Relationship of crop water status with wheat grain yield in a Mediterranean type climate

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Abstract

Available water in the Mediterranean type of climate usually gets scarce during grain filling of wheat. A crop water based yield-predicting index towards anthesis would be useful. Most of the available plant water indices use measurements on leaves only and ignore other green plant parts. We measured the amount of water contained in the crop/area and related it to grain yield in combination with other parameters. Crop water/area was concluded to be the preferred term over biomass/area for accounting grain yield variance.

Key Words

Wheat, crop water status, grain yield, crop management.

Introduction

In wheat, maximising water use (the sum of evaporation and transpiration), to the benefit of the crop implies managing crop for maximising transpiration. Water use efficiency (WUE) has been demonstrated to be water, nutrition, soil type and cultivar dependent. This term will affect the range of crop yield, which has to be targeted through optimum management and cultivar choice. Choices for water use management are generally possible in the beginning and sometimes during the season as well, but the benefits of all crop management options available under these strategies are evident only after the end of the crop season. Since the water available in this Mediterranean type of climate usually gets scarce during grain filling of wheat, a crop water based yield-predicting index towards anthesis would be useful.

Low water availability renders high concentration of ABA in the xylem, which leads to closure of stomata, followed by decreased CO_2 assimilation rate and stomatal conductance (6,7). This reduction of net photosynthesis is critically important in the post-anthesis period when crop is accumulating carbohydrates for grain filling. Idso et al (4) proposed a “crop soil water index” based on the linear increase of canopy temperature in relation to adequately watered crop which has a good relation to available soil water but its relation with plant water potential at higher intensity of water stress is not so linear (3). Karamanos and Papatheohari (5) suggested a new index, the water potential index, as a measure of the total water stress experienced by any crop in a given environment for a specific time interval. The index is useful for relative adaptability studies and requires repeated observations during the season. Moreover, the measurement of water potential in pre-anthesis period may not be very useful in the WA climate where pre-anthesis growth is not water-limited. The assessment of water loss from excised leaves was useful for detecting inherited differences among genotypes for drought tolerance in wheat (1,8). Leaf relative water content is yet another indicator of water status and has been proposed to be more important than other water potential indices as it reflects the cell volume differences (2,9,10).

Many of these indices use water potential measured on leaves and ignore other green parts of the plant which are also photosynthetically active but might have water potential and water retention capabilities different from leaves because of their different anatomical structure and spatial position in the canopy. Further, parameters measured on crop basis than individual plants would perhaps be better indicators of final grain yield.

Materials and Methods

We measured the crop water status in wheat agronomy trials and studied its relation to grain yield. Ten field trials were conducted in the Northern Agricultural Region of Western Australia in 1998 and 1999 on light to medium soil types after canola or lupin rotations. Differences of fresh weight and dry biomass at anthesis (anthesis crop water per unit area [*awa*]; g/m^2) were used to calculate crop water parameters. Other parameters were measured as usual. Data were analysed using Genstat.

Results and Discussion

Of all the pre-anthesis variables, correlations with grain yield were higher for variates anthesis biomass per unit area *aba* (0.514), anthesis crop water per unit area *awa* (0.513), days to anthesis *da* (0.588), days to stem elongation *ds* (0.702) and plant density *pd* (0.548) but not all of these variates could sufficiently account for grain yield. Correlation between *aba* and *awa* was 0.757.

The grain yield variances accounted for by variate combinations differing for number and nature were compared and the prominent ones are given in Table 1. Number of grains per unit area *ga* alone accounted for 59% grain yield variance. *aba* explained only 41.9% compared to *awa* (51.8%). In combination with *ga*, *awa* accounted for 70.0% while *aba* was again 10% less efficient than *awa*. Upon adding another variate to the model, little but important accountability was evident with plant water content at anthesis (*awp*; g/plant) and *pd*; each combination accounting for 74.1% variation in grain yield. Similar predicability influences of *pd* and *awp* on grain yield are not unexpected as the two traits are significantly, though negatively, correlated (-0.687). Further addition of measured variates to the model was not effective. However, inclusion of soil type and location improved grain yield accountability to 80.9%.

Table 1. Grain yield variance accounted for by different variate* combinations. Data are estimated over three locations for 40 varieties in two years.

*Explanatory Variate**	Residual df	v.r.	F pr.	Percentage variance accounted for
aba	456	330.9	<.001	41.9
awa	469	506.7	<.001	51.8
awp	469	56.7	<.001	10.6
ga	494	727.9	<.001	59.5
pd	494	31.2	<.001	5.8
aba+ga	455	446.6	<.001	59.2
awa+aba	455	270.4	<.001	54.0
awa+ga	468	549.4	<.001	70.0
awa+pd	468	296.1	<.001	55.7
awa+awp	468	309.2	<.001	56.7

awa+ga +awp	467	448.7	<.001	74.1
awa+ga +pd	467	450.0	<.001	74.1
awa+ga +awp+pd	466	350.4	<.001	74.8
awa+ga +awp+location+soil type	463	285.7	<.001	80.9

*[*] *aba*=anthesis dry matter/area; *awa*=crop water content /area at anthesis; *awp*= plant water content at anthesis; ga =number of grains to be developed/area; pd =plant density/area

Table 2. *t*-probabilities for parameter estimates of *aba* and *awa* in the presence of others.

Explanatory Variate	$t_{estimate}$ [*]		
	aba	awa	ga
aba+awa+ga	-0.05 (0.961)	7.97 (<0.001)	15.7 (<0.001)
aba+ga	7.53 (<0.001)		18.06 (<0.001)
awa+ga		11.32 (<0.001)	15.98 (<0.001)

[*] Values in parenthesis are the *t*-probabilities of estimates

Since *aba* and *awa* are highly correlated, their relative importance was judged from the significance levels of estimated parameters (Table2) in the presence of others as suggested by Snedecor and Cochran (11). $t_{estimate}$ for *aba* (-0.05) was not significant (t pr 0.961) in the presence of *awa* and *ga* while that for *awa* (7.97) was highly significant (t pr <0.001) in the presence of *aba* and *ga*, thus making *awa* as the preferred parameter for predicting grain yield in Western Australia.

Influence of management on the three important variates (*awa, ga, awp*) was highly significant (Table3). Both the water terms, *awa* and *awp* were greatly influenced by genotype, nitrogen, time of sowing, and genotype*time of sowing interaction while *awp* was a function of plant density as well. *ga* was more a function of variety than plant density but the variety influences are masked by nitrogen and time of sowing variation. The relatively higher importance of nitrogen and time of sowing on crop water status terms (*awa* and *awp*) than seed rate highlights the extent to which these agronomic factors can influence crop productivity.

Table 3. Influence of agronomic factors on regression parameters. Data are estimated over three locations for 40 varieties in two years.

Parameter[*]	**Trial Type @ location**	F-probability		
		Variety	**Input**	**CV*Input Rate**

awa	Variety*Applied Nitrogen @ Yuna	<0.001	<0.001	0.088
	Variety*Seed Rate @ Yuna	<0.001	0.11	0.214
	Variety*Seed Rate @ Morawa	0.01	0.49	0.368
	Variety*Time of Sowing @ Morawa	<0.001	<0.001	0.018
awp	Variety*Applied Nitrogen @ Yuna	<0.001	<0.001	0.121
	Variety*Seed Rate @ Morawa	0.27	<0.001	0.618
	Variety*Time of Sowing @ Morawa	<0.001	<0.001	<0.001
ga	Variety*Time of Sowing @ Morawa	0.13	<0.001	0.614
	Variety*Applied Nitrogen @ Morawa	0.36	<0.001	0.737
	Variety*Seed Rate @ Morawa	<0.001	0.31	0.49
	Variety*Seed Rate @ Yuna	<0.001	0.04	0.855

[*]*awa*=crop water content /area at anthesis; *awp*= plant water content at anthesis; *ga*=number of grains to be developed/area

Conclusions

The results presented here indicate the possibility of in-crop prediction of grain yield through the use of crop water status and relative plant or crop water content. The third parameter, *ga*, accounts for nutrition and varietal phenology in the early crop growth stages and can possibly be determined nearly two weeks before anthesis when the wheat plant determines its number of grains per spike. The parameters proposed here are based on crop stand rather than individual plants.

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