# Maryland Center for Agro-Ecology Final Report

## Management and Selection of Hulless Barley Cultivars in Maryland

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## **Executive Summary**

At the time this proposal was funded by the Maryland Center for Agro-Ecology, the Maryland Grain Producers Association (MGPA) was actively exploring the feasibility for construction of a fuel ethanol plant in Maryland that would use hulless barley as its primary feedstock. Since that time, the MGPA decided not to proceed with construction of a barley ethanol plant. However, in 2008, another business entity, Osage Bio Energy, LLC, announced that it was planning to build a barley ethanol plant in the mid-Atlantic region. Osage started construction on a 55 Mgy barley ethanol plant near Hopewell, VA during late 2008 with an anticipated date to begin operations in May 2010. Osage plans to purchase the estimated 25 Mby of barley needed from a seven state area surrounding the Virginia plant site. This amount will create a barley demand that will require over 300,000 acres of production annually from the area. Osage currently plans to use hulled barley rather than hulless barley as the feedstock because of the yield constraints (10-30% less yield) that have been associated with the hulless type. Osage has not ruled out the possibility of using hulless barley in the future if newer varieties help close the yield gap.

Over a three year period hulless and hulled cultivars and new experimental lines were evaluated at 2 locations in Maryland. Yields of hulled barleys were higher than hulless, while test weight and starch were higher for hulless. Protein content, heading date, height and lodging were similar for both types. The highest correlation was observed between grain starch content and test weight which indicated that test weight could be used as an indirect indicator of starch content.

Two growth characteristics for hulless barley became very apparent during this study. First, hulless barley does not establish good stands when it experiences wet soil conditions post-planting. Barley, in general, does not fare well under wet conditions and hulless barley is even more sensitive when those conditions prevail. Second, best success for hulless barley is attained when it is planted earlier (latter third of September to mid-October) rather than after mid-October.

In all cases when both hulless and hulled barley were evaluated in the same experiments, hulled barley produced significantly more yield. This outcome corresponds to the yield drag for hulless barley that has been reported previously by others.

Nitrogen management practices were evaluated during the three year study period. Each year, two locations were planted but only one location was harvested due to varying reasons described in the report. The response to nitrogen rates and times of application varied each year. The use of 20 lb $a^{-1}$ fall N produced significantly more barley ($P \leq 0.10$) during two of the three years. While any decision to use fall nitrogen for hulless barley is dependent upon numerous factors (location, year, previous crop, time of planting, etc.) it should also include consideration of the cost of nitrogen. During each of the three years and regardless of the fall nitrogen choice, spring split applications of nitrogen [at greenup (Feekes growth stage 2) and jointing (Feekes growth stage 5/6)] proved better than a single spring application. The amount of total nitrogen required to optimize yield ranged between 70 and 120 lb N $a^{-1}$ indicating that N requirements are highly dependent upon year (weather) and location (soil type) effects.

Seeding rates were also evaluated during the three year study period. Seedling emergence that was measured three weeks post-planting and at similar seeding rates for both hulless and hulled barley, determined that hulless barley established significantly less plants acre$^{-1}$ than hulled barley at the same seeding rates. Optimum seeding rate for hulless barley was determined to be 1.75 million viable seed acre$^{-1}$. The optimum seeding rate for hulled barley varied somewhat but a rate of 1.5 million viable seed acre$^{-1}$ was determined to be adequate.

## Introduction

Barley is an important crop in the state of Maryland. Barley acreage currently covers approximately 55,000 acres with a yield of 70 bushels/acre (2009 data, Maryland Department of Agriculture). This acreage, however, is much lower than the acreage planted in the 1980's when barley occupied between 80,000 and 100,000 acres. The low price of barley has had a major impact in the reduction of cultivated area. Barley, however, has several agronomic advantages over wheat such as an earlier harvest date which allows for earlier planting and higher yields of the subsequent soybean crop. Alternative uses such as ethanol production from barley grain would create a new market for barley and help to increase its value.

In a previously funded study (Costa and Kratochvil, 2005), we determined that hulless barleys have a higher starch content than the hulled barleys traditionally grown in the mid-Atlantic. Protein and Beta-glucan content were similar for both hulled and hulless barleys.

Profitable and sound nitrogen management practices will also be a key criterion for hulless barley production. Since only limited information was obtained with the previously funded project (Costa and Kratochvil, 2005; MD Agroecology report), we proposed to continue researching nitrogen management strategies for hulless barley production to fine-tune the nitrogen recommendations for this crop.

The previously funded research determined that hulless barley seed producers will want to be particularly careful when harvesting the crop in order to minimize the damage to the seed. Much less aggressive combine settings than are commonly used for hulled barley seed will be required to minimize the amount of damage to the kernels and maximize the germination potential of the harvested seed. During the previously funded research, hulless barley seeds subjected to germination tests had more damaged germs than hulled barley seeds. These damaged germs will result in seedling emergence problems. Since seedling emergence is an important trait necessary for successful establishment of a suitable plant population and since the optimum plant population is directly correlated to the yield potential of the crop, information about seeding dates and seeding rates is required in order to develop production recommendations for farmers.

All of the barley currently produced in Maryland is hulled barley. New hull-less barley cultivars are becoming available with a greater potential for ethanol production. The current drawback for growers of hulless varieties is that grain yields are significantly lower than those of hulled varieties. Current breeding of hulless barley for the mid-Atlantic will likely close this productivity gap in the future. New cultivars and lines of hulless barley were tested as part of this study as well as management techniques that can enhance the productivity and profitability of this crop for Maryland growers.

The objectives of this research were:

1. To screen hulless barley cultivars for grain yield, test weight, disease reaction, heading date, height, starch, and protein content.
2. To determine nitrogen rates and timings of nitrogen applications that will be both agronomically and environmentally sound as well as economically feasible for farmers.
3. To determine optimum planting dates and seeding rates for recommendation as best management practices for hulless barley production for farmers.

## Objective One

To screen hulless barley cultivars for grain yield, test weight, disease reaction, heading date, height, starch, and protein content.

## Justification

New improved cultivars and advanced lines of hulless and hulled barley are being released by breeding programs and need to be tested for their local adaptation, disease resistance, grain yield, grain starch and protein content.

## Methodology

Advanced lines and varieties of hulled and new hull-less barleys from the Virginia breeding program were tested during the 2006, 2007 and 2008 harvest years in Maryland for grain yield, test weight, heading date, plant height, resistance to lodging, grain protein content, and grain starch content. Grain yield was expressed in bushels/acre. The grain yields were measured in pounds/acre and the same bushel weight of 48 pounds was used as a bushel of barley grain for both hulled and hulless barley.

A sample of grain (approximately 1000 grams) was used to determine test weight using a Seedburo GMA-128. A sub-sample of 100 grams was used for further tests. Protein content and starch content were assayed with an Infratec Model 1255 Food and Feed analyzer. Starch and protein content of the grain were expressed as percentage of grain corrected to 13.5 moisture content. The data were entered into an Excel worksheet. These data were converted to a file format that was analyzed with the statistical package Statistical Analysis System (SAS) for Windows Release 6.12 (SAS Institute, 1985). An analysis of variance of the data was conducted using the procedure PROC GLM and means were calculated for each location and growing season. A Fisher Protected LSD (0.05) was used to separate means and correlations coefficients were calculated using PROC CORR of SAS.

## Results

Detailed average performance data of the barley advanced lines and varieties in the Virginia State Variety Trial grown in Maryland are presented in Table 1 (hulless, 2006), Table 2 (hulled, 2006), Table 3 (hulless, 2007), Table 4 (hulled, 2007), Table 5 (hulless, 2008), and Table 6 (hulled, 2008). The 2006 season was warmer than average with early heading and harvest dates. Grain yields and test weights in 2006 were relatively high (Tables 1 and 2). The 2007 harvest season was cooler than average with lower grain yields and test weights (Tables 3 and 4). Early barley varieties were damaged by late frosts in 2008. Grain yields were high in 2008, favored by the cool spring, but test weights were lower than average (Tables 5 and 6).

Overall performance data of hulled and hulless genotypes are presented in Table 7. The hulless genotypes had lower grain yields, higher test weights, and higher grain starch than the hulled cultivars across years and locations (Table 7). There were no significant differences for grain protein content, heading date, plant height, and lodging.

Correlations were calculated for all measured traits. The highest correlation was observed between grain starch content and test weight (0.70) which was significantly different from zero. This indicated that test weight could be used as an indirect indicator of starch content.

**Table 1. Mean values of hulless barley genotypes grown in Maryland in 2006.**

| **Name** | **Grain yield Bu/A** | **Starch %** | **Test weight lb/Bu** | **Protein %** | **Heading Julian** | **Height Inches** | **Lodging 0-9** |
|---|---|---|---|---|---|---|---|
| VA01H-125 | 94.0 | 61.4 | 58.5 | 10.8 | 119 | 28 | 1.0 |
| VA04H-53 | 92.1 | 61.9 | 58.9 | 10.2 | 122 | 38 | 0.8 |
| Doyce | 92.0 | 63.1 | 57.7 | 9.9 | 121 | 35 | 4.0 |
| VA04H-59 | 85.9 | 61.1 | 58.6 | 10.7 | 119 | 41 | 0.5 |
| VA04H-111 | 81.9 | 61.6 | 59.4 | 11.2 | 120 | 38 | 0.3 |
| H-585 | 78.7 | 61.1 | 58.3 | 11.1 | 119 | 36 | 0.8 |
| VA03H-100 | 78.6 | 61.2 | 58.5 | 11.0 | 121 | 42 | 0.5 |
| Eve | 78.5 | 61.7 | 59.6 | 11.3 | 122 | 37 | 0.3 |
| VA01H-1 | 78.3 | 62.0 | 57.7 | 10.6 | 120 | 34 | 0.3 |
| VA03H-61 | 77.9 | 61.4 | 60.1 | 11.4 | 123 | 37 | 0.0 |
| VA03H-58 | 74.8 | 60.9 | 58.6 | 11.4 | 123 | 34 | 0.0 |
| VA04H-25 | 73.9 | 61.6 | 61.2 | 11.1 | 121 | 38 | 0.3 |
| VA03H-64 | 70.5 | 59.8 | 58.4 | 11.3 | 122 | 40 | 1.3 |
| **Means** | 81.3 | 61.4 | 58.9 | 10.9 | 121 | 36 | 0.8 |
| **LSD (0.05)** | 11.5 | 1.0 | 0.9 | 0.6 | 3 | 2 | 1.4 |
| **C.V. (%)** | 9.7 | 1.1 | 1.1 | 3.7 | 1.6 | 3.1 | 85.2 |

**Table 2. Mean values of hulled genotypes grown in Maryland in 2006.**

| Name | Grain yield Bu/A | Starch % | Test weight lb/Bu | Protein % | Heading Julian | Height Inches | Lodging 0-9 |
|---|---|---|---|---|---|---|---|
| VA04B-86 | 97.7 | 59.6 | 48.3 | 11.1 | 124 | 35 | 0.3 |
| VA03B-59 | 96.7 | 59.3 | 48.2 | 10.6 | 122 | 29 | 0.0 |
| VA03B-183 | 96.4 | 59.4 | 47.6 | 10.8 | 120 | 32 | 0.3 |
| VA04B-7 | 95.4 | 59.4 | 46.2 | 10.8 | 125 | 32 | 0.0 |
| VA04B-180 | 94.1 | 60.3 | 48.8 | 10.7 | 122 | 29 | 1.0 |
| VA04B-178 | 93.2 | 60.1 | 48.8 | 10.7 | 121 | 29 | 0.5 |
| VA03B-44 | 92.1 | 59.9 | 47.9 | 11.1 | 123 | 30 | 0.0 |
| VA03B-58 | 91.8 | 59.5 | 48.9 | 11.0 | 122 | 30 | 1.5 |
| VA03B-171 | 91.7 | 59.3 | 47.8 | 10.8 | 123 | 37 | 3.3 |
| VA04B-54 | 91.0 | 59.5 | 47.7 | 10.6 | 123 | 32 | 0.0 |
| VA04B-8 | 89.1 | 60.0 | 46.4 | 10.8 | 126 | 34 | 0.5 |
| VA03B-176 | 89.1 | 59.4 | 47.5 | 10.9 | 123 | 32 | 0.3 |
| Callao | 88.6 | 59.6 | 50.9 | 10.8 | 120 | 30 | 3.5 |
| VA04B-120 | 88.5 | 59.0 | 47.8 | 11.1 | 123 | 33 | 1.8 |
| VA96-44-304 | 88.4 | 59.0 | 48.3 | 10.9 | 121 | 29 | 1.8 |
| Thoroughbred | 87.4 | 60.4 | 50.1 | 11.0 | 123 | 33 | 0.0 |
| Price | 87.2 | 59.3 | 48.3 | 11.3 | 123 | 30 | 0.0 |
| Nomini | 86.4 | 59.7 | 47.0 | 10.7 | 119 | 38 | 0.8 |
| VA03B-25 | 86.1 | 58.7 | 42.8 | 11.0 | 126 | 36 | 0.3 |
| Wysor | 82.7 | 60.0 | 46.8 | 10.8 | 122 | 39 | 2.5 |
| VA92-42-46 | 78.9 | 59.4 | 47.3 | 10.9 | 122 | 37 | 1.0 |
| Barsoy | 74.8 | 59.0 | 49.9 | 11.5 | 114 | 34 | 1.3 |
| **Means** | 89.4 | 59.5 | 47.9 | 10.9 | 122 | 33 | 0.9 |
| **LSD (0.05)** | 12.5 | 0.7 | 1.6 | 0.4 | 1 | 2 | 0.9 |
| **C.V. (%)** | 9.8 | 0.8 | 2.4 | 2.4 | 0.7 | 4.9 | 45.4 |

**Table 3. Mean values of hulless barley genotypes grown in Maryland in 2007.**

| Name | Grain yield Bu/A | Starch % | Test weight lb/Bu | Protein % | Heading Julian | Height Inches |
|---|---|---|---|---|---|---|
| VA04H-53 | 79.5 | 61.4 | 60.8 | 14.7 | 128 | 33 |
| VA05H-147 | 79.0 | 62.0 | 61.7 | 14.8 | 125 | 36 |
| VA03H-100 | 77.8 | 60.8 | 61.8 | 14.6 | 125 | 35 |
| Doyce | 73.3 | 63.7 | 61.3 | 15.4 | 124 | 28 |
| H-585 | 71.1 | 60.9 | 60.1 | 14.7 | 121 | 31 |
| VA04H-113 | 68.8 | 61.8 | 62.8 | 14.9 | 124 | 34 |
| VA03H-64 | 68.4 | 61.1 | 61.6 | 14.6 | 125 | 34 |
| VA04H-114 | 67.1 | 60.6 | 61.1 | 14.4 | 125 | 33 |
| VA05H-59 | 66.9 | 60.9 | 62.6 | 14.3 | 127 | 27 |
| VA03H-61 | 64.3 | 61.5 | 62.7 | 14.6 | 126 | 31 |
| VA03H-58 | 62.4 | 61.8 | 62.2 | 14.7 | 126 | 29 |
| VA05H-162 | 61.7 | 61.3 | 62.0 | 14.5 | 127 | 34 |
| VA04H-111 | 60.2 | 61.7 | 62.3 | 13.9 | 125 | 32 |
| VA05H-120 | 59.9 | 61.9 | 62.3 | 14.7 | 125 | 31 |
| VA05H-161 | 59.0 | 61.3 | 61.9 | 14.8 | 127 | 33 |
| VA04H-25 | 57.2 | 61.9 | 64.0 | 14.6 | 125 | 33 |
| Eve | 56.4 | 61.4 | 61.0 | 14.7 | 124 | 30 |
| VA05H-159 | 54.6 | 61.5 | 61.9 | 14.6 | 124 | 31 |
| VA05H-158 | 52.3 | 61.1 | 63.0 | 14.5 | 126 | 32 |
| VA01H-125 | 50.6 | 61.0 | 60.3 | 14.5 | 122 | 26 |
| **Means** | 65.0 | 61.5 | 61.8 | 14.6 | 125 | 31 |
| **LSD (0.05)** | 14.4 | 1.8 | 1.5 | 0.7 | 1 | 3 |
| **C.V. (%)** | 10.5 | 1.4 | 1.1 | 2.3 | 0.5 | 4.1 |

**Table 4. Mean values of hulled genotypes grown in Maryland in 2007.**

| Name | Grain yield Bu/A | Starch % | Test weight lb/Bu | Protein % | Heading Julian | Height Inches |
|---|---|---|---|---|---|---|
| Nomini | 100.4 | 59.8 | 47.8 | 15.9 | 123 | 41 |
| Wysor | 99.6 | 61.3 | 46.8 | 16.5 | 125 | 36 |
| MD 931046-93 | 99.3 | 61.0 | 50.9 | 16.8 | 124 | 34 |
| VA04B-125 | 98.4 | 60.4 | 50.2 | 16.0 | 125 | 33 |
| VA04B-95 | 97.8 | 60.5 | 49.9 | 15.9 | 127 | 33 |
| Price | 96.8 | 60.0 | 49.0 | 15.8 | 125 | 33 |
| VA04B-8 | 96.8 | 61.4 | 49.9 | 16.7 | 128 | 31 |
| VA05B-97 | 95.8 | 60.1 | 50.1 | 16.3 | 127 | 31 |
| VA04B-120 | 95.6 | 60.6 | 48.5 | 16.6 | 127 | 30 |
| VA03B-176 | 95.5 | 60.5 | 51.2 | 16.7 | 127 | 32 |
| VA03B-171 | 94.6 | 60.8 | 49.5 | 16.3 | 124 | 36 |
| VA04B-127 | 91.2 | 60.9 | 50.3 | 16.6 | 126 | 32 |
| VA04B-29 | 91.0 | 60.2 | 48.6 | 16.2 | 122 | 32 |
| Callao | 90.9 | 59.7 | 48.6 | 15.8 | 122 | 29 |
| Thoroughbred | 90.6 | 61.5 | 48.1 | 16.5 | 127 | 29 |
| VA04B-7 | 90.4 | 61.2 | 50.4 | 16.6 | 127 | 30 |
| VA05B-141 | 90.2 | 60.3 | 49.9 | 16.2 | 124 | 34 |
| VA05B-64 | 88.9 | 60.5 | 49.6 | 16.5 | 127 | 29 |
| VA03B-25 | 88.1 | 61.0 | 49.7 | 16.9 | 128 | 35 |
| VA04B-54 | 87.9 | 60.0 | 47.3 | 15.5 | 125 | 31 |
| VA04B-93 | 87.9 | 60.3 | 49.5 | 15.9 | 126 | 30 |
| VA04B-178 | 87.1 | 61.3 | 49.0 | 16.3 | 124 | 29 |
| VA96-44-304 | 86.5 | 59.7 | 47.5 | 16.7 | 122 | 28 |
| VA04B-180 | 86.0 | 61.7 | 50.4 | 16.6 | 124 | 29 |
| VA04B-62 | 85.6 | 60.0 | 49.1 | 16.3 | 122 | 31 |
| VA05B-98 | 85.1 | 60.3 | 49.6 | 16.1 | 125 | 30 |
| VA03B-58 | 83.8 | 60.1 | 49.7 | 16.6 | 125 | 28 |
| VA03B-44 | 83.6 | 60.4 | 50.0 | 15.9 | 126 | 26 |
| VA92-42-46 | 79.9 | 60.3 | 47.1 | 16.1 | 125 | 33 |
| Barsoy | 77.3 | 60.5 | 51.5 | 16.2 | 123 | 31 |
| **Means** | 90.8 | 60.5 | 49.3 | 16.3 | 125 | 31 |
| **LSD (0.05)** | 13.2 | 0.6 | 2.4 | 0.7 | 2 | 3 |
| **C.V.** | 7.1 | 0.5 | 2.4 | 2.2 | 0.6 | 4.7 |

**Table 5. Mean values of hulless barley genotypes grown in Maryland in 2008.**

| Name | Grain yield Bu/A | Starch % | Test weight lb/Bu | Protein % | Heading Julian | Height Inches | Lodging 0-9 |
|---|---|---|---|---|---|---|---|
| VA06H-47 | 114.7 | 62.1 | 59.0 | 15.2 | 115 | 42 | 1.0 |
| VA06H-98 | 110.5 | 64.7 | 58.3 | 15.4 | 118 | 38 | 1.0 |
| VA03H-61 | 110.4 | 62.6 | 59.8 | 15.0 | 119 | 40 | 0.5 |
| VA06H-25 | 106.4 | 64.0 | 57.1 | 15.4 | 120 | 43 | 4.0 |
| VA06H-95 | 104.6 | 64.1 | 57.8 | 15.1 | 117 | 37 | 3.0 |
| Eve | 104.4 | 62.4 | 59.3 | 15.1 | 115 | 39 | 2.5 |
| VA06H-72 | 101.9 | 64.6 | 58.1 | 15.5 | 118 | 38 | 0.5 |
| VA05H-158 | 100.7 | 60.3 | 55.3 | 14.5 | 115 | 44 | 6.0 |
| VA01H-125 | 99.0 | 60.8 | 56.8 | 14.7 | 114 | 32 | 4.0 |
| VA05H-162 | 98.9 | 62.1 | 58.8 | 15.1 | 118 | 43 | 4.0 |
| VA06H-81 | 96.5 | 64.1 | 57.2 | 15.2 | 118 | 36 | 2.5 |
| VA05H-147 | 94.5 | 62.0 | 56.7 | 14.9 | 116 | 44 | 5.5 |
| VA06H-8 | 93.2 | 60.9 | 55.3 | 14.8 | 116 | 39 | 5.5 |
| VA04H-111 | 92.5 | 62.3 | 56.6 | 15.0 | 118 | 41 | 1.5 |
| VA06H-23 | 92.3 | 61.5 | 57.6 | 14.8 | 118 | 42 | 3.5 |
| VA04H-25 | 90.9 | 62.5 | 58.9 | 15.1 | 116 | 41 | 1.5 |
| VA06H-149 | 90.9 | 63.6 | 56.0 | 15.6 | 117 | 39 | 4.5 |
| DOYCE | 90.3 | 62.4 | 58.3 | 15.2 | 114 | 37 | 2.5 |
| VA04H-53 | 89.7 | 64.0 | 57.9 | 15.2 | 119 | 38 | 0.0 |
| VA05H-59 | 88.0 | 61.2 | 58.6 | 14.8 | 120 | 39 | 1.0 |
| VA05H-120 | 85.9 | 61.9 | 57.3 | 14.8 | 117 | 40 | 3.0 |
| VA03H-100 | 84.6 | 61.8 | 55.8 | 14.8 | 118 | 41 | 3.0 |
| VA06H-48 | 83.4 | 62.3 | 59.0 | 15.2 | 117 | 41 | 0.0 |
| VA06H-31 | 82.8 | 61.5 | 55.7 | 14.9 | 118 | 42 | 7.0 |
| VA05H-161 | 82.3 | 62.1 | 56.5 | 15.0 | 119 | 42 | 5.0 |
| VA06H-3 | 82.0 | 60.8 | 56.5 | 14.9 | 120 | 40 | 5.5 |
| VA05H-114 | 81.1 | 61.6 | 55.8 | 15.1 | 114 | 38 | 8.0 |
| H-585 | 80.2 | 61.9 | 52.4 | 15.1 | 117 | 39 | 6.5 |
| VA06H-7 | 79.9 | 60.6 | 55.5 | 14.9 | 115 | 39 | 7.5 |
| VA06H-182 | 76.2 | 61.1 | 56.0 | 14.9 | 119 | 35 | 7.0 |
| VA03H-58 | 69.4 | 60.4 | 54.9 | 14.8 | 119 | 36 | 7.5 |
| VA06H-14 | 59.1 | 60.9 | 55.5 | 14.8 | 120 | 39 | 8.5 |
| **Means** | 91.2 | 62.1 | 57.0 | 15.0 | 117 | 39 | 3.8 |
| **LSD (0.05)** | 22.9 | 1.9 | 3.2 | 0.5 | 2 | 4 | 5.2 |
| **C.V.** | 12.3 | 1.5 | 2.8 | 1.6 | 1.0 | 5.5 | 66.9 |

**Table 6. Mean values of hulled barley genotypes grown in Maryland in 2008.**

| Name | Grain yield Bu/A | Starch % | Test weight lb/Bu | Protein % | Heading Julian | Height Inches | Lodging 0-9 |
|---|---|---|---|---|---|---|---|
| Thoroughbred | 128.7 | 61.8 | 46.6 | 15.1 | 120 | 42 | 1.0 |
| Price | 115.6 | 60.5 | 45.7 | 14.8 | 117 | 40 | 3.0 |
| VA04B-180 | 113.5 | 59.4 | 45.3 | 14.5 | 115 | 40 | 8.0 |
| VA05B-141 | 112.6 | 59.4 | 47.6 | 14.8 | 115 | 41 | 7.5 |
| VA04B-178 | 111.2 | 60.1 | 46.7 | 14.8 | 118 | 40 | 3.0 |
| VA03B-44 | 110.7 | 59.5 | 44.2 | 14.6 | 118 | 41 | 3.0 |
| VA06B-48 | 109.5 | 60.2 | 46.9 | 14.5 | 116 | 37 | 7.0 |
| VA06B-44 | 108.6 | 59.8 | 46.2 | 14.7 | 115 | 39 | 7.0 |
| VA04B-62 | 107.1 | 59.3 | 46.3 | 14.5 | 115 | 38 | 8.0 |
| VA96-44-304 | 105.8 | 59.4 | 46.0 | 14.6 | 114 | 37 | 8.0 |
| Callao | 104.7 | 59.6 | 45.9 | 14.4 | 114 | 35 | 8.0 |
| VA05B-64 | 104.5 | 59.9 | 45.2 | 14.7 | 119 | 37 | 7.5 |
| Barsoy | 103.7 | 60.3 | 47.5 | 14.8 | 111 | 39 | 4.5 |
| Nomini | 102.7 | 59.5 | 44.1 | 14.6 | 113 | 43 | 1.5 |
| VA03B-58 | 102.3 | 60.1 | 46.3 | 14.8 | 119 | 38 | 0.0 |
| VA03B-171 | 101.1 | 60.3 | 44.9 | 14.7 | 120 | 41 | 6.5 |
| VA05B-58 | 101.1 | 60.0 | 47.4 | 14.6 | 119 | 37 | 3.5 |
| VA06B-60 | 100.7 | 60.5 | 46.4 | 14.8 | 115 | 33 | 5.0 |
| VA06B-53 | 100.6 | 60.1 | 47.5 | 14.7 | 115 | 37 | 7.0 |
| VA05B-72 | 97.0 | 60.4 | 47.2 | 14.8 | 119 | 37 | 1.0 |
| VA04B-95 | 96.5 | 60.2 | 46.2 | 14.7 | 118 | 38 | 5.0 |
| VA04B-8 | 96.2 | 59.7 | 47.5 | 14.6 | 118 | 36 | 7.0 |
| VA06B-19 | 92.5 | 59.7 | 46.2 | 14.6 | 115 | 37 | 6.0 |
| VA03B-25 | 92.5 | 60.1 | 41.7 | 14.3 | 120 | 43 | 5.5 |
| VA92-42-46 | 91.8 | 59.8 | 43.8 | 14.5 | 116 | 44 | 7.0 |
| VA05B-65 | 90.1 | 60.2 | 45.9 | 15.0 | 118 | 39 | 7.5 |
| VA04B-125 | 89.1 | 59.8 | 45.9 | 14.6 | 118 | 38 | 8.5 |
| VA03B-176 | 89.1 | 59.7 | 45.2 | 14.4 | 122 | 38 | 7.5 |
| Wysor | 87.9 | 59.4 | 42.3 | 14.3 | 118 | 44 | 5.0 |
| VA06B-32 | 87.3 | 60.2 | 46.1 | 14.8 | 115 | 33 | 6.0 |
| **Means** | 101.4 | 59.9 | 45.8 | 14.6 | 117 | 39 | 5.5 |
| **LSD (0.05)** | 22.9 | 1.2 | 2.3 | 0.4 | 1 | 4 | 5.0 |
| **C.V.** | 11.0 | 0.9 | 2.4 | 1.3 | 0.6 | 4.7 | 44.2 |

**Table 7. Average performance of hulled and hulless barley genotypes grown in Maryland in 2006-2008.**

| Barley Type | Grain yield Bu/A | Starch % | Test weight lb/Bu | Protein % | Heading Julian | Height Inches | Lodging 0-9 |
|---|---|---|---|---|---|---|---|
| **Hulled 2006** | 89.4 | 59.5 | 47.9 | 10.9 | 122 | 33 | 0.9 |
| **Hulled 2007** | 90.8 | 60.5 | 49.3 | 16.3 | 125 | 31 | NA |
| **Hulled 2008** | 101.4 | 59.9 | 45.8 | 14.6 | 117 | 39 | 5.5 |
| **Hulled Average** | 93.9 | 60.0 | 47.7 | 13.9 | 121 | 34 | 3.2 |
| **Hulless 2006** | 81.3 | 61.4 | 58.9 | 10.9 | 121 | 36 | 0.8 |
| **Hulless 2007** | 65.0 | 61.5 | 61.8 | 14.6 | 125 | 31 | NA |
| **Hulless 2008** | 91.2 | 62.1 | 57.0 | 15.0 | 117 | 39 | 3.8 |
| **Hulless Average** | 79.2 | 61.7 | 59.2 | 13.5 | 121 | 35 | 2.3 |

## Objective Two

To determine nitrogen rates and timing of nitrogen applications that have agronomic feasibility, are considered environmentally acceptable, and are economical for farmers.

## Justification

Sound nitrogen management of agronomic crops is of critical importance for the sustainability of agriculture in Maryland. Not only must it be agronomically sound and cost-effective for the farmer but it also must be environmentally acceptable.

## Introduction

Sound nitrogen management that is profitable for the farmer is considered key for successful hulless barley production. The addition in 2007 of a commodity cover crop aspect to Maryland's Cover Crop Program added additional demand for information about barley response to nitrogen, particularly for the use of fall nitrogen which is not permitted when participating in the commodity oriented program.

## Methodology

*Locations:* (1) Wye Research and Education Center; and (2) Central Maryland Research and Education Center-Beltsville.

*Experimental Design*: A randomized complete block design with a factorial arrangement of treatments was used to assess the effect of nitrogen rates and timing of applications upon hulless and hulled (2007-2008 only) barley agronomic characteristics.

*Treatments:* 2005-2006 and 2006-2007

Factor A = Fall nitrogen (no fall N or 20 lb N $a^{-1}$)
Factor B = Feekes growth stage 2 (greenup) application of N (0, 40, 60, and 80 lb N $a^{-1}$ in 2005-2006 and 0, 40 and 60 lb N $a^{-1}$ in 2006-2007).
Factor C = Feekes growth stage 5/6 (jointing) application of N (0, 40, 60, and 80 lb N $a^{-1}$ for 2005-2006 and 2006-2007).

*Treatments:* 2007-2008

Factor A = Cultivars ('Doyce' hulless barley and 'Thoroughbred' hulled barley).
Factor B = Fall nitrogen ((no fall N or 20 lb N $a^{-1}$)
Factor C = Feekes growth stage 2 (greenup) application of N (0, 40, and 60 lb N $a^{-1}$).
Factor D = Feekes growth stage 5/6 (jointing) N rates (0, 30, and 60 lb N $a^{-1}$)

*Cultural Practices:* Plots were planted (Table 8) as close to 1 October as field conditions and weather permitted each year. The seeding rate was 1,750,000 viable seeds $a^{-1}$. Seed was treated with an approved fungicide to provide seedling emergence protection. Weed management was supplied with Harmony Extra herbicide at the appropriate time and rate. No insecticides or plant growth regulator products were used. Plots were harvested with a Massey Ferguson 8-XP plot combine equipped with a HarvestMaster weighing system.

**Table 8. Plant dates, harvest dates, and comments for barley nitrogen management study conducted at two locations over three years.**

| Location | Year | Plant Date | Harvest Date | Comments |
|---|---|---|---|---|
| Beltsville | 2005-2006 | 5 October | 16 June | |
| | 2006-2007 | 11 October | 18 June | |
| | 2007-2008 | 31 October | 23 June | |
| Wye | 2005-2006 | 19 October | 15 June | Yield data not used at this location; severe goose grazing during winter. |
| | 2006-2007 | 16 October | Not harvested | Plots were abandoned during early spring of 2007; site was very wet after planting and it caused poor stands. |
| | 2007-2008 | 15 October | 16 June | Only Thoroughbred was harvested; Doyce had poor emergence during fall that resulted in highly variable stands for its plots. |

*Data Analyses:* Data were analyzed using PROC Mixed analysis of variance procedure of SAS (SAS Institute, Cary NC). Mean separation analyses were conducted when significant F-test differences were indicated by the ANOVA procedure.

*Economic Analyses:* This analysis focused primarily upon the profit or loss that was achieved with the use of 20 lb N $a^{-1}$ in the fall. A 2009 nitrogen price of \$0.50 $lb^{-1}$ N was used to calculate the cost. The selling price of barley was \$2.50 - \$3.00 $bu^{-1}$. The amount of yield necessary to recoup the expenses associated with the fall N application was determined. In addition, a second economic calculation was done based upon the 2008 incentive payment (\$30 $a^{-1}$) received by farmers who participated in Maryland's Commodity Cover Crop Program.

## Results: 2005-2006

Wye

Barley plots at Wye were not harvested in 2006 because of the high amount of variability among them caused by severe geese grazing during the 2005-2006 winter.

Beltsville (see Tables 9 and 10)

- Not using fall nitrogen produced approximately 95% (~75 bu $a^{-1}$) of the yield (p=0.092) attained with 20 lb N $a^{-1}$ in the fall (~79 bu $a^{-1}$). In order to cover this cost, an additional 3-4 bu $a^{-1}$ of barley was needed. The 4 bu $a^{-1}$ yield advantage with the use of fall N for the 2006 crop was enough to cover this expense. For a farmer who did not participate in Maryland's 2008 commodity cover crop program, the use of fall N would need to produce 10-12 bu $a^{-1}$ more. This did not occur.
- Regardless of fall N application choice, a significant yield benefit was observed with the use of N at GS 2.
    - If no fall N was used, yield was maximized with 80 lb N $a^{-1}$.
    - If 20 lb fall N was used, yield was maximized with 40 lb N $a^{-1}$.
- There was no interaction between GS 5/6 and fall N and/or GS 2 N treatments. Regardless of fall N choice and GS 2 application rate, the use of 40 lb $a^{-1}$ topdress N at GS 5/6 provided a significant yield response compared to no GS 5/6 application.
- Total N requirement to optimize yield was 100-120 lb N $a^{-1}$ with the lesser amount successful when fall N was used.

**Table 9. Hulless barley (cv. 'Doyce') yield response to fall and Feekes growth stage 2 (greenup) rates of nitrogen fertilizer (averaged over all GS 5/6 treatments) at Beltsville, MD for 2005-2006.**

| Growth Stage 2 (lb N $a^{-1}$) | Fall N (lb N $a^{-1}$) | |
|---|---|---|
| | 0 | 20 |
| | ------------Yield in bu $a^{-1}$------------ | |
| 0 | 52 a† A‡ | 51 a A |
| 40 | 80 b A | 86 b A |
| 60 | 79 b A | 90 b B |
| 80 | 90 c A | 88 b A |
| Average | 75 A | 79 A |

†Means within a column for a specific fall N treatment that have the same lower case letter are not significantly different at P=0.05.

‡Means within a row for a specific GS 2 N treatment that have the same upper case letter are not significantly different at P=0.05.

**Table 10. Hulless barley (cv. 'Doyce') yield response to Feekes growth stage 5/6 (jointing) rates of nitrogen fertilizer (averaged over all fall N and GS 2 treatments) at Beltsville, MD for 2005-2006.**

| Growth Stage 5/6 (lb N $a^{-1}$) | Yield bu $a^{-1}$ |
|---|---|
| 0 | 66 a† |
| 40 | 79 b |
| 60 | 79 b |
| 80 | 83 b |

†Means that have the same lower case letter are not significantly different at P=0.05.

## Results: 2006-2007

Wye

Barley plots at Wye were not harvested in 2007 because the site where the plots were planted remained excessively wet after planting and during the winter causing poor stand establishment. The plots were abandoned during early spring.

Beltsville (see Tables 11 and 12)

- The yield when no fall nitrogen was used was only 85% (62 bu $a^{-1}$) of the yield for 20 lb fall N $a^{-1}$ (73 bu $a^{-1}$) ($p<0.05$). In order to cover the cost of the nitrogen, an additional 3-4 bu $a^{-1}$ of barley was needed and was attained.
- For a farmer choosing not to participate in Maryland's commodity cover crop program, the use of fall N needed to produce 10-12 bu $a^{-1}$ more barley, an outcome that was just realized.
- A spring split application of nitrogen at GS 2 (40 lb N $a^{-1}$) and at GS 5/6 (60 lb N $a^{-1}$) was the best practice to follow regardless of the fall N use choice.

**Table 11. Hulless barley (cv. 'Doyce') yield response to fall and Feekes growth stage 2 (greenup) rates of nitrogen fertilizer (averaged over all fall N and GS 2 treatments) at Beltsville, MD for 2006-2007.**

| Growth Stage 2 (lb N $a^{-1}$) | Fall N (lb N $a^{-1}$) | |
|---|---|---|
| | 0 | 20 |
| | ------------Yield in bu $a^{-1}$------------ | |
| 0 | 42 a† A‡ | 63 a B |
| 40 | 69 b A | 75 b A |
| 60 | 75 b A | 81 b A |
| Average | 62 A | 73 B |

†Means within a column for a specific fall N treatment with the same lower case letter are not significantly different at P=0.05.

‡Means within a row for a specific GS 2 N treatment with the same upper case letter are not significantly different at P=0.05.

**Table 12. Hulless barley (cv. 'Doyce') yield response to Feekes growth stage 5/6 (jointing) rates of nitrogen fertilizer (averaged over all fall N and GS 2 treatments) at Beltsville, MD for 2006-2007.**

| Growth Stage 5/6 (lb N $a^{-1}$) | Yield bu $a^{-1}$ |
|---|---|
| 0 | 59 a[†] |
| 40 | 64 a |
| 60 | 74 b |
| 80 | 72 b |

[†]Means that have the same lower case letter are not significantly different at P=0.05.

**Results: Hulless Barley 2007-2008**

Wye

Hulless barley plots were not harvested in 2008 because there was poor stand establishment during fall 2007. This was the second year that poor stands were observed at the Wye. This outcome affirms previously experienced difficulties with establishing hulless barley. This was particularly apparent at this site because the hulled barley plots were planted the same day and into the same area as the hulless barley plots. Poor stands for hulless barley can result when soil conditions remain wet, if planting occurs too late in the season, and if the seed is placed too deep in the soil. These stand establishment factors are all associated with the poorer seed viability that has previously been observed for hulless barley. This poor viability has been attributed to the seed becoming more easily damaged during harvest and/or conditioning.

Beltsville (see Tables 13 and 14)

- Overall, hulless barley yield was very poor at Beltsville in 2008. This was the result of poor stand establishment that led to considerable variability within the plots compared to the hulled barley plots at this location.
- Averaged over all GS 2 and GS 5/6 N rates, the yield when no fall N was used was 91% (~ 41 bu $a^{-1}$) (P=0.179) of the yield attained when 20 lb fall N $a^{-1}$ was applied (~ 45 bu $a^{-1}$). In order to cover the cost of the nitrogen and application costs, 3-4 bu $a^{-1}$ more barley would have been needed and did occur.
- In order for a farmer who does not participate in Maryland's commodity cover crop program, the use of fall N would have had to produce 10-12 bu $a^{-1}$ more barley. This did not occur.
- Regardless of fall N choice, a spring split application of nitrogen was the best practice.
    - With no fall N, 40 lb $a^{-1}$ at greenup optimized yield.
    - With 20 lb $a^{-1}$ fall N, 60 lb $a^{-1}$ at greenup was required to optimize yield.
    - At GS 5/6, 30 lb $a^{-1}$ was required to optimize yield.

**Table 13. Hulless barley (cv. 'Doyce') yield response to fall and Feekes growth stage 2 (greenup) rates of nitrogen fertilizer (averaged over all fall N and GS 2 treatments) at Beltsville, MD for 2007-2008.**

| Growth Stage 2 (lb N $a^{-1}$) | Fall N (lb N $a^{-1}$) | |
|---|---|---|
| | 0 | 20 |
| | ------------Yield in bu $a^{-1}$------------ | |
| 0 | 26 a[†] A[‡] | 37 a B |
| 40 | 46 b A | 42 a A |
| 60 | 49 b A | 55 b A |
| Average | 41 A | 45 A |

[†]Means within a column for a specific fall N treatment with the same lower case letter are not significantly different at P=0.05.
[‡]Means within a row for a specific GS 2 N treatment with the same upper case letter are not significantly different at P=0.05.

**Table 14. Hulless barley (cv. 'Doyce') yield response to Feekes growth stage 5/6 (jointing) rates of nitrogen fertilizer (averaged over all fall N and GS 2 treatments) at Beltsville, MD for 2007-2008.**

| Growth Stage 5/6 (lb N $a^{-1}$) | Yield bu $a^{-1}$ |
|---|---|
| 0 | 32 a[†] |
| 30 | 46 b |
| 60 | 50 b |

[†]Means that have the same lower case letter are not significantly different at P=0.05.

**Results: Hulled Barley 2007-2008**

Beltsville (see Tables 15 and 16)

- Averaged over all GS 2 and GS 5/6 N rates, the yield for no fall N (84 bu $a^{-1}$) was no different (P=0.473) compared to the yield attained with 20 lb fall N $a^{-1}$ (82 bu/acre). In order to cover the cost of the nitrogen, an additional 3-4 bu $a^{-1}$ was needed but it did not occur.
- For a farmer who does not participate in Maryland's commodity cover crop program, the use of fall N would need to produce 10-12 bu $a^{-1}$ more barley. This did not occur.
- A split application of nitrogen at GS 2 and GS 5/6 was the best practice to follow for spring N applications regardless of the fall N use choice.
  - When no fall nitrogen was used, a GS 2 rate of 60 lb N $a^{-1}$ performed best when followed by a GS 5/6 application of 30 lb N $a^{-1}$ was used.
  - When 20 lb N $a^{-1}$ was applied in the fall, a spring split application of 40 lb N $a^{-1}$ at GS 2 followed by 30 lb N $a^{-1}$ at GS 5/6 optimized yield.
- At this location, best response occurred with no fall nitrogen followed by spring split applications of 60 lb N $a^{-1}$ at GS 2 plus 30 lb N $a^{-1}$ at GS 5/6.

**Table 15. Hulled barley (cv. 'Thoroughbred') yield response to fall and Feekes growth stage 2 (greenup) rates of nitrogen fertilizer (averaged over all GS 5/6 treatments) at Beltsville, MD for 2007-2008.**

| Growth Stage 2 (lb N $a^{-1}$) | Fall N (lb N $a^{-1}$) | |
|---|---|---|
| | 0 | 20 |
| | ------------Yield in bu $a^{-1}$------------ | |
| 0 | 66 a† A‡ | 64 a A |
| 40 | 81 b A | 89 b A |
| 60 | 105 c A | 92 b B |
| Average | 84 A | 82 A |

†Means within a column for a specific fall N treatment with the same lower case letter are not significantly different at P=0.05.
‡Means within a row for a specific GS 2 N treatment with the same upper case letter are not significantly different at P=0.05.

**Table 16. Hulled barley (cv. 'Thoroughbred') yield response to Feekes growth stage 5/6 (jointing) nitrogen fertilizer rates (averaged over all fall N and GS 2 treatments) at Beltsville, MD for 2007-2008.**

| Growth Stage 5/6 (lb N $a^{-1}$) | Yield bu $a^{-1}$ |
|---|---|
| 0 | 67 a† |
| 30 | 83 b |
| 60 | 99 c |

†Means that have the same lower case letter are not significantly different at P=0.05.

Wye (see Tables 17 and 18)

- Averaged over all GS 2 and GS 5/6 N rates, the yield without fall N was 94% (101 bu $a^{-1}$) of the yield attained with 20 lb fall N $a^{-1}$ (108 bu $a^{-1}$). In order to cover the cost of the nitrogen, an additional 3-4 bu $a^{-1}$ was needed and was attained.
- For a farmer who does not participate in Maryland's commodity cover crop program, the use of fall N would need to produce 10-12 bu $a^{-1}$ more barley. This did not occur.
- A spring split application of N at GS 2 and again at GS 5/6 was the best practice to follow regardless of the fall N use choice.
  - With no fall N, a GS 2 application rate of 40 lb N $a^{-1}$ followed by 60 lb N $a^{-1}$ at GS 5/6 optimized yield.
  - When 20 lb fall N $a^{-1}$ was used, a spring split application of 60 lb N $a^{-1}$ at both GS 2 and GS 5/6 was required to maximize yield.
- At this location, there was no difference in response for the use of fall N when 60 lb N $a^{-1}$ was used at GS 2 and it was followed by 60 lb N $a^{-1}$ at GS 5/6.

**Table 17. Hulled barley (cv. 'Thoroughbred') yield response to fall and Feekes growth stage 2 (greenup) rates of nitrogen fertilizer (averaged over all GS 5/6 treatments) at Wye, MD for 2007-2008.**

| Growth Stage 2 (lb N $a^{-1}$) | Fall N (lb N $a^{-1}$) | |
|---|---|---|
| | 0 | 20 |
| | ------------Yield in bu $a^{-1}$------------ | |
| 0 | 88 a† A‡ | 105 a A |
| 40 | 104 b A | 104 a A |
| 60 | 112 b A | 116 b A |
| Average | 101 A | 108 B |

†Means within a column for a specific fall N treatment with the same lower case letter are not significantly different at P=0.05.
‡Means within a row for a specific GS 2 N treatment with the same upper case letter are not significantly different at P=0.05.

**Table 18. Hulled barley (cv. 'Thoroughbred') yield response to Feekes growth stage 5/6 (jointing) rates of nitrogen fertilizer (averaged over all fall N and GS 2 treatments) at Wye, MD for 2007-2008.**

| Growth Stage 5/6 (lb N $a^{-1}$) | Yield bu $a^{-1}$ |
|---|---|
| 0 | 94 a† |
| 30 | 105 b |
| 60 | 115 c |

†Means that have the same lower case letter are not significantly different at P=0.05.

## Objective Three

To determine optimum seeding rates for hulless and hulled barley that will become best management recommendations for Maryland barley production.

## Justification

Hulless barley seed germ is more easily damaged during both harvest and seed processing. This causes less seedling emergence when a seeding rate common for hulled barley is used. Reduced stand may contribute to the yield drag seen with hulless barley compared to hulled varieties.

## Introduction

Field observations made during previous research with hulless barley indicated that the hulless barley type had more difficulty establishing a comparable stand to that established by hulled barley when the same seeding rate was used. Research indicated that this likely was associated with seed damage that possibly occurred with overly aggressive combine settings during harvest and possibly additional damage happening during seed processing. This led to speculation that part of the yield drag for hulless barley may be associated with the inability to establish an adequate number of plants acre$^{-1}$ and that an increased seeding rate for hulless barley may alleviate some of the yield drag as well as improve its yield potential.

## Methodology

*Locations:* (1) Wye Research and Education Center; and (2) Central Maryland Research and Education Center-Beltsville (2004/2005 through 2006/2007 crop years).

*Experimental Design*: A randomized complete block design (4 blocks per location) with a factorial arrangement of treatments was used to assess the effects of a range of seeding rates upon agronomic performance for a hulless ('Doyce') and a hulled ('Thoroughbred') barley cultivar. Each plot consisted of 7 rows of barley spaced 7 or 7.5 inches apart (dependent upon row spacing for drill at a location) and 30 feet in length.

Factor A = 2 Cultivars
Factor B = Seeding rates varied slightly by year and ranged from a low of 750,000 to a high of 2,500,000 viable seeds a$^{-1}$ during the course of the study.

*Cultural Practices:* Seed was treated with an approved fungicide to provide seed emergence protection. Plots were fertilized with P and K according to soil test results. Nitrogen fertilizer was a split application of 40 lb N a$^{-1}$ at greenup and 40 lb N acre$^{-1}$ at Feekes growth stage 5/6 (jointing). Plots were protected from insect pests as needed. Weed management was supplied with Harmony Extra herbicide at the appropriate rate. No plant growth regulator products were used.

*Measured Variables:*

*Plant population*: to be measured 3 weeks post-planting by counting the number of emerged seedlings in three 1 m sections of 3 randomly selected rows in each split plot.

*Winter survival:* will be measured by determining percentage of plot that survived the winter in the early spring following crop greenup.

*Grain yield* @ 12% moisture. Grain will be harvested with a Massey Ferguson plot combine equipped with HarvestMaster weighing system that will measure grain yield (lb plot$^{-1}$), test weight (lb bu$^{-1}$) and grain moisture content.

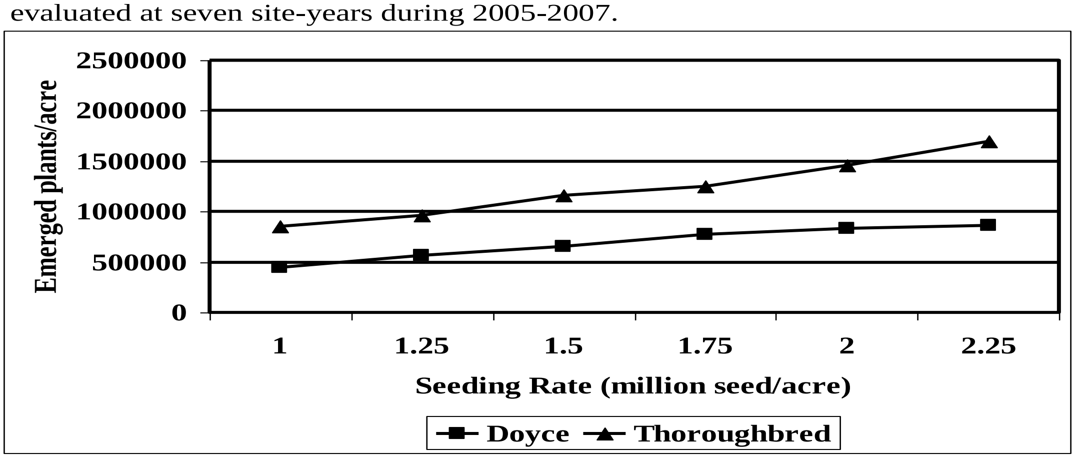
*Data Analysis:* Data were analyzed using PROC Mixed analysis of variance procedure of SAS (SAS Institute, Cary NC). Mean separation analysis was conducted at the .05 level using a Fisher's protected LSD. Regression analyses were applied to the average data across the two locations for each crop year because the seeding rate ranges varied during each of those production seasons.

**Results: Seedling Emergence**

The number of emerged plants at three weeks post-planting increased as seeding rate increased for both varieties. Averaged over the seven site years where the study was conducted between 2005 and 2007, Thoroughbred had significantly greater seedling emergence at three weeks post-planting for each of the seeding rates (Figure 1) compared to Doyce. As seeding rate increased for Thoroughbred, the percentage of emerged plants per number of seeds planted decreased (~85% for 1 M seeds to ~75% for 2.25 M seeds). As seeding rate increased for Doyce, the percentage of emerged plants per number of seeds planted also decreased (~44% for 1 M seeds to ~38% for 2.25 M seeds).

**Fig. 1. Seedling emergence of hulled and hulless barleys (2005-2007)**

Figure 1. Average number of seedlings emerged three weeks post-plant for a range of seeding rates for `Doyce' hulless and `Thoroughbred' hulled barley evaluated at seven site-years during 2005-2007.



## Results: Yield

At the seven location-years, Doyce produced less barley [67% (Wye-07) to 82% (Beltsville-2, 2006] than Thoroughbred (Table 19). These results coincide with the yield drag characteristic that has been reported for hulless barley.

**Table 19. Yield by location and year for Doyce hulless and Thoroughbred hulled barley averaged over a range of seeding rates during 2005-2007.**

| Cultivar | Location | | | | | | |
|---|---|---|---|---|---|---|---|
| | Beltsville 05 | Wye 05 | Beltsville-1 (06) | Beltsville-2 (06) | Wye 06 | Beltsville 07 | Wye 07 |
| | ------------------------Yield in bu $a^{-1}$--------------------------- | | | | | | |
| Doyce | 61 a | 68 a | 57 a | 63 a | 85 a | 57 a | 87 a |
| Thoroughbred | 81 b | 119 b | 75 b | 77 b | 102 b | 80 b | 130 b |

Regression analysis was applied to the data averaged over the locations used for each of the production seasons. The results of those analyses are shown in Figures 2-4. Doyce showed significant improvement in yield each year as seeding rate increased to 1.75 million viable seed $acre^{-1}$. Thoroughbred had a more variable response to seeding rate during each of the three years. During 2004-2005, it reached optimum yield at the same seeding rate as Doyce, 1.75 million viable seed $acre^{-1}$(Figure 2). During 2005-2006, it showed very little change in yield across the range of seeding rates (Figure 3). And, for the 2006-2007 crop year (Figure 4), it optimized yield at 1.5 million seed $acre^{-1}$.

**Fig. 2. Yield response to seeding rates of hulled and hulless barleys (2004-2005)**

Figure 2. Yield response to a range of seeding rates for `Doyce' hulless and `Thoroughbred' hulled barley during 2004-2005.

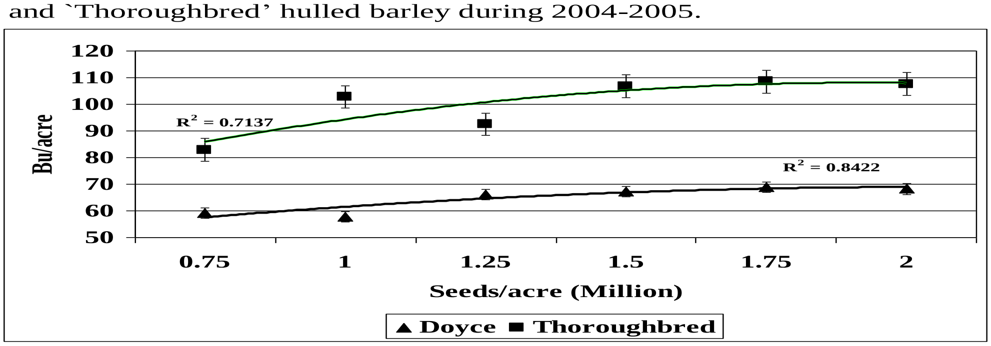


**Fig. 3. Yield response to seeding rates of hulled and hulless barleys (2005-2006)**

Figure 3. Yield response to a range of seeding rates for `Doyce' hulless and `Thoroughbred' hulled barley during 2005-2006.

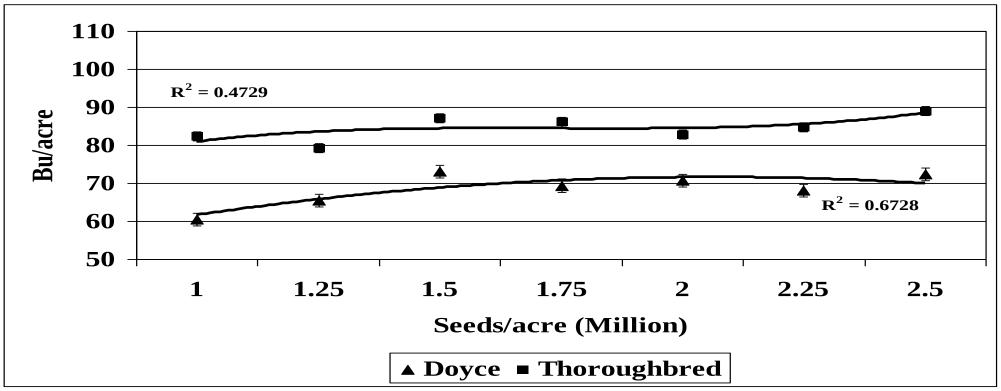



**Fig. 4. Yield response to seeding rates of hulled and hulless barleys (2006-2007)**

Figure 4. Yield response to a range of seeding rates for `Doyce' hulless and `Thoroughbred' hulled barley during 2006-2007.