

**PROJECT PROPOSAL
TO
THE VIRGINIA SOYBEAN BOARD**

Title: Physiology of Soybean Yield and Variety Advancement in Virginia Cropping Systems

Cooperators: Drs. Maria Balota and David Holshouser
Assistant Professor, Crop Physiology, Associate Professor & Ext. Agronomist

Location: Virginia Tech – Tidewater AREC
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Duration of Request: July 1, 2012 to June 30, 2013

Estimated Cost: \$20,000

Objectives of Research:

1. To determine the magnitude of change in dryland soybean yield with variety improvement in full-season and double-cropped soybean systems.
2. Determine the physiological mechanisms contributing to yield and variety improvement.

Significance of Research:

Over the last 30 years, soybean yields in the U.S. and Virginia have increased by an average of 0.5 and 0.35 bushels per acre per year, respectively (Fig. 1). Virginia soybean variety test results show a similar yield improvement over the last 23 years. When these data are separated by cropping system, the yield improvement of full-season soybean approach an average of 0.6 bushels per acre per year but yield improvements in a double-cropped system are flat (Fig. 2a). A more detailed evaluation of these data indicates that most of the full-season yield increase occurred before 1998 and is relatively flat afterwards (Fig. 2b). More concerning is that double-crop yields have gradually declined until the last 2 years, when late-season rains pushed double-crop yields above full-season yields. There is a need to more fully investigate why these yield trends are occurring. Physiological measurements of old and new varieties should improve our knowledge, allow us to better understand yield as related to variety improvement, and better direct breeding programs in search of greater yields.

Prior and Current Research:

Improvements in yield should involve genetic changes that counteract yield-limiting resources such as water and light. Water is likely the most limiting factor in Virginia due to the low water-holding capacity of our soils and hectic precipitation distribution. The ability of one variety to more efficiently use water in relation to other varieties, i.e., produce more yield with less water or have greater water use efficiency (WUE), could result in greater yields under rainfed environments. Water use efficiency in soybean and other crops can be estimated directly by measurements of yield and water use, which is difficult to do with large numbers of breeding lines, and indirectly by transpiration efficiency (TE) from leaf gas exchange measurements. It can also be estimated from measurements of specific leaf area (SLA) and leaf chlorophyll concentration (SPAD values). The SPAD measurements are easy and inexpensive and they correlated well with WUE in other crops, peanut for example, therefore they can be used as a surrogate of WUE in breeding populations. Carbon 13 isotope discrimination is also well correlated with WUE and TE in many crops. While this analysis is fast, its cost is higher than other

physiological analyses, but much less expensive than molecular marker analysis. Water availability is also interrelated with the other resources and, therefore, can greatly affect their utilization. For example under drought, plants supply with CO₂ for photosynthesis, growth, and development is severely reduced by stomata closure. In this case plants will cease to grow. They will also reach temperatures well above ambient because transpirational cooling will be impeded. Plants will undergo heat stress with negative effects on reproductive organs. Canopy temperature depression (CTD) can be evaluated with a handheld infra-red thermometer (IRT); measurements are easy and inexpensive.

Effective utilization of light in soybean is largely dependent on accumulating the necessary leaf area (LA) and leaf area index (LAI). In soybean, LAI should be 3.5 to 4.0 by early pod development. If this can be achieved, the crop can capture approximately 95% of the incident radiation. The lack of leaf area accumulation is largely responsible for the yield difference between full-season (high LAI) and double-crop (low LAI) soybean. Genetically selecting a soybean variety with rapid vegetative growth may favor the variety in double-crop systems. However, one should not assume that optimizing only LAI suffices for maximum yields. The effectiveness of leaves to transform the radiation into energy can be of great importance and may be genetically linked. For instance, thicker leaves measured as SLA may contain more chloroplasts and be more effective users of sunlight. Genetic yield improvements in soybean have been reported to be related to photosynthesis (Wells et al., 1982; Boerma and Ashley, 1988), leaf greenness as measured by the normalized difference vegetative index (NDVI), greater leaf area duration, and dry matter accumulation during seed fill (Kumudini et al., 2001). Both water and light can limit nutrients in soybean, especially nitrogen (N), and therefore yield.

Little to no research has been done in Virginia in relation to genetic gains due to breeding of soybean and to elucidate what plant mechanisms are associated with these gains. In 2010 and 2011, the Crop Physiology and Soybean Agronomy Programs at Tidewater AREC started an experiment on ten soybean cultivars released during 1973-2010. While these cultivars seem to show an increase in yield potential (Fig. 1), it is not known which are the yield components and physiological mechanisms associated with the yield increase. Cultivars and their release year used in this test were: Essex, 1973, Hutcheson, 1988, Graham, 1996, USG5601T, 2001, CL54RR (99VPI-67), 2003, AG5605, 2004, Teejay, 2005, Glenn, 2009, USG 75J50R, 2010, and V03-3650, not yet released. These cultivars were planted on 27 May as full season, and 17 June as double crop at TAREC, Suffolk, VA, and EVAREC, Warsaw, VA. Within each cropping system, cultivars were replicated four times in a randomized complete block design. Based on the 2010 data we found that soybean cultivars are significantly different for yield as well as the physiological characteristics listed in Table 1. Yield was significantly correlated with CTD, LAI, SLA, and SPAD (Table 1). We also found that full pod stage (R4) could be the optimum stage to get better yield prediction. From the study in 2011 we clearly saw a photosynthetic depression in double crop *vs.* full season soybean (Fig. 2) that may explain why double-cropped beans are less productive than full season beans. From this study, more data will continue to be collected on plant samples collected at physiological maturity including yield components, seed m⁻², seed size, pod m⁻², seed per pod, ¹³C discrimination, and N concentration in leaves and grains.

Table 1. Correlation between grain yield and physiological measurements taken at Tidewater AREC, 2010 (r values; n = 30). Data from Full season (FS) and Double crop (DC) tests were combined. The DC test was approximately one growth stage behind the FS test.

Stage/Trait	Canopy temperature depression (CTD) [†]	Leaf area index (LAI) [‡]	Dry Matter (DM)	Specific leaf area (SLA) [¶]	Chlorophyll content estimate (SPAD)	¹³ C discrimination (WUE) ^ξ	N content
V10-V12	0.023 NS	0.530**	-	0.036 NS	-0.149 NS	-	-
R2 (full bloom)	-0.580**	0.312 #	0.044 NS	0.132 NS	0.335 #	-	-
R4 (full pod)	-0.463**	0.329 #	0.084 NS	-0.590**	0.397*	-	-
R6 (full seed)	-0.168 NS	0.397 *	0.141 NS	-0.316 NS	0.142 NS	-	-
R7 (Physiological maturity)	-	-	To be determined	-	-	To be determined	To be determined

[†]CTD. Calculates temperature canopy (°C) – Temperature air (°C); negative r signifies that cooler canopies had greater yield than hotter canopies.

[‡]LAI obtain with a LAI-2000 Plant Canopy Analyzer (LI-COR Bioscience)

[¶] SLA (cm² g⁻¹) = LA (cm²) / DM (g). Smaller & thicker leaves appear to be better suited for dry environments.

^ξ At maturity, leaves and seed will be used for ¹³C analysis

* Significance at the 0.05 probability level

**Significant at the 0.01 probability level

#Significant at the 0.1 probability level

NS, not significant. [¶] SLA (cm² g⁻¹) = LA (cm²) / DM (g)

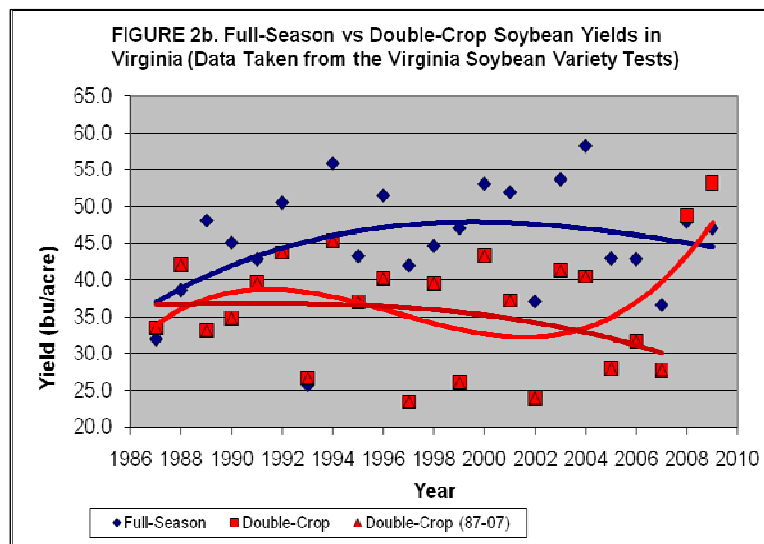
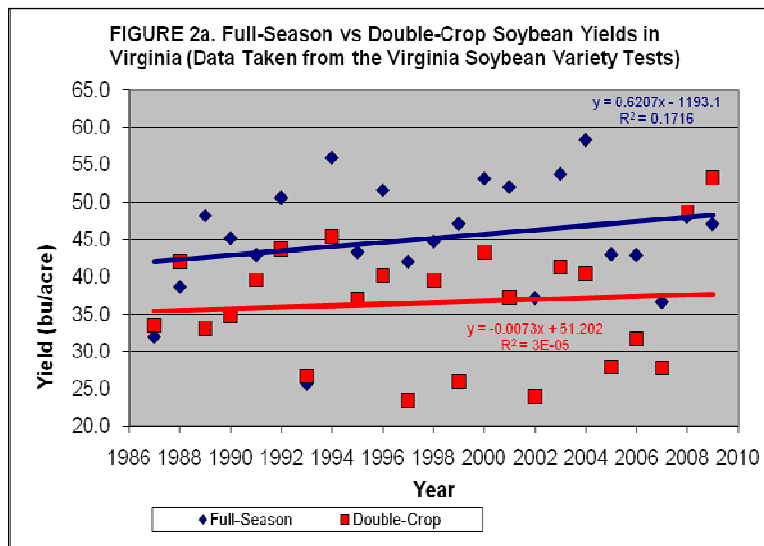
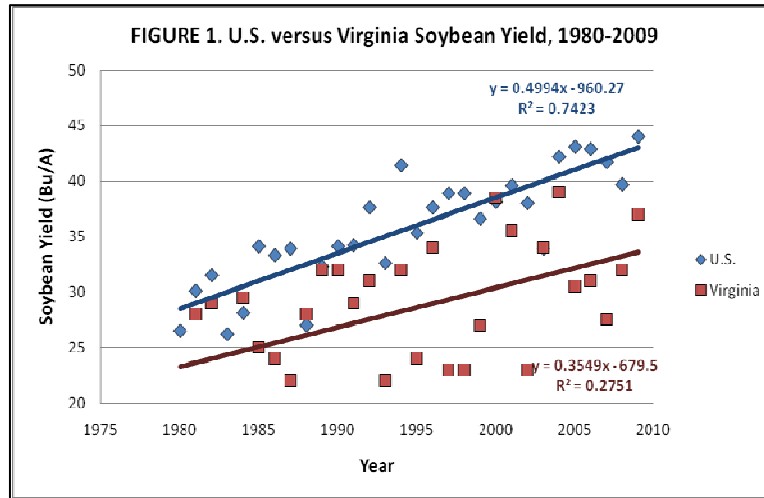


Figure 1. Effect of year of release on US and Virginia soybean yields.

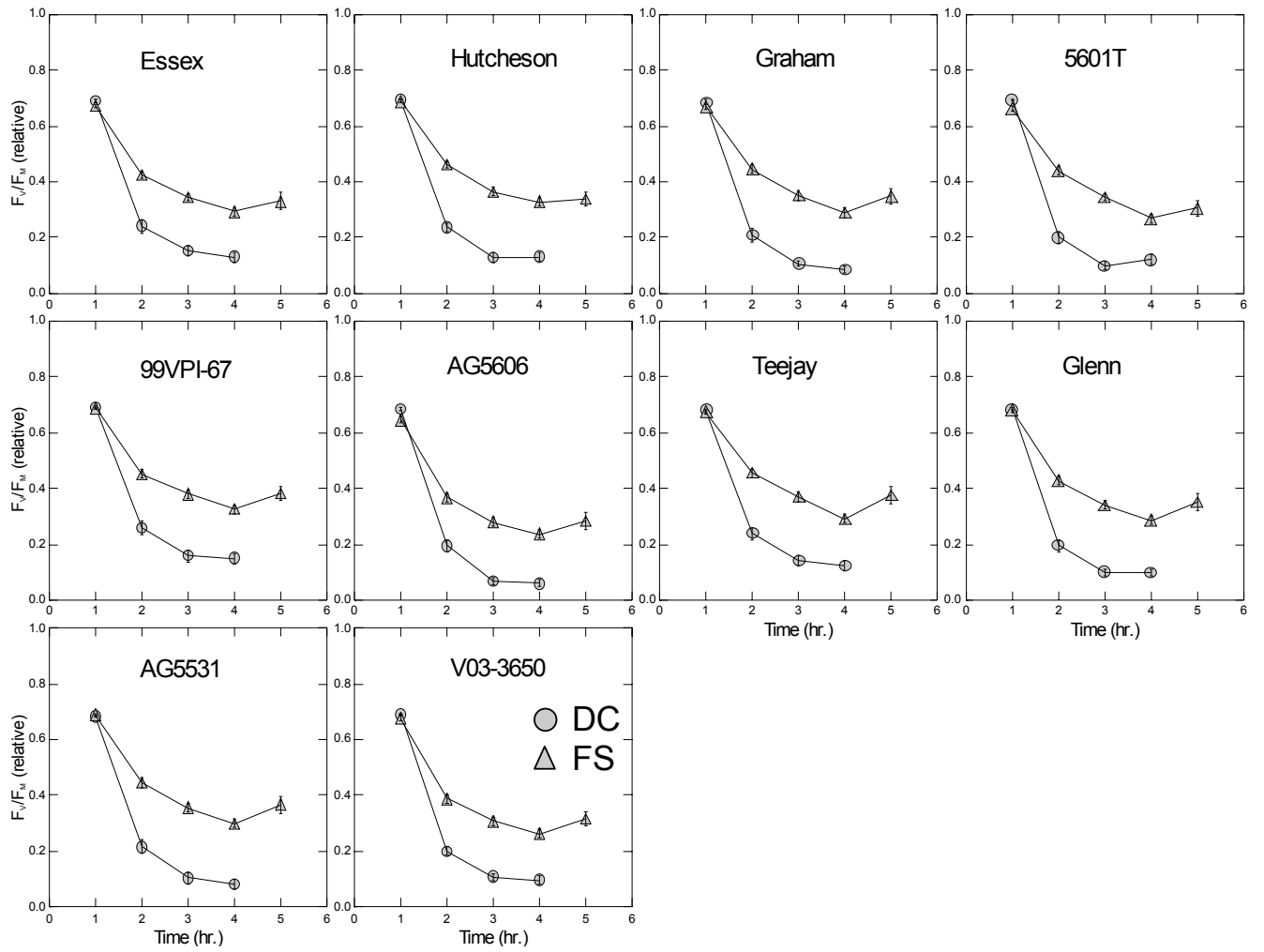


Figure 2. Photosynthetic quantum efficiency in full-season and double-cropped soybean cultivars measured in 2011.

Plan of Work:

In 2012 we plan on repeating the 2011 experiments at Suffolk and Warsaw. The experiment will be arranged as a split-plot with the cropping system (full season vs. double crop) as the main plot, and soybean variety as the subplot. Cultural practices for maximum economic yields will be performed.

Data collected will include the following: plant population density, emergence rate, maturity date, height at V12 (12-leaf stage), R2 (full flower stage), R4 (full pod), R6 (full seed), and R7 (physiological maturity), lodging, yield, yield parameters (seed size, number of seeds per pod, number of pods per plant), and number of reproductive nodes. Other physiological measurements are listed in Table 1. In addition to those in Table 1, data will be collected on leaf gas exchange rates and the maximum quantum yield of the PS II of the photosynthetic apparatus, measured as the ratio of variable (Fv) vs. maximum (Fm) chlorophyll fluorescence

Physiological measurements will be related to yield and yield components of varieties. Data will be subjected to analysis of variance (ANOVA) and means will be separated using appropriate statistical analysis. If varieties are found to be significantly different, old versus new soybean varieties will be contrasted with appropriate statistical techniques. If a variety by treatment interaction occurs, the interaction term will be tested for validation of difference in response due to genetic improvement.

Technical Resources and Cooperators:

Technical resources to conduct this work include expertise and support of the Virginia Tech Extension Agronomist and Crop Physiologist (Balota and Holshouser) based at the Tidewater AREC. Agronomic technical staff at Tidewater AREC will also support the work. A graduate student will be involved with data collection, analysis, and interpretation, as part of his research project.

References:

- Boerma, H.R., and D.A. Ashley. 1988. Canopy photosynthesis and seedfill duration in recently developed soybean cultivars and selected plant introductions. *Crop Sci.* 28:137–140.
- Kumudini, S., D.J. Hume, and G. Chu. 2001. Genetic improvement in short season soybeans: I. Dry matter accumulation, partitioning and leaf area duration. *Crop Sci.* 41:391–398.
- Kumudini, S., D.J. Hume, and G. Chu. 2002. Genetic improvement in short season soybeans: II. Nitrogen accumulation, remobilization and partitioning. *Crop Sci.* 42:141–145.
- Kumudini, S., J. Omielan, and D.J. Hume. 2008. Soybean genetic improvement in yield and the effect of late-season shading and nitrogen source and supply. *Agron. J.* 100:400-405.
- Shiraiwa, T., T. Sinclair, and U. Hashikawa. 1994. Variability in nitrogen fixation activity among soybean cultivars grown under field conditions. *Jpn. J. Crop Sci.* 63:111–117.
- Wells, R., F.H. Schulze, D.A. Ashley, H.R. Boerma, and R.H. Brown. 1982. Cultivar differences in canopy apparent photosynthesis and their relationship to seed yield in soybean. *Crop Sci.* 22:886–890.

Budget:

Category	Fund Requested
PERSONNEL (LABOR)	
Wage worker	\$ 14,977
Fringe Benefits	\$1,423
PERSONNEL SUBTOTAL	\$ 16,400
DOMESTIC TRAVEL	\$500
MATERIALS AND SUPPLIES Expendable supplies (fertilizer, flags, stakes, soil moisture probes, etc.)	\$1,000
CONTRACTUAL SERVICES Soil and plant analysis)	2,100
PROJECT TOTAL	\$20,000

*ONR negotiated rates for Virginia Tech