RECENT DEVELOPMENTS IN VEGETABLE CROP PROPAGATION WHICH MAY HAVE IMPLICATIONS FOR THE NURSERYMAN

TONY BIGGS

Horticultural Department, Hawkesbury Agricultural College Hawkesbury, New South Wales

Vegetative propagation is very important in the nursery industry, but propagation from seed is the usual method employed by vegetable crop producers. Conventional vegetative methods are used, however, including the use of stem tubers for potato (*Solanum tuberosum*) and cuttings or division for herbs such as mint (*Mentha* spp.), thyme (*Thymus vulgaris*) and rosemary (*Rosmarinus officinalis*). The advent of micropropagation technology has allowed virus-free clones of rhubarb (*Rheum rhabarbarum*) to be produced from apical meristems.

Vegetable growers are very well served by their seedsmen and, although seed prices continue to rise, they still form a very small proportion of the total costs of production. Seedsmen are required by law to provide information on *minimum percentage germination*, and *percentage purity*. Seed must then conform to these percentages. Bedding plant and flowering pot plant seed may also carry similar guarantees, but it is less likely. Tree and shrub seed rarely has this information. Consequently the nurseryman who raises specimen plants, rootstocks, forest trees, or hedging plants from seed has very little idea about the likely performance of that seed. He may carry out a *viability test* but that only demonstrates that the seed is alive. Germination tests indicate the percentages of seed which germinate under perfect and controlled laboratory conditions. Commercial germination conditions are usually far from perfect and it is necessary for growers to modify laboratory results in order to predict likely field performance. Thus, although the vegetable grower usually has an advantage over the nurseryman in terms of information supplied by the seedsman, the germination percentage figures require further interpretation. A more useful assessment would be of seed *vigour*.

The International Seed Testing Association defines seed vigour as "the sum total of those properties of the seed which determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence". The concept of seed vigour is used to explain field differences of seed lots with identical laboratory performances Seed with high germination percentages usually gives good field establishment but seed ageing — caused particularly by high temperatures and humidities — causes severe and unpredictable reductions in emergence. This is particularly serious when the necessary programmed plant populations cannot be achieved for processing and contract grown crops such as carrots, beetroot, brussels sprouts, etc. Similar disadvantages occur when seeds of nursery and ornamental crops germinate and seedlings emerge over long periods of time.

Seeds can be classified into vigour categories ranging from low to high. Low vigour seeds give low field emergence which is worse in adverse soil conditions such as sub-optimal temperatures (carrots) or excessive moisture content (beetroot). Reduction in seedling emergence caused by soil pathogens are also more prevalent with low vigour seed. High and medium vigour seeds perform better but close correlations between laboratory germination and likely field emergence can only be drawn when field conditions are most favorable and there are few stresses on the seed.

Vigour tests have been devised for certain crops. The vigour of pea seed can be determined by measuring the electro-conductivity of the water in which seeds have been soaked for 24 hours (4). Leachate from the highest vigour seeds — which produce the best field emergence — gives the lowest electro-conductivity readings. The development of vigour tests for other seeds would help the most suitable quality of seed to be used for appropriate crop production systems.

Seed vigour information would provide the basis for much more accurate production programmes and schedules but the problem of non-synchronous seedling emergence remains. Sowing untreated, dry seed often leads to variable emergence of seedlings, particularly when growing conditions and seed factors are sub-optimal. Satisfactory vegetable crop growth occurs only during periods of suitable growing conditions, and short growing seasons make it impossible to grow some vegetables in particular locations. Quicker seedling emergence may give sufficient time for previously impossible crops to be grown while earlier, synchronous crop emergence enables leaf canopies to develop more rapidly so that plants are better able to convert radiant energy into harvestable products.

Certain types of vegetable production need precise control over plant populations in order to govern crop size and development while synchronized crop maturity is needed for "once-over" mechanical harvesting. This is particularly true for processing crops (vining peas, dwarf beans, sweet corn, etc.) but more precise, programmed production is now being demanded for crops such as lettuce which are traditionally selectively hand-harvested. The need for uniform, synchronous development of nursery seedlings is increasingly important as more precise growing schedules are devised. A number of seed treatments have been used for vegetables in order to improve synchronous emergence and some of these may be worthy of investigation with nursery and ornamental seed.

Beetroot "seeds" are really fruits which contain two or three seeds within a corky pericarp. The fruits are irregularly shaped and are often mechanically rubbed by seedsmen to produce a more spherical unit which can be size-graded and space sown The pericarp contains water-soluble germination inhibitors which can be washed out by soaking the "seeds" in running water at 21°C for an hour before sowing.

Workers in Colorado (2) hastened the emergence of tomato seedlings at low temperatures (10°C) by wetting the seed with nutrient solutions of 1 to 2% tripotassium orthophosphate ($K_3PO_4 \cdot H_2O$), or 0.5 to 2% potassium nitrate (KNO_3), and then re-drying before sowing. Emergence rate was up to 5 days quicker if seeds were soaked for 4 to 6 days. Water is imbibed and enzymes activated during the pre-sowing wetting but the nutrients maintain a high osmotic pressure around the seed and prevent the entry of sufficient water to permit germination at this stage.

Russian work (5) indicates that alternate wetting and drying of seeds before sowing confers drought hardiness on the ensuing crops. Three cycles of this technique — "hardening" or "advancement" — improved the rate of emergence in carrots and gave a 10% increase in yield. Hardening increases embryo size which, in turn, gives rise to quicker germination and seedling emergence. It seems likely that the effects of hardening are similar to using large seeds, i.e. — larger embryos give larger seedlings which emerge earlier and give yield increases.

The late Walter Heydecker at Nottingham University, England devised a technique (3) of placing seeds in contact with solutions of a high molecular weight fraction of polyethylene glycol (P E.G.). Very rapid germination follows the "priming" treatment in solutions with osmotic potentials of −10.0 to −15.0 bars for between 7 and 21 days depending on the vegetable species. The principle is similar to that demonstrated by the workers in Colorado (2). The P.E.G. acts as a germination barrier and seeds take up sufficient water to reach the "brink of germination" but are prevented from taking up any more until the P.E.G. solution is removed. Rapid and synchronous germination then follows; e.g. 50% of viable celery seed germinated in 48 hours after treatment. The best results are obtained when seeds are surface dried before sowing rather than being completely re-dried and stored. Improvements were also demonstrated with flower seeds such as *Antirrhinum*, *Mesembryanthemum* and *Nemesia*. Heydecker used polyethylene glycol as Carbowax 6000 which was supplied by Union Carbide.

(290g. P.E.G. in a litre of distilled water produces a solution with an osmotic potential of −10.0 bars while 324g. in a liter gives an osmotic potential of −12 5 bars.)

Light is required for the germination of some vegetable seeds but there are considerable variations even among cultivars of a particular crop. Seed germination of some cultivars of celery (particularly at temperatures above 15°C), tomato, and lettuce (particularly when freshly harvested) is reduced in the dark Light is unable to penetrate more than 5 mm into the soil and the performance of light-sensitive cultivars of celery is markedly reduced when they are direct seeded. The light requirement can be overcome by soaking seeds in a mixture of gibberellins ($GA_{4/7}$) before sowing (6). Incorporation of ethephon (Ethrel), daminozide (B9), or benzylamino purine (BA) into the mixture helps to overcome thermodormancy factors.

Pre-sowing treatments of some vegetable seeds have given encouraging results but the seeds were still sown dry. Synchronous emergence of the majority of seeds is desirable but it would be valuable to know just which ones will emerge.

Germination of seed before sowing provides the grower with the potential only to sow seeds which are obviously capable of producing plants. Pre-treatment of the seed before the pre-sowing germination could help to ensure synchronous development. Seed which has germinated needs careful handling and a special method of sowing. Workers at the National Vegetable Research Station, Wellesbourne, England have devised a system of fluid drilling by which germinated seed can be sown. The technique and drilling equipment were originally devised for sowing cereals in an aqueous solution into killed grass swards (1). Modifications were made to the machinery and it has been possible to demonstrate the value of fluid drilling germinating vegetable seeds. Seeds are germinated in controlled environments where specific requirements of light, temperature (about 21°C for most common vegetables) and aeration can be provided. Germinating seeds are separated from the remainder by their differential resistance to a stream of water flowing through sloping tubes and are carried along while the ungerminated seeds remain behind.

Germinated seeds of most vegetables can be stored at low temperatures (1°C) in water or high humidity environments if conditions for sowing are unfavourable.

The germinated seeds are mixed into a protective gel immediately prior to sowing. Alginate gels were used initially but many other materials have now been tested. Mineral colloid and polyacrylate gels have given consistently better seedling emergence than alginates. Thorough mixing and correct gel consistency ensure that seeds remain evenly suspended during sowing.

Fluid drilling of germinating vegetable seeds has produced earlier emergence in widely varying soil conditions. More uniform emergence can also occur and produce uniform growth of some crops right through until harvesting. British research shows 5 to 12 days earlier emergence and up to 20% increase in total emergence of carrots, while celery has emerged up to 21 days earlier with an increase of up to 58% in the total number of seedlings emerging.

Direct seeding pre-germinated seeds has important implications for extending growing seasons and allowing the grower more accurate control over crop production, but there are other prospects. Materials such as fertilizers for seedling growth, fungicides, insecticides or growth regulating compounds could be incorporated with the seed-gel mix and provide a completely artificial environment around the seed.

These seed treatments have not been tried with many ornamental or Australian native plants but I feel that they are worthy of investigation.

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TEACHING PLANT PROPAGATION TO HORTICULTURE STUDENTS

A.W. VINK

Ryde School of Horticulture
Ryde, New South Wales

Abstract. Horticulture students are instructed in the principles and practices of plant propagation which are employed in commercial nurseries It