PHYSIOLOGICAL RESPONSES OF SIX SPRING WHEAT VARIETIES TO NITROGEN FERTILISER

A.F. van Herwaarden[1,2], G.D. Farquhar[2], J.F. Angus[1], and R.A. Richards[1]

[1]CSIRO Division of Plant Industry, GPO Box 1600, Canberra, ACT 2601
[2] Research School of Biological Sciences, ANU, PO Box 475, Canberra, ACT 2601

Summary. Yield response to applied nitrogen (N) differed between six spring wheat varieties in a dry season (164 mm sowing to maturity rainfall) in southern NSW. Differences were associated by a seven-day range in flowering date. Later maturing varieties outyielded earlier maturing varieties at low N status but the rankings were largely reversed at high N status. At low N status, the later varieties took up more soil water and mineral N and developed more leaf area but contained less water soluble carbohydrate (WSC) reserves at anthesis than earlier varieties. Their yield advantage was due to greater leaf area and hence additional assimilation during grain filling. At high N status, the later maturing varieties also extracted more soil water and nitrogen than earlier varieties but extracted so much soil water by anthesis that lower reserves of WSC and reduced post-anthesis assimilation due to greater water stress resulted in lower yields than for earlier maturing varieties.

INTRODUCTION

Time of flowering greatly affects the water economy of dryland wheat and is a primary consideration in breeding programs (5). Water relations are also important in the response of dryland wheat to applied nitrogen and varietal differences in yield response have been reported (1, 3, 6). The aim of this study was to identify physiological factors responsible for differences in yield and yield response between six Australian spring wheat varieties to applied nitrogen (N) in water-limited conditions.

MATERIALS AND METHODS

Varieties were chosen for their expected similarity of anthesis date and diverse genetic background. (Table 1). The experimental site, at *Harmon's Tank*, Pucawan, 250 km west of Canberra, was chosen following a breakcrop (2) to minimise the detrimental effects of soil-borne disease on nitrogen response (7). Varieties were sown on 19 June 1991 at a rate of 170 seeds/m^2 with triadamefon double superphosphate (17.4% P, 4.1% S) supplying 21 kg P/ha. Treatments imposed were control or 80 kg/ha of N as urea (46% N) broadcast soon after sowing or at late tillering. Time of N application had a minor effect on yield and N uptake so data were analysed as control and 80 kg N/ha unless otherwise stated. Triadamefon and Benomyl were sprayed prophylactically at the end of tillering and Triadamefon again one week after flowering to protect varieties from foliar diseases.

Table 1. Characteristics of varieties grown in field trial.

Variety	Breeding	Grain	Year of release	Origin
Comet	Hybrid	Hard	1986	Cargill, Tamworth, NSW
Corella	Inbred	Soft	1984	NSW Agriculture, Wagga
Dollarbird	Inbred	Hard	1987	CIMMYT-NSW Agriculture Wagga
Janz	Inbred	Hard	1989	QWRI, Toowoomba, Qld

Kulin	Inbred	Soft	1985	Dept. of Agriculture, Perth, WA
Vulcan	Inbred	Hard	1985	Cargill, Tamworth, NSW

The soil profile was sampled using a tractor mounted hydraulic soil corer at the time of sowing, anthesis and harvest to determine volumetric soil water content. When the variety Janz reached anthesis, quadrat samples were harvested from all crops to estimate above-ground dry matter production (biomass). Samples were separated into spikes, stem plus sheath, flag leaves, penultimate leaves, rest of green leaves and dead leaf, oven dried at 70?C, and ground in a Cyclotec mill with a 0.5 mm sieve. Nitrogen content was determined using an elemental analyser (Carlo Erba 1108). Water soluble carbohydrate (WSC) concentration in the stems was determined (4). At maturity standard methods were used for harvesting and sample analyses (8).

RESULTS AND DISCUSSION

Rainfall from sowing to maturity was 164 mm. The rainfall distribution varied from the long term mean such that 25% more rain fell during winter but spring was 50% drier. The onset of terminal drought corresponded to the grain filling period and coincided with a sharp rise in ET and VPD in October. Post-anthesis rainfall amounted to 22 mm while class A pan evaporation for the same period was 220 mm.

Contrary to expectations, varieties differed in anthesis date by up to 7 days. Time to anthesis and nitrogen uptake accounted for most of the variation in grain yield (Fig 1, Table 2). There was a positive relationship between grain yield and anthesis date for low nitrogen crops, yield increasing by 74_?29 kg/ha/day, but for high nitrogen crops, grain yield decreased by 46_?28 kg/ha/day (Figure 1a). The variety Kulin had the lowest grain yield at low nitrogen but produced the highest yield with nitrogen fertilisation. In contrast, Janz was the highest yielding variety at low nitrogen but was one of the lowest yielding at high nitrogen.

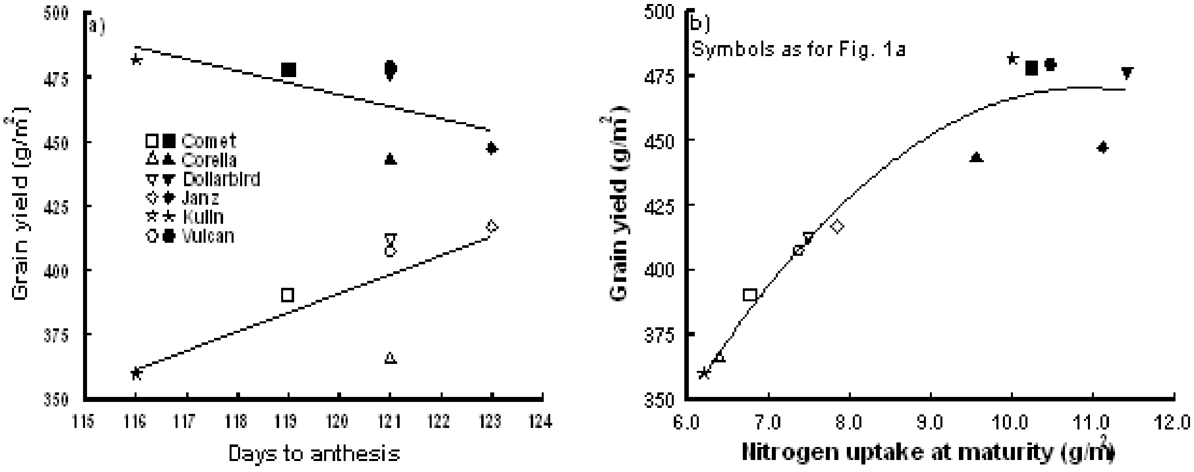

Figure 1. Relationships between grain yield and a) anthesis date and b) N uptake at maturity for six spring wheat varieties without supplementary N (open symbols) and with N fertiliser (closed symbols).

The yield advantage of Janz over Kulin at low N was probably due to more assimilation during grain filling, as suggested by the higher leaf area index (LAI), rather than by retranslocation of stored WSC (Table 3). Janz had higher leaf N concentration and leaf area duration during grain filling than Kulin (data not shown). The yield advantage of Kulin over Janz at high N was probably due to more retranslocation rather than assimilation during grain filling, as indicated by the levels of WSC and LAI (Table 3). The contrasts between the earliest and latest flowering varieties are supported by a positive correlation

(r^2=0.63) between grain yield and LAI at the anthesis harvest for all varieties at low N status and a negative correlation (r^2=0.53) at high N.

Table 2. Responses of six Australian spring wheat varieties to application of N fertiliser.

Variety and Anthesis date	N rate	Spike density	Grain yield[a]	HI	Kernel wt	Grain protein[b]	MaturityN uptake
	(kgN/ha)	(spk/m^2)	(g/m^2)		(mg)	(%)	(g/m^2)
Comet	0	282	390	0.40	38.9	7.2	6.8
16 Oct.	80	346	478	0.41	35.6	9.3	10.3
Corella	0	320	366	0.41	34.6	7.2	6.4
18 Oct.	80	362	443	0.43	31.6	9.4	9.6
Dollarbird	0	351	412	0.42	35.9	7.8	7.5
18 Oct.	80	416	476	0.42	30.7	10.5	11.4
Janz	0	361	417	0.42	33.9	8.0	7.9
20 Oct.	80	396	447	0.42	28.9	11.0	11.1
Kulin	0	245	360	0.44	37.2	7.7	6.2
13 Oct.	80	311	482	0.45	35.2	9.5	10.0
Vulcan	0	359	407	0.43	32.8	7.7	7.4
18 Oct.	80	421	479	0.44	29.1	9.7	10.5
(l.s.d. $P < 0.05$)		n.s.	16.2	n.s.	1.1	0.5	n.s.

n.a., not available; n.s., interaction not significant, main effect of variety and N significant

(*P*<0.001); [a] expressed as dry weight at 70?C; [b] expressed at 12% moisture.

Table 3. Water soluble carbohydrate (WSC) and LAI at anthesis harvest for the earliest (Kulin) and latest (Janz) flowering varieties at low and high N status.

	Kulin		Janz	
	Low N	High N	Low N	High N
WSC (g/m^2)	130	121	115	80
LAI (m^2/m^2)	1.6	2.2	2.3	3.6

Potential yield (kernels/m^2) was positively correlated with N uptake (r^2=0.88). The yield differences at low N status were correlated with N uptake at maturity (Fig 1b), with an additional 38 kg of grain for each additional kg of N uptake. At high N status, there was no correlation between yield and N uptake, presumably because yields were close to the water-limited potential. At high N status, differences in N uptake at maturity were poorly correlated with anthesis date (r^2=0.23) because the varieties differed in amounts of N lost from the biomass between anthesis and maturity. N uptake to the date of anthesis harvest improved the correlation (r^2=0.53) with anthesis date. N uptake increased by 2.4?1.0 kg N/ha for each day's delay in anthesis, and with no significant difference between the low and high N crops.

The application of N fertiliser produced greater anthesis biomass at the expense of WSC reserves (Table 3) and led to additional water use (Table 4). Water use to the anthesis harvest was strongly correlated with anthesis LAI (r^2 =0.96) while LAI was negatively correlated with stem WSC (r^2 =0.67). Therefore despite an increase in leaf N concentration (data not shown) canopy architecture was such that as LAI increased, shading of lower leaves increased, resulting in inefficient water use lower in the canopy and lower stem WSC at high N. This point is illustrated by a measure of leaf area efficiency (LAE) defined as biomass produced over a given period of time per unit of mean leaf area for the same period. The mean LAE for all varieties between the start of stem elongation and anthesis decreased from 300 to 231 $g/m^2/m^2$ with the application of N.

The application of N fertiliser resulted in a decrease in post anthesis water use for Janz, Comet and Kulin relative to controls but Janz experienced the greatest water stress due to its increased water use to anthesis and greater total water use (Table 4). Reduced yield response to N due to water stress was associated with large decreases in kernel weight and greater increases in grain protein (Table 2).

Table 4. Water use (mm) for growth periods sowing to anthesis, anthesis to maturity and sowing to maturity for three varieties for control and 80 kg N/ha broadcast at sowing.

	Comet		Janz		Kulin		l.s.d.
	Low N	High N	Low N	High N	Low N	High N	($P<0.05$)
			Sowing to anthesis				
Water use (mm)	226	248	227	260	216	238	n.s.[a]
			Anthesis to maturity				
Water use (mm)	96	82	90	82	95	87	n.s.[b]

			Sowing to maturity				
Water use (mm)	322	330	317	342	310	325	10

n.s.[a] interaction not significant, main effect of variety and N significant $P < 0.001$;

n.s.[b] interaction not significant, main effect of N significant $P < 0.01$

CONCLUSIONS

The results show that varieties differ in their response to applied N, their ability to take up soil N and that the differences can be explained by the interaction of maturity type and soil water supply. The reversal of variety rankings for yield at the low and high levels of N shows the importance of evaluating varieties at a representative level of fertility. If dryland wheat crops receive additional N input to meet the goal of the Australian Wheat Board for a national yield of 2 t/ha and protein to 10%, there is a risk of more haying-off in extreme conditions (8), or relatively small yield responses of the later maturing varieties shown in the dry environment of this study. In such environments, additional N input may need to be accompanied by a change to earlier maturing and/or reduced tillering varieties.

ACKNOWLEDGMENTS

This project was largely supported by the Grains Research and Development Corporation.

REFERENCES

1. Anderson, W.K. 1985. Field Crops Res. 12, 191-202.

2. Angus, J.F., van Herwaarden, A.F. and Howe. G.N. 1991. Aust. J. Exp. Agric. 31, 669-77.

3. Barley, K.P. and Naidu, N.A. 1964. Aust. J. Exp. Agric. Anim. Husb. 4, 39-48.

4. Borrell, A.K., Incoll, L.D., Simpson, R.J. and Dalling, M.J. 1989. Ann. Bot. 63, 527-539.

5. Fischer, R.A. 1979. J. Aust. Inst. Agric. Sci. 45, 83-94.

6. Gardener, C.J. and Rathjen, A.J. 1975. Aust. J. Agric. Res. 26, 219-30.

7. McDonald, G.K. 1991. Factors affecting the responses to nitrogen fertiliser in wheat. (Waite Agric. Res. Inst.: Glen Osmond, South Australia)

8. van Herwaarden, A.F. 1996 Proc. 8th Aust. Agronomy Conf., Toowoomba.