بسم الله الرحمن الرحيم

In the Name of Allah,
the Compassionate, the Merciful,

INTERACTIONS BETWEEN SIZE GRADING AND THE PHYSIOLOGICAL FACTORS LIMITING THE GERMINATION OF SUGAR BEET FRUITS

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INTERACTIONS BETWEEN SIZE GRADING AND THE PHYSIOLOGICAL FACTORS LIMITING THE GERMINATION OF SUGAR BEET FRUITS

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ABSTRACT

The quality and quantity of the sugar produced from sugar beet is strongly dependent on optimizing plant spacing in the field. Poor germinability and, in particular, low plant establishment, has long been a problem in sugar beet production, particularly in precision drill sowing systems designed to omit thinning, which is a time consuming process with high labour costs. In addition to physical and environmental stresses accruing in the field during germination and seedling emergence, fruit size and the physiological characteristics of the fruit itself have also been considered as very important factors involved in poor plant establishment.

This experiment was carried out using samples of three lots of a diploid monogerm cultivar (9597) which was released in Iran in 1985 and continues to be produced by the Sugar Beet Seed Institute of Iran (S.B.S.I.). According to the germination capacity of ungraded fruit, these lots were categorized as medium (LOT A), low (LOT B) and high (LOT C) quality lots and were selected to determine whether there was any similarity in the relationships between fruit size and quality within different lots.

Despite there being a linear and highly significant correlation (r= 0.96***) between fruit diameter and germination as well as fruit diameter and plant establishment in the low quality lot, the nature of these relationships in the medium and high quality lots

were different in that the large fruits showed equal or lower germination and planting value than the medium fruit sizes. No apparent relationship was found between fruit thickness and germination performance of the seed lots. Although there was no significant correlation between the laboratory standard germination result for both thickness and diameter graded fruits and plant establishment of the high quality lot, highly significant correlations were found between the laboratory germination and plant establishment of the size grades of the medium and poor quality lots ($r= 0.91$ and 0.99 for Lots A and B, respectively). This appeared to be a function of the variation in germination performance of the size grades and suggests that, although in poor and medium quality lots the germination percentage of the fruit can sometimes be used as an index of field performance, in high quality lots more emphasis should be placed on the vigour of the seed.

The results obtained via size grading of the seed lots used in this study illustrated that 60% of harvested fruits of each lot were either too small or too big to be used for the precision drill sowing system. Further, it was also found that 24% of the fruits within the suitable size grades were either seedless (seeds aborted) or contained under-developed seed. X-radiography of the size graded fruits of the medium quality lot (A) illustrated that, despite the fact that immaturity was mostly associated with the smallest fruits (where 64% of the fruits were immature), about 18% of the larger fruits (4-5mm diameter) also contained immature seed.

An important point to note is that 11-12 % of fruits with fully mature seed in the small and larger size grades did not germinate when incubated in optimal conditions. In contrast, only 3% of the fruits of the medium size grade did not germinate. This indicates that other germination limiting factors besides immaturity are involved and that they may vary between size grades. Because of its role in impeding radicle emergence and/or oxygen entrance into the seed cavity, cap tightness is known to be an important germination limiting factor in sugar beet. Thus the tighter the seed cap, the lower the germination of the fruit. Direct measurement of the force required for cap movement indicated that cap removal in larger fruits required a greater force than in small fruits. These results were in a similar range to those found by Morris *et al.* (1985) via indirect estimates, suggesting that enzymatic action on cap loosening is unlikely to play an important role in cap removal and therefore the direct method used in this study may be useful for selection of progenies with a reasonably loose seed cap.

Chemical inhibitory substances in the fruit pericarp have been shown to be the other important factors inhibiting germination of the seed. As they are water soluble, germination improvement may be obtained following prewashing of the fruits. Despite significant germination improvement on pleated paper after prewashing of the fruits of the high quality lot (C), no improvement was obtained via prewashing the size grades of the medium and poor quality lots. However, a significant germination improvement was achieved when prewashed fruits of the medium seed quality lot were incubated on a wetter substrate in Petri-dishes. It was found that the pericarp base is the main entry route of oxygen to the seed cavity and removal of this resulted in a 29% increase in germination percentage of the thick fruit of lot A when incubated in Petri-dishes. This is attributed to shortening the path for oxygen transfer to the seed cavity. However, a similar improvement in germination was also obtained via prewashing the intact fruit and a synergistic improvement in germination (45% increase) was found as a result of prewashing plus pericarp base removal. This could be explained on the basis of increased oxygen uptake into the embryo via the removal of both chemical and physical barriers to oxygen entry to the seed cavity, but requires confirmation by further research.

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CHAPTER I

1. INTRODUCTION

1.1 THE IMPORTANCE OF PLANT ESTABLISHMENT IN SUGAR BEET PRODUCTION

Sugar beet (*Beta vulgaris*), which was recognized as early as the 16th century as a plant with valuable properties (Thomas Theis 1971), is presently grown on over nine million hectares, mainly in the temperate regions of the Northern Hemisphere. The most important production areas are the former USSR with 3,526,000 ha., Europe 3,873,000 ha., Germany 418,000 ha. and USA 418,000 ha., (Durrant *et al.*, 1986).

Sugar beet is a biennial plant which accumulates a reserve food supply in the root during its first growing season to enable the plant to survive over the winter and produce flowering stems and seed, (correctly fruit) in the following year. In sugar beet, the term 'monogerm'is used when a cluster includes one fruit and 'multigerm' when more than one fruit makes a cluster. Normally sugar beet fruit are monocarpic; therefore, each fruit contains a single seed which is called a true seed or germplasm, comprising the embryo, food reserves (perisperm and cotyledons) and testa. The true seed lies horizontally in the cavity of a cup-shaped pericarp (commonly referred to as the seed coat rather than the fruit coat) and is covered by a removable cap (usually termed the seed cap) which is usually strongly attached to the pericarp.

Except when grown for seed production, the life cycle is usually interrupted by harvesting the root during the first season of growth when the sugar content is high. Besides being grown for sugar production, beet tops are used for animal feed, as is the pelleted mixture of pulp and molasses which remains after the sugar extraction process. In addition, this crop may be grown for ethanol production.

Usually the quality and the quantity of sugar produced from sugar beet is strongly dependent on the plant density and, in particular, optimizing the plant spacing. Normally 50-60 cm rows are prepared with inter- row distances of 15 - 20 cm (see section 2.1). Planting high vigour seed is an essential pre-requisite for obtaining suitable plant establishment. According to the literature (discussed in section 2.2), poor germinability and, in particular, low plant establishment, has long been a problem in sugar production, particularly in the precision drill system which has been designed to omit thinning, a time consuming process with high labour costs.

1.2 GERMINATION LIMITING FACTORS IN SUGAR BEET SEED

Because of the plants, cross pollinating nature, indeterminate flowering habit, and also extensive intra- and inter-plant competition on the parent plant, every lot of sugar beet seed comprises a wide range of seed size and maturity grades and these may not be of equal value for sowing. Owing to these problems, the producers of commercial fruit have to reject large amounts of the seed bulk during processing to provide a good quality seed lot of a standard size to use in the precision drill system (2.25-3.25mm thickness, 3.25- 4.5mm diameter and more than 85 % germination under optimal conditions). Besides losing lots which are under and over standard grades, this grading process is time consuming and also needs a high level of expertise. Thus this kind of seed is expensive to produce. Nevertheless, even after grading poor establishment still remains a problem for commercial sugar beet production.

There is some debate about the reason for poor seed germination. Snyder (1963), for example, showed that the presence of physico-chemical inhibitors in the seed coat of beet seed may delay the emergence and/or diminish final germination, while Grimwade *et al.* (1987) suggested that the presence of underdeveloped and shrivelled seed and seedless or empty fruits are the main causes of poor quality in beet seed. However, the interactions between these factors and involvement of others should also be taken into account in explaining low germination and,in particular, the poor stand establishment characteristic of the beet seed.

Although a lot of effort has been made to highlight the relative effects of the different factors involved, there is still argument in this area, no doubt because of the wide range of different variables and multiple interactions between them, and with the environmental conditions of the seed bed (see literature review). In addition,there are some aspects of seed performance which have not yet been investigated: for example, the effect of fruit thickness on germination and establishment, the rate of water and oxygen uptake in different sized fruits, and the effects of seed quality on seedling establishment after field emergence.

1.3 OBJECTIVE

By building on previous research, this study was carried out with the following objectives:

1.3.1 To assess the effect of two different size grading methods (based on thickness and diameter grading) on fruit and true seed weight.

1.3.2 To determine the relationship between size grades and percentage, speed, and uniformity of seedling emergence.

1.3.3 To investigate the relationships between fruit size, true seed weight and the seedling dry weight.

1.3.4 To investigate and determine the relative importance of the factors limiting germination, including inhibitory substances in the seed coat and the physical inhibitory functions of the seed coat and the cap.

1.3.5 To evaluate whether the X-ray technique can be use as a reliable method for predicting the germinability of seed.

1.3.6 To determine the relationship between standard germination results and plant establishment.

1.3.7 To define the relationships between the fruit diameter and thickness and plant establishment and seedling dry weight in the field.

1.3.8 To identify the factors which reduce plant establishment after emergence in the field under New Zealand conditions.

To fulfil these objectives, two series of experiments were conducted in this study:

The first stage was designed to define the relationship between fruit size and true seed, seedling dry weight, seed cap and seed coat weight and to evaluate percentage and speed of seedling emergence in both optimal laboratory conditions and also in the field. In addition, factors which may reduce plant establishment after seedling emergence were also investigated. All these results are discussed in chapter four. The second set of experiments was designed to investigate the physiological basis of the germination performance of monogerm sugar beet seed including, the relationship between the stage of seed maturity as determined by X-radiography and germination percentage in size graded fruits, the assessment of the effects of physical and chemical inhibitors in the fruits on seed germination, and also to investigate the physiological properties fruit pericarp bases in relation to germination. The results of this set of experiments are presented and discussed in chapter five.