A STUDY OF EFFECTS OF LOW TEMPERATURE STRESS ON SEED DEVELOPMENT AND YIELD IN WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

Temperature affects the growth, development, fertility and yield of cereals. The degree of sterility and subsequent yield reduction caused by extreme temperature stress depends upon the minimum level and duration of the stress temperature applied and the stage of plant development at the time of stress.

An experiment was conducted in which three low temperature regimes (-4^{o}, $-2^{o}C$ and $+3^{o}C$) were applied at 5 different stages of plant growth (from 1 day before anthesis to 9 days after anthesis) for a period of 6 hours with pre- and post-conditioning periods of 6 and 4 hours respectively.

The results showed that the minimum temperature reached determined the nature and severity of temperature injury in Karamu wheat.

Complete floret sterility was evident when a $-4^{o}C$ temperature was imposed at the pre-anthesis or anthesis stages of plant development; florets in any position of the head being equally affected. A $-4^{o}C$ temperature stress applied 3 days after anthesis produced 50% and 5% seed formation in primary and secondary heads, respectively. This seed formation mainly occurred in the basal florets of the apical and central spikelets of the head, however the seeds formed did not develop after stress and subsequent viable seed yield was zero.

At the later stages, 6 or 9 days after anthesis a $-4^{o}C$ temperature stress had no significant effect on seed numbers. However there was a substantial negative effect on seed development and viability so that subsequent viable seed yield was zero.

Temperature stresses of $+3^{o}C$ and $-2^{o}C$ had no significant effects on seed formation, development and viable seed yield

when stresses were applied at any of the stages of plant development tested.

The percentage of seed formation was highest in the two basal florets of the central and apical portions of the head compared to that in the two basal florets of the bottom of the head and to the distal florets of all spikelets.

The percentage sterility in terms of relative sterility (percentage 'D + R' type ovules) and sterility index (percentage of 'D' type ovules) was also described. It was found that in 'Karamu' wheat 16% to 33% rudimentary florets were a common feature, such structures included tiny basal, sterile spikelets and the terminal florets of all spikelets.

Morphological and anatomical differences in ovules harvested at different stages of development from different treatments were observed. Ovules were classified into 6 groups for assessment of seed development. (A = apparently not fertilised, B = swollen and conical shaped, C = developing, D = shrivelled and shrunken, E = shrunken with reduced conical shape, R = rudimentary).

Possible pathways to seed formation and development can be estimated from the data. A probable pathway to normal seed development is A to B to C. However, in the case of unsuccessful seed formation and development, the pathway is likely to be A to D, A to B to D or A to B to C to D. Further detailed electron microscope work is needed to enable a complete description and understanding of the pathways of seed development in stressed and unstressed plants. Such knowledge is needed to provide a logical basis for the development of cultivars with increased cold tolerance, fertility and yield.

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1. INTRODUCTION

Wheat is the third most important crop in Nepal, after rice and maize, the area under wheat having trebled in the last decade. The present area under wheat cultivation is 348,000 hectares which is about 15% of the total cultivated area. Many factors such as the introduction of high yielding varieties, irrigation, fertiliser and plant protection measures have been extended in an attempt to increase average yields per hectare, but significant yield increases have yet to be achieved.

CIMMYT (1977) has suggested three main causes for low yields per hectare i.e.: -

1. Inadequate physical facilities in remote northern hilly areas.
2. Extension of cultivation into marginal and rainfed areas.
3. Expansion of cultivation areas in Tarai regions (Southern plain areas).

In the Tarai regions, the growth cycle of the wheat crop is 50% shorter than in hilly areas, this reduction in growth cycle tending to result in low yields. In addition, a partial environmentally induced sterility in improved high yielding cultivars has been recorded during the last few years. This is particularly a feature important in the production of the most popular variety RR21 (Sonalika). Sonalika is claimed to be one of the most widely adapted cultivars, being capable of growth in winter on the plains as well as in hilly elevated areas and covering a wide range of agroclimatic conditions. However, in 1975 sterility was recorded in agronomic trials with Sonalika conducted by agricultural stations. In 1976, several farmers in the hills and plain areas reported the same effect. In 1977, head sterility occurred not only in this variety, but also in another improved variety NL30. (CIMMYT Report on Wheat Improvement 1975, 1976, 1977). Although, at the moment

head sterility is not a major problem, occurring only in small scattered areas, it is still a potential problem influencing farmers wheat yields particularly when the crop is grown as an additional winter crop.

Many observations have been made in the field which suggest that the inability to set seed in some cultivars under certain circumstances is caused by abrupt changes in temperature and humidity during the flowering period which kills the pollen in the anthers. However, the problem may not be as simple as stated above.

The occurence of sterility caused by high or low temperature stress has been widely accepted. Several countries, including New Zealand and Australia have reported such damage caused by low temperature stress during the reproductive stage of development of wheat plants (Suneson 1941, Livingstone and Swinbank 1950, Single 1961, 1964, 1966, Gott 1961, Asana and Williams 1965, Toda 1965, 1966, Olugbemi 1968, Meredith 1977). Much work has been done to measure the effects on plant tissue of internal ice formation, and the expression of this effect on final grain yield during the screening of resistant varieties. These studies have shown that the degree of sterility caused by extreme temperature stress depends upon the stage of plant growth, and the intensity and duration of stress temperature. Although sterility is reported in several studies on the effects of temperature stress; the physiological causes underlying the failure of seed setting is not elaborated. Hill (1971) has suggested that successful seed development depends on a number of processes including floret development, anthesis, pollination, fertilisation and embryogenesis. Temperature is an essential environmental factor affecting these processes. So, an understanding of the causes of sterility under stress conditions requires detailed studies on seed development and the anatomical causes underlying the failure of seed formation in wheat.

The present study was undertaken on a wheat cultivar derived from Mexican parentage, bred in New Zealand, and commercially released under the name 'Karamu' in 1972-73. The characteristic features of this cultivar are short straw, awned seed and resistance to lodging. The grains are oval in shape, light in colour and are of satisfactory milling and baking quality. 'Karamu' is moderately susceptible to mildew and smut, but is resitant to rust and pre-harvest sprouting damage (McEwan et al 1972). It is early maturing and yields higher than other New Zealand varieties of comparable quality such as Aotea and Kopara. According to Langer (1978) it tends to set more grains per spikelet, and exhibits a higher proportion of floret fertility than other varieties. It was released as a spring sown wheat; but may also be sown in the early autumn. In the latter situation its very early maturity may result in yield losses from frost (McLeod and Upton 1978).

Because of the importance of environmental stress in general, and low temperature stress in particular, on the quality and quantity of wheat seed produced under temperate conditions a study was conducted at Massey University during 1979/80, the objects of which were to: -

1. Determine the effects of low temperature on seed development and seed head fertility and sterility in 'Karamu' wheat.

2. Determine the influence of low temperature stress imposed at various stages of plant development on the components of seed yield.

3. Carry out microtome sectioning of florets to try to determine the morphological pathways of early seed development in both temperature stressed and unstressed wheat plants.