VARIATION IN THE GRAIN PROPERTIES OF MAIZE HYBRIDS WITH DIFFERENT GRAIN HARDNESS CHARACTERISTICS AND THEIR RESPONSE TO NITROGEN FERTILIZER IN TERMS OF MILLING QUALITY

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ABSTRACT

The proportion of grits and flour produced during the dry milling of maize (*Zea mays* L.) grain is related to the ratio of hard to soft endosperm. The quality standards required vary widely with different end uses, and for dry milling a hybrid with a 'hard' endosperm will usually yield the highest proportion of grits. The texture of the maize endosperm is variable and depends on the maize hybrid and agronomic conditions. In general the available literature showed protein concentration of the grain can be improved by nitrogen fertilizer application, and as the protein content increases, the amount of hard endosperm increases along with value to the miller.

A field trial to investigate the effect of nitrogen fertilizer on grain yield and quality, especially grain protein content and hardness, was carried out at the Frewens block, Massey University in the 1994/95 season. Three maize hybrids (P3751, P3787 and A82-8 xNZ84) with three different endosperm textures (soft, intermediate and hard) were grown at two sowings (October and November) with three different nitrogen levels (0, 250, 500kg urea/ha). Urea fertilizer was applied as a side dressing and split into three application times, i.e. at the three leaf stage, at canopy closure and at the 50% silking stage. Plant growth and development were measured by counting the leaf number and leaf appearance rate, formation of the black layer and grain moisture dry down for each hybrid. Grain yields and yield components were measured for different nitrogen treatments at both sowings. Grain protein content was measured from total nitrogen percentage as determined by the Macro Kjeldhal method. Grain hardness was measured by a Stenvert Hardness Tester, while bulk density and grain moisture content were measured by a grain analysis computer.

The total number of leaves per plant was greater in hybrid A82-8xNZ84 than hybrids P3787 and P3751 at both sowings, but rate of leaf appearance was faster for the November sowing than the October sowing. Formation of the 'black layer' (i.e physiological maturity) and moisture dry down rate was faster in hybrid P3787 than in hybrids P3751 and A82-8xNZ84 at both sowings.

Grain yield was significantly increased at both sowings by the application of 250kg/ha urea, but not by the 500kg urea/ha treatment. Hybrid A82-8xNZ84 gave the highest yield and P3787 gave the lowest. The main yield components which differed between hybrids were number of grains per cob and 100-grain weight.

Grain protein content increased progressively in response to the applied nitrogen fertilizer. Protein percentage increased from 8.81% in the control to 10.13% for 500kg urea/ha in the October sowing, and 8.72% in the control to 10.13% for 500kg urea/ha in the November sowing. At both sowings all three hybrids contained the highest amount of protein at the highest urea treatment i.e. 500kg urea/ha.

Increased nitrogen application improved grain hardness. For those grains grown under higher nitrogen levels grinding resistance time, energy required for grinding and milling duration time were higher than grains grown when no urea was applied. Grain bulk density (test weight) increased as nitrogen increased. Hybrids A82-8xNZ84 and P3787 had higher grain hardness under the high nitrogen treatment than hybrid P3751.

There was a strong, positive relationship between grain protein content and Stenvert Hardness Test parameters at both sowings. When nitrogen was applied grain contained a higher amount of protein (which presumably made grain harder) than the no applied nitrogen treatment. Inherent endosperm texture was not changed by the increased protein percentage as the soft endosperm hybrid did not show an improved hardness, but the intermediate and hard endosperm hybrids showed an improvement in this regard. Results from both sowings indicated grain yield, protein and hardness quality can be improved by applying nitrogen fertilizer. This has implications for dry milling, where hard grain is a necessity for higher grits recovery.

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CHAPTER I
INTRODUCTION

Maize or corn (*Zea mays* L.) is a cereal crop grown for both grain and forage. It is the world's most widely distributed crop (CIMMYT, 1982) and is used as a staple food for humans, as feed for livestock and as the raw material for many industrial products. It is one of the most important cereals and on a world scale ranks third in production after wheat and rice (FAO, 1992). In New Zealand, it is the third ranked crop after wheat and barley, and has a diverse range of uses. Seventy percent of maize production is used by the feed industry and the remaining 30% is used by the wet and dry milling industries to produce starches, food oils, dextrose, flours and a range of grits (Chappell, 1985; Hardacre, et al., 1991).

Maize is milled by dry and wet processes. In the dry milling process, the primary products are isolated pieces of endosperm (i.e. grits), which are recovered by progressive grinding, sieving and aspiration. Grain hardness has always been the major concern of dry millers because it determines grinding times and energy requirements, as well as the performance of the final products. The quality standards required vary widely with different end uses, and to some extent, with the type of plant used to process the grain. For gritting, a hybrid with a 'hard' endosperm will usually yield the highest proportion of grits and the lowest proportion of flour (Watson, 1977; Wu et al., 1991; Hardacre, 1994). Processors pay more for grits than for flour.

In New Zealand, the corn-based snack food market is growing at about 25% per year due to the increasing consumption of convenience and snack foods (Hardacre, 1995). This has prompted food processors to look for more consistent, higher quality maize grits and flour from millers, and in turn millers are looking for more 'hard' grain from growers. Generally, maize hybrids containing soft endosperm are preferred by wet millers, because a softer grain requires less steeping time and gives better starch-protein separation (Wu et al., 1991). Therefore, maize hardness is of great significance to producers, millers and processors in the grain trade.

The maize seed is a single fruit called a kernel, which has three main morphological parts: the pericarp, endosperm and embryo or germ. Each part of the kernel has a different composition. The endosperm is the largest fraction of the kernel, composed largely of starch, and is usually 82-84% of the kernel dry weight (Watson, 1987). The endosperm is of two types: hard (horny) and soft (floury). In the hard endosperm, the protein matrix is thicker and remains intact on drying, so binding the starch granules tightly together in a strong structure with a translucent glassy appearance. In the floury endosperm, the starch granules shrink during drying, tearing the thin protein matrix, resulting in round loosely bound starch granules. The endosperm often contains voids and is structurally quite weak (Duvic, 1961). The outer region of the kernel tends to be comprised of hard endosperm while the inner region tends to be comprised of soft endosperm. The hard endosperm contains a high level of protein while soft endosperm contains a higher level of starch throughout the kernel (La'sztity, 1984).

The texture of the maize endosperm is variable according to the type of maize and the region of the kernel. There are six major types of kernels: dent, flint, flour, sweet, pop and pod corn. Major differences are largely based on the hard and soft endosperm ratio, quantity and pattern of endosperm composition. The endosperm of flour maize (eg. opaque-2) has a thin protein matrix throughout, while the endosperm of hard maize (eg. dent and flint) has a thicker protein matrix (Robutti et.al., 1974). The endosperm of the maize types differs not only in protein matrix thickness but also in hard to soft (H/S) ratios, thickness of the subaleurone layers, cell size and protein components (Christenson et al., 1969). In the hard endosperm, starch granules are tightly packed together, each held firmly in a protein matrix, while in soft endosperm, the starch granules are held together more loosely (Eckhoff, 1992). The protein content of the whole kernel varies from 6-18% depending on the hybrid and agronomic conditions (Pomeranz and Bechtel, 1978).

The composition of the maize kernel depends on the different constituents present and well documented evidence shows that the protein content is influenced by the available nitrogen and genetic makeup. Duvic (1961) has shown that the total protein content of maize grain can vary from 4.4 to 26.6% without influencing grain yield. Changes in total protein content are primarily changes in endosperm protein content, mainly zein, and as the protein content increases, the amount of hard endosperm also increases (Hinton, 1953).

Kernel hardness is related to the physical and chemical properties of the endosperm. Physical properties of the grain depend on kernel density, breakage susceptibility, kernel hardness, water absorbity and average kernel weight (Weller et. al., 1988) and intrinsic quality characteristics depend on starch, oil and protein content which ultimately affect the value of the end product (Hurburgh, 1989). However, maize hardness is correlated with differences in the hard to soft (H/S) endosperm ratio. Although these quality differences mainly depend on the genetic make up of the hybrid, differences are also caused by environmental factors such as temperature, moisture and soil nitrogen supply (Watson, 1987).

Response of crops to nitrogen is highly variable, due to the complex interplay of soil factors affecting its availability and also environmental conditions. As nitrogen is the major constituent of plant proteins, enzymes, amino acids and ribonucleic acid which constitute the genetic code, it is important not only for the production but also for the quality of the grain. In general, the grain yield of maize and the concentration of protein in the kernel increases in response to nitrogen, while nitrogen stress generally decreases grain protein concentration, yield and kernel texture quality (Tsai et al., 1992).

Differences in kernel protein and yield responses to soil nitrogen levels may also be influenced by genetic differences in the capacity of genotypes to take up nitrogen from the soil and translocate it to the sink kernels (Pollner et al., 1979). In general, grain yields among maize hybrids are negatively correlated with protein concentration or positively correlated with C:N ratio. For a given hybrid, the grain yield induced by nitrogen fertility is highly correlated with its protein concentration and grain protein concentration may serve as a parameter for estimating the amounts of nitrogen fertilizer required for maximum yield of a given hybrid (Tsai et al., 1992).

It also seems (Hardacre unpublished data) that some hybrids show more variability in endosperm quality in a given range of environments than others. Clearly, for stability in a variable climate, hybrids with more uniform grain quality are preferred.

Environmental factors can influence the relationship between grain protein and yield. Temperatures over the grain-fill period in wheat have been shown to influence this relationship (Stevenson, 1987). The influence of temperature on grain growth is reflected in its effect on sink capacity, and the rate and duration of grain filling during the effective grain filling period (Jones et al., 1981). Mock and Pearce (1975) suggested that the grain filling period in maize should be as long as possible to allow maximum production and storage of dry matter.

In New Zealand there is little information on grain quality and nitrogen fertilizer relationships, and such data are urgently needed by growers and contractors. The rapidly growing snack food industry requires high quality grits and flour from the dry milling industries, which can be produced more effectively from hard grain. Therefore, this study was undertaken to examine the effects of three different rates of nitrogen fertilizer on three different hybrids sown at two different sowing times. The following objectives were set:

- To investigate the influence of different rates of nitrogen fertilizer on grain quality, especially grain protein and hardness of three different hybrids;

- To investigate the influence of different sowing times on grain yield and quality of three different hybrids.