RELATIONSHIP BETWEEN COTTON SEEDLING COLD TOLERANCE AND PHYSICAL AND CHEMICAL PROPERTIES

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Abstract

Increasing cotton's ability to germinate under cool night conditions would benefit the entire cotton industry. On the Texas High Plains, essentially every night during the planting period is below 16°C. Over half the night's have low temperatures below 10°C. These cool nights result in slow erratic emergence of weakened seedlings resulting in poor stands. The objective of our research was to determine if any physical or chemical properties of the seed were related to the seedling's ability to germinate and grow at temperatures less than 15°C. Six commercial varieties were grown at six locations across the High Plains. At harvest seed and lint were collected and physical and chemical properties assayed. Seed index, seed density, fiber properties, and total oil and fatty acid composition of the oil were determined. Regression analysis was used to correlate seed properties to germination ability. Seed density and fiber micronaire were both positively associated with germination capability at 15°C. The total oil was unrelated to germination; however, the relative concentrations of the saturated and unsaturated fatty acids in the oil were related to germination ability at 15°C. Our results indicated that the ability to germinate at 15°C was related to a low unsaturated to saturated ratio of fatty acids in the oil. This result is contrary to the literature on cold tolerance. However, we found that a high unsaturated fatty acid content was inversely related to seed density which was a measure of seed maturity which is highly correlated to cold tolerance. Research is continuing on the deposition of the fatty acids in the storage lipid fraction and the phospholipid fraction of the membranes and their relationship with cold tolerance of cotton seedlings during germination.

Introduction

Tropical species such as cotton (Gossypium hirsutum) when moved to temperate climates are usually adversely affected by cool temperatures. Physiological zero for cotton has been described to 15°C (60°F). This minimum temperature appears to affect essentially all phases of cotton growth and development.

In much of the Cotton Belt, planting occurs when the night temperatures are well below this minimum temperature requirement. Seed germination and early seedling growth are especially sensitive to cool temperatures with significant chilling injury occurring when the germinating seed or young seedling are exposed to temperatures in the 10°C range. Due to the fatty acid composition of the lipid fraction of cellular membranes of cotton, the physiological response to cool temperatures appears to be loss of membrane function. Not only is permeability a problem, but many metabolic processes are associated with membrane-bound enzyme systems. The high percentage of saturated fatty acids in cottonseed lipids is the apparent cause of membrane crystallinity at temperatures below 16°C. A high unsaturated/saturated ratio of fatty acids in the storage oil has been related to cold tolerance in both upland and Pima varieties.

The genetic background as well as the environmental conditions during seed maturation play major roles in seedling vigor and tolerance of environmental stresses during germination and stand establishment. The purpose of this project was to determine the relationship between physical and chemical properties of the seed and its ability to germinate at suboptimal temperatures.

Density which is a measure of seed maturity has been related to both germination percentage and rate of seedling emergence. It has not been evaluated as a factor influencing cold tolerance during germination.

Materials and Methods

Seed produced during the 1994 growing season were used for this project. Six varieties were grown at six different locations from north to south across the Texas High Plains. The field projects were part of the Extension Service variety trials in each county. At harvest, samples were collected to determine plot yield. The fuzzy seed were delinted and physical characteristics of seed index (g / 100 seed) and density (g / cm^3) determined. Chemical properties evaluated included total oil contents and fatty acid composition of the oil. Total oil was extracted using petroleum ether and expressed as percentage of total seed weight. An aliquot of the oil was hydrolyzed and methyl esters produced for analyses using gas chromatography.

Fiber quality parameters were measured by the International Textile Center (TTU) using HVI instrumentation.

All data were analyzed for statistical significance using AOV for a completely randomized block design. Regression analysis was used to correlate germination at cool temperatures with the physical and chemical properties of the seed source.

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Results and Discussion

The physical seed and fiber properties which were positively correlated with germination ability at 15°C were seed density and fiber micronaire. The relationship between germination percentage at 15°C and seed density (g/cc) depicted in Fig. 1. Seed index (g/100 seed) was not correlated with germination percentage. Seed index was highly variety dependent. Fiber micronaire which is usually considered a measure of fiber maturity was also positively correlated with germination ability at 15°C (Fig 2). If the fiber is mature, the seed is mature.

Among the chemical properties evaluated, total oil content expressed either as percent of seed dry weight or as mg oil per seed was not positively associated with germination under cool temperatures. Increasing concentrations of palmitic acid C°16 were positively associated with germination; whereas increasing concentrations of linoleic acid $C18^2$ were negatively associated with germination at 15°C. The unsaturated:saturated ratio is usually used as an indicator of cold tolerance. The higher the ratio the greater the cold tolerance. In this analyses we found a negative relationahip between the U/S ratio (Fig 3) and the germination percentage at 15°C, a measure of cold tolerance (Fig 4). Linoleic acid represents between 54-59% of the total fatty acid composition of cottonseed oil; whereas palmitic concentrations range from 22 to 27%. The more immature the seed, as indicated by seed density, the higher the concentration of linoleic acid and the greater the un saturated: saturated ratio. Cold tolerance during germination was positively associated with seed maturity and negatively associated with the U:S ratio. Although the oil should have a lower melting point and thus remain liquid at cooler temperatures, the immature seedlings are of such low vigor that they can't grow.

In summary, measures of maturity, i.e. seed density and fiber micronaire, were positively associated with germination at cool temperatures indicating cold tolerance. The fatty acid composition of the oil was also associated with cold tolerance with a negative relationship between the unsaturated:saturated ratio and seed germination. The negative relationship is contrary to published literature on the relationship between fatty acid composition and cold tolerance of plants. One of the reasons for the contradition is related to the fact that the more immature the seed, the greater the ratio of unsaturated to saturated fatty acids in the oil. Another possible reason for the contradiction may be that we analyzed storage oil fatty acids instead of lipids in membranes. Although the literature would suggest a strong relationship between the two that may not be the case for cotton. We are currently developing fatty acid profiles during lipid deposition during seed development. The results of this study should provide insight into the contradition between our results and the literature.

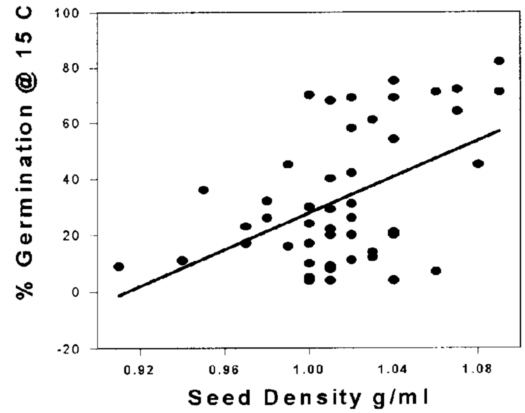

Figure 1. Regression analysis of % germination @ 15 C as a function of seed density.

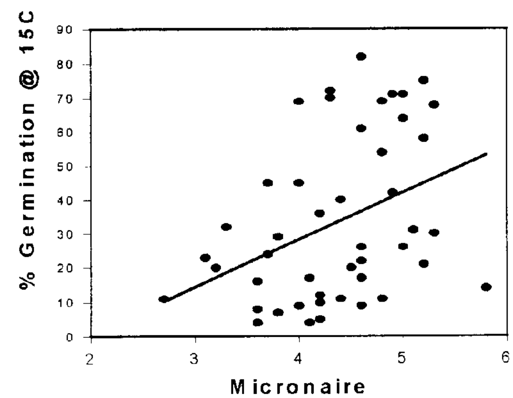

Figure 2. Regression analysis of % germination @ 15 C as a function of fiber micronaire.

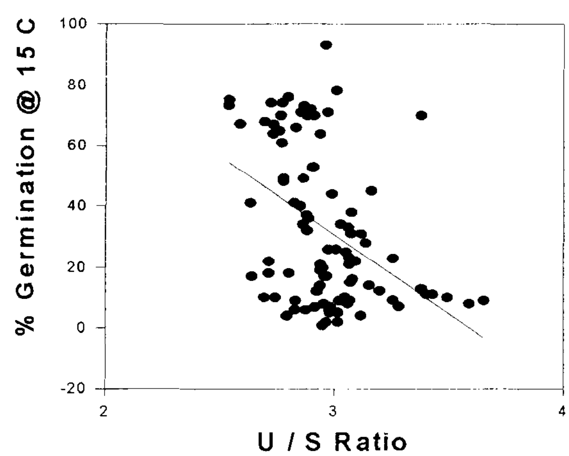

Figure 3. Regression analysis of % germination @ 15°C as a function of U / S ratio.

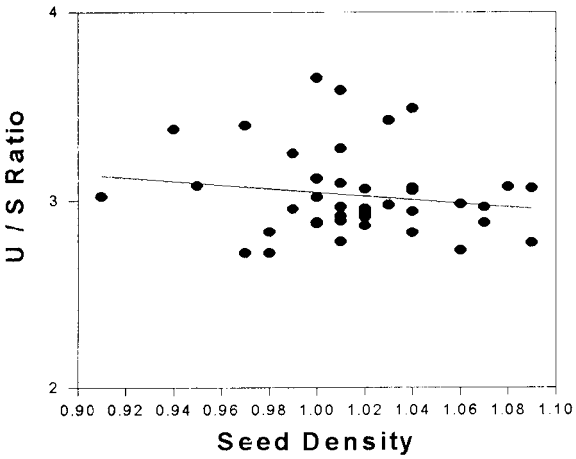

Figure 4. Regression analysis of U / S ratio as a function of seed density.