THE EFFECT OF PLANT DENSITY, CULTIVAR AND SEASON ON THE GROWTH AND DEVELOPMENT OF BROCCOLI

A Thesis
Presented in Partial
Fulfillment of the Requirements for the Degree of
Master in Horticultural Science
(Vegetable Production)
Massey University
New Zealand

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April 1995

ABSTRACT

Two field trials (summer and winter) were conducted at the Plant Growth Unit (PGU) to investigate the effects of density and season of planting on different cultivars of broccoli. Different aspects of growth and development were studied including dry matter accumulation, leaf production, curd initiation and curd maturity.

Polynomial regression equations were fitted to the primary data and resulted in typical growth curves from which growth analysis parameters were derived. The season of planting significantly effected the developmental stages of the crop. RGR calculated according to the functional approach declined linearly with time in both winter and summer trial. It was initially highest in the summer trial but declined much faster than in winter trial. One of the components of RGR, namely LAR also showed the reduction over time, in both summer and winter plantings. The other component, NAR decline with time in summer, but showed slight increase over time in the winter trial.

LAR was consistently lower during the summer trial compared with the winter trial. This consistent reduction is associated mainly with a lower specific leaf weight (SLW) because plants have thicker leaves which may absorb more radiation and therefore be more efficient in dry matter production.

Differences in growth between seasons can be explained primarily by differences in accumulated heat units. In this study, it was evident that the number of leaves produced varied with planting season. The higher the temperature regime the more leaves produced hence, leaf count per plant was slightly higher in the summer than during the winter season. The time of head initiation were affected by planting density for both season. In the summer planting, widely spaced plants had higher leaf areas, number of leaves produced and curd yield but in the winter planting showed no significant differences in the number of leaves produced and the curd weight per plant between densities. The final number of leaves at initiation time showed variations with season of planting which suggests that leaf number can be useful index for the morphological age of the plant at curd initiation stage.

Curd initiation (an important developmental event) was found to be strongly influenced by temperature. The number of days from transplanting to curd initiation was shorter in summer and longer in winter season. Considering a normal time scale, variations in the number of days from planting to curd initiation until maturity for both season was influenced by the two developmental stages of the crop:

1) planting to curd initiation.

2) curd initiation up to maturity.

It took almost twice as long period for the plant to initiate curd during winter than during summer and the time from curd initiation to maturity was longest during the winter. The potential of the plants to produce dry matter varied with season. Total dry matter production was considerably lower in the winter crop which strongly suggests that the lower the temperature regime, the lower the potential for dry matter production. The heat unit accumulation necessary to bring the crop to the same stage of maturity varied in such a manner that it was lower when the season was cool, and higher when the season was warm.

Total biomass per unit area increased with later harvests in the summer planting. Density influenced the curd and total dry weight per plant only in the summer planting. Varietal differences were found for both season of planting. Cultivar Shogun, with the longer growing period, had the lowest dry weight per plant for both plantings.

ACKNOWLEDGEMENTS

I am greatly indebted to the following people who have helped in various aspects of this research work:

To Dr. Mike Nichols for his constant encouragement, valuable advice during this study and close supervision in my data analysis and the compilation of the manuscript;

To Dr. Keith J. Fisher for his patience, constructive comments and suggestions;

To the Executive Officials of the Isabela State University (ISU) Echague, Isabela, Philippines and the New Zealand Ministry of Foreign Affairs and Trade for the scholarship grant;

To the staff and post graduate students, Department of Plant Science likewise the Plant Growth Unit (PGU) personnel for their all-out support during the conduct of the experiments;

To Eddie and Jan Welsh, Neville and Sheryll, Hans, Sis. Desiree and Bro. Jerry for their wholehearted support and encouragement during my stay at Massey University;

To the Filipino community (Mr. Angel Carambas and Family; Mr. Jimmy Baker and Family) and all my friends at Massey University, New Zealand for their pleasant company;

To my friends: Andy and Rebecca, Caloy, Gideon, Mon for their bountiful help during the conduct of the experiments;

To my parents, brothers and sister for their great moral support;

And finally, I acknowledge my deep appreciation and gratitude to my lovely wife, REBECCA and my children, Len-Len and Aiza for their love, support, encouragement and understanding during the course of my study.

MY SINCERE THANKS AND APPRECIATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

The effect of plant density, cultivar and season on the growth and development of broccoli

1.0 Introduction

Broccoli (*Brassica oleracea* L. var. *italica* Plenck) production and consumption in the US has risen dramatically over the past several decades. Production has tripled over the past 30 years with a remarkable 160% rise in the consumption in 1983 alone (Love, 1986). While 90 to 95% of the production remains in California, increased demands has resulted in an expansion of production into such areas as Mexico, Texas and to a lesser extent, parts of the Northeastern United States.

In the UK, the demand for broccoli, which is also known as calabrese, is increasing all the time and swing to healthy eating should provide a further boost. Broccoli is one of the most rapidly expanding vegetable and grown commercially throughout Europe. It has been regarded as the "growth vegetable of the eighties", with sales having increased significantly. This trend appears to be continuing into the 1990's with some Spanish farmers growing over 1,000 hectares. In addition to the fresh market, there is a rapidly increasing demand as a frozen product with UK estimated production to be over 32,000 tonnes (Sergeant, 1994). Most people now regard traditional green vegetable as being

uninspiring but calabrese could change the situation dramatically. This growing awareness of the value of vitamin C rich crops as a constituent of a healthy diet provides the multiple retailers who are not currently handling calabrese with the golden opportunity to introduce it as a new product (Long, 1988). Fresh broccoli had a meteoric rise in popularity when estimated consumption increased by 940 % from 1970 to 1985 and continued to climb as more positive health attributes were discovered by nutritionist (Klassen, 1993).

In New Zealand, there is increasing interest in the production of green sprouting broccoli in the home garden and commercially acreage as both a fresh market and a processing crop, however, there are problems in maintaining the continuity of supply year round because an unpredictable climate affects both the time of curd initiation and the rate of head development.

Individual broccoli plants have essentially only one yield component of commercial importance; the head or harvested portion of the main stem including the immature inflorescence. When yield is expressed on an area basis, an additional component of yield is the plant population which can have a considerable influence on the size and weight of individual heads. Seddon (1988) found that calabrese growers have not achieved the yield potential offered by the crop because it has been grown at high plant densities to meet the supermarket's specifications for thin stems. He found out that "there is another important

knock-on effect from having to use high densities-an increased risk of disease". Seddon (1988) believes growers will eventually widen their spacings to lower crop density to meet the new demands and take advantage of varieties such as Marathon and Shogun.

Yield and quality are two important attributes which will determine success in the commercial production of broccoli for processing or for fresh market. Although, the total market returns are determined primarily by crop yield, curd quality can be as important as it determines the marketability and the value of the crop (Diputado, 1989). A knowledge of the rate of development and maturity characteristics of the crop would be useful in formulating planting and harvesting schedules which ensures the efficient use of farm resources and are important in marketing aspects. For fresh vegetable crops, product quality must be considered when examining the effects of plant population on yield. The way in which plant density, variety and harvest date interact to determine yield is of interest in the quest towards maximizing the yield of a particular size at harvest.

1.1 Plant spacing

Several investigators revealed an increase in marketable yield per unit land area for many vegetables as plant population increases (Knavel, 1991; Stoffella and Bryan, 1988; Widders and Price, 1987). The relationship between plant density and yield has been extensively reviewed by Willey and Heath (1969)

where the relationship is shown to conform to two curves -parabolic where the yield of crop reaches a maximum at a given plant densities and then decreases, and asymptotic curve where yield approaches maximum as population increases, but does not decline (Holliday, 1960 and Duncan, 1958). Population density and spatial arrangement of plants are very important attributes in achieving maximum crop yield. In many species when populations exceed the optimum density they often show a marked decline in yield (Field and Nkumbula, 1986). With vegetables, density is usually more important than arrangement since these crops are normally grown at densities where competition is of high intensity (Frappell, 1979). Plant density is an important variable in obtaining maximum yield and uniform maturity of vegetable crops. Of the many improved cultural practices, the use of optimum seedling age and proper spacing are important as these tremendously influence yield (Islam *et al.*, 1989).

Studies with broccoli and cauliflower (Dufault and Waters, 1985), and cabbage (Mulkey and Porter, 1987) indicated that increasing plant density by decreasing in-row spacing can result in higher yields. Optimum plant densities are likely to be achieved by varying both in-row and between-row spacing. Wang'ati (1983) states that optimum spacing should be closely tied to overall plant population up to the point where the competition between plants cannot be compensated by wider spacings between rows or groups of plants. This is particularly important in the event of reduced soil moisture where plants may not

be able to develop an adequate root system to explore all the soil between widely spaced rows. There are reports that the yield of cabbage increases with increase in plant density although the size of the individual head becomes smaller (Rahman and Haque, 1982; Hossain *et al.*, 1983; Farooque and Mondal, 1987).

Broccoli yield per hectare increased with close plant spacing (Cutcliffe, 1975; Palevitch, 1970) however, high population density decrease head size (Cutcliffe, 1971, 1975). Dufault and Waters (1985) found out that increasing plant populations increased the competition among plants and subsequently reduced marketable yield and that curd weight decreased linearly as the population increased from 24,000 to 72,000 plants per hectare.

Broccoli crop can be grown at a higher population than most other brassicas. Trials can be direct drilled and therefore, a high plant stand can be established and subsequently thinned (Chowings, 1974). The effect of plant density on the maturity characteristics of broccoli had been reported by Palevitch (1970), Cutcliffe (1971 and 1975) and Chung (1982, 1985) although, the growth of heads over time has not been studied. Little work has been reported on the agronomy of broccoli in the U.K. but research elsewhere had examined the ways plant population affects yield and spear size (Zink and Akana (1951); Massey *et al.*,1962). These workers dealt with low plant populations, aimed at the production of spears larger than those required in the U.K. for freezing. The

highest population examined by Zink and Akana (1951) was 14.6 m^{-2} which produced spears averaging 7 cm in diameter while Palevitch, (1970) states that 11 plants m^{-2} gave spears of 11 cm in diameter. The relationship between plant density, yield and head size also differed between spatial arrangement and planting date. At comparable densities plants grown on the square always gave higher yields than those grown at 6:1 rectangularity whereas Thompson and Taylor (1976) found that yield of calabrese were relatively insensitive to spatial arrangement. In practice however, the effect of modifying plant arrangement is likely to be small compared with the effect of modifying plant density (Nichols, 1987). Several cultivars could be used for drilled or transplanted crops to predict when heads of any required size would be produced. However, these models are based on crops grown at very high densities up to 22 plants m^{-2}. Commercially however, broccoli is grown at a range of plant densities to produce heads of different size and weight specification. This study considers how plant density and planting season affects curd development of broccoli hybrid.

1.2 Objectives of the study

This study was conducted primarily to determine:

1) the effect of planting season, cultivar, and density on yield of broccoli;

2) the combined effects of these factors on the growth, components of yield, and developmental processes of broccoli.