CHAPTER 8

GENERAL DISCUSSION

This investigation demonstrated that wheat cultivars differ in grain yield, components of yield, grain nitrogen content, grain protein yield, grain protein content, flour yield, loaf volume and in bread-making quality characteristics as a result of varying soil fertility situations. The four wheat cultivars tested generally reacted similarly across the range of soil nutrient regimes. However, significant interactions between cultivar and soil fertility were observed for grain yield, number of grains, mean kernel mass, aboveground biomass, grain protein yield, grain protein content, flour yield and mixograph water absorption, showing differential cultivar reaction.

The effects of long-term NK, NP, PK, NPK and NPK with manure application on yield, yield components and grain quality characteristics were quantified. The hypothesis that wheat cultivars differ in their ability to produce yield and quality under varying or limited soil fertility situations was proven. The hypothesis that tillers affect grain protein content to a greater degree than their contribution to grain yield was disproved. The data indicated that grain protein content of main stems and tillers, as well as grains in different floret positions in the spikelet, did not differ significantly. Fertilization, particularly of the macro-nutrients nitrogen, phosphorus and potassium, is a major input in wheat production, affecting yield and quality (Fischer, 1989; FAO, 1992; Bacon, 1995). Exploiting differences in nutrient utilization efficiency is a strategy on which to focus in the future (Arnon, 1974; Clarkson & Hannon, 1980; Fischer, O'Brien & Quail, 1989). Wheat cultivars with the potential to utilize limited soil nutrients may be important in South Africa and other areas with relatively infertile soils. For example, the ability of Kariega to produce better than the other three cultivars in the K limiting soil fertility situation deserves further investigation. This may be due to Kariega being able to obtain potassium more efficiently from the soil or to lower requirements at the functional sites. This observation may serve as a motivation for deliberate selection of wheat cultivars efficient in nutrient utilization for sustained productivity.

Several authors have reported differential responses for various nutrients in maize, rice, rye, oats and barley (Roberts, Weaver & Phelps, 1972; Wilkes & Scarisbrick, 1974; Mullins & Coffey, 1975; Haag, Adams & Wiersman, 1978). Rice cultivars with differential response to N, P and K have been reported by Fageria, Wright & Baligar (1988) and Fageria (1989). Rye is reported to be more nutrient efficient than other cereals (Nuttonson, 1958; Graham, 1984). Different responses of tomatoes and maize genotypes to N and K are inherited (Clark, 1982). Selection of plants with improved P utilization may be due to plants with root systems capable of intercepting more soil phosphorus, producing large quantities of dry matter and having low metabolic P requirements (Goodwin & Wilson, 1976; Gabelman & Gerloff, 1982; Fageria, 1989). Heritabilty estimates for P or K nutrient utilization efficiency are high but vary with each crop species (Epstein, 1972; Cooke, 1987; Gabelman & Gerloff, 1982). Data on genetics of nutrient utilization variation are still scarce, but evidence exists of single-gene control of micro-nutrient efficiency factors (Graham, 1984). Breeding for nutritional efficiencies is justified in the context of reducing the cost of fertilizer application and environmental pollution (Loneragan, Snowball & Robson, 1976; Graham, 1984). In wheat and rice efficiency of translocation of N from vegetative to reproductive parts during maturation have been responsible for a higher harvest index (Fischer, 1981; Graham, 1984). Identifying wheat genotypes or cultivars, which are efficient in K utilization and uptake may increase yield and quality. This study has indicated that wheat cultivars differ in their utilization of P and K. These differences point to the strategic importance in breeding and selection for wheat genotypes efficient in nutrient utilization.

Data presented in this thesis indicated that the magnitude of compensation between yield components was relatively small. For example, a decrease in number of spikes per m^2 was not adequately compensated for by either grains per spike or kernel mass. Each yield component varied comparatively independently of the others, in agreement with results reported by other researchers (Willey & Holliday, 1971; Gallagher & Biscoe, 1978; Gales, 1983; Hay & Walker, 1989). While no single yield component was predominant in determining yield, number of grains per unit area (a composite component) was highly correlated ($r^2 = 0.95$) with grain yield. Evans (1989) argued that components of yield are inter-dependent to a greater or lesser degree, and that greater number of spikes per unit area is counteracted by a smaller number of grains per spike. The polygon representation of yield and some yield component data (Figure 8.1) shows that the higher grain yield of the cultivar Carina was associated with high number of ears per unit area, spikelets per ear, grains per ear, aboveground biomass production and duration of grain-filling period as indicated by time between anthesis and maturity. The lower yield of SST 86 was due to the low number of ears, low number of spikelets, low grain number and low biomass yield.

In general, results indicated that differences among cultivars in grain yield (Chapter 2), grain protein content and bread-making quality (Chapter 5) occurred mainly in plots low in N, P or K. Significant cultivar x soil fertility interactions were observed for grain yield and some components of yield, biomass and harvest index showing differential cultivar reaction. These results show that in breeding, selection and evaluation the soil fertility conditions should be borne in mind.

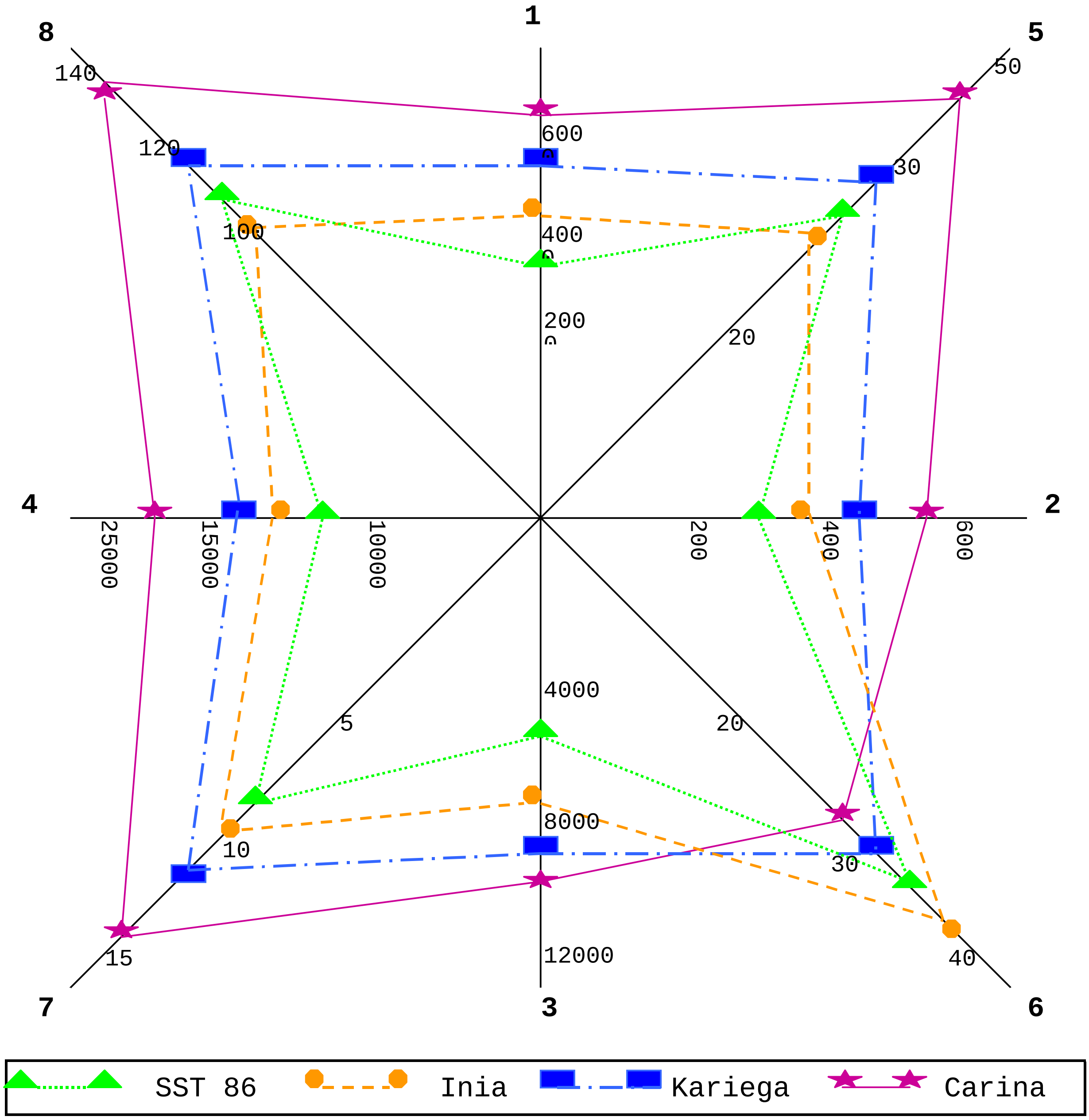

FIGURE 8.1 A polygon representation of average yield and some components of yield of four South African wheat cultivars under six soil fertility situations and date of anthesis (1. Grain yield (kg ha^{-1}); 2. Number of ears (m^{-2}); 3. Number of spikelets (m^{-2}); 4. Grain number (m^{-2}); 5. Grains per ear; 6. Mean grain weight (mg); 7. Biological yield (t ha^{-1}) and 8. Days to 50% anthesis)

The cultivars studied differed in aboveground biomass, harvest index and in ear:vegetative dry-mass ratio with varying soil fertility situations (Chapters 2 and 6). Yield increases have been attributed to genotypic improvements of dry-mass distribution, ear growth rates and phenological developmental pattern from studies comparing old and modern wheat and barley varieties (Austin, Bingham, Blackwell, Evans, Ford, Morgan & Taylor, 1980; Hucl & Baker, 1987; Loss, Kirby, Siddique & Perry, 1989; Perry & D'Antuono, 1995; Siddique, Kirby & Perry, 1995). My data indicated cultivar differences in dry-matter allocation to the ear, and that ear dry weight was positively correlated ($r^2 = 0.65$) to cultivar grain yield. Other studies have shown that increases in potential grain yield have resulted from improvement of the harvest index (Donald & Hamblin, 1976; Austin *et al*., 1980; Blum, 1989). My study extended the concept of harvest index to the individual shoots of a wheat plant. The data indicated that individual wheat ears differ in source-sink potential and partitioning of assimilates to the grain. This may be important in the identification of cultivars efficient in nutrient utilization and improved grain yield.

Few studies have been specifically focused on individual kernel mass and grain protein content by relative floret positions in the spikelet (Briggs, 1991; Gan & Stobbe, 1995). Data obtained during this study is rarely available because data collection is tedious. Nevertheless such information is valuable in crop yield modelling, and may have future benefits in management strategies for maximum yield and quality. Bulman & Smith (1993) reported on the stable nature of main stem ear yield components, and on the relatively small contribution of tillers to grain yield of spring barley. Gan & Stobbe (1995) reported that main stem grain yield was relatively uniform, but tiller yield was highly variable in spring wheat. Briggs (1991) reported that approximately 50% of a plant's productivity in total grains and kernel biomass was produced by the first spike (MS) and 80-90% by the first two spikes (MS and T_1). Our data indicated that main stems (MS) contributed 69%, first tillers (T_1) 25%, second tillers (T_2) 4% and the remaining tillers 2% of the mean yield per unit area, depending on cultivar and growing situation. On average, main stems accounted for 52% of the total fertile ear number per unit area, first tillers 30% and the second tillers 14%, and lower order tillers 4%.

Increasing soil fertility status increased number of main stems, first tillers and second tillers, grain number and hence grain yield and grain protein content. The relative kernel size and grain protein content in the spikelet was not affected by varying fertility. Variability in soil fertility and type are known to have a greater impact on crop yield and quality than other production factors (Carr, Jacobsen, Carlson & Nielsen, 1992).

The four South African wheat cultivars varied significantly in grain quality characteristics. A correlation analysis showed that grain protein content accounted for 65% of the variation in bread-making potential. Positive correlations between grain protein content and loaf volume have been reported (Payne, Holt, Jackson & Law, 1984; Blechl & Anderson, 1998).

Evidence from this study shows that grain protein yield, grain protein content and loaf volume increased with increasing soil fertility and was affected by both wheat cultivar and soil fertility. Several workers have reported increased grain protein content by applying N fertilizer (Dubetz, 1972; Moss, 1973; Laubscher, 1981; Strong, 1986; Carr *et al*., 1992), and breeding and selection for nutrient use efficiency (Noaman, Taylor & McGuire, 1987; Fischer, 1989). In addition, the interface between actual field nutrient status, cultivar productivity and product characteristics as affected by soil fertility situations were demonstrated (Metho, Taylor, Hammes & Randall, 1999; Chapter 5).

The good performance by the cultivar Kariega in the K and P limiting soil fertility situations

(Chapters 3 and 6) and its high loaf volume potential is probably genetic. It is concluded that wheat genotypes and varying soil fertility situations affect bread-making quality characteristics. Further investigation focusing on the variability in loaf volume between cultivars is suggested. For example, information on the relative amounts and quality of the HMW-GS and end-use quality may contribute to the understanding of the variability that exist in loaf volume between wheat genotypes not attributed to grain protein content.

Temperature, photoperiod and vernalization responses of the four wheat cultivars were investigated in the growth chamber experiment. Long, cool days (13:11 hr/15-5 ^{0}C treatment) produced higher grain yield, grain number, larger mean kernel mass and higher grain protein content. In contrast, the short, warm days (11:13 hr/20-15 ^{0}C) resulted in poor performance. Understanding the effects of photoperiod, temperature and vernalization on local wheat cultivars is important for selection, climatic adaptation and yield improvement.

The quantitative information obtained in this study should be of value for crop modelling, especially in wheat yield and quality modelling. In the future, growth models based on the plant's physiological responses will have universal applicability compared to statistical models which are largely site-specific (Sinclair & Amir, 1992; Aggarwal *et al*., 1994). Modelling offers the opportunity to integrate and account for different factors, in addition to acting as a tool for greater understanding of the responses observed experimentally (Sinclair & Amir, 1992; Aggarwal et al., 1994). This is illustrated by the Crop Environmental Resource Synthesis, CERES-Wheat model which forms the basis of the International Benchmark Sites Network for Agrotechnology Transfer, IBSNAT (Uahera, 1985; Ibsnat, 1989).

In my view, and supported by the experience of this research project a wheat plant is able to sense its environment and to adapt its growth and development accordingly, on a continuous basis not yet fully understood. The unravelling or unlocking of this wheat-environment sensor mechanism may be key to accurate modelling of wheat growth, development, yield and grain quality in future.

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