plant^{-1}$ remained steady until an increase at the end of June, followed a sharp decline in July. The seed weight increased into the later planting dates, as the crop compensated for the lower number of pods per plant, though not enough to maintain the highest seed yield potential.

In 2010, soybean experienced one of the hottest and driest growing seasons of the last century. At TAREC, rainfall during the summer months of June, July, and August totaled 99 mm in 2010 compared to 295 mm in 2009. Ambient temperatures were also much hotter in 2010 than in 2009, frequently reaching or exceeding 40ºC. Soil temperature was measured at depths of 15 and 30 cm in July and August that frequently exceeded 27ºC. At the end of the growing season, soybean plots received 324 mm of rainfall in one week from the end of September to the start of October. TAREC3 was irrigated (25mm) twice during the worst of the drought, but TAREC4 did not have access to irrigation. The addition of irrigation provided for a more even soil moisture distribution with time. Consequently, the yields and yield components at TAREC3 are more uniform than at TAREC4. The fallow plots in particular at TAREC4 experienced extremely poor emergence because of reduced surface soil moisture. Still, yields at TAREC4 were greater overall due to a more productive soil.

These data indicate that planting date has a greater effect on yield than the small grain residue; therefore, the type of residue does not appear to be a major concern. The yield component data strengthen results and indicate that the lower seed yield in the later planting dates is due most importantly to a decrease in the number of pods, which validates the research by Pedersen and Lauer (2004) and Robinson et al. (2009). The information presented here needs to be kept in context with the unusual and contrasting weather conditions present during the two years of the study. This research should be repeated to avoid any erroneous conclusions due to the very unusual weather patterns experienced during both years.

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Table 4.1. Soil Series and yield potential† for 2009 and 2010 experimental locations.

Year	Location‡	Soil series	Yield potential Corn	Barley	Wheat	Soybean (early / late)§
			--------------------------kg ha $^{-1}$	--------	--------	--------
2009	EVAREC	Kempsville	8780	4730	4700	2690 / 2280
	SPAREC	Appling	7525	4730	4700	2350 / 1680
	TAREC1	Eunola	8150	4730	4700	2690 / 2280
	TAREC2	Rains (drained)	10660	4730	4700	3020 / 2280
2010	TAREC3	Nansemond¶	10030	6180	5375	2690 / 2280
	TAREC4	Dragston	10030	6180	5375	2690 / 2280

† All yield potentials based on VALUES, Virginia Agronomic Land Use Evaluation System (Simpson, 1993; Virginia Soil and Water Conservation, 2005).
‡ Location: Tidewater (TAREC), Eastern Virginia (EVAREC), and Southern Piedmont (SPAREC) Agricultural Research and Extension Centers.
§ Late season soybean assumed planted on or after 21 June.
¶ These yield potentials do not correspond to those experienced at the TAREC in numerous experiments. The Nansemond is a loamy find sand whose subsoil consists of sandy loam from 20 to 74 cm then becomes a loamy fine sand to 168 cm, where it changes to a sand. Yields in the City of Suffolk Soil Survey lists the soil as yielding 672 and 336 kg ha^{-1} less than a Dragston and similar to the Eunola. We think that this soil has less yield potential than any soil listed except for the Appling.

Table 4.2. Locations and soybean cultivars used at various planting dates in 2009.

		Planting date					
Location	Cultivar	1	2	3	4	5	6
EVAREC	AG 4907	27 May R	8 June RB	23 June RBW	---- ‡	8 July R*B***W**¶	15 July R*B***W**
SPAREC	AG 5605	21 May R	9 June RB	22 June RBW	30 June BW	9 July RB*W*	15 July RB*W*
TAREC1	95Y70	21 May R†	4 June RBW	17 June RBW	29 June BW	7 July RBW	14 July RBW
TAREC2	AG 4907	21 May R	2 June RB	11 June RBW	29 June BW	8 July RB*W*§	14 July RB*W*

† Soybean grown after rye (R), barley (B), and wheat (W) planted (i.e. four subplots per small grain).
‡ Unable to plant due to equipment malfunction.
§ Soybean grown after barley (*B)* or wheat (*W)* planted in six subplots instead of four.
¶ Soybean grown after wheat (**W**) planted in eight plots per small grain.

Table 4.3. Locations and soybean cultivars used at various planting dates in 2010.

		Planting date								
Location	Cultivars	1	2	3	4	5	6	7	8	9
TAREC3	AG 5605	21 May	28 May	3 June	11 June	17 June	24 June	1 July	8 July	16 July
TAREC4	AG 4907	22 May	28 May	3 June	11 June	17 June	23 June	1 July	8 July	16 July

Table 4.4. Treatment effects for soybean yield component measurements at four locations in 2009.

	Yield component measurement								
Location	Seed yield ($g\ m^{-2}$)	Biomass ($g\ m^{-2}$)	Height $plant^{-1}$	Plants m^{-2}	Pods m^{-2}	Pods $plant^{-1}$	Seed m^{-2}	Seed pod^{-1}	Seed weight ($g\ 100\ seed^{-1}$)
					P value				
EVAREC	.0003	.0049	<0.0001	<0.0001	.0047	<0.0001	.0031	.1884	<0.0001
SPAREC	<0.0001	<0.0001	<0.0001	.0004	<0.0001	<0.0001	<0.0001	.0123	<0.0001
TAREC1	<0.0001	----†	<0.0001	<0.0001	.0048	<0.0001	<0.0001	<0.0001	.0105
TAREC2	.2877	.4334	.2270	.0015	.3486	<0.0001	.2639	.6576	.6254

† Not determined.

Table 4.5. Treatment effects for soybean yield component measurements at two locations in 2010.

		Yield component measurement								
Location	Effect	Seed yield (g m^{-2})	Biomass (g m^{-1})	Height $plant^{-1}$	Plants m^{-2}	Pods m^{-2}	Pods $plant^{-1}$	Seed m^{-2}	Seed pod^{-1}	Seed weight (g 100 $seed^{-1}$)
						P value				
TAREC3	WG†	.5491	.8494	.0394	.0746	.6619	.1226	.4110	.4238	.2661
	PD‡	.4252	.5615	.0036	.0069	.3760	.2966	.2695	.6241	.0074
	WG*PD	.5201	.5110	.4530	.2126	.6518	.9019	.3084	.6422	1.0000
TAREC4	WG	.0354	.0061	.2424	<0.0001	.0052	.0004	.0117	.3091	<0.0001
	PD	.0004	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	.0012	<0.0001
	WG*PD	.9480	.9555	.7112	.9009	.9094	.9673	.9099	.6279	.3160

† WG, winter grain.
‡ PD, planting date.

Table 4.6. Seed yield, plant biomass, height, and yield components of soybean planted on different dates into a rye cover crop, or barley or wheat harvested for grain at EVAREC in 2009.

	Planting date				
	27 May	8 June	23 June	8 July	15 July
Seed yield (g m^{-2})					
Full-season	501.5a†	500.0a	403.3abcd	336.3bcd	275.3d
Barley-Soybean		497.0a	421.2abc	333.5bcd	290.5d
Wheat-Soybean			449.4ab	315.5cd	326.7cd
Biomass (g m^{-2})					
Full-season	834a	890a	737abc	659abc	527c
Barley-Soybean		857a	721abc	621bc	531c
Wheat-Soybean			814ab	583c	597c
Height $plant^{-1}$ (cm)					
Full-season	74abcd	80ab	84a	72bcde	69cdef
Barley-Soybean		77abc	76abc	66def	61f
Wheat-Soybean			78abc	62f	63ef
Plants m^{-2}					
Full-season	24f	38def	44cde	66ab	50bcd
Barley-Soybean		26ef	39def	62abc	54abcd
Wheat-Soybean			51abcd	67a	68a
Pods m^{-2}					
Full-season	1803a	1675abc	1400abcd	1272bcd	984d
Barley-Soybean		1694ab	1497abc	1274cd	1006d
Wheat-Soybean			1550abc	1291cd	1301cd

Table 4.6. Continued.

	Planting date				
	27 May	8 June	23 June	8 July	15 July
Pods plant^{-1}					
Full-season	80.3a	44.4c	37.1c	19.9e	20.6de
Barley-Soybean		66.0b	40.7c	20.9e	19.2e
Wheat-Soybean			32.7c	19.6e	19.2e
Seed m^{-2}					
Full-season	3527a	3622a	2891abcd	2513bcd	2076d
Barley-Soybean		3553a	3151abc	2529bcd	2210d
Wheat-Soybean			3252ab	2404cd	2478bcd
Seed pod^{-1}					
Full-season	2.0	2.2	2.1	2.0	2.1
Barley-Soybean		2.1	2.1	2.0	2.3
Wheat-Soybean			2.1	1.9	1.9
Seed weight (g 100 seed^{-1})					
Full-season	14.2a	13.8bcd	14.0ab	13.5cde	13.3e
Barley-Soybean		14.0ab	13.4de	13.2e	13.2e
Wheat-Soybean			13.8abc	13.1e	13.2e

†Means within the same measurement followed by the same letter are not significantly different at p = 0.05 using Fisher's Protected LSD.

Table 4.7. Seed yield, plant biomass, height, and yield components of soybean planted on different dates into a rye cover crop, or barley or wheat harvested for grain at SPAREC in 2009.

	Planting date					
	21 May	9 June	22 June	30 June	9 July	15 July
Seed yield (g m^{-2})						
Full-season	282.8ab†	349.7a	174.9bcde		113.1de	108.6de
Barley-Soybean		242.6bc	162.2cde	118.1de	104.2de	101.2e
Wheat-Soybean			187.5cd	122.0de	131.9de	119.1de
Biomass (g m^{-2})						
Full-season	643ab	736a	374cd		261d	266d
Barley-Soybean		520bc	345d	270d	243d	246d
Wheat-Soybean			391cd	262d	274d	271d
Height $plant^{-1}$ (cm)						
Full-season	64a	56ab	49bc		37def	37def
Barley-Soybean		55b	44cd	35ef	37def	32f
Wheat-Soybean			42cde	37def	33f	32f
Plants m^{-2}						
Full-season	27ef	22f	32def		62abc	79a
Barley-Soybean		38cdef	39cdef	59abcd	57abcd	79a
Wheat-Soybean			49bcde	62abc	67ab	72ab
Pods m^{-2}						
Full-season	1374a	1548a	626bc		559bc	551bc
Barley-Soybean		866b	621bc	564bc	530bc	625bc
Wheat-Soybean			734bc	503c	578bc	592bc

Table 4.7. Continued.

	Planting date					
	21 May	9 June	22 June	30 June	9 July	15 July
Pods plant^{-1}						
Full-season	52b	80a	27c		11c	7c
Barley-Soybean		25c	19c	11c	10c	8c
Wheat-Soybean			15c	8c	9c	8c
Seed m^{-2}						
Full-season	1911ab	2469a	1314bcd		948d	994d
Barley-Soybean		1702bc	1202cd	869d	862d	915d
Wheat-Soybean			1349bcd	934d	1084d	1029d
Seed pod^{-1}						
Full-season	1.4d	1.6bcd	2.1a		1.7bcd	1.8abc
Barley-Soybean		1.9ab	1.9ab	1.5cd	1.7bcd	1.5d
Wheat-Soybean			1.8abc	1.8abc	1.9ab	1.7bcd
Seed weight (g 100 seed^{-1})						
Full-season	14.7a	14.2a	13.7ab		11.8def	11.1ef
Barley-Soybean		14.3a	13.5ab	13.5abc	12.2cdef	11.0f
Wheat-Soybean			13.8ab	12.8bcd	12.2cde	11.5ef

†Means within the same measurement followed by the same letter are not significantly different at $p = 0.05$ using Fisher's Protected LSD.

Table 4.8. Seed yield, plant biomass, height, and yield components of soybean planted on different dates into a rye cover crop, or barley or wheat harvested for grain at TAREC1 in 2009.

	Planting date					
	21 May	4 June	17 June	29 June	7 July	14 July
Seed yield (g m^{-2})						
Full-season	677.1a	584.8a	535.7abc		309.5cd	232.2d
Barley-Soybean		708.4a	651.8a	480.7abc	216.3d	203.9d
Wheat-Soybean		581.4ab	552.1ab	345.3bcd	181.6d	168.2d
Biomass (g m^{-2})						
Full-season	----‡	----	----	----	----	----
Barley-Soybean	----	----	----	----	----	----
Wheat-Soybean	----	----	----	----	----	----
Height $plant^{-1}$ (cm)						
Full-season	74fg	95bc	111a		92bcd	79defg
Barley-Soybean		81cdef	94bc	80def	90bcde	73fg
Wheat-Soybean		76efg	96ab	90bcde	73fg	65g
Plants m^{-2}						
Full-season	27fg	17g	45cde		65b	82a
Barley-Soybean		28efg	34def	36def	54bc	82a
Wheat-Soybean		25fg	48bcd	33def	64b	64b
Pods m^{-2}						
Full-season	2259a	1903ab	1812abc		1295bcd	1393bcd
Barley-Soybean		2232a	2205a	1690abc	1242bcd	1213bcd
Wheat-Soybean		1927ab	1713abc	1277bcd	1039cd	957d

Table 4.8. Continued.

	Planting date					
	21 May	4 June	17 June	29 June	7 July	14 July
Pods plant^{-1}						
Full-season	93b	142a	51bcde		21de	17e
Barley-Soybean		81bc	66bcd	48bcde	25de	15e
Wheat-Soybean		95ab	39cde	43cde	16e	16e
Seed m^{-2}						
Full-season	4204a	3700ab	3394abc		2016cd	1548d
Barley-Soybean		4557a	4235a	3221abc	1393d	1341d
Wheat-Soybean		3731ab	3619ab	2276bcd	1191d	1159d
Seed pod^{-1}						
Full-season	1.86a	1.96a	1.85ab		1.51bc	1.12d
Barley-Soybean		2.06a	1.88a	1.91a	1.13d	1.06d
Wheat-Soybean		1.96a	2.01a	1.78ab	1.11d	1.19cd
Seed weight (g 100 seed^{-1})						
Full-season	16.1a	15.8ab	15.6ab		15.5abcd	14.9de
Barley-Soybean		15.5abcd	15.4abcd	14.9cde	15.7abc	15.5abcd
Wheat-Soybean		15.5abcd	15.5abcd	15.2bcde	15.0cde	14.6e

†Means within the same measurement followed by the same letter are not significantly different at p = 0.05 using Fisher's Protected LSD.

‡Data not collected.

Table 4.9. Seed yield, plant biomass, height, and yield components of soybean planted on different dates into a rye cover crop, or barley or wheat harvested for grain at TAREC2 in 2009.

	Planting date					
	21 May	2 June	11 June	29 June	8 July	14 July
Seed yield (g m^{-2})						
Full-season	429	343	558		423	354
Barley-Soybean		433	472	311	429	364
Wheat-Soybean			502	587	549	346
Biomass (g m^{-2})						
Full-season	742	626	1040		794	697
Barley-Soybean		694	796	718	815	698
Wheat-Soybean			927	1001	977	744
Height $plant^{-1}$ (cm)						
Full-season	66	84	76		79	75
Barley-Soybean		70	78	75	72	73
Wheat-Soybean			84	78	73	64
Plants m^{-2}						
Full-season	16c†	20c	26bc		58a	68a
Barley-Soybean		19c	38abc	25bc	47abc	60a
Wheat-Soybean			26bc	52ab	65a	67a
Pods m^{-2}						
Full-season	1600	1106	1638	1368	1200	
Barley-Soybean		1355	1533	1330	1378	1205
Wheat-Soybean			1606	1872	1748	1266

Table 4.9. Continued.

	Planting date					
	21 May	2 June	11 June	29 June	8 July	14 July
Pods $plant^{-1}$						
Full-season	79ab	55abcd	67abc		25efg	18g
Barley-Soybean		78a	45cde	53bcd	30efg	21fg
Wheat-Soybean			61abc	39def	27efg	20g
Seed m^{-2}						
Full-season	2994	2406	3780		2904	2398
Barley-Soybean		2972	3205	2171	2944	2474
Wheat-Soybean			3491	4126	3753	2378
Seed pod^{-1}						
Full-season	2.2	2.2	2.3		2.1	2.0
Barley-Soybean		2.1	2.1	1.5	2.2	2.0
Wheat-Soybean			2.2	2.3	2.1	1.9
Seed weight (g 100 $seed^{-1}$)						
Full-season	14.3	14.3	14.7		14.6	14.7
Barley-Soybean		14.5	14.8	14.3	14.6	14.7
Wheat-Soybean			14.4	14.2	14.6	14.6

†Means within the same measurement followed by the same letter are not significantly different at p = 0.05 using Fisher's Protected LSD.

Table 4.10. Seed yield, plant biomass, height, and yield components of soybean planted on different dates into rye, barley, wheat, or previous crop residue at TAREC3 in 2010.

	Planting date									
	21 May	28 May	3 June	11 June	17 June	24 June	1 July	8 July	16 July	LS means
Seed yield (g m^{-2})										
Fallow-Soybean	165.4	195.1	204.7	144.2	187.1	209.1	245.8	168.1	218.8	193.1
Rye-Soybean	147.4	167.3	175.5	145.9	219.2	174.2	181.4	188.9	214.2	179.3
Barley-Soybean	216.1	282.9	207.8	194.0	159.8	138.4	226.5	164.3	219.2	201.0
Wheat-Soybean	225.2	145.5	178.7	214.2	124.0	166.5	241.5	175.9	170.3	182.4
LS means	188.5	197.7	191.6	174.6	172.5	172.1	223.8	174.3	205.6	
Biomass (g m^{-2})										
Fallow-Soybean	419	482	487	340	453	495	543	385	538	460
Rye-Soybean	410	462	444	385	538	446	444	434	484	450
Barley-Soybean	535	550	495	518	383	385	547	428	448	476
Wheat-Soybean	612	375	497	542	352	458	562	432	420	472
LS means	494	467	481	446	432	446	524	420	472	

Table 4.10. Continued.

	Planting date									
	21 May	28 May	3 June	11 June	17 June	24 June	1 July	8 July	16 July	LS means
Height $plant^{-1}$										
Fallow-Soybean	56	58	62	63	68	73	68	65	63	64b
Rye-Soybean	68	64	73	72	69	75	75	53	60	68ab
Barley-Soybean	52	64	65	74	68	67	77	73	66	67ab
Wheat-Soybean	74	62	71	75	70	81	74	71	64	71a
LS means	62c	62c	68abc	71ab	69abc	74a	73a	65bc	63c	
Plant m^{-2}										
Fallow-Soybean	45	45	37	32	38	39	35	39	82	43
Rye-Soybean	47	45	49	47	56	41	41	57	52	48
Barley-Soybean	51	33	35	51	33	30	45	41	56	42
Wheat-Soybean	45	29	37	53	32	35	31	49	40	39
LS means	47ab	38b	40b	45b	40b	36b	38b	46ab	57a	

Table 4.10. Continued.

	Planting date									
	21 May	28 May	3 June	11 June	17 June	24 June	1 July	8 July	16 July	LS means
Pods m^{-2}										
Fallow-Soybean	764	1029	1035	724	867	888	1118	720	1073	913
Rye-Soybean	877	886	936	774	1213	890	776	868	986	912
Barley-Soybean	1180	1199	1174	839	780	789	1042	780	1112	988
Wheat-Soybean	1163	775	1135	1085	757	963	876	881	902	976
LS means	1070	1018	1014	996	972	904	883	855	812	
Pods $plant^{-1}$										
Fallow-Soybean	22.0	25.0	28.0	32.9	22.0	30.6	32.2	20.0	16.6	26.8
Rye-Soybean	21.2	22.0	20.4	17.3	21.6	23.0	19.3	17.3	20.3	21.4
Barley-Soybean	24.4	37.5	33.5	16.5	24.2	31.7	23.6	22.7	23.3	27.4
Wheat-Soybean	26.8	26.2	35.0	21.6	26.1	29.9	34.8	20.1	61.3	30.9
LS means	24.7	31.0	29.8	22.4	22.8	34.1	27.6	19.8	27.4	

Table 4.10. Continued.

	Planting date									
	21 May	28 May	3 June	11 June	17 June	24 June	1 July	8 July	16 July	LS means
Seed m^{-2}										
Fallow-Soybean	1713	1831	2097	1395	1797	2117	2315	1462	1933	1851
Rye-Soybean	1463	1673	1802	1416	2183	1733	1728	1703	1937	1738
Barley-Soybean	2298	2744	2157	1937	1533	1421	2209	1609	2101	2001
Wheat-Soybean	2497	1506	1919	2095	1306	1692	2527	1725	1569	1871
LS means	1993	1939	1994	1711	1705	1741	2195	1625	1885	
Seed pod^{-1}										
Fallow-Soybean	3.03	1.79	2.03	1.92	1.99	2.37	2.07	2.04	1.81	2.12
Rye-Soybean	1.67	1.94	1.92	1.85	1.81	1.96	2.25	1.94	1.98	1.92
Barley-Soybean	1.98	2.76	1.80	2.40	1.94	1.85	2.11	2.04	1.93	2.09
Wheat-Soybean	2.11	2.02	1.66	1.09	1.77	1.77	2.41	2.02	1.84	1.95
LS means	2.20	2.13	1.85	2.02	1.88	1.99	2.21	2.01	1.89	

Table 4.10. Continued.

	Planting date									
	21 May	28 May	3 June	11 June	17 June	24 June	1 July	8 July	16 July	LS means
Seed weight (g 100 seed^{-1})										
Fallow-Soybean	9.7	10.55	9.6	10.5	10.3	9.9	10.6	11.4	11.2	10.4
Rye-Soybean	10.1	10.2	9.6	10.3	9.7	10.2	10.5	11.0	11.1	10.3
Barley-Soybean	9.6	9.9	9.4	10.0	10.1	9.9	10.2	10.6	10.7	10.3
Wheat-Soybean	9.1	10.0	9.2	10.1	9.3	9.9	9.7	10.8	10.9	9.9
LS means	9.6b	10.2ab	9.5b	10.2ab	9.9b	10.0b	10.2ab	11.0a	11.0a	

†Means within the same measurement followed by the same letter are not significantly different at $p = 0.05$ using Fisher's Protected LSD.

Table 4.11. Seed yield, plant biomass, height, and yield components of soybean planted on different dates into rye, barley, wheat, or previous crop residue in 2010.

	Planting date									
	22 May	28 May	3 June	11 June	17 June	23 June	1 July	8 July	16 July	LS means
Seed yield (g m^{-2})										
Fallow-Soybean	240.6	223.5	165.2	219.7	243.3	89.0	128.4	197.1	161.6	185b†
Rye-Soybean	326.2	244.8	239.6	213.2	204.2	255.7	158.6	184.5	151.7	220ab
Barley-Soybean	267.7	319.4	272.0	273.7	262.5	204.2	203.9	192.8	191.3	243a
Wheat-Soybean	270.7	242.7	183.1	233.0	255.1	196.9	161.1	151.9	178.5	208ab
LS means	276a	258ab	215bcde	235abcd	241abc	186cde	163e	182de	171e	
Biomass (g m^{-2})										
Fallow-Soybean	513	495	370	461	492	177	265	390	312	386b
Rye-Soybean	676	576	533	486	480	559	306	382	307	478a
Barley-Soybean	584	745	609	617	596	456	398	386	406	533a
Wheat-Soybean	591	559	423	548	583	402	301	316	374	455ab
LS means	591a	594a	484ab	528a	538a	398bc	317c	368bc	350c	

Table 4.11. Continued.

	Planting date									
	22 May	28 May	3 June	11 June	17 June	23 June	1 July	8 July	16 July	LS means
Height plant^{-1}										
Fallow-Soybean	76	73	74	64	65	60	51	56	42	62
Rye-Soybean	71	74	69	81	78	70	56	49	53	67
Barley-Soybean	67	67	70	80	69	62	58	66	57	66
Wheat-Soybean	70	72	74	83	77	68	54	51	62	68
LS means	71ab	71ab	72ab	77a	72ab	65b	55c	55c	53c	
Plant m^{-2}										
Fallow-Soybean	26	27	18	33	27	5	10	26	43	24b
Rye-Soybean	45	34	42	43	41	33	20	42	42	38a
Barley-Soybean	45	42	43	51	60	26	29	30	49	42a
Wheat-Soybean	38	37	35	49	43	16	18	34	53	36a
LS means	39abc	35bc	35bc	44ab	43abc	20d	19d	33c	47a	

Table 4.11. Continued.

	Planting date									
	22 May	28 May	3 June	11 June	17 June	23 June	1 July	8 July	16 July	LS means
Pods m^{-2}										
Fallow-Soybean	975	924	730	905	961	291	446	745	627	734b
Rye-Soybean	1361	1081	1049	1005	951	1105	553	727	563	933a
Barley-Soybean	1102	1329	1153	1280	1175	888	749	719	757	1017a
Wheat-Soybean	1173	1073	883	1077	1196	780	554	567	652	884ab
LS means	1153a	1102a	954ab	1066a	1071a	766bc	576c	689c	650c	
Pods $plant^{-1}$										
Fallow-Soybean	43.7	30.1	40.5	35.7	41.0	66.0	47.1	29.6	16.8	41.0a
Rye-Soybean	32.2	30.7	24.2	21.9	23.8	38.4	29.8	17.5	14.8	25.5b
Barley-Soybean	28.0	31.6	30.9	27.1	23.4	45.7	27.9	25.1	17.0	27.3b
Wheat-Soybean	29.7	35.0	27.4	23.5	30.0	50.6	32.8	16.7	14.5	28.0b
LS means	34.3bc	27.2bc	29.8bc	27.6bc	32.1bc	48.6a	35.7b	23.2cd	15.3d	

Table 4.11. Continued.

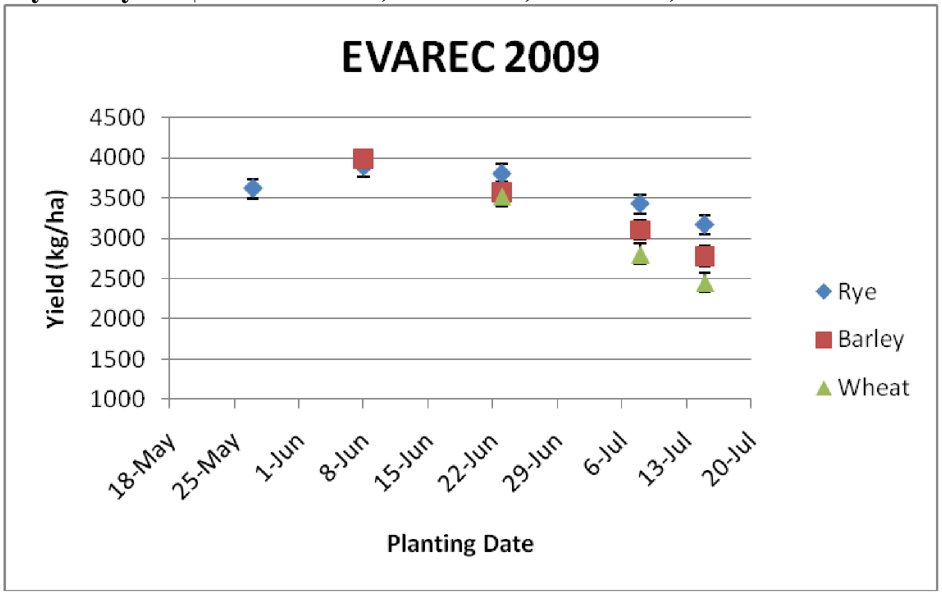
	Planting date									
	22 May	28 May	3 June	11 June	17 June	23 June	1 July	8 July	16 July	LS means
Seed m^{-2}										
Fallow-Soybean	1924	1768	1399	1930	2060	736	966	1453	1235	1497b
Rye-Soybean	2611	1972	2132	1838	1924	2216	1201	1374	1126	1821a
Barley-Soybean	2139	2644	2438	2443	2450	1886	1606	1421	1448	2054a
Wheat-Soybean	2287	1969	1621	2079	2337	2056	1232	944	1353	1791ab
LS means	2240a	2088ab	1897ab	2072ab	2193ab	1724bc	1251c	1360c	1290c	
Seed pod^{-1}										
Fallow-Soybean	1.98	1.85	1.93	2.18	2.18	2.39	2.13	1.95	1.95	2.06
Rye-Soybean	1.88	1.85	2.03	1.83	2.05	2.00	2.15	1.84	2.03	1.96
Barley-Soybean	1.98	1.93	2.13	1.90	2.13	2.08	2.15	1.94	1.90	2.01
Wheat-Soybean	1.98	1.75	1.83	2.01	1.90	2.21	2.25	2.12	2.18	2.02
LS means	1.95cd	1.84d	1.97cd	1.98cd	2.06abc	2.16ab	2.18a	1.96cd	2.02bc	

Table 4.11. Continued.

	Planting date									
	22 May	28 May	3 June	11 June	17 June	23 June	1 July	8 July	16 July	LS means
Seed weight (g 100 $seed^{-1}$)										
Fallow-Soybean	12.5	12.6	11.8	11.5	11.6	13.0	13.7	13.6	13.3	12.6a
Rye-Soybean	12.5	12.6	11.2	11.4	10.6	11.5	13.3	13.5	13.5	12.2b
Barley-Soybean	12.5	12.1	11.2	11.3	10.7	10.8	12.7	13.5	13.2	12.0b
Wheat-Soybean	12.0	12.3	11.2	11.2	10.9	11.0	13.1	13.0	13.2	12.0b
LS means	12.4b	12.4b	11.3cd	11.4cd	10.9d	11.6c	13.2a	13.4a	13.3a	

† Means within the same measurement followed by the same letter are not significantly different at $p = 0.05$ using Fisher's Protected LSD.

Fig. 4.1. Influence of planting date and winter grain on full-season and double-cropped soybean yield† at EVAREC, SPAREC, TAREC1, and TAREC2 in 2009.



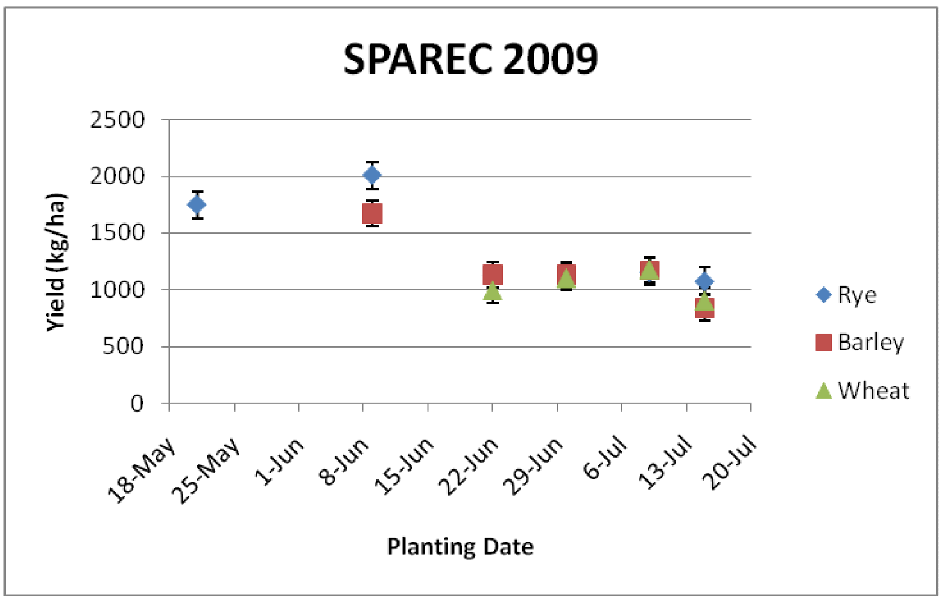
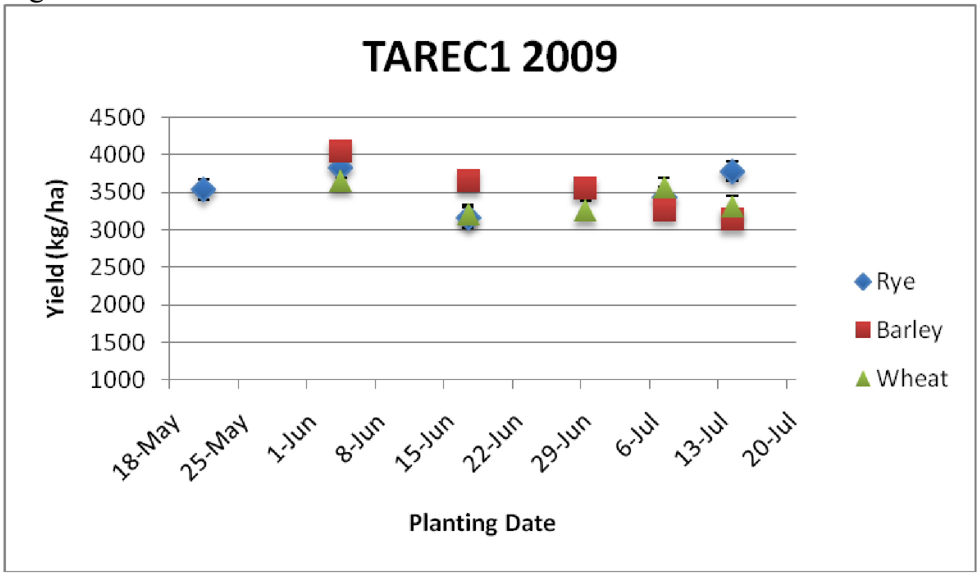
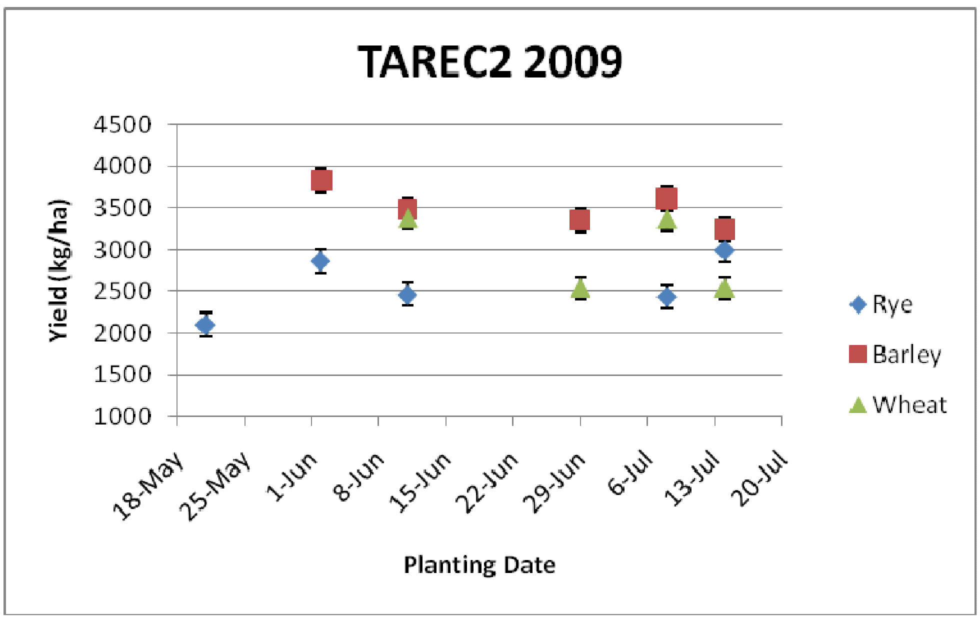


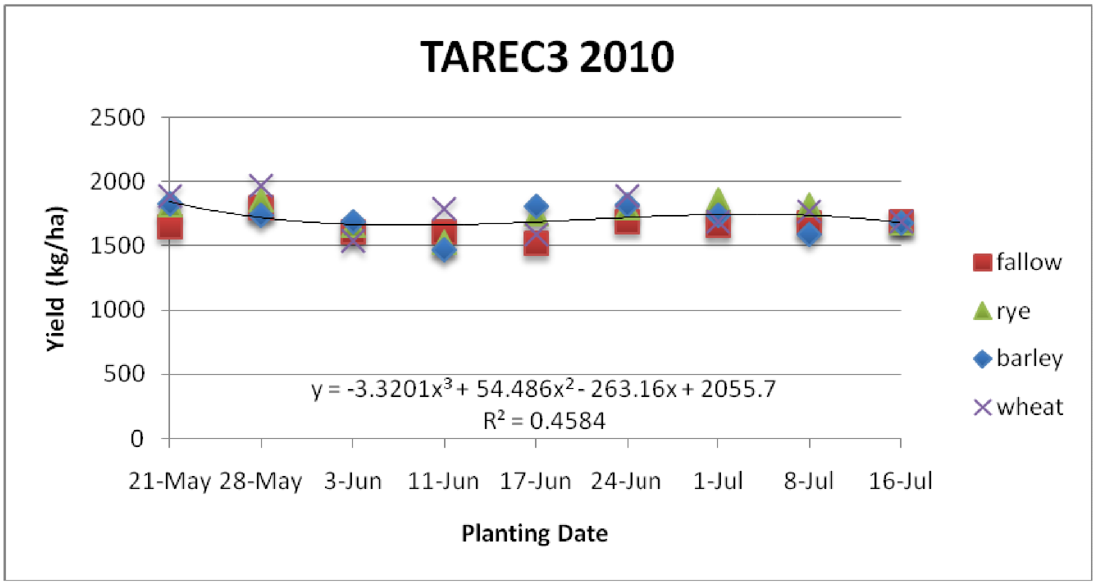
Fig. 4.1. Continued.





† Least squares means with standard error.

Fig. 4.2. Influence of planting date on full-season and double-cropped soybean yield at TAREC3 and TAREC4 in 2010.



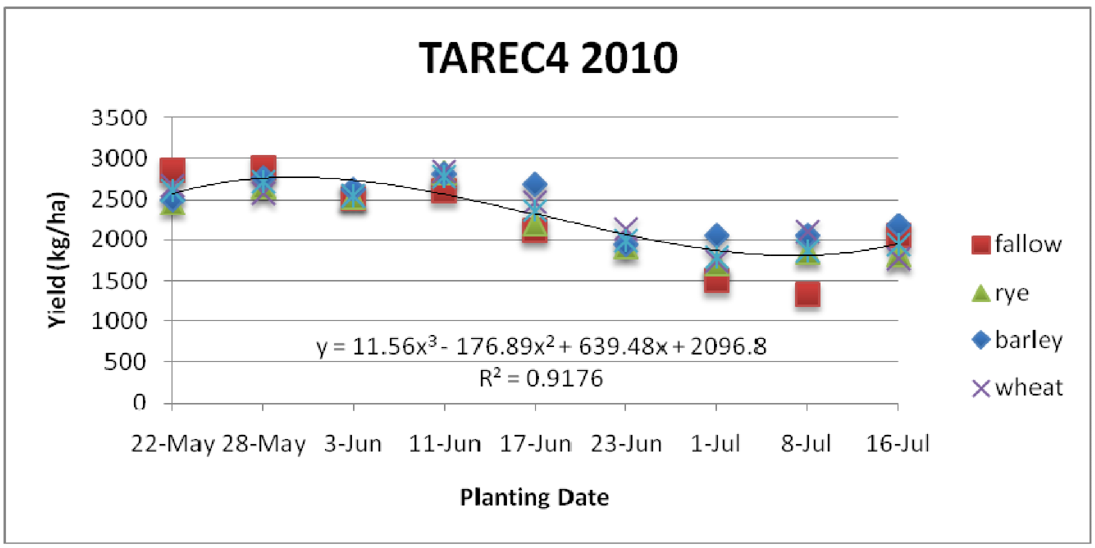
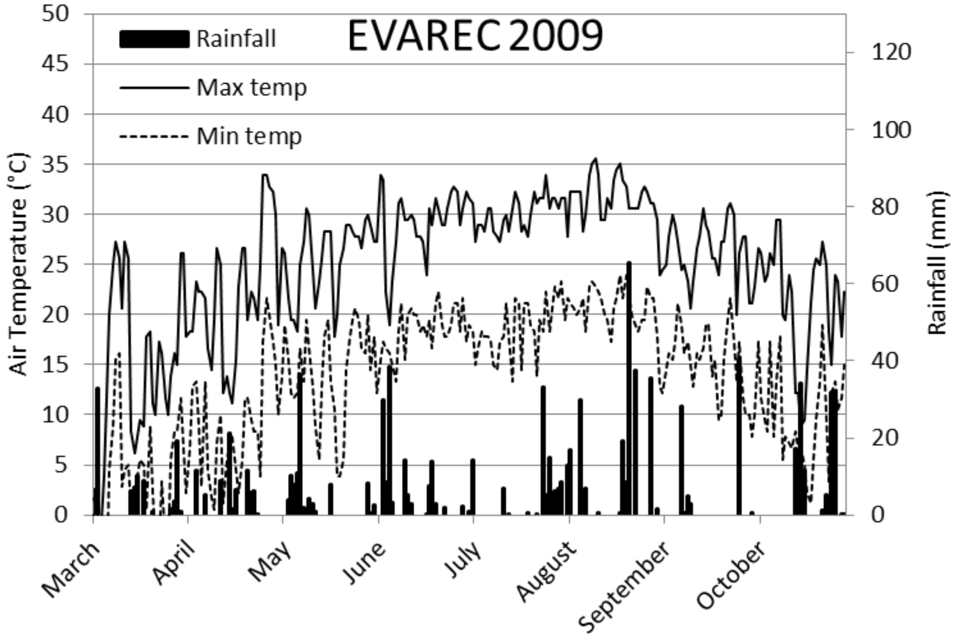


Fig. 4.3. Maximum and minimum temperatures and rainfall† at EVAREC, SPAREC, and TAREC in 2009, and TAREC in 2010.



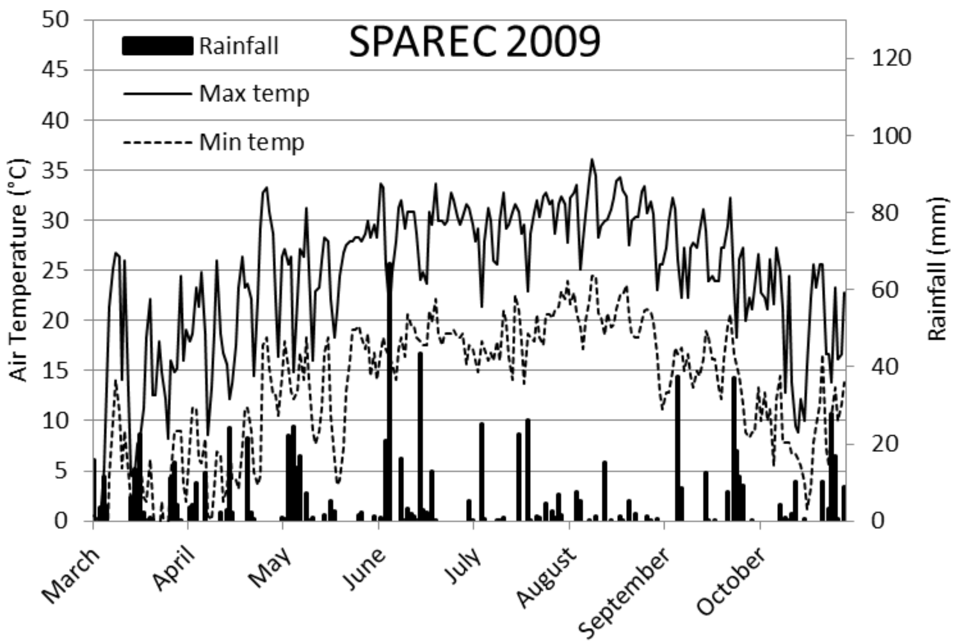
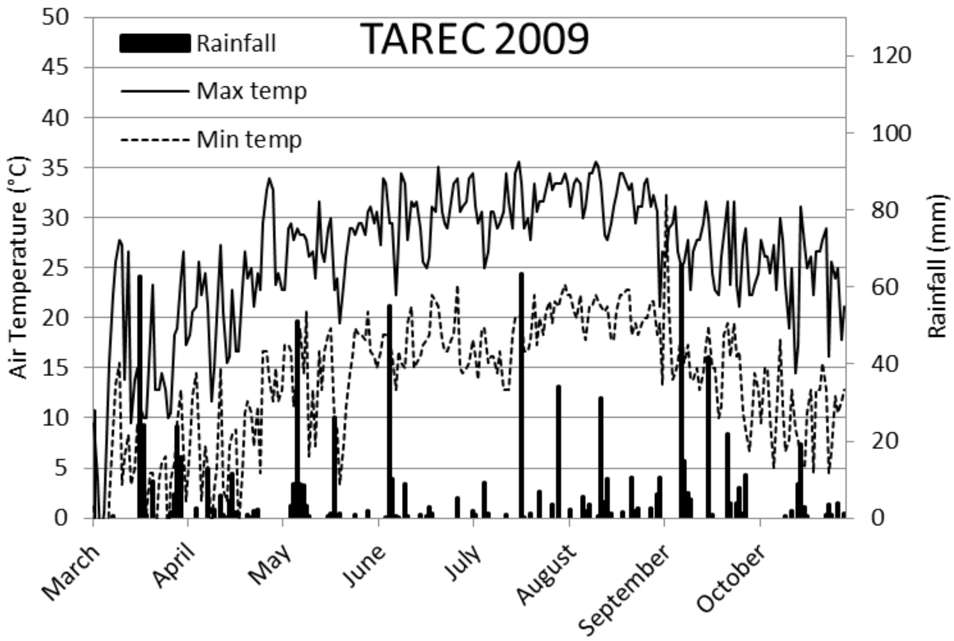
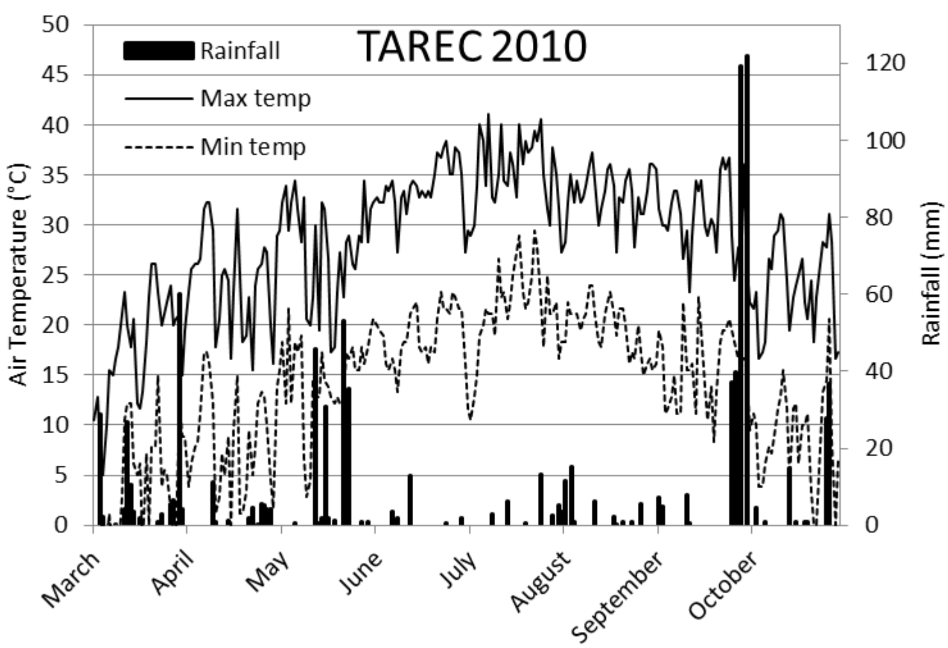


Fig. 4.3. Continued.





†TAREC rainfall does not include 50 mm of irrigation on 15 July 2009 and 25 mm on two occasions on 1 and 20 July 2010.

APPENDIX A

Appendix A: Production costs used to calculate net returns for full-season and double-cropped soybean systems from 2008-2010.

	Full-Season Fallow-Soybean	Full-Season Rye-Soybean	Double-Cropped Barley-Soybean	Double-Cropped Wheat-Soybean
Pre-harvest variable costs				
Seed				
Small Grain	----	30.00	22.50	35.00
Soybean	32.00	32.00	48.00	48.00
Fertilizer	VARIES	VARIES	VARIES	VARIES
Fertilizer Application	7.25	7.25	7.25	7.25
Lime (Prorated)	16.25	16.25	16.25	16.25
Pesticides	28.00	28.00	49.19	47.94
Fuel, Oil, Lube	3.71	6.74	8.74	8.74
Repairs	7.44	12.60	13.16	13.16
Pre-Harvest Labor	2.90	4.93	6.67	6.67
Crop Insurance	13.36	13.36	19.26	24.82

Appendix A. Continued.

	Full-Season Fallow-Soybean	Full-Season Rye-Soybean	Double-Cropped Barley-Soybean	Double-Cropped Wheat-Soybean
Harvest Variable Costs				
Fuel, Oil, Lube	5.05	5.05	10.10	10.10
Repairs	6.26	6.26	12.52	12.52
Harvest Labor	2.61	2.61	5.08	5.08
Hauling	8.75	8.75	30.75	24.00
Fixed Costs				
Machinery	29.20	40.60	60.79	60.79
General Overhead	14.14	17.28	30.18	32.79

APPENDIX B

Appendix B. Annual, average, and median prices for soybean, barley, wheat, and corn across Virginia and at several delivery stations from 2006 to 2010.

Appendix B1. Annual, average, and median prices of soybean, barley, wheat, and corn across Virginia, and at delivery stations in Petersburg and Tappahannock, Virginia, from 2006 to 2010.

	Soybean	Barley	Wheat	Corn
	$ / bushel			
Virginia				
2006	6.54	1.54	3.24	3.07
2007	11.40	2.76	5.78	4.39
2008	9.10	4.22	5.88	4.51
2009	9.40	2.37	4.07	3.66
2010	11.80	2.45	5.00	5.10
Average	9.65	3.33	4.79	4.15
Median	NA†	NA	NA	NA
Petersburg				
2006	5.63	1.35	3.35	2.70
2007	8.15	2.11	5.87	3.91
2008	11.93	3.21	6.38	5.44
2009	9.95	2.04	4.00	4.09
2010	10.28	----	5.13	4.59
Average	9.19	2.18	4.95	4.15
Median	9.19	2.25	4.08	4.04

Appendix B1. Continued.

Tappahannock				
2006	5.73	----	3.33	2.58
2007	8.32	2.62	5.57	3.83
2008	12.12	3.87	6.91	5.04
2009	10.11	2.70	3.67	3.90
2010	9.33	----	2.69	3.76
Average	9.12	2.18	4.43	3.82
Median	9.15	2.25	3.99	3.78

† NA, not applicable.

Appendix B2. Annual, average, and median prices for Chicago Mercantile Exchange July corn and estimated annual, average, and median prices for Osage Bio Energy barley at Hopewell and Tappahannock, Virginia, from 2006 to 2010.

	Chicago Corn	Hopewell Barley†	Tappahannock Barley‡
		$ / bushel	
2006	2.87	2.29	2.04
2007	3.97	3.18	2.93
2008	5.57	4.45	4.20
2009	3.93	3.15	2.90
2010	4.48	3.58	3.33
Average	4.16	3.33	3.08
Median	3.99	3.19	2.92

† Hopewell barley prices are calculated as 20% of Chicago Mercantile Exchange July corn prices.
‡ Tappahannock barley prices are calculated as 20% of Chicago Mercantile Exchange July corn prices less a $.25 per bushel basis.

APPENDIX C

Appendix C: Full-Season, Double-Cropped Barley-Soybean, and Double-Cropped Wheat-Soybean Example Enterprise Budgets.

Appendix C1: Full-Season Soybean Example Enterprise Budget

Virginia Cooperative Extension

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SOYBEANS - RR, Minimum Tillage (Group 1 - 2 Soils)

						Acres
ESTIMATED COSTS AND RETURNS PER ACRE						1
	35	BUSHEL YIELD				
		UNIT	QUANTITY PER ACRE	PRICE OR COST/UNIT	TOTAL PER ACRE	YOUR FARM
1. GROSS RECEIPTS						
SOYBEANS		BU.	35.00	$9.19	$321.65	
TOTAL RECEIPTS:					**$321.65**	
2. PRE-HARVEST VARIABLE COSTS						
SEED: SOYBEANS-RR		BAG	0.80	$40.00	$32.00	
FERTILIZER*	Soil Test Recommendation					
NITROGEN		LBS	0.00	$0.50	$0.00	
PHOSPHATE		LBS	28.00	$0.54	$15.12	
POTASH		LBS	49.00	$0.48	$23.52	
FERTILIZER APPLICATION		ACRE	1.00	$7.25	$7.25	
LIME (PRORATED)		TON	0.50	$32.50	$16.25	
HERBICIDES		ACRE	1.00	$22.50	$22.50	
INSECTICIDES		ACRE	1.00	$1.23	$1.23	
FUNGICIDES		ACRE	1.00	$4.27	$4.27	
CHEMICAL APPLICATION		ACRE	0.00	$7.00	$0.00	
FUEL, OIL, LUBE		Eq Gallons	1.45	$2.56	$3.71	
REPAIRS		ACRE	1.00	$7.44	$7.44	
PRE-HARVEST LABOR		HRS	0.20	$14.50	$2.90	
CASH RENT OR LAND CHARGE		ACRE	1.00	$0.00	$0.00	
CROP INSURANCE		ACRE	1.00	$13.36	$13.36	
SCOUTING		ACRE	1.00	$0.00	$0.00	
OTHER COSTS		ACRE	1.00	$0.00	$0.00	
PRODUCTION INTEREST	6	MONTHS	$74.78	6.0%	$4.49	
TOTAL PRE-HARVEST COSTS			**$4.40**	**PER BU.**	**$154.04**	
3. HARVEST VARIABLE COSTS						
FUEL, OIL, LUBE		Eq Gallons	1.97	$2.56	$5.05	
REPAIRS		ACRE	1.00	$6.26	$6.26	
HARVEST LABOR		HRS	0.18	$14.50	$2.61	
HAULING		BU.	35.00	$0.25	$8.75	
STORAGE		BU.	35.00		$0.00	
DRYING		BU.	35.00		$0.00	
TOTAL HARVEST COSTS:			**$0.65**	**PER BU.**	**$22.67**	
	Breakeven Yield			Breakeven Price		
4. TOTAL VARIABLE COSTS	**19**	**Bushels**	**$5.05**	**PER Bushel**	**$176.71**	
5. RETURN OVER TOTAL VARIABLE COSTS					**$144.94**	
6. MACHINERY FIXED COSTS (BASED ON NEW EQUIPMENT COST)						
TRACTOR & MACHINERY		ACRE	1.00	$29.20	$29.20	
7. OTHER FIXED COSTS						
GENERAL OVERHEAD		DOL.	$176.71	8.0%	$14.14	
8. TOTAL FIXED COSTS:					**$43.34**	
9. TOTAL VARIABLE & FIXED COSTS			**$6.29**	**PER Bushel**	**$220.05**	
10. PROJECTED NET RETURNS TO LAND, RISK AND MANAGEMENT:					**$101.60**	

* This BUDGET is for PLANNING PURPOSES ONLY. Fertilizer rates are based on projected nutrient removal of harvested crop.

* Fertilizer requirements will vary with application method, manure use and/or residual nutrient levels in the soil.

Appendix C2: Double-Cropped Barley-Soybean System Example Enterprise Budget

Virginia Cooperative Extension

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BARLEY INTENSIVE MANAGEMENT, SOYBEANS RR Double Crop

ESTIMATED COSTS AND RETURNS PER ACRE

Acres 1

	UNIT	QUANTITY PER ACRE	PRICE OR COST/UNIT	TOTAL PER ACRE	YOUR FARM
1. GROSS RECEIPTS					
BARLEY	BU	90.00	$3.19	$287.10	
SOYBEANS	BU	33.00	$9.19	$303.27	
TOTAL RECEIPTS:				**$590.37**	
2. PRE-HARVEST VARIABLE COSTS					
SEED: BARLEY Thoroughbred	BAG	2.50	$9.00	$22.50	
SEED: SOYBEANS-RR	BAG	1.20	$40.00	$48.00	
FERTILIZER*	Soil Test Recommendation				
NITROGEN	LBS	102.00	$0.50	$51.00	
PHOSPHATE	LBS	61.00	$0.54	$32.94	
POTASH	LBS	72.00	$0.48	$34.56	
FERTILIZER APPLICATION	ACRE	1.00	$7.25	$7.25	
LIME (PRORATED)	TON	0.50	$32.50	$16.25	
HERBICIDES	ACRE	1.00	$31.42	$31.42	
INSECTICIDES	ACRE	1.00	$1.62	$1.62	
FUNGICIDES	ACRE	1.00	$16.15	$16.15	
CHEMICAL APPLICATION	ACRE	0.00	$7.00	$0.00	
FUEL,OIL, LUBE	Eq Gallons	3.41	$2.56	$8.74	
REPAIRS	ACRE	1.00	$13.16	$13.16	
PRE-HARVEST LABOR	HRS	0.46	$14.50	$6.67	
CASH RENT OR LAND CHARGE	ACRE	1.00	$0.00	$0.00	
CROP INSURANCE	ACRE	1.00	$19.26	$19.26	
SCOUTING	ACRE	1.00	$0.00	$0.00	
OTHER COSTS	ACRE	1.00	$0.00	$0.00	
PRODUCTION INTEREST	6 MONTHS	$154.76	6.0%	$9.29	
TOTAL PRE-HARVEST COSTS				**$318.81**	
3. HARVEST VARIABLE COSTS					
FUEL,OIL, LUBE	Eq Gallons	3.95	$2.56	$10.10	
REPAIRS	ACRE	1.00	$12.52	$12.52	
HARVEST LABOR	HRS	0.35	$14.50	$5.08	
HAULING	BU.	123.00	$0.25	$30.75	
STORAGE	BU.	123.00	$0.00	$0.00	
DRYING	BU.	123.00	$0.00	$0.00	
TOTAL HARVEST COSTS:				**$58.45**	
	Breakeven Yield	Breakeven Price			
4. TOTAL VARIABLE COSTS				**$377.26**	
5. RETURN OVER TOTAL VARIABLE COSTS				**$213.11**	
6. MACHINERY FIXED COSTS (BASED ON NEW EQUIPMENT COST)					
TRACTOR & MACHINERY	ACRE	1.00	$60.79	$60.79	
7. OTHER FIXED COSTS					
GENERAL OVERHEAD	DOL.	$377.26	8.0%	$30.18	
8. TOTAL FIXED COSTS:				**$90.97**	
9. TOTAL VARIABLE & FIXED COSTS				**$468.23**	
10. PROJECTED NET RETURNS TO LAND, RISK AND MANAGEMENT:				**$122.14**	

* This BUDGET is for PLANNING PURPOSES ONLY. Fertilizer rates are based on projected nutrient removal of harvested crop.

* Fertilizer requirements will vary with application method, manure use and/or residual nutrient levels in the soil.

Appendix C3: Double-Cropped Wheat-Soybean System Example Enterprise Budget

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INTENSIVE MANAGEMENT WHEAT, SOYBEANS RR Double Crop

ESTIMATED COSTS AND RETURNS PER ACRE

Acres 1

		UNIT	QUANTITY PER ACRE	PRICE OR COST/UNIT	TOTAL PER ACRE	YOUR FARM
1. GROSS RECEIPTS						
WHEAT		BU	70.00	$4.08	$285.60	
SOYBEANS		BU	26.00	$9.19	$238.94	
TOTAL RECEIPTS:					**$524.54**	
2. PRE-HARVEST VARIABLE COSTS						
SEED: WHEAT		BAG	2.50	$14.00	$35.00	
SEED: SOYBEANS-RR		BAG	1.60	$40.00	$64.00	
FERTILIZER*	Soil Test Recommendation					
NITROGEN		LBS	114.00	$0.50	$57.00	
PHOSPHATE		LBS	65.00	$0.54	$35.10	
POTASH		LBS	64.00	$0.48	$30.72	
FERTILIZER APPLICATION		ACRE	1.00	$7.25	$7.25	
LIME (PRORATED)		TON	0.50	$32.50	$16.25	
HERBICIDES		ACRE	1.00	$30.17	$30.17	
INSECTICIDES		ACRE	1.00	$1.62	$1.62	
FUNGICIDES		ACRE	1.00	$16.15	$16.15	
CHEMICAL APPLICATION		ACRE	0.00	$7.00	$0.00	
FUEL,OIL, LUBE		Eq Gallons	3.41	$2.56	$8.74	
REPAIRS		ACRE	1.00	$13.16	$13.16	
PRE-HARVEST LABOR		HRS	0.46	$14.50	$6.67	
CASH RENT OR LAND CHARGE		ACRE	1.00	$0.00	$0.00	
CROP INSURANCE		ACRE	1.00	$24.82	$24.82	
SCOUTING		ACRE	1.00	$0.00	$0.00	
OTHER COSTS		ACRE	1.00	$0.00	$0.00	
PRODUCTION INTEREST	6	MONTHS	$173.33	6.0%	$10.40	
TOTAL PRE-HARVEST COSTS					**$357.05**	
3. HARVEST VARIABLE COSTS						
FUEL,OIL, LUBE		Eq Gallons	3.95	$2.56	$10.10	
REPAIRS		ACRE	1.00	$12.52	$12.52	
HARVEST LABOR		HRS	0.35	$14.50	$5.08	
HAULING		BU.	96.00	$0.25	$24.00	
STORAGE		BU.	96.00	$0.00	$0.00	
DRYING		BU.	96.00	$0.00	$0.00	
TOTAL HARVEST COSTS:					**$51.70**	
	Breakeven Yield		Breakeven Price			
4. TOTAL VARIABLE COSTS					**$408.75**	
5. RETURN OVER TOTAL VARIABLE COSTS					**$115.79**	
6. MACHINERY FIXED COSTS (BASED ON NEW EQUIPMENT COST)						
TRACTOR & MACHINERY		ACRE	1.00	$60.79	$60.79	
7. OTHER FIXED COSTS						
GENERAL OVERHEAD		DOL.	$408.75	8.0%	$32.70	
8. TOTAL FIXED COSTS:					**$93.49**	
9. TOTAL VARIABLE & FIXED COSTS					**$502.24**	
10. PROJECTED NET RETURNS TO LAND, RISK AND MANAGEMENT:					**$22.30**	

* This BUDGET is for PLANNING PURPOSES ONLY. Fertilizer rates are based on projected nutrient removal of harvested crop.

* Fertilizer requirements will vary with application method, manure use and/or residual nutrient levels in the soil.