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GROWTH RESPONSE TO TEMPERATURE OF TWO MAIZE  
(Zea mays L) HYBRIDS WITH DIFFERING  
LEVELS OF COLD TOLERANCE.

A thesis presented in partial fulfillment  
of the requirement for the  
Degree of Master of Agriculture Science  
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MWANGALA STEPHEN MUKUMBUTA.

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**ABSTRACT.**

Low temperatures are a hazard to maize production especially in high altitude and high latitude areas (Eagles, 1979; Hardacre and Eagles, 1986) where it may cause substantial yield reductions through its accumulated effect on vegetative and reproductive growth. Cold tolerant cultivars with rapid emergence and growth at low temperatures have been identified in highland tropical genotypes and are being developed in New Zealand (Eagles, 1979; Hardacre and Eagles, 1986).

Growth of one such hybrid A665 x NZ1A was compared in this study to that of an established hybrid, A665 x H99, but identified as of warm weather at two field and one glass house environments. The hybrids were planted in the field on 26<sup>th</sup> October and 26<sup>th</sup> November, 1991, and in the glass house on 30<sup>th</sup> April, 1992. Glass house grown plants were later transferred to two controlled temperature environments set at 28/22°C and 16/6°C during the grain filling period.

Both hybrids had comparable high percentage laboratory germination. However A665 x NZ1A emerged earlier than A665 x H99 at all plantings, though only significantly so at the October planting where mean temperatures were lowest (< 15°C). Seedling emergence rates did not differ significantly. Seedling dry weights at about 7 weeks after planting were highest in the glass house planting where mean temperatures were highest (19°C) and lowest in the

October planting, where temperatures the lowest.

A665 x H99 had faster leaf growths than A665 x NZ1A at all plantings although differences were not significant between the hybrids. Across plantings the hybrids had their greatest leaf appearance rates and leaf area growth rates in the November planting where temperatures were the highest and their lowest rates in the glass house where the photoperiod was longest (14 hrs). Maximum leaf area and leaf area index were however attained in the October planting where although temperatures were lowest and hence suppressed leaf growth, the extended growth periods resulted in larger leaf areas and leaf area indices. The lowest leaf areas and leaf area indices were obtained in the glass house primarily because the plants there were much smaller than those in the field.

Days to anthesis did not differ significantly between the hybrids though A665 x NZ1A reached mid-silk earlier than A665 x H99 at all plantings. Across plantings the hybrids reached mid-silk earliest in the November planting and latest in the glass house planting where temperatures were highest and the photoperiod longest, respectively.

At anthesis total plant dry weights (TPDWT) at all plantings did not differ significantly between the hybrids. Across plantings the TPDWT were highest in the October planting and lowest in the glass house where temperatures were

lowest and highest, respectively. During the reproductive period A665 x H99 still maintained a larger but non significant TPDWT than A665 x NZ1A in the field plantings. At both temperatures (28/22°C and 16/6°C) in the controlled temperature environments, A665 x H99 had significantly greater TPDWT than A665 x NZ1A. These temperatures did not influence the coefficients of growth, which must already have been established during the first 30 days of grain growth prior to moving plants from the glass house.

A665 x H99 had significantly greater cob and grain growths than A665 x NZ1A in the October and glass house plantings where mean temperatures were higher ( $> 16^{\circ}\text{C}$ ) during the early reproductive period and the onset of the linear dry matter accumulation phase. In the November planting where mean temperatures were low ( $< 16^{\circ}\text{C}$ ) during the early phase of reproduction and then further declined, cob and grain growth of the hybrids did not differ significantly. However the cob and grain growths of A665 x H99 were more retarded than those of A665 x NZ1A. In the October planting and at 28/22°C where the hybrids had time to reach physiological maturity days, to physiological maturity and the duration of the grain filling period did not differ significantly between the hybrids.

A665 x H99 had greater final crop grain yield than A665 x NZ1A in the environments where temperatures were higher during the reproductive growth (October and glass house plantings). In the November planting where temperatures were lower A665 x NZ1A yielded higher though only slightly.

Across plantings grain yields were highest in the October planting where temperatures were the highest during grain growth, and lowest in the controlled environments which was mainly a reflection of the small plant size. The main yield component which was different between the hybrids was total grain number. A665 x H99 had more total grains than A665 x NZ1A at all plantings and these differences were significant so in the October and glass house plantings.

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## CHAPTER 1.

### INTRODUCTION.

Maize is a warm weather crop which requires frost free conditions during the growing season for reliable yields (Shaw, 1977). Its growth and developmental processes occur within a temperature range of between 10 and 30°C (Duncan and Hesketh, 1968; Duncan, 1975), and are optimal at temperatures of between 21 and 27°C (Sprague, 1955; Shaw, 1977).

Temperature forms one of the major environmental variables which influences grain yield of maize through its accumulated effect on vegetative growth (McCormick, 1979), assimilate production and supply to the developing grain (Tollenaar and Daynard, 1978b; McCormick, 1979; Tollenaar and Bruulsema, 1988), and directly on grain growth (i.e., rate and duration of grain filling) (Hunter et al., 1977; Jones et al., 1981, 1984, 1985; Badu-Apraku et al., 1983; Muchow, 1990).

In high altitude and high latitude regions low temperature is a common hazard to maize production during the vegetative and/or the reproductive phase (Derieux, 1978; Eagles, 1979; McCormick, 1979; Hardacre and Eagles, 1986). Low temperatures will adversely affect the growth of maize plants



from sowing to maturity in one or more of the following ways (Eagles, 1979; Dolstra and Miedema, 1986):

- (1) by promoting seed and seedling rot by soil fungi in cold and wet soil,
- (2) by inhibiting or slowing germination and seedling emergence,
- (3) by inhibiting or slowing autotrophic (photosynthetically) based growth,
- (4) by freezing plant tissue after emergence or mature plants at the end of the season,
- (5) by stopping dry matter accumulation in the grain.

The minimum temperature for germination and emergence of maize is about 10°C (Lehenbauer, 1974; Grobbelaar, 1963; Blacklow, 1972; Eagles and Hardacre, 1979a; Eagles, 1982; Warrington and Kanemasu, 1983a; Menkir and Larter, 1987) while for photosynthesis it is generally considered to be about 15°C (McWilliam and Naylor, 1967; Duncan and Hesketh, 1968; Alberda, 1969). Cold tolerant cultivars which are capable of rapid and reliable emergence and growth are therefore desirable in the low temperature areas. Perhaps because of faster and/or more efficient respiration based growth at low temperature, faster emerging genotypes utilize endosperm reserves faster than slower genotypes and thus maintain a growth and developmental advantage (McWilliam and Naylor, 1967).

Photosynthesis occurs slowly or not at all at temperatures below 15°C.

Continual exposure to temperatures below 15°C in light, for example, results in the failure of the photosynthetic system, characterised by chlorosis of the

leaves and ultimately death of the plant (McWilliam and Naylor, 1967; Miedema, 1982). Reduced photosynthetic rates drastically reduce growth rates and consequently reduce grain yield (Teeri et al., 1977).

Total plant dry weight, leaf area and leaf area duration (Beauchamp and Lathwell, 1966; Wilson et al., 1973; Thiagarajah and Hunt, 1982; Badu-Apraku et al., 1983; Hardacre and Turnbull, 1986), and leaf number (Stevenson and Goodman, 1972; Hunter et al., 1974; Bonaparte, 1975; Aitken, 1977; Warrington and Kanemasu, 1983c; Hardacre and Turnbull, 1986) decrease with increase in mean temperature over the 15 to 30°C temperature range. However, Duncan and Hesketh (1968), Arnold (1969), Hesketh et al. (1969), Coligado and Brown (1975), Eagles (1979), and Tollenaar et al. (1979) among others have reported leaf number increases over the same temperature range.

Rates of leaf initiation (Beauchamp and Lathwell, 1966; Eagles, 1979), leaf appearance (Brouwer et al., 1973; Aitken, 1977; Warrington and Kanemasu, 1983b; Hardacre and Turnbull, 1986), and leaf expansion (Grobbelaar, 1963; Beauchamp and Lathwell, 1966; Kleinendorst and Brouwer, 1970; Barlows and Boersma, 1972; Watts, 1972a,b; Auld et al., 1978; Gallanger, 1979) increase with increase in mean temperature over the 15 to 30°C temperature range.

Grain yield in maize is a function of the rate and duration of dry matter accumulation in the grain (Johnson and Tanner, 1972). The influence of temperature on grain growth is reflected by its effect on sink capacity (i.e., grain size and number) (McCormick, 1979; Capitanio et al., 1983; Jones et al., 1981,1984,1985; Reddy and Daynard, 1983) during cell division (lag phase), and the rate and duration of grain filling (Hunter et al, 1977; Jones et al, 1981,1984,1985; Badu-Apraku et al, 1983; Muchow, 1990) during the effective grain filling period (EGFP).

Increased rates and duration of grain filling have been reported to correlate well with grain yield (Hanway and Russel, 1969; Daynard et al., 1971). Mock and Pearce (1975) suggested that the grain filling period in maize should be as long as practically possible to allow maximum production and storage of dry matter.

In the temperature range of 15 to 30°C, Jones et al. (1984), Major and Schaalje (1885), and Tollenaar and Bruulsema (1988) found that lowering temperature promoted sink development, while rates and duration of grain filling decreased and increased, respectively. Cool temperature extends the cell division phase resulting in increased sink capacity (Wardlow, 1970; Kolderup, 1979), and it has been concluded from long term weather data that higher mean season temperature is correlated with lower grain yield (Kiesselbach, 1950; Thompson, 1986).

In the high altitude and high latitude areas grain yields may therefore be maximised by the use of cold tolerant genotypes. Such genotypes should allow early planting so as to extend the length of the growing season and be able to withstand adverse low temperature effects during the vegetative and the reproductive periods.

The objectives of this study were therefore to compare the effect of seasonal temperature (field) and controlled temperature (controlled environment) on:

- (1) plant growth and development,
- (2) grain growth, and
- (3) yield components of two genotypes,

one a warm weather hybrid and another bred for cold tolerance. Hereafter, growth is defined as dry matter production and development as progression toward maturity.