CHAPTER 5

EFFECTS OF CULTIVAR AND SOIL FERTILITY ON GRAIN PROTEIN YIELD, GRAIN PROTEIN CONTENT, FLOUR YIELD AND BREAD-MAKING QUALITY OF WHEAT

5.1 ABSTRACT

Grain protein content affects bread-making quality characteristics of wheat (*Triticum aestivum* L.). In this study grain protein yield, grain protein content, flour yield and loaf volume were quantified for four wheat cultivars (Inia, Carina, Kariega and SST 86) grown at six different soil fertility regimes in a long-term fertilization and irrigation experiment at the University of Pretoria. The experimental design was a randomized complete block replicated four times, with fertility as the main-plots and cultivars as the sub-plot treatments. Grain protein yield, flour yield, loaf volume and mixograph dough peak mixing time varied between cultivars and soil fertility situations. Grain protein content differed between cultivars but mixograph water absorption and dough characteristics did not differ. The highest grain protein yield was 873 kg ha^{-1} for Carina, and the lowest 527 kg ha^{-1} for SST 86. Grain protein content averaged 13.1% for Carina and 12.2% for Kariega. Bread-making performance showed that in a well-balanced soil fertility situation, Kariega produced 1025 cm^3 of loaf volume while Inia averaged 950 cm^3. Grain protein yield increased with increasing soil fertility but grain protein content, flour yield, loaf volume, water absorption and mixograph peak mixing time did not vary in a consistent pattern with changing soil fertility. The interaction between cultivar and soil fertility was significant for grain protein yield, grain protein content, flour yield, loaf volume and water absorption, but not for peak dough mixing time. The results indicate cultivar differences in bread-making quality characteristics, and that soil fertility status affects grain protein yield, grain protein content, flour yield, loaf volume potential, water absorption, but not mixograph peak mixing time and dough characteristics.

Key words: Bread-making quality, flour yield, grain protein, soil fertility, wheat.

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5.2 INTRODUCTION

The relationship between wheat (*Triticum aestivum* L.) grain protein content and bread-making quality has been well established (Bushuk, Rodriquez-Bores & Dubetz*,* 1978; Payne Corfield, Holt & Blackman, 1981; Payne, Holt, Jackson & Law, 1984). Wheat grain protein content is important in bread-making because high protein flours generally have a high loaf volume potential, high water absorption and produce loaves with good keeping quality (Finney, Meyer, Smith & Fryer*,* 1957). The grain protein content of wheat is genetically controlled, but may vary widely for a given variety or cultivar according to location, soil fertility, rainfall or temperature (Moss, 1973; Laubscher, 1981). The plant-available soil N affects grain protein which determines bread-making quality. Wheat protein content may also be increased by breeding and selection for N use efficiency (Noaman, Taylor & McGuire, 1987; Fischer, 1989).

Increases in wheat grain protein with application of N fertilizers have been reported (Finney *et al.,* 1957; Dubetz, 1972). Correcting a soil fertility deficiency may result in higher economic returns from better grade for the producer (Hunter & Stanford, 1973; Laubscher, 1981). Grain protein content when studied independently of other plant characteristics acts as an inherent trait (Haunold, Johnson & Schmidt, 1962; Johnson, Schmidt & Mattern, 1968), but studied in conjuction with related characteristics, it seems largely determined by plant growth responses (Fischer, 1989; Cox, Qualset & Rains, 1985).

Positive correlations between grain protein content and loaf volume have been reported by many researchers (Finney *et al.,* 1957; Schlehuber & Tucker 1959; Pendleton & Dungan, 1960; Terman, Ramig, Dreier & Olson, 1969). Johnson *et al,* (1968), Borghi, Corbellini, Cattaneo, Fornasari & Zucchelli (1986) and Perenzin, Pogna & Borghi (1992) reported wheat progeny with high grain protein content. Increasing grain protein content have been obtained by applying N fertilizer (Bauer, 1970; Dubetz, 1972). Laubscher (1981) also reported increased grain protein content from improved soil nutrient concentrations. Genotype and environment interaction, however, plays a major role in determining protein level (Moss, 1973; Laubscher, 1981).

Attempts have been made to establish a molecular basis for wheat proteins responsible for bread-making quality (Payne *et al.,* 1981; 1984; Anderson, Blechl & Weeks, 1995). Randall, Manley, McGill & Taylor (1993) reported a close association between the presence of certain high-molecular-weight (HMW) subunits of glutenin with the bread-making quality of South African bread wheat cultivars.

The HMW-glutenins are highly correlated with specific parameters important for dough functionality (MacRitchie, Kasarda & Kuzmicky, 1991; Randall *et al.,* 1993). The total amount of HMW glutenins have been reported to determine the strength characteristics of bread doughs (Blechl & Anderson 1998).

Grain protein content is, however, still one of the most important single factors causing variation in bread-making quality potential of wheat genotypes (Pomeranz, 1973; Laubscher, 1981). It is apparent that soil fertility, and especially soil N, plays a major role in grain protein level (Liang, Heyne & Walter, 1966; Lee & Spinalle, 1970; Carr, Jacobsen, Carlson & Nielsen, 1992). Improving grain protein content will depend on increasing soil fertility status and/or using cultivars with the ability to produce higher yield and improved grain protein content under nutrient limiting growing situations. This may be important for South Africa, where a higher price is normally paid for class B with grain protein equal to or greater than 12% (Wheat Board 1994,1995).

The objectives of this study were: (i) to quantify the effects of varying soil fertility on grain protein yield, grain protein content, flour yield and bread-making quality of four South African wheat cultivars, and (ii) to test the hypothesis that all these characters are affected by soil fertility and varying soil nutrient situations.

5.3 MATERIALS AND METHODS

General

Four wheat cultivars Inia, Carina, Kariega and SST 86 were grown at Hatfield Farm, University of Pretoria (Lat. 25^0 45'S, Long. 28^0 16'E, elevation 1372 masl), using a long-term fertilization and irrigation experiment started in 1939. The experimental design was a randomized complete block replicated four times, with soil fertility as the main-plot and cultivars as the sub-plot treatments. The cultivars were planted in unrandomized strips on the sub-plots. Main plot size was 8.25 m by 6.30 m and the sub-plot size 1.20 m by 6.30 m. Experimental treatments are given in Table 5.1, and weather data in Table 5.2. Detailed experimental procedures were reported in Chapter 2 and in Metho, Hammes, De Beer & Groeneveld (1997).

Soil analysis data are presented in Table 5.3 for the 0-200 mm soil layer for the selected treatments, and reflect the actual site pH and fertility status representing the effect of differential fertilization over more than 50 years. In general, soil analysis of the individual plots (NPKM, NPK, PK, NP and NK treatments) indicate differences in soil pH, N, P, and K status maintained under long-term fertilization. The site soil details were described by Nel, Barnard, Steynberg, De Beer & Groeneveld (1996).

Protein content analysis

Grain protein (N X 5.7) was measured by a Kjeldahl method (A.A.C.C., 1989 method 46-12) and by Dumas method (A.A.C.C., 1989 method 46-30), and expressed on dry weight and 12% moisture.

Grain protein yield

Grain protein yield (g m^{-2}) was calculated as: grain yield (g m^{-2}) x grain protein content (%) /100.

Flour yield and quality assessment

Wheat samples were conditioned to 12.0% moisture for 20 hours, and milled using the Quadrumat mill (A.A.C.C., 1989 method 54-30). This accounts for the very low atypical percentage flour yields obtained. For the dough tests, the Mixograph method was used (A.A.C.C., 1986 method 46-30). Bread-making tests were by the method of Moss (1980) on breeder's standard 100 g sample loaves.

Data recorded

Plants from a 1 m^2 area were harvested at physiological maturity. Grain yield (g m^{-2}), mean grain weight (g), grain protein yield (g m^{-2}), and grain protein content (%) were determined from the 1 m^2 bulk samples. To cause minimum interference with long-term rotation practices only treatments 'O' Control, NPK and NPKM were retained for determination of grain protein yield, grain protein content and flour yield in the case of the late maturing cultivar Carina.

To get an indication of bread-making quality, analysis was performed based on only two of the four wheat cultivars (Inia and Kariega) grown under four fertility treatments (NPK, PK, NP and NK) where NPK plots represent a well-balanced soil fertility situation producing strong healthy plants with good yield, while the other treatments represented N, K and P limiting soil fertility situations.

Table 5.1 Details of experiment conducted on four local wheat cultivars grown under irrigation at Hatfield, Experimental Farm, University of Pretoria

Practices	Long-term fertility experiment
Crop rotation	Wheat grown during the winter period may to October and soybean from November to March, except the year prior to 1995 when the plots were fallowed during summer.
Planting date	15 and 16 May using Planet Junior, planter USA.
Wheat cultivars	Inia – Pureline, semi-dwarf spring type released in 1966 by the Department of Agriculture. Carina – Hybrid, semi-dwarf winter type released in 1989 by Carnia Kariega – Semi-dwarf spring type released in 1993 by the Small Grain Institute (SGI). SST 86 – Dwarf spring type, released in 1987 by Sensako.
Seeding rate (Based on seed size)	Inia – 100 kg ha^{-1} Carina – 70 kg ha^{-1} Kariega – 100 kg ha^{-1} SST 86 – 150 kg ha^{-1}
Nutrient treatments	N – 100 kg N ha^{-1} (KAN 28%) P – 70 kg P ha^{-1} (Single superphosphate, 8.3%) K – 50 kg K ha^{-1} (Potassium chloride 50%) M – 15 tons ha^{-1} (Farmyard manure) Lime – 180 kg ha^{-1} (Agricultural lime, ($Ca(OH)_2 + MgSO_4$)
Diseases & Pests	No major disease was recorded. Loose smut (*Ustilago tritici*) was controlled by removing infected plants. Harvester termites (*Hodotermes sp*) was controlled by Parathion (Folimat, WP) at 1.5 kg ha^{-1}. Birds controlled with netting.
Maturity	Inia and SST 86 reached physiological maturity on 16 October, Kariega on 23 October and Carina by 16 November.

TABLE 5.2 Meteorological data for Hatfield Farm in 1995 and long-term mean rainfall (1974-1995)

Months	Temperature (°C)		Pan evaporation	Rainfall	Long-term rainfall
	Max	Min	(mm/day)	(mm/day)	(mm/month)
January	29.3	16.8	8.2	69.8	126.1
February	30.3	16.6	8.2	103.4	109.0
March	26.6	15.4	6.1	168.8	98.2
April	23.6	11.0	4.9	80.8	39.7
May	20.4	8.3	3.4	7.0	11.6
June	19.2	2.6	3.3	0.0	6.5
July	19.6	4.0	4.2	0.0	3.8
August	22.8	7.4	5.4	5.0	6.6
September	27.0	11.4	7.5	3.5	20.2
October	27.7	14.3	8.0	63.2	71.6
November	27.2	15.3	7.9	213.0	105.2
December	26.5	14.5	7.3	154.7	119.6
Year	25.0	11.5	74.4	868.8	717.6

Table 5.3 Soil analysis (0-200 mm) results for experimental site, 1995

Treatment	pH (H_2O)	Bray 2 P mg kg^{-1}	K mg kg^{-1}
NPKM	5.8	109	120
NPK	5.4	63	66
PK	6.0	43	92
NP	5.1	37	21
NK	5.2	1,8	81
Control "O"	6.1	1,7	22
CV %	3.7	46.5	49.1

Statistical analyses

Data was analysed by analysis of variance using the SAS/STAT programme (SAS Institute Inc. Cary, NC., USA 1989 Copyright). Differences at the $P \leq 0.05$ level of significance are reported. Tests for heterogeneity of variances for all characteristics were done and probabilities calculated according to Steel & Torrie (1980). Direct correlation and stepwise regression analyses were performed to determine the relationship between loaf volume and rain protein yield, grain protein content, flour yield, water absorption, mixograph peak dough mixing time and soil fertility.

5.4 RESULTS

The main effects of genotype and soil fertility on grain protein yield, grain protein content, flour yield and bread-making quality (water absorption, mixograph peak dough mixing time, loaf volume and dough characteristics) are shown in Tables 5.4, 5.5, 5.6 and 5.7 respective-ly. Significant cultivar and soil fertility interactions were observed for grain protein yield, grain protein content, flour yield, loaf volume and water absorption, and are illustrated in Figure 5.1.

The main effects of cultivar and soil fertility on grain yield, yield components and grain nitrogen content and significant interactions are reported in Chapter 2 and in Metho *et al*. (1997).

Effect of cultivar

Grain protein yield

Under conditions of the experiment, grain protein yield differed with Carina producing the highest protein yield (873 kg ha^{-1}) and SST 86, Inia and Kariega producing lower yield in the range 527, 539 to 586 kg protein ha^{-1} (Table 5.4).

Grain protein content

The cultivars differed significantly in grain protein content (Table 5.4; Tables 9.A9 and A.10). The cultivar Carina had the highest grain protein content averaging 13.1% while SST 86, Inia and Kariega had significantly lower grain protein contents in the range 12.2% to 12.6%. Table 5.4 shows that the cultivars differed in high molecular weight sub-units of glutenin but not in Glu-1 score.

Flour yield

Flour yield differed significantly between the cultivars (Table 5.4). The cultivar Kariega had the highest flour yield averaging 53.6% but did not differ significantly from Inia (51.8%), while SST 86 (47.7%) and Carina (48.7%) had lower flour yields and did not differ significantly.

Loaf volume

Loaf volume comparisons were made for only Inia and Kariega (Table 5.6). The cultivars differed in loaf volume, and averaged over all fertility levels Kariega produced on average 981 cm^3 of loaf volume and Inia 910 cm^3 (Table 5.6; Appendix Table 9.A9).

Mixograph water absorption, mixograph peak mixing time and dough characteristics

The two wheat cultivars Inia and Kariega did not differ significantly in mixograph water absorption and peak mixing time (Table 5.6).

TABLE 5.4 Effects of cultivar on grain protein yield, grain protein content, high-molecular weight glutenins, glu-1 score and flour yield of four South African wheat cultivars

Cultivar[1]	Grain protein yield (kg ha^{-1})	Grain protein content (dry basis) (%)	High-molecular[2] weight glutenins (HMW-GS)	Glu-1 score[2]	Flour yield[3] (%)
SST 86	527a[+]	12.6a	(13 + 16) (5 + 10)	3	47.7a
Inia	539a	12.6a	(13 + 16) (5 + 10)	3	51.8b
Kariega	586a	12.2a	(17 + 18) (5 + 10)	3	53.6b
Carina	873b	13.1b	-	-	48.7a
CV %	22.3	6.9			6.2

+ Within columns, means followed by the same lowercase letter had P > 0.05 and hence were not significantly different according to an Duncan's multiple range test.

1 Cultivar data based on NPKM, NPK and 'O' fertilization.

2 Values for quality characteristics measured for the allelic response of chromosome 1B and 1D according to Randall *et al.* (1993).

3 Flour yield based on the Quadrumat method.

TABLE 5.5 Effects of fertilization treatment on grain protein yield, grain protein content and flour yield of wheat (mean data from cultivars SST 86, Inia and Kariega)

Treatment	Grain protein yield ($kg\ ha^{-1}$)	Grain protein content (dry basis) (%)	Flour yield[2] (%)
NPKM[1]	898c[+]	13.8c	50.8b
NPK	854c	13.3c	52.7bc
PK	473b	9.7a	49.2ab
NP	366b	10.9b	48.2ab
NK	156a	11.9b	54.4c
'O' Control	143a	10.4b	46.6a
CV %	23.9	6.9	12.0

\+ Within columns, means followed by the same lowercase letter had $P > 0.05$ and hence were not significantly different according to an Duncan's multiple range test.

1 Data based on cultivars SST 86, Inia and Kariega.

2 Flour yield based on Quadrumat method.

TABLE 5.6 Effects of cultivar on bread-making quality characteristics of two South African wheat cultivars

Cultivar	Loaf-volume[2] (cm³)	Mixograph water absorption (%)	Mixograph peak mixing time (min)	Dough characteristics
Inia	910a[+]	62.5a	3.68a	Normal
Kariega	981b	62.2a	3.55a	Normal
CV %	1.3	1.5	3.5	

+ Within columns, means followed by the same lowercase letter had P > 0.05 and hence were not significantly different according to Duncan's multiple range test.

1 Bread-making quality data based on NPK, PK, NP and NK fertilization treatments only.

2 Based on breeder's standard 100 g loaf size.

Effect of soil fertility status
Grain protein yield

The main effect of soil fertility on grain protein yield is shown in Table 5.5. The NPKM treatment resulted in the highest grain protein yield (898 kg protein ha^{-1}), while the control '0' fertilization and NK treatments were the lowest and ranging from 143 to 156 kg protein ha^{-1}. In general, grain protein yield increased with increasing soil fertility although not all the differences were significant ($P > 0.05$).

Grain protein content

Grain protein content differed significantly with soil fertility status (Table 5.5; Appendix Tables 9.A9 and 9.A10). The NPKM treatment resulted in the highest grain protein content averaging 13.8% but did not differ significantly from the NPK treatment, while the PK treatment had the lowest at 9.7%.

In general, plots which received unbalanced soil nutrient treatments resulted in decreased protein content levels, showing the dependence of grain protein content on well-balanced soil nutrient status. The treatment generally lacking in N (PK treatment) resulted in the lowest grain protein level.

Flour yield

Flour yield differed significantly between the different soil fertility treatments (Table 5.5), with the NK treatment resulting in the highest flour yield (54.4%), while the control '0' treatment was the lowest averaging 46.6%.

The NPKM, NPK, PK and NP treatments varied slightly but did not differ in flour yield. In general, flour yield did not follow any definite pattern with increasing soil fertility status.

Bread-making quality

Loaf volume

Loaf volume differed with soil fertility as shown in Table 5.7. The NPK treatment, representing a well-balanced soil fertility situation averaged a volume of 988 cm^{3}, while the PK treatment, in which soil N was limiting, averaged 880 cm^{3}. In the NPK treatment representing a well-balanced soil fertility situation, Kariega's loaf volume averaged 1025 cm^{3} while Inia had 950 cm^{3} of loaf volume (Appendix Table 9.A10).

Mixograph water absorption, mixograph mixing time and dough characteristics

Mixograph water absorption differed significantly with varying soil fertility status but not mixograph peak mixing time (Table 5.7). Water absorption was highest in the well-balanced NPK soil fertility treatment averaging 63.3%, and lowest (61.2%) in the N limiting soil fertility situation (PK treatment). As shown in Figures 5.2 and 5.3, comparison of mixograms of the two wheat cultivars tested show similar bread-making potential in all four soil fertility treatments with the exception of PK treatment (N limiting plots) which resulted in low protein content, low loaf volume and poor mixograph.

TABLE 5.7 Effects of soil fertility status on bread-making quality characteristics based on two South African wheat cultivars (mean data from cultivars Inia and Kariega)

Treatment	Loaf volume[1] (cm^3)	Mixograph water absorption (%)	Mixograph peak time (min)	Dough characteristics
NPK[2]	988c[+]	63.3d	3.5a	Normal
PK	880a	61.2a	3.8a	Normal
NP	980c	62.2b	3.6a	Normal
NK	935b	62.6c	3.8a	Normal
CV %	1.3	1.5	3.5	

\+ **Within columns, means followed by the same lowercase letter had P > 0.05 and hence were not significantly different according to Duncan's multiple range test.**

1 **Loaf-volume based on breeder's standard 100g loaf size.**

2 **Fertilization treatments NPK, PK, NP and NK (N - nitrogen; P - phosphorus; K - potassium).**

In general, increased soil fertility tended to decrease mixograph peak mixing time. Dough characteristics were not affected by less favourable soil fertility situations (Table 5.7).

Cultivar and soil fertility interaction

Grain protein yield

A significant interaction between cultivar and soil fertility was observed for protein yield, indicating cultivar differences in protein yield under differing soil fertility situations, particularly in soils low in N, K and P (PK, NP and NK treatments) as shown in Figure 5.1A. The cultivars generally reacted similarly except in NP and NPK treatments where Kariega performed better than the other cultivars producing the highest grain protein yield. In general, grain protein yield varied with cultivar and increased with increasing soil fertility.

Grain protein content

The cultivar and soil fertility interaction was significant for protein content indicating differential cultivar response in grain protein content to varying soil nutrient situations (Figure 5.1B). The interaction was due to SST 86 having the highest protein content in NK treatment plots and Inia the lowest, while in NP treatment plots, Kariega had the highest and Inia the lowest grain protein content.

Flour yield

The significant interaction between cultivar and soil fertility for flour yield shows differential cultivar performance mainly in P and K soil limiting situations (NK and NP treatments), as illustrated in Figure 5.1C.

Loaf volume

The significant interaction between cultivar and soil fertility observed for loaf volume was due to the differential increase and decrease in loaf volume in the PK, NP and NPK treatment plots (Figure 5.1D). Kariega produced larger loaves than Inia, but grain from the PK plots where nitrogen supply was limited resulted in similar sized loaves.

Mixograph water absorption, peak mixing time and dough characteristics

Significant interaction between cultivar and soil fertility was observed for mixograph water absorption (Figure 5.1E), but not for mixograph peak mixing time indicating cultivar differences in water absorption under varying soil fertility situations. This was mainly due to the fact that

Kariega flour from the PK-plots (Nitrogen limiting) exhibited poor absorption characteristics. (Figures 5.2 and 5.3)

5.5 DISCUSSION

High grain protein content has long been associated with good bread-making quality, and for a specific cultivar an increase in grain protein content normally results in increases in water absorption, loaf volume and general bread-making quality potential (Tipples, Dubetz & Irvine, 1977). In this investigation differences in the bread-making quality of the wheat cultivars under varying soil fertility situations were demonstrated, although differences in loaf volume could not be explained by differences in protein content levels only. Finney & Barmore (1948) studied US hard winter and spring wheats and found that the relation between grain protein content and loaf volume was linear.

In this study, the cultivar Carina had the highest protein yield and grain protein content but was lower in flour yield. The cultivars SST 86, Inia and Kariega did not differ in grain protein yield and grain protein content but varied in flour yield.

Grain protein yield generally increased with increasing soil fertility from the '0' Control and NK treatments to NP, PK, NPK and NPKM treatments. The high grain protein content obtained under conditions of well-balanced nutrient situations (NPK and NPKM treatments) compared to plots which generally were limited in N (PK treatment) showed that grain protein content was affected by both cultivar and soil nitrogen status (Tables 5.4 and 5.5).

The relatively high grain protein yield and grain protein content levels obtained can partly be attributed to soybean (*Glycine max*. L.), a nitrogen fixing legume, grown in rotation with wheat plots during the summer season.

The significant interactions between cultivar and soil fertility observed for protein yield and grain protein content indicated that the cultivars SST 86 and Inia reacted similarly to varying soil fertility. The good performance by Kariega in both P and K limiting soil fertility situations (NK and NP treatments) requires detailed investigation (Figure 5.1A, 5.1B and 5.1C).

The results show that for both Inia and Kariega grain protein content was positively correlated (P > 0.05) with loaf volume ($r^2 = 0.65$) as was evident in plots in which N was continuously applied (NK, NP, NPK and NPKM treatments).

Decreased grain protein content and loaf volume in N limiting plots (PK treatment) indicated the influence of N on grain protein content and loaf volume (Figures 5.1B and 5.1D). Figures 5.2 and 5.3 show that the cultivars reacted similarly to varying soil fertility situations, but for Kariega, in PK treatment, which showed reduced water absorption (%) compared to Inia (Figure 5.1E), probably due to its significant decrease in grain protein content. The high loaf volume produced by Kariega was unexpected but may be due to cultivar characteristics other than grain protein content level. The two wheat cultivars studied, however, produced good and comparable flours under varying soil fertility situations.

These results are in agreement with those of Dubetz (1972) who showed that, on irrigated land, grain protein content is usually increased with increments of N.

The same author reported that very high grain protein content was consistently obtained by controlled nutrient and moisture supply in Neepawa wheat grown on a field scale. Bushuk *et al.* (1978) and Rodriquez-Bores & Bushuk (1975) reported that when Neepawa wheat was grown under different fertilizer levels to produce grains varying in protein content from 9.6% to 16.9%, grain protein content was positively correlated with indices of bread-making quality. Similarly, Petrakora, Domanevskaia & Bredikhin (1974) found that gluten content and quality improved with increasing N application. Stoddard & Marshall (1990) found that most variation in protein content was environmental, although the genetic component was also significant.

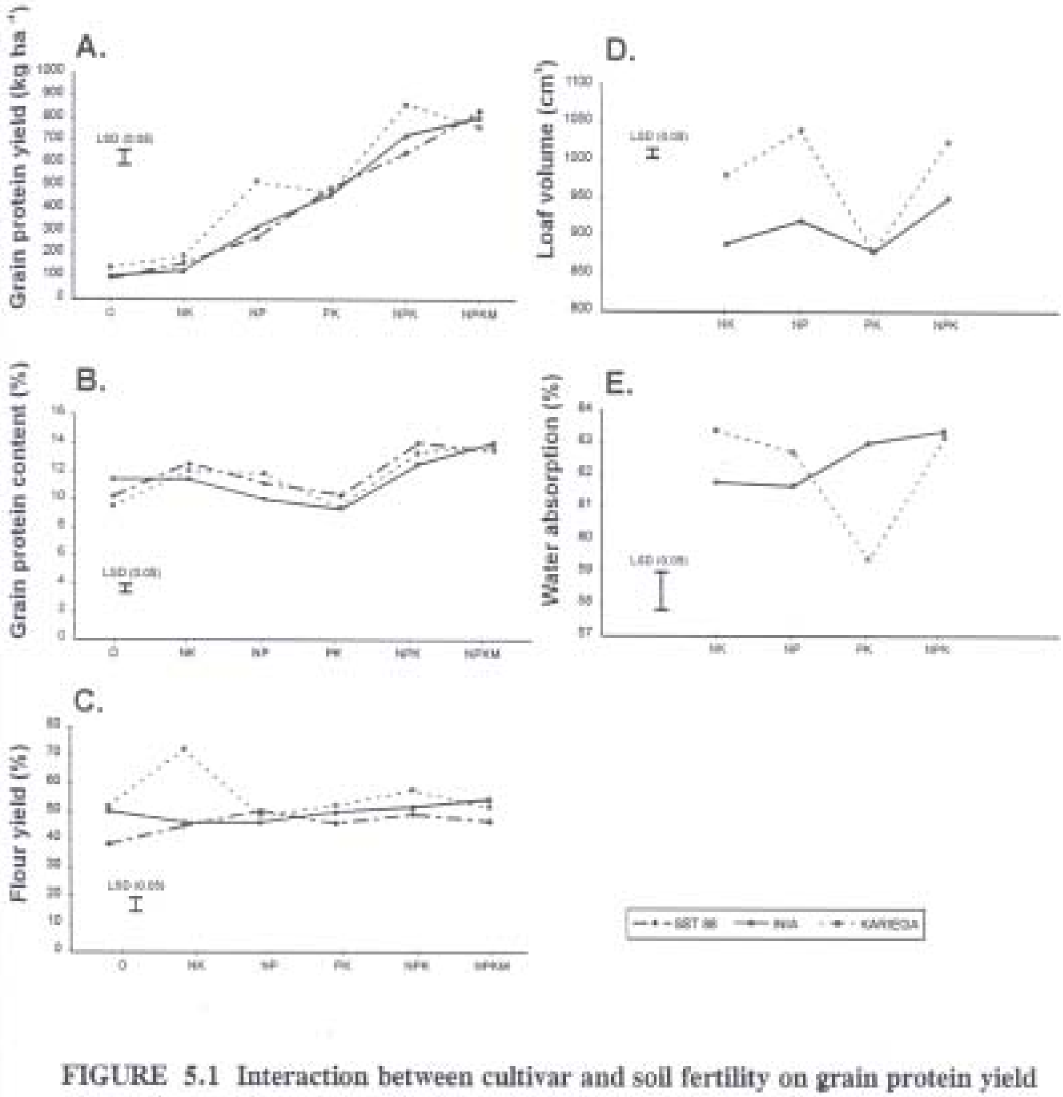

FIGURE 5.1 Interaction between cultivar and soil fertility on grain protein yield (A), grain protein content (B), flour yield (C), loaf-volume (D) and mixograph water absorption (E) of three South African wheat cultivars.

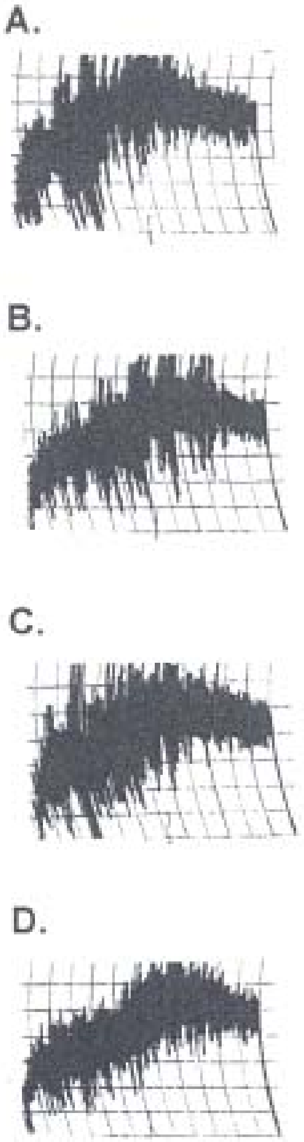

FIGURE 5.2 Response (mixograms) of wheat cultivar Inia to NPK(A), PK(B), NP(C)and NK(D) fertilization.

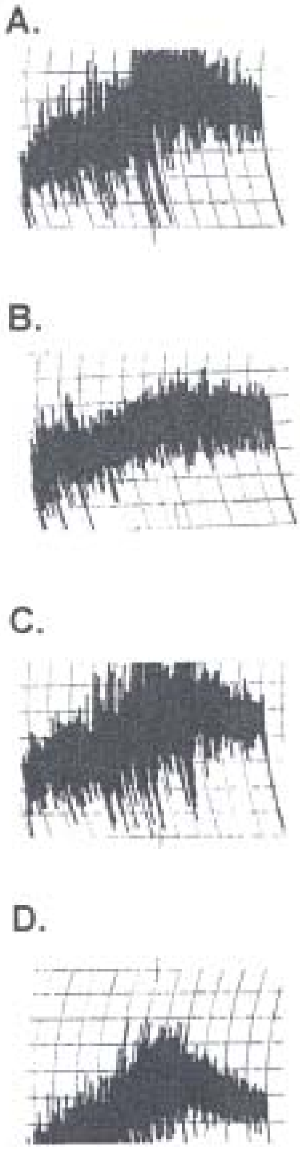

FIGURE 5.3 Response (mixograms) of wheat cultivar Kariega to NPK(A), PK(B), NP(C) and NK(D) fertilization.

Increasing attention is being focused on the possible role that certain high-molecular weight subunits of glutenin (HMW-GS) play in determining bread-making quality of wheats (Law & Payne, 1983). Randall *et al.* (1993) carried out a comprehensive study of the HMW-GS patterns of 38 South African bread wheat cultivars grown extensively in the past 15 years and reported that specific band patterns of HMW-GS were significantly correlated with end use quality, and were as good as rheological analysis in predicting loaf volume.

5.6 CONCLUSIONS

Under the conditions of this experiment, a correlation analysis showed that grain protein yield and grain protein content accounted for 65% of the variation in loaf volume. It was observed that cultivars with high grain protein content (%) were high protein yielders as well. This is in agreement with other studies which have reported the existence of wheat genotypes with both enhanced protein content and grain yield (Cox *et al.,* 1985; Löffler & Busch, 1982; Van Lill & Purchase, 1994). Thus on the basis of parameters of grain quality studied the cultivars varied significantly, although differences in loaf volume could not be adequately explained from the point of view of grain protein content only. Randall *et al*. (1993) reported that the Glu-1 scores, which are the sum of scores for the individual HMW-GS were the same (Table 5.4), except for differences in HMW-GS combinations. In this study, the effects of varying soil fertility on some of the grain quality characteristics were quantified, and the hypothesis that wheat genotype and soil fertility affect bread-making quality was proven. We hypothesize that the high loaf volume potential of the cultivar Kariega was probably genetical and may be due to factors other than grain protein content level which require detailed investigation.

The data indicate that soil fertility affects loaf volume, but differences in loaf volume between cultivars could not be explained solely by protein content level. Grain protein content was, however, associated with bread-making quality.

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