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Evaluation of maize inbreds for cold tolerance when grown in controlled and field environments

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EVALUATION OF MAIZE INBREDS FOR COLD TOLERANCE WHEN GROWN IN CONTROLLED AND FIELD ENVIRONMENTS

by

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Evaluation of Maize Inbreds for Cold Tolerance when

Grown in Controlled and Field Environments

BY

Jeffrey S. Posch

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GRADUATE COLLEGE
UNIVERSITY OF NEBRASKA

EVALUATION OF MAIZE INBREDS FOR COLD TOLERANCE WHEN GROWN IN CONTROLLED AND FIELD ENVIRONMENTS

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The objectives were to: 1) determine light and temperature effects on chlorophyll concentration and ascertain if this effect could be detected with a chlorophyll meter, 2) evaluate cold tolerant traits using a diallel mating design. 3) evaluate inbred lines for cold tolerance and yielding potential, 4) and compare results from controlled environments with field trials. Inbreds developed at the University of Nebraska-Lincoln were evaluated in field. greenhouse, and growth chamber trials. Inbreds were categorized and evaluated in four groups: Group 1, high yielding; Group 2, freeze tolerant; Group 3, B population; and Group 4, 100% germination. Greater quantities of chlorophyll were found in plants grown in the light warm than in the light cool growth chamber. A linear relationship existed between the chlorophyll meter and total chlorophyll. Therefore, the chlorophyll meter was found to be useful in predicting changes in chlorophyll concentration. Reciprocal differences in diallel hybrids were found for emergence index. leaf greenness (measured with the chlorophyll meter). dry weight. and total plants emerged. Additive effects were predominant for inheritance of emergence index. leaf greenness, and dry weight since GCA and SCA ratios [GCA/(GCA + SCA)] were large. Crosses having cold tolerant maternal parents emerged sooner, had greater leaf greenness, dry weight, and grain yield than crosses having susceptible maternal parents when grown in cool environments. Checks emerged in less time in late field plantings but later in growth chambers than groups. Groups 1 and 4 had greater dry weights in inbred and hybrid trials than checks. All groups had a higher percentage of emerged plants than checks. Groups 3 and 4 had nonsignificantly greater means for grain yield than checks. Positive and significant rank correlations were obtained between early field planting and growth chamber for dry weight and total plants emerged

and greenhouse and growth chamber for dry weight. Rankings of groups grown as inbreds and testcrosses were significantly positive for emergence index, leaf greenness, dry weight, and total plants emerged.

In memory of my father

Leonard J. Posch

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Chapter I.

Introduction

Seedling cold tolerance of maize (*Zea mays* L.) is the ability of plants to germinate, emerge, and grow under cold wet conditions. Low temperature is a major environmental factor limiting the range of adaptation for maize. In short season environments, such as areas of high altitudes and high latitudes, maize yields could be improved by earlier planting, which allow plants to utilize more of the growing season.

In Nebraska, maize is planted when soil temperatures warm sufficiently to initiate germination and sustain seedling growth. Therefore, planting is predominantly completed during the last week of April and the first two weeks of May. By planting prior to traditional planting dates growers may realize the following advantages: 1) earlier canopy development and increased competition against weeds, 2) reduced water evaporation and increased water availability to aid in seedling establishment due to early shading, 3) possible pollination prior to hot, dry days of summer, 4) pollination and grain-filling during periods of the growing season with maximize daylength, 5) greater photosynthetic potential for deposition of starch in grain, 6) longer grain-filling periods, and 7) early harvest with reduced grain moisture.

Tropical plants, such as maize, grow poorly when temperatures are less than optimum. Maize, when grown under cool conditions (10° C to 15° C), can suffer severe symptoms such as chlorosis and even death. These symptoms generally do not occur in species such as wheat, which are adapted to temperate zones of the world. Generally, in maize, germination is slow, seedlings are weak, plant stands are poor, and longer periods are required for plant establishment when temperatures are below 13° C. As plant tolerance to chilling increases, growth is sustained at lower temperatures and chilling injury arising from temperatures just above freezing takes longer to develop. Inbreds and hybrids with cold tolerance can have an advantage to producers wishing to utilize longer growing seasons. In addition, use of technology that allows producers to minimize soil erosion and more effectively utilize available moisture, such as no-till or minimum tillage, leaves soils cooler and wetter than conventional tillage practice. Therefore, maize with seedling cold tolerance is desirable when cool wet conditions limit early growth and development of maize seedlings.

Chapter II

Effectiveness of a chlorophyll meter in determining chlorophyll response to temperature, light, and stage of plant development in maize

Abbreviations: LW, light warm; LC, light cold; DW, dark warm; DC, dark cold; LG, leaf greenness.

ABSTRACT

Cool spring environments can damage cold-sensitive crops such as maize (*Zea mays* L.). Low temperatures can result in crop damage and reduced yields. Therefore, development of a simple rapid screening test for cold tolerance is the focus for many maize breeding programs. The objectives of this study were to: 1) determine if relative chlorophyll concentrations can be detected using a Minolta chlorophyll meter (SPAD 502); 2) determine effects of temperature and light on chlorophyll concentration in maize; and 3) ascertain which leaf, in maize, to use to screen for cold tolerance when using the chlorophyll meter. Four growth chambers were used: light warm (light/dark; 29/24° C); light cold (light /dark; 13/10° C); dark warm (dark; 29/24° C); dark cold (dark; 13/10° C). Plants were exposed to a 13.5 h photoperiod in lighted chambers (LW and LC). Differences ($p<0.05$) were found among origins of plants (environments in which plants were germinated) for chlorophyll concentration and leaf greenness (LG). Differences among leaves were significant only for chlorophyll *a* and LG. Correlations between total chlorophyll, chlorophyll *a*, and chlorophyll *b* were positive ($p<0.01$) in chambers LW and LC and in analyses combined across both chambers. Correlations between LG and total chlorophyll were highly significant ($p<0.01$) in the LW ($r = 0.88$), LC ($r = 0.92$), and combined chambers ($r = 0.93$). Correlations between LG and chlorophyll *b* ($r = 0.84$) were lower than those associated with LG and chlorophyll *a* ($r=0.93$). Significant correlations between LG and total chlorophyll were obtained for leaf one, two, three, and four. Mean LG (21.78), total chlorophyll (1.05 mg chl g^{-1} fresh wt), chlorophyll *a* (0.89 mg chl g^{-1} fresh wt), and chlorophyll *b* (0.162 mg chl g^{-1} fresh wt) was highest in the first leaf. Chlorophyll concentration was the highest in the LW chamber; LG(22.3), total chlorophyll (1.129 mg chl g^{-1} fresh wt), chlorophyll *a* (0.943 mg chl g^{-1} fresh wt), and chlorophyll *b* (0.186 mg chl g^{-1} fresh wt). Plants originating in the DC chamber had greater ($p>0.05$) chlorophyll concentrations than those originating in the DW. Total chlorophyll was greater in plants originating in the DC (1.055 mg chl g^{-1} fresh wt) chamber than in the DW (0.611 mg chl g^{-1} fresh wt) chamber. Also, LG was higher ($p<0.05$) in plants originating in the DC (20.36) than in the DW (12.46) chamber. A linear relationship exists between the chlorophyll meter

and total chlorophyll concentration indicating the chlorophyll meter is able to detect changes in chlorophyll concentration. Plants grown in cool temperatures had less chlorophyll and leaf greenness than those grown in optimum conditions (LW). Significantly positive correlations between LG and chlorophyll concentration in cool environments suggest leaves one through three can be used to screen maize for cold tolerance.

INTRODUCTION

Unfavorable environmental conditions can result in damage to crops and reduced yields. Many important annual crops cultivated in temperate climates, such as maize, have been introduced from the tropics. Low temperatures in spring can injure cold-sensitive crops of tropic origin. Therefore, development of a simple and rapid screening test for cold tolerance is a focus for many maize breeding programs. Cold-sensitive species, such as maize, are susceptible to photochemical damage (photoinhibition of photosynthesis) if exposed to high light at temperatures below 13° C (Greer and Hardacre, 1989). Taylor and Rowley (1971) showed that severe inhibition of photosynthesis in maize leaves occurred when leaves were given prolonged exposure to high light at low temperatures. This treatment also resulted in permanent photooxidation of chlorophyll. Chlorophyll concentration declined in leaves of maize when grown at low temperatures and moderate photon irradiance (Hardacre and Turnbull, 1986; McWilliam and Naylor, 1967). Hodgins and van Huystee (1985) found the largest difference in chlorophyll content due to cold stress was expressed in the lower basal regions of the leaf with little difference detected in the older (tips) regions. Hetherington et al. (1989) found photoinhibition dependent on both temperature and light, increasing nonlinearly with decreasing temperature and linearly with increasing light.

Chilling damage may be manifest, at least initially, as a photoinhibitory inactivation of the primary photo chemistry (Greer and Hardacre, 1989). Leaves of maize hybrids that differ in tolerance to low temperature should, therefore, show variation in susceptibility to photo inhibition and photo-oxidation, especially at low temperatures. Chloroplast function, and potential productivity, in developing or stressed leaves is often closely associated with thylakoid membrane integrity and associated pigments, particularly chlorophyll (McWilliam and Naylor, 1967; Taylor and Rowley, 1971). McWilliam and Naylor (1967) suggested that high light in conjunction with low temperatures did not damage the mechanism leading to chlorophyll production. However, high light and low temperatures destroyed chlorophyll at a greater rate than could be synthesized. Genetic variation for chlorophyll concentration