APPENDIX 3.

Water Use and Water Use Efficiency (WUE) in the Additive Series Experiment.

Competition is the most common interference mechanism in plants. It has been stated that in quackgrass-cereal mixtures, under British conditions, competition for water is less important than is competition for light and nutrients (Thurston and Williams, 1968). This suggestion conflicts with field research in North America that has shown that much of the interference by quackgrass in corn and soybeans can be alleviated by the addition of supplemental water (Young *et al*, 1983, 1984). Further research is needed to determine the relative importance of competition for water in quackgrass interference.

Experimental Design

Soil moisture use below the additive replacement series was monitored using a neutron attenuation technique to determine if the technique has potential to detect competition for water between quackgrass and wheat. The general experimental layout and procedures have been described in detail elsewhere (Manuscript 1).

Water Use

In both 1987 and 1988 one block of the additive replacement series experiment was monitored for soil water. Volumetric water content was determined at depths of 15, 30, 45, 60, and 100 cm using a neutron moisture meter[22]. Access tubes were installed at the centre of each plot just prior to planting and readings were taken at approximately weekly intervals until plot harvest at wheat maturity. The neutron probe readings were converted to volumetric moisture using the relationship described in Figure 22. Soil field capacity and permanent wilting point of the soil at each monitored depth was determined and the maximum potential available water was defined as the difference between field capacity and the permanent wilting point. Soil physical characteristics at the site are listed in Table 25. Daily precipitation was determined by a tipping bucket rain gauge attached to a minimum dataset recorder[23]. The mean monthly precipitation at the site has been presented elsewhere (Appendix 1).

Water use efficiency at the site was determined as

$$\mathrm{WUE} = \mathrm{Y}_k/\mathrm{Wc} = \mathrm{Y}_k/\Sigma_k(\mathrm{Wo}_k+\mathrm{PPT}_k-\mathrm{Wf}_k).$$

Where Y_k is the per area variable yield in the monitored block, Wc is the total water consumed over the growing season, Wo_k is the intervals initial volume of available soil water to the 1.0 m depth, PPT_k is the total precipitation over the interval, and Wf_k is the intervals final volume of available soil water to the 1.0 m depth. The calculated water use efficiencies

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[22]Troxler, Model 3000

[23]LI-1200S. LI-COR Inc., Lincoln, Nebraska.

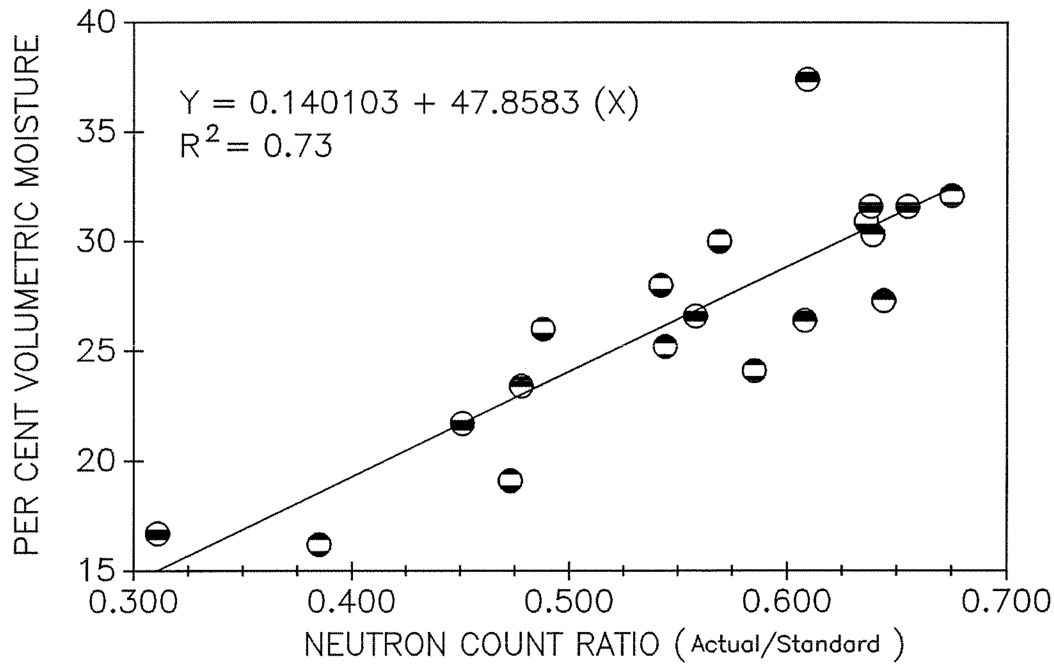


Figure 22. Calibration line for the neutron probe developed for range 10 of the Portage Research Station. Each point is the mean of at least three soil samples.

Table 25. Soil physical properties at the site of the wheat-quackgrass additive series experiment.

Depth	Bulk Density	Wilting Point[a]	Field Capacity	Potential Available Water
--(cm)-	-(g cm^{-3})-		---(%)---	
15	1.01	17.7	34.1	16.4
30	0.99	15.1	30.5	15.4
45	1.17	13.1	32.7	19.6
60	1.16	11.4	29.0	17.6
100	1.23	10.9	26.6	15.7

[a] Wilting point determined using tomato plants.

for each treatment were analyzed by ANOVA as a randomized complete block design with each years data being considered a replicate. When significant by ANOVA at α=0.05 means were separated by the LSD test at α=0.05.

Results and Discussion

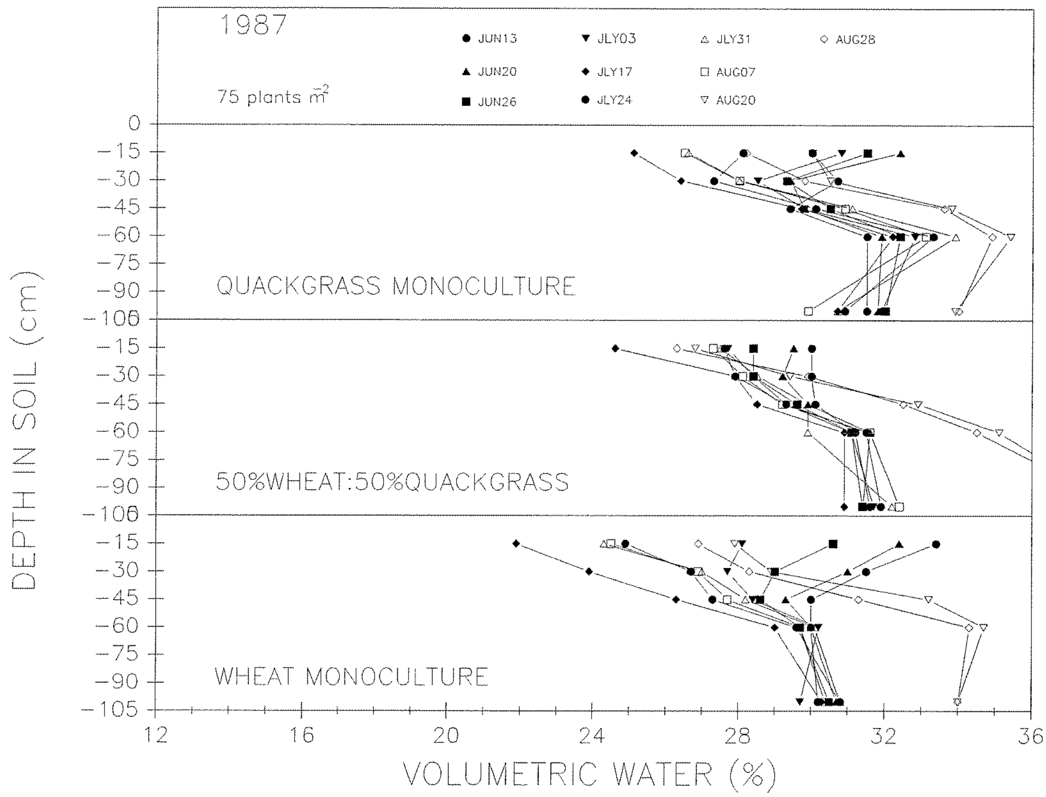
The months of May and June in 1987 were dryer than average and the entire growing season in 1988 was considerably dryer than average (Appendix 1). However the experimental site had a high water table and the soil water content from as shallow as 60 cm exceeded or was equal to soil field capacity throughout both growing seasons. The dry conditions in the surface soil layers would have been expected to encourage competition for soil water between plants.

The plot area covered by plants at the 150 and 300 plants m^{-2} was determined to be inadequate for comparing soil moisture use in the treatments. It was initially assumed that because there was greater than a 15 cm radius of plants around the axis tubes, that moisture use could be adequately assessed. This assumption failed to account for horizontal water flow in the soil. The guard-rows did not adequately buffer the higher density treatments from horizontal water movement. This was demonstrated by the counter-intuitive result of 300 plants m^{-2} having more soil water available than the lower density treatments (Data not presented). However the 150 plants m^{-2} treatment did have less soil water available than did the 75 plants m^{-2} treatments and thus it was assumed that the size of the 75 plant m^{-2} plots adequately buffered the monitored area from horizontal water movement. As a result the water use results for the 150 and 300 plant m^{-2} treatments are not considered accurate.

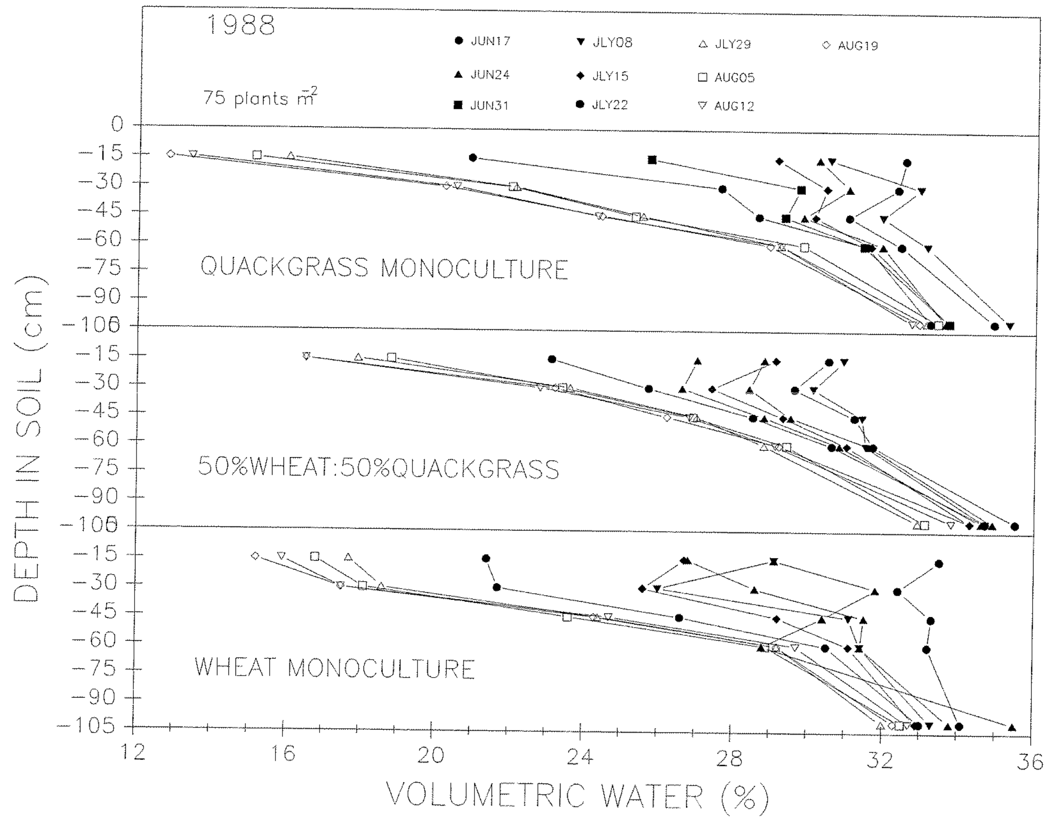
The seasonal water use patterns for three of the 75 plant m^{-2} treatments are illustrated in Figures 23 and 24 . The graphs illustrate the high volumetric water contents at the 60 and 100 cm depths. They also show the extreme variability in soil water contents from one year and one week to the next.

The calculated values of WUE in 1988 were approximately twice that of 1987 (Data not presented). For ease of presentation and discussion the pooled mean WUE for both years is presented (Table 26).

The magnitude of the WUE values depended on yield variables selected. WUE based on TFEC yield variables showed the widest relative range in values and WUE based on TBIO yield variables the narrowest range in values (Table 26). For every yield variable there was a trend that high wheat mixture proportions at high densities had larger WUE values than low density high quackgrass mixture proportions. However a significant mixture by density interaction was not detected. The non-significance is attributable to a lack of sensitivity for mixture by density interactions because of only two years data and the horizontal water movement obscuring density effects. For the reproductive yield variables there were significant mixture effects with the 75 and 100 percent quackgrass mixture proportions having significantly lower WUE values than the 50, 75, and 100 percent wheat mixture proportions. A similar trend was observed for the vegetative yield variables. There was a significant density effect where the 75 plants m^{-2} treatment had significantly lower WUE than the 300 plants m^{-2} treatments. A similar trend also occurred with the reproductive yield variables. In the case of TBIO this WUE difference due to stand density was only detected when α was raised from 5 to 6 percent. For vegetative yield variables there



<u>Figure 23</u>. Growing season volumetric water content in relation to soil depth beneath 3 treatments of the wheat-quackgrass additive series at the Portage Research Station in 1987.



<u>Figure 24</u>. Growing season volumetric water content in relation to soil depth beneath 3 treatments of the wheat-quackgrass additive series at the Portage Research Station in 1988.

Table 26. Wheat-quackgrass additive series water use efficiency (WUE) values calculated for selected variables.

Total Stand Density	Mixture Proportion Wheat	Mixture Proportion Quackgrass	Variable[a] WUE[b] TBIO	TREP	TSHT	TFEC
(# m^{-2})	-----(%)-----		-----(g Kg^{-1})-----		-----(# Kg^{-1})-----	
75	0	100	2.39	2.20	0.60	8.48
75	25	75	2.71	2.32	0.76	20.06
75	50	50	2.75	2.31	0.94	30.00
75	75	25	2.36	1.97	0.80	29.16
75	100	0	2.85	2.37	0.98	38.39
150	0	100	2.85	2.56	0.62	11.65
150	25	75	3.19	3.11	0.78	21.43
150	50	50	3.88	3.17	1.22	39.43
150	75	25	3.56	3.06	1.20	45.94
150	100	0	2.86	2.64	0.99	38.60
300	0	100	2.29	2.54	0.32	8.52
300	25	75	2.86	3.41	0.64	26.70
300	50	50	4.53	4.58	1.33	42.41
300	75	25	4.08	3.68	1.43	56.28
300	100	0	3.45	3.48	1.04	40.36
		S.E.M.[c]	(0.507)	(0.502)	(0.168)	(7.121)
Pooled	0	100	2.51	2.43	0.51	9.55
Pooled	25	75	2.92	2.94	0.73	22.73
Pooled	50	50	3.72	3.35	1.16	37.28
Pooled	75	25	3.33	2.90	1.14	43.79
Pooled	100	0	3.05	2.83	1.00	39.12
		S.E.M.	(0.293)	(0.290)	(0.097)	(4.111)
75	Pooled		2.61	2.23	0.81	25.22
150	Pooled		3.26	2.9	0.96	31.41
300	Pooled		3.44	3.53	0.95	34.85
		S.E.M.	(0.226)	(0.224)	(0.075)	(3.180)

[a] Abbreviations: TBIO=vegetative size, TREP=reproductive effort, TSHT=vegetative dispersion, and TFEC=reproductive fecundity.

[b] Average of the 1987 and 1988 WUE.

[c] Standard error of means for combined 1987 and 1988 results.

was no significant mixture response and for the reproductive yield variables there was no significant density response. Stand density effects for all variables can not be unambiguously interpreted as there was horizontal water movement into the smaller plots of the higher density treatments which would skew the results of these treatments to higher WUE values. However, mixture effects that were detected are likely realistic and strong despite the horizomtal water movement into the smaller plots.

The results of this investigation demonstrate the promising potential of the neutron attenuation technique for investigating competition for water beneath an additive replacement series design. However, the minimum plot size should be at least as large as the 75 plant m^{-2} plot (40 cm radius) used in this trial. A site with a lower water table than this location would also be desirable to better promote and measure competition for water between these species.