improving crop establishment as well as grain yields (Bacon and Cooper, 1985). The effects of mulching are indicative of the relative improvements in root environments. Heat and moisture stress could play an important role in determining early establishment, growth and yield of wheat in this environment.

The objectives of this investigation were (i) to examine the changes of soil temperature and soil moisture status under rice straw mulching; (ii) to evaluate the influences of straw mulching on growth and grain yields in wheat; and (iii) to determine the relative significance of soil moisture and soil temperature-mediated effects in determining wheat grain yields.

2. LITERATURE REVIEW

2.1 Effects of Temperature

2.1.1 Shoot Temperature

Shoot temperature is the primary environmental factor influencing the rate of morphological development of the spring wheat plant (Frank et al., 1988). The optimum temperature for photosynthesis and reproductive growth of wheat is near 20°C (Al-Khatib and Paulsen, 1984). High temperature could limit grain yield in wheat, but the magnitude of the response is often difficult to assess owing to parallel changes in other environmental factors such as the availability of water (Rawson, 1987 and Wardlaw et al.,1989). The influence of temperature on wheat yield components vary depending on the growth stage of the plant (Johnson and Kanemasu, 1983). During early spike development, high temperatures generally reduced number of kernels/spike by reducing the number of spikelets or kernels on a spike (Fischer and Maurer, 1976). Increasing temperature from 10 to 26^{0}C during this period significantly reduces kernel number/spike from 27.2 to 18.5 (Frank and Bauer, 1982). Moreover, the duration of apex growth stage was also shortened by about 3 days at high temperature (26^{0}C) as compared to cool temperature (18^{0}C) (Frank et al., 1987). Consequently, potential spike size of wheat is morphologically determined early in the growing season and can be strongly affected by air temperature (Frank et al.,1988). High temperature has been reported to accelerate phenological development of wheat (Midmore et al.,1982; Johnson and Kanemasu, 1983; Fischer, 1984 and Rawson, 1987). Shpiler and Blum (1986) reported that high temperature stress shortens the duration of all developmental stages in wheat and accelerates senescence.

Rising temperature at the later stages of wheat development, particularly after heading, has been reported to be an important factor limiting yield (Wardlaw et al.,1989). A high temperature during booting stage greatly reduced grain number/spike but only had a small effect on grain size. On the other hand, the main effect of high temperature during grain development was to reduce grain size with only a small effect on grain number. Exposure to high temperature ($30/25^{0}$C) during the period of grain development reduced grain dry weight by 30-35% when compared with the 18/13^{0}C control. Increased temperature over 12-26^{0}C during grain filling has also been reported to reduce grain weight from 4-8% per degree (Fischer, 1984). In addition to the reduction in grain weight, duration of grain growth was also shortened by high temperature (Wiegand and Cuellar, 1981). The data indicated a 3-days shortening of grain filling per degree celsius increase in mean daily air temperature during grain filling.

2.1.2 Root Temperature

Surface soil temperature significantly influenced the growth and development of spring wheat (Boatwright et al.,1976). Sojka et al. (1975) reported that high soil temperature increased root respiration and hence reduced oxygen supply to root. Temperature above 22^{0}C has been observed to reduce dry yield of shoot and decreased nutrient concentration in the shoot in comparison to the plant grown at 11^{0}C (Boatwright et al.,1976). Average soil temperature at seed depth has been reported to have a strong effect on the median germination time of wheat (Tripathi et al.,1985; Lafond and Baker, 1986). It accounted for almost 90% of the variation in the time taken for 70% wheat emergence whereas air temperature accounted for only 50% of this variation. The final germination percentage was not, however, affected by temperature. Kuroyanagi and Paulsen (1988) demonstrated that growth and senescence of shoot and grain were influenced more by root temperatures than by shoot temperatures. Karyanto and Paulsen (1990) further reported that viable leaf area was greatly reduced by high root temperature (32^{0}C) at high (32^{0}C) or low (22^{0}C) shoot temperature. Photosynthesis, stomatal conductance and viable chlorophyll fluorescence were reduced more by high root temperature than by high shoot temperature. High root temperature promoted senescence and less plant mass. They later concluded that root temperature is involved in shoot senescence which, in turn, may regulate photosynthate partitioning and grain development.

2.2 Effects of Water Stress

Water stress injury to wheat crop is related to the growth stage when stress occurs and to the degree of stress imposed. Day and Intalap (1970) found that jointing stage was more critical to water stress while Fischer (1973) observed that the most sensitive stage was 15 days before anthesis and the effect was mainly on the number of grains/spike. Musick and Dusek (1980) reported that yield reduction from water stress was apparently due to a reduction of grain number and harvested spikes associated with increasing tiller number and stem senescence. They also found that the rate of dry matter accumulation in stressed treatments were lower than in well-watered treatments. Hochman (1982) showed that stress imposed during tillering to anthesis reduced leaf area index and grain number while stress from booting to grain filling reduced grain number and 1,000-grain weight. In addition, stress during grain filling reduced 1,000-grain weight and yield.

Angus and Moncur (1977) studied water stress effects on wheat phenology. The results showed that mild stress hastened development whereas severe stress delayed development. They further explained that the delay was possibly due to the cessation of shoot apex development and cell division during severe stress. The hastening development under mild stress was attributed to the increased leaf temperature known to accompany water stress and which has an effect in hastening development similar to that of increase in ambient temperature. Hang and Miller (1983) reported that water stress hastened maturity and shortened the grain filling period. This was consistent with the previous studies done by Day and Intalap (1970) and Musick and Dusek (1980).

In northern Thailand, Rerkasem and Rerkasem (1984) found that omitting one irrigation at anthesis caused pronounced grain yield reduction. However, irrigating three times during the first four weeks resulted to a wheat crop yield of 75% that of the maximum yield with full irrigation (six irrigations of approximately 50 mm. each). They also found that yield was unaffected by omission of one irrigation at crown root initiation, tillering or grain filling. In contrast, Youngsuk and Hawmdawk (1987) reported that omitting the anthesis irrigation caused significant reduction on grains/spike and grain yield. Omission at crown root initiation and anthesis caused reduction on spikes/m^2 and grains/spike. The effect of water stress on wheat at different planting dates was studied by Meechoui (1985) at Chiang Mai University. He found that water stress at flowering and at early grain filling halved the potential yield at all seeding dates (between November 12. and December 13.). The yield reduction was associated with a reduced number of grains/spike and grain size.

2.3 Effects of Mulching

Chaudhary and Chopra (1983), in India, reported that maximum soil temperatures at 5 cm. depth were lower under rice straw mulch plots compared to bare soil. In addition, water depletion in the top 120 cm. soil layer is lower under rice straw mulched than in bare soil treatment. They also found that straw mulch treatment prolonged the period to 50% seedling emergence and 50% heading while grain filling period was shortened consequently resulting to a lower dry matter accumulation. They further mentioned that mulching not only caused significant thermal effects during the early growth, but it also influenced throughout the crop cycle. Furthermore, they indicated that wheat grain yields were closely related with soil temperature at 5 cm. depth (r=0.93) than at 15 cm.(r=0.46). Bacon and Cooper (1985), in Australia, indicated that straw management had greatest effect on wheat growth by affecting crop establishment, tillering and dry matter production. Rice straw management accounted for 69% of the variance in crop establishment. They also found that direct drilling with rice straw retained on the soil surface doubled the growth of wheat compared to stubble incorporation or burnt treatments. Although early growth was slow on straw retention plots, tillering was extensive and dry matter accumulation increased rapidly after ear initiation. Tripathi et al. (1985) found that rice straw lowered the maximum soil temperature by 3.2-4.4^{0}C over bare soil but raised the minimum temperature by 1.8-2.8^{0}C. Although soil temperature in bare soil was higher than straw mulched plots, seedling emergence was greater in the straw mulched treatment due to higher soil moisture.