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RELATIONSHIP BETWEEN WATER CONTENT AND GRAIN WEIGHT IN DEVELOPING WHEAT GRAINS

ABSTRACT

Grains from basal (4^{th}), central (8th) and apical (12^{th}) spikelets of a wheat (*Triticum aestivum* L.) cultivar Lok–1 were investigated for their fresh weight, dry weight and water content. Each spikelet had 3 grains and so in all 9 grains were analyzed. Grain dry weight data was fitted to polynomial equations and biphasic linear regression analysis. The experiments described here indicated that grains having maximum water content had maximum grain weight and vice versa. Maximum water content and maximum grain weight showed a highly significant linear correlation ($P < 0.001$). It is suggested that in genetic manipulation in wheat, maximum water content can be a used as a reliable criterion to help in selection for final grain weight.

Key words: biphasic regression analysis, grain growth analysis, water content, *Triticum aestivum*.

INTRODUCTION

Grain yield of a wheat plant may be described as a product of grain number per plant and the average final grain weight. The grain weight is determined by the rate at which the grain accumulates dry matter and the duration over which it occurs. In wheat, as in other cereals, grain yield is dependent on two major components: number of grains per unit area and individual grain weight. Grain weight is a decisive yield factor and differences in this character between different wheat cultivars are frequently associated with differences in yield. The differences in grain weight may be associated with differences in the rate of dry matter accumulation; and differences in the rate of dry matter accumulation may be due to genotype as well as grain position on the ear (Tollenaar and Daynard 1978).

Grain yield is directly dependent on sink size, which is largely determined during the vegetative period and on photosynthetic capacity of the crop during the grain filling period. Grain size in wheat is dependent upon both the supply of photosynthate from the plant as well as the

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growth capacity of the grain. Nevertheless, which of these limits the yield is as yet unresolved (Slafer and Savin, 1994), but breeding for greater yield through increased size of the grain will depend on first identifying and then modifying such factors in the overall regulation of growth of grains.

Plants increase in size mostly by increasing cell water content (Boyer 1988). The enlargement occurs because solute concentrations are high enough inside the cell to extract water osmotically from the surroundings. As a result, the pressure in the cell rises and extends the walls irreversibly, enlarging the cell compartment. The complex process of cell elongation is mediated by a series of metabolic events coordinated within the wall matrix. Cosgrove (1987) suggested that the coupling of water uptake to wall yielding is an essential aspect of cell enlargement because wall relaxation creates the initial driving force for water uptake by reducing wall–loosening enzymes. The importance of glycosidases in cell wall loosening has already been reported in our earlier work (Chanda and Singh 1998).

The main aim of the present work was to study grain growth in terms of dry weight and water content over a number of seasons over the entire period of grain development in wheat.

MATERIAL AND METHODS

Seeds of wheat (*Triticum aestivum* L.) cultivar Lok–1 were sown in a farmer's field (black cotton soil vertisol) adjacent to the University campus for three consecutive years (1988–1991). The experimental plot was ploughed and layered with farmyard manure. At the time of sowing, it was fertilized with 9 g × m^{-3} of diammonium phosphate as a basal dose. 30 rows, 25 m long and 0.3 m apart were prepared. After 15 days, the plants were thinned and a density of 50 plants m^{-2} was maintained. Irrigation was done at weekly intervals until maturity. At regular intervals weeding was done and all unwanted plants were removed. After 40 and 70 days of sowing, another dose of urea fertilizer was provided at the rate of 9 gm^{-3}. The plants reached anthesis after 57, 51 and 59 days after sowing in the three year respectively. On the day of anthesis, the main tiller spikes with 13 spikelets were tagged. More than 3000 spikes were tagged and these tagged spikes were harvested at an interval of 3 to 4 days after anthesis until maturity for growth analysis.

In this wheat cultivar, each spike had 13 spikelets and each spikelet had 3 florets. At maturity, the grain weight of middle spikelets was largest followed by lower and upper spikelets respectively. Even in a floret, the basal grains were larger than apical grains. Such differences were reported earlier in wheat (Bremner and Rawson 1978). Considering the above stated fact grains of three spikelets were selected for the analysis. The spikelets selected were 4th spikelet (basal), 8^{th} spikelet (central) and 12^{th} spikelet (apical). However, all the nine grains (three from each spikelet) irrespective of their position on the spike showed a similar trend, hence only the data of three representative grains is given in the present paper except in regression analysis where data of all 9 grains (of the three seasons) is considered. The three grains selected were apical grain of 4^{th} spikelet named as grain 1, basal grain of 8^{th} spikelet named as grain 2 and apical grain of 12^{th} spikelet named as grain 3.

Growth analysis

On the day of analysis, the tagged spikes were randomly harvested, placed in plastic bags and taken to the laboratory. Ten to fifteen grains were used for fresh and dry weight measurements. The difference in these two weights gave the water content in mg at each time.

Statistical analysis

The grain dry weight data was fitted to polynomial functions and the selection of an appropriate polynomial was made statistically by the 'lack of fit' method (Nicholls and Calder 1973). The instantaneous rate of grain filling, dw/dt, was calculated as the derivative of the appropriate polynomial. Grain dry weight data was also fitted to a biphasic linear regression of intersecting segments (Green *et al*., 1985). Details of the method followed are as described earlier (Chanda and Singh, 1996). A linear regression analysis was also worked out between maximum water content and maximum dry weight of 9 grains from all the 3 seasons.

RESULTS AND DISCUSSION

All the three grains showed a similar trend with initial lag phase, a linear dry matter accumulation phase and a final lag phase before maximum weight was reached at physiological maturity (Fig. 1a). The rate of dry matter accumulation in the three grains is shown in Fig. 1b. Maximum rate of dry matter accumulation was achieved by 31 days in grain 2 while in grain 1 and grain 3, it was around 34 days after anthesis. Subsequently, the rate decreased in all the 3 grains, reaching physiological maturity around 51–53 days after anthesis. Grain 2 had higher rate through out and was followed by grain 1 and 3 respectively. The lower rate of grain filling in these grains may be a consequence of a decreased water potential, resulting from the lower cell water content (Renwick and Duffus 1987).

Grain dry weight data was also fitted to biphasic linear regression analysis. In all the 3 grains, there was an initial lag phase during which the growth rate was low, and a later linear dry matter accumulation phase was discernible (Fig. 2a). The initial lag phase ranged from 12 to 15 days after anthesis, while the linear dry matter accumulation phase ranged from 13 to 47 days. Then the dry matter declined. The changes in

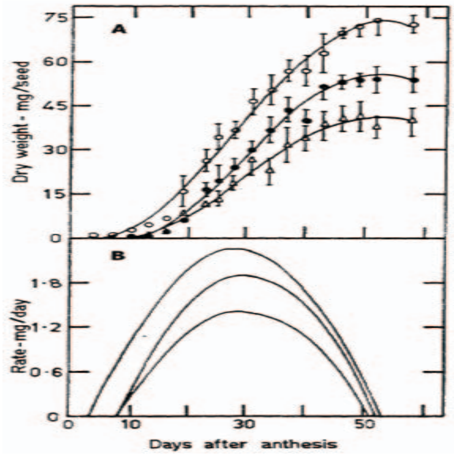

Fig. 1

a) Grain dry weight data versus days after anthesis predicted from a cubic polynomial regression equation (n=15) of 3 representative grains: o apical grain of 4^{th} spikelet; o basal grain of 8^{th} spikelet; apical grain of 12^{th} spikelet of a wheat cultivar Lok–1. Vertical bars represent ± SD.

b) The predicted rate of dry matter accumulation of the 3 grains calculated using the cubic polynomial.

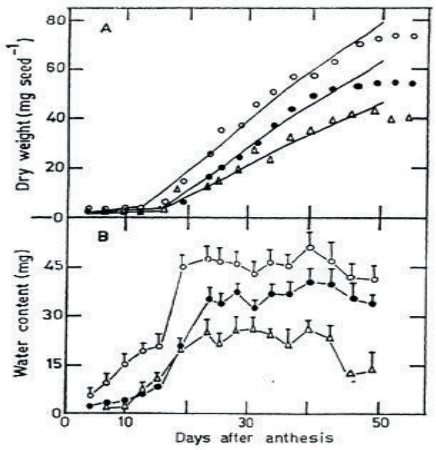

Fig.2

a) Biphasic regression analysis for grain dry weight of three representative grains grown during the year 1989. Other details as per Fig. 1.

b) Water content of developing wheat grains versus days after anthesis during the entire period of grain growth. Other details as per Fig. 1

water content of 3 wheat grains is given in Fig. 2b. The lowest water content was on day 4; it gradually increased and reached a maximum level by days 23, 28 and 23 in grain 1, 2 and 3 respectively. After day 28, the water content almost remained constant up to 44 days after anthesis and declined thereafter. In different plant species, it has been observed that during grain development, the water content increases in parallel with dry weight, reaches to a maximum level and declines before the grain reaches to physiological maturity. Egli (1990) suggested that seed water status plays an important role in regulating seed development. Even *in vitro* studies on soybean seed culture revealed that increase in water content and associated tissue expansion is required to support a rapid dry weight growth rate (Saab and Obendorf 1989). Similar patterns of dry matter accumulation and water uptake has been reported in other crop plants (Martinez–Carrasco *et al.* 1988, Chanda and Singh 1997, Saroop *et al.* 1998, Rabadia *et al.* 1999).

On the basis of biphasic linear regression analysis and data of water content, four phases of wheat grain development can be delineated viz. cell division, cell elongation, dry matter accumulation and maturation, as described earlier (Chanda and Singh 1996). Identification of these critical phases is important as it may prove fruitful as alternative or additional source of variation for increasing yield potential (Kuhn and Stucker 1976).

During grain development, the water concentration declines steadily causing differences in grain growth rate and final grain weight (Egli, 1990). Pande *et al.*, (1992) also showed that the cultivars having more water content had more dry weight. Similar relationship between water content and grain size was observed in 3 genotypes of cotton (Rabadia *et al.* 1999). During development, the increase in grain size is associated with increase in grain volume and this requires a net uptake of water and it has been suggested that seed water status may play an important role in regulating seed development (Egli, 1990).

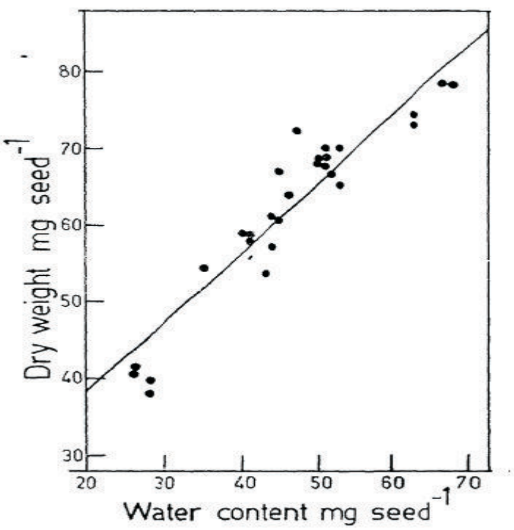

Fig.3. Regression analysis of water content plotted against grain dry weight.

In the present work, maximum water content and maximum dry weight of 9 grains from 3 growing seasons were fitted to a linear regression equation which gave a highly significant correlation ($P<0.001$) (Fig. 3) thus, indicating that the process of cell enlargement may be an important determinant of sink capacity. Considering the above stated facts i.e. a close correspondence between water content and rate of dry matter accumulation of developing wheat grains in the present study suggest that rapid water uptake may be required to support rapid rate of dry matter accumulation. And this was supported by the fact that grain with high water content achieved higher grain weight at maturity and vice–versa. It is proposed that water content of grain plays an important role in determining dry weight and hence yield potential in wheat.

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