EFFECTS OF PLANT DENSITY ON SEED YIELD AND QUALITY IN DIFFERENT COMMON BEANS (Phaseolus vulgaris L.)

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FILIPE JOSÉ ALMEIDA MESQUITA

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ABSTRACT

Common beans (*Phaseolus vulgaris* L.) are an annual legume used for human consumption. While many cultivars/genotypes have long been a feature of New Zealand home gardens and the frozen food market, there has recently been an interest in the production of new genotypes of this crop legume suitable for use particularly in fresh and canned salads, as well as for other commercial purposes.

In New Zealand, little is known of the growth and performance of many genotypes of this plant as the agro-climatological conditions are different from the original native South American habitat. Therefore this study covered an evaluation of five unnamed but different seed coloured bean genotypes obtained originally from the CIAT collection by New Zealand Seed Bank Ltd. The objectives of this research were to: determine plant growth habit of the genotypes; describe plant growth habit of the genotypes; and assess the effect of plant density on vegetative and reproductive growth, seed yield and cooking quality. To facilitate the recognition of each genotype, they were named *white, mottled brown, mottled black, black and brown* according to their seed colour, after a visual selection of seeds at the beginning of this study.

Plant morphological characteristics were assessed in a trial conducted in a glasshouse at the Seed Technology Centre, Massey University, from September to November 1994. A field trial from November 1994 to March 1995 was aimed at determining the effects of plant density and genotype on seed production and quality for sowing and eating purposes.

The minimum and maximum temperatures in the glasshouse were 16°C and 25°C respectively. The daylength in September was around 11 h and gradually increased to about 14.5 h at the end of November. No supplementary illumination and no pesticides and insecticides were used in this trial. For this study, five plants of each colour group were used to determine plant morphological characteristics which included: leaf length and width for the 1st, 3rd and 8th trifoliolate leaves,

recorded from the terminal leaf; length of pedicellate bracts; flower (standard and wing) colour; pod colour, length and width; plant height and branch number; main stem internode number and internode length; pods per plant; and seeds per pod.

Trifoliolate leaf length was around 22 cm for all genotypes irrespective of leaf position, but leaf width increased from the 1st to the 8th trifoliolate leaf and differed with genotype. For example the 8th trifoliolate leaf width ranged from 11.0 cm in the mottled brown genotype to 14.6 cm in the brown genotype. Pedicellate bract length, main stem internode number and maximum internode length all varied with genotype, with the result that average plant height ranged from 166 cm for the brown genotype to 362 cm for the white genotype. None of the genotypes produced branches in the glasshouse.

Flower colour was assessed using the Dictionary of Colour Standards and the Horticultural Colour Chart from the British Colour Council. The standard and wing were white in the white, mottled brown and brown genotypes, mauve in the mottled black genotype, and were either white or mauve to rose purple in the black genotype. The colour of the wing was mauve in the mottled black genotype and was either white or mauve in the black genotype.

Pod colour for the white genotype was mimosa yellow to naples yellow, or mottled with either aster violet or hyacinth blue, while in the mottled brown genotype pod colour was predominantly naples yellow, mottled with china rose or also with chrysanthemum crimson. Pods from the mottled black genotype were mimosa yellow to amber yellow in colour, and sometimes mottled with purple brown. Pods from the black genotype were mimosa yellow or naples yellow and were either slightly mottled with lilac purple or with pansy violet, while pod colour from the brown genotype was erythrite red. Dried pod length varied from 9.3 to 12.1 cm in the brown and white genotypes respectively, while dried pod width ranged from 11.8 mm in the mottled black to 12.8 mm in the white genotype. The number of pods per plant varied from 13 in the mottled brown to 16 in the brown genotype, while seeds per pod varied from 4.4 in the brown genotype to 5.8 in the white genotype.

Daylength for the field trial ranged from 14.5 h (November) to around 12.3 h (March), with a maximum daylength of about 15 h in December. Seeds from the same seed colour groups used for the glasshouse studies were used in the field trial which was located at the Frewen's block, Massey University. Seeds were sown at three different rates (2.8, 5.6 and 8.4 g/m^2) by cone seeder on 28 November 1994 to obtain densities of 6.6, 13.3 and 20.0 plants/m^2 at row spacings of 60, 30 and 20 cm respectively. Within the rows a uniform space of 25 cm was maintained. Each treatment (plant density x genotype) was replicated four times in a split plot design.

For seed development studies, a total of 450 - 460 flowers per genotype (from the 13.3 plants/m^2 density) were randomly selected and labelled at anthesis, and 60 pods per individual genotype were harvested manually at 14, 20, 26, 32, 40 and 50 days after labelling for the determination of seed moisture content, fresh weight, dry weight and percentage seed germination. Seed yield and seed yield components (number of pods per plant and seeds per pod) were recorded after hand harvesting of 10 sample plants/plot.

The quality of seed for sowing purposes was assessed by germination, conductivity and accelerated ageing (AA) tests, while for cooking quality, seeds were assessed for their imbibition rate, seed texture and seed integrity after cooking. All the data acquired from this study were analyzed with the statistical analysis system of SAS with least significant differences at the 5% level.

The white and black bean genotypes produced 11 and 17% plants with indeterminate climbing characteristics respectively, while the other genotypes each produced 1 - 3% of plants with indeterminate climbing characteristics. All other plants were bush-indeterminate. Plant height in all bean genotypes at all the densities measured between 50 - 60 cm with a min./max. height of 40/85 cm.

The onset, peak and duration of flowering in all genotypes were not affected by plant density. The typical three phase sequence of seed development was recorded and physiological maturity, or the attainment of maximum dry weight, occurred at around 40 days after anthesis (d.a.a.) at more or less the same time for all genotypes. Seed germination started around 20 d.a.a. and reached a maximum (of 100%) about the same time as the attainment of maximum seed dry weight at 40 d.a.a. However differences in seed coat permeability influenced the rate of seed desiccation and caused differences in seed moisture content (smc) among genotypes.

The number of branches per plant differed significantly from 4.6 in the brown genotype to 5.2 - 5.8 in other genotypes. At the 6.6 plants/m^2 density the number of branches per plant was 7.0 and decreased to 3.8 at the 20.0 plants/m^2 density. Flowers per plant varied from 46.9 to 63.9 in the brown and mottled brown genotypes respectively but did not differ with density.

Pods per plant were similar for all genotypes, and reached 32.2 at the 6.6 plants/m^2 density but decreased to 19.0 at the 20.0 plants/m^2 density. Seeds per pod varied slightly from 4.1 in the brown genotype to 4.6 in the mottled black genotype, but did not differ with density. Seed weight/100 seeds varied from 35.7 g in the mottled black genotype to 45.2 g in the black genotype, and was similar for all densities. The black genotype produced an average seed yield of 5,705 kg/ha (the highest), while the brown genotype had an average of 4,723 kg/ha (the lowest) at 10% smc. The average seed yield from the white, mottled brown and mottled black genotypes did not differ from that of the black genotype. There was no genotype x density interaction and the average seed yield for all genotypes was 3,800 kg/ha at the 6.6 plants/m^2 density, 5,366 kg/ha at the 13.3 plants/m^2 density and 6,715 kg/ha at the 20.0 plants/m^2 density.

The conductivity test result varied from 4.7 $\mu S\ cm^{-1}\ g^{-1}$ in the brown genotype to 15.5 $\mu S\ cm^{-1}\ g^{-1}$ in the white genotype, which demonstrated the differences in seed coat characteristics among genotypes. The germination before AA was 100% for all genotypes, and did not differ after AA (between 97 and 99%). The conductivity test result, as well as the percentage germination before and after AA did not differ with density. The brown genotype produced an average of 53.5% of seeds with 'delayed permeable' seed coats, while this property varied from 3.5 to 10.0% in the white and mottled brown genotypes respectively.

Seeds from all genotypes became soft after cooking for 20 min. However the force required to cut the seeds after cooking varied from 6.83 Newton in the white genotype to 15.23 Newton in the brown genotype. The high seed coat permeability in the white genotype caused 19.3% seed coat/cotyledonary damage, while the brown genotype had only 8.9%. The white, mottled brown, mottled black and black genotypes produced a high yield (between 5,136 and 5,705 kg/ha) of good quality seed for both sowing and eating purposes. The brown genotype had a lower seed yield (4,723 kg/ha), but the seed was also of good quality for sowing and eating purposes. Differences in the seed coat characteristic of different bean genotypes may mean a requirement for different lengths of cooking time to attain the same level of seed softness without seed coat splitting as required for human consumption.

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CHAPTER 1
INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is an herbaceous annual legume which has epigeal germination, can be either determinate or indeterminate in plant growth, has pinnately compound trifoliolate leaves and flowers on axillary racemes. It is self-pollinated and the fruit is a pod, each of which contains several seeds (Chapman and Carter, 1976). The seeds vary in size, shape and colour.

For hundreds of years this crop has had the image of "poor man's meat" (Morrow, 1991) and was only consumed largely by people in developing countries (Aykroyd and Doughty, 1964). In many developing countries, common bean is consumed as a major supplementary source of protein. On average, common beans contain 22.1% protein; 1.7% fat; 61.4% carbohydrate; 0.137% calcium; 6.7 mg iron/100 g; 0.54 mg thiamine/100 g; 0.18 mg riboflavin/100 mg; and 2.1 mg nicotinic acid (niacin)/100 g (Aykroyd and Doughty, 1964), with a total soluble dietary fibre of between 1.7 - 4.2%, and 66 - 73% of insoluble fibre (Bressani, 1993). However since it was found that bean products have hypocholesterolemic effects (i.e. they can reduce blood cholesterol) (Uebersax et al., 1991), consumption has markedly increased in the USA and in other developed countries. In America, the USDA (1991) stated that the consumption levels of common beans in 1990 was increased by 30.9% over previous years. Bean products have now been introduced in restaurants in exotic salads, dips, pates and even as an essential ingredient in desserts (Morrow, 1991). Uebersax et al., (1991) reported that a daily consumption of 100 - 135 g of dry beans can reduce serum cholesterol levels by approximately 20% in the short-term, hypothetically reducing risk for coronary heart disease by 40%.

The world's total production of common bean is around 14 million t/year (Dessert and Bliss, 1991); Latin America is the leading bean producer, with approximately 30% or 4.0 million t/year. In New Zealand common beans have been grown in private home gardens for over 100 years, but commercially they were initially trialled in the early 1970s in Wairarapa, Manawatu, Marlborough and Hawkes Bay. Common bean cultivars such as Great Northern (GN), Small Red (SR), Pinto and Black were first grown in 1975, and occupied an area of 4 ha for GN cultivar and 1.2 ha for each of the other three cultivars. The crop yield ranged from 1 to 4 t/ha with an average of 1.6 t/ha (Goulden and Malone, 1978). McKenzie (1989), reported that in New Zealand common beans were produced primarily for use in tinned baked beans. However more recently there has been an increasing interest in this country in the production of new varieties of this crop legume suitable for use in fresh salads as well as for canning (A. K. Hardacre, 1995, pers. comm.). The main beans used for these purposes are Red Kidney bean and Pinto. However a combination of several colours of bean will make bean salads more attractive which will lead to greater demand (R. Coulson, 1995, pers. comm.). This idea has encouraged bean producers and traders to introduce new common bean varieties with different colours.

Seed production is commonly related to cultivar, but growing conditions can markedly affect it. In New Zealand, little is known of the growth and performance of many genotypes of this plant in a habitat where the agro-climatological conditions and edaphic conditions are different from the original native South American habitat.

This study was an evaluation of five unnamed but different coloured bean genotypes obtained originally from the CIAT collection by New Zealand Seed Bank Ltd. The objectives were to:

1. determine plant growth habit of the genotypes;
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