CHAPTER 1

GENERAL INTRODUCTION

Grain yield and grain protein content are important in the production and marketing of wheat (*Triticum aestivum* L.). Recent changes in the balance of supply and demand as a result of the new global economy mean that growers must produce grain that matches demand more closely and reliably (Moss, 1973; Laubscher, 1981; Van Lill & Purchase, 1994). In South Africa wheat is grown under irrigation and rainfed conditions, varying soil fertility situations and a wide range of climatic conditions. Breeding programmes are aimed at developing high yielding cultivars with appropriate quality characteristics (Laubscher, 1981; Purchase, Botha, Maritz & Van Tonder, 1992; Van Lill & Purchase, 1994). The factors determining wheat yield, grain protein content and bread-making quality have been investigated by many researchers (Terman, Ramig, Dreier & Olson 1969; Takeda & Frey, 1979; Laubscher, 1981; Ciha, 1984; Fischer, 1989; Randall, Manley, McGill & Taylor, 1993). These studies indicate that when soil moisture and weather conditions are favourable the variation in wheat yield, grain protein content and bread-making quality are determined by genotype and soil fertility status.

The breeding and selection for higher grain yield, improved grain protein content and bread-making quality is often a lengthy and costly process. Normally, it takes about 14 to 15 years to produce, multiply and release a new wheat variety, while the life span of a cultivar may be only 5 to 6 years (Balla, 1986; Bell, 1987).

In this investigation interaction effects between cultivar and soil fertility on yield, grain protein content and bread-making quality were studied in a long-term fertilization experiment. The results presented and discussed were obtained during a two year (1995 and 1996) field study and in growth chambers (1997). The 1995 and 1996 results were similar, and for economy of resources only 1995 results are presented, except where otherwise indicated. The 1996 data is available, and if required, may be obtained on request from the Head, Department of Plant Production and Soil Science, University of Pretoria, Pretoria 0002, South Africa.

1.1 LONG-TERM FERTILIZATION EXPERIMENTS

A long-term field experiment is considered to be one in which the original treatments are repeated on the same plots year after year, for many years (Frye & Thomas, 1991; Mitchell, Westerman, Brown & Peck, 1991). If the treatments are changed every few years, all that occurs is a series of short-term experiments conducted on the same site for a long period of time. Long-term experiments are essential for obtaining information on the long-term sustainability of agricultural systems Leigh & Johnston (1994). They play an essential role in understanding the complex interaction of plants, soils, pests, climate and management problems, and their effects on sustainable crop production. The classical experiment at Rothamsted in England (Jenkinson, 1991) is a typical example. Four of America's oldest, continuous agronomic research trials, the Illinois "Morrow Plots" (1876), Missouri's "Sanborn Field" (1888), Oklahoma's "Magruder Plots" (1892) and Alabama's "Old Rotation" (1896) have been reviewed in detail by Mitchell et al. (1991). These studies show that long-term crop production can be sustained and improved in different regions and on different soils.

A fertilizer and irrigation experiment on the Experimental Farm of the University of Pretoria was established in 1939 and is one of the oldest long-term experiments in southern Africa (Nel, Barnard, Steynberg, De Beer & Groeneveld, 1996). Studies have been published on facets of this trial. Nel (1972) reported on traits in maize grain yields during the first 32 years of the trial; Verwey (1974) on growth and yield of maize at different fertilizer and water levels in the 1972-1973 growing season; Stoch (1983) on the variability in certain individual treatments over the first 28 years of the trial; Steynberg (1986) on growth, development and water use efficiency of maize in 1983-1984 and 1984-1985 seasons; Annandale, Hammes & Nel (1987) on the effect of soil fertility on the vegetative growth, yield and water use of wheat and Nel *et al*. (1996) on trends in maize grain yields in a long-term fertilization trial.

After more than 50 years of different fertilization treatments, the long-term trial at the University of Pretoria offers a unique opportunity to study the effect of soil fertility on growth, yield and quality of wheat on one site under the same climatic conditions. The range of divergent soil fertility conditions available also presents a rare opportunity to investigate cultivar x soil fertility interactions. This valuable site was therefore utilized for the field experiments reported in this thesis. Publications emanating from this includes Metho, Hammes, De Beer & Groeneveld (1997) on the interaction between cultivar and soil fertility on grain yield, yield components and grain nitrogen content of wheat; Metho, Hammes & Beyers (1998) on the effect of soil fertility on the contribution of main stem, tillers, kernel position to grain yield and grain protein content of wheat and Metho, Taylor, Hammes & Randall (1999) on the effects of cultivar and soil fertility on grain protein yield, grain protein content, flour yield and bread-making quality of wheat.

1.2 INTERACTION EFFECTS BETWEEN SOIL FERTILITY AND CROP CULTIVARS

High grain yield, grain nitrogen content, protein yield and grain protein content in wheat can be associated with relatively high and balanced soil fertility regimes. Nutrient imbalances have been reported to cause drastic reduction in grain yield and quality both in field and growth chamber conditions (Laubscher, 1981; Fischer, 1989).

Many researchers have reported that soil variability has a greater impact on crop yield and quality than other production factors (Liang, Heyne & Walker, 1966; McMullan, McVetty & Urquhart**,** 1988). Carr, Jacobsen, Carlson & Nielson (1992) reported that grain yield and protein content of a barley cultivar and a wheat cultivar differed across three soils, and observed soil fertility x cultivar interactions for test weight and grain protein content. Other workers have reported significant variety x location and variety x year x environmental interactions (Liang, *et al*., 1966; Ciha, 1984; Baenziger, Stephen, Clements, McIntosh, Yamazaki, Starling, Sammons & Johnson, 1985; Carr, *et al.,* 1992). The significant soil fertility and cultivar interactions clearly indicate that wheat genotypes react differently to different soil fertility situations. Published research data show that variations in soil nutrient status can result in grain yield and grain quality differences, often in the same field (Laubscher, 1981; McMullan *et al*., 1988; Carr *et al*., 1992). Such results show that breeding and cultivar evaluation should place more emphasis on soil fertility and crop genotype interactions for improved yield and quality.

1.3 YIELD COMPONENTS

Cereal yields vary as a result of combined effects of ears per unit area, grains per ear and kernel mass. These yield components vary widely with cultivar, moisture supply, soil fertility level and other growth limiting factors. Increases in the various yield components as a result of breeding, increased availability of nitrogen, or improved soil fertility status, have been reported by many researchers (Donald, 1968; Nass, 1973; Darwinkel, 1978; Nerson, 1980; Briggs, 1991).

The relative contribution of main stems and tillers as well as the relative contribution of first, second and third kernels in the spikelet, to grain yield and grain protein content, are seldom quantified. This may be important in South Africa where late maturing tillers are reportedly affecting grain yield and wheat quality (Wheat Board Technical Reports, 1990/95). Therefore, the hypothesis that tillers affect the quality of grain to a greater degree than their contribution to grain yield was tested. This kind of data is rarely available, but may be be useful in management strategies to improve yield and quality for different environments.

1.4 GRAIN PROTEIN CONTENT AND QUALITY

Grain protein content has been found to increase with the amount of applied nitrogen whether or not a yield increase resulted (Finney, Meyer, Smith & Fryer, 1957; Schleuber & Tucker, 1959; Terman, *et al*., 1969; Laubscher, 1981). Grain protein content affects the flour yield and bread-making quality of wheat. Grain protein content is genetically and environmentally controlled, and may vary with cultivar, soil fertility, location and climate. Genotype and environment interaction plays a major role in determining grain protein content level.
The interface between actual field nutrient status, cultivar productivity and product quality is important for South Africa where the price of wheat grain is determined on the basis of grain protein content and bread-making quality. For a specific cultivar an increase in grain protein content normally results in increases in water absorption and loaf volume (Finney & Barmore, 1948; Tipples & Kilborn, 1974; Tipples,Dubetz & Irvine, 1977). Wheat yield and grain protein content have been increased through breeding and selection as independent traits (Pendleton & Dungan, 1960; Terman *et al*., 1969; Jenner, Ugalde & Aspinall, 1991).

Improved grain protein content and higher yield from crosses between high yielding and good quality wheat genotypes have been reported (Borghi, Corbellini, Cattaneo, Fornasari & Zucchelli 1986; Perenzin Pogna & Borghi, 1992). Payne (1987) and Randall, *et al*. (1993) have reported a significant correlation of certain high molecular weight subunits of glutenin

(HMW-GS) with end-use quality of wheat, specifically dough strength. These results indicate that greater precision may be introduced into selection for bread-making quality in the future, but the relationship between the quality and quantity of high molecular weight subunits of glutenin and end-use quality properties still requires detailed investigation.

1.5 PHOTOPERIOD, TEMPERATURE AND VERNALIZATION

In South Africa wheat is grown under divergent climatic conditions varying from cool short days to warm long days. This affects yield and grain quality. Several studies on the effects of photoperiod, temperature and vernalization of wheat have been reported (Nel & Small, 1969; Wardlaw, 1970; Joubert & Laubscher, 1974; Warrington, Dunstone & Green, 1977; Human, Nel, Hammes & Beyers, 1981), but none of these reported on the interactive effects between photoperiod, temperature and vernalization on grain yield and grain protein content. Understanding the interactive effects of photoperiod, temperature and vernalization on cultivar grain yield, its components and grain protein content may contribute towards wheat yield, quality and regional adaptability.

1.6 EXPERIMENTAL OBJECTIVES

The objectives of this investigation were:

1. To quantify the effect of soil nutrient status on the grain yield, components of yield, and grain protein content of four South African spring wheat cultivars, thus to test the hypothesis that wheat cultivars differ in their potential to produce yield and quality under varying soil fertility situations.
2. To determine whether main stems, first tillers and second tillers differ in grain protein content, and thus to test the hypothesis that tillers affect the quality of grain to a greater degree than their contribution to grain yield.
3. To determine kernel size distribution in the spikelets of four wheat cultivars.
4. To determine whether grain protein percentage differ between kernels at different positions on the spikelet.
5. To determine the harvest index of main stems, first and second tillers of four South African wheat cultivars under different soil fertility regimes.

6. To quantify the effects of six soil fertility regimes on grain protein yield, grain protein content, flour yield and bread-making quality characteristics of different cultivars cultivars.
7. To quantify the effects of photoperiod and temperature on grain yield, yield components and grain protein content of vernalized and unvernalized wheat in growth chambers.

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