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RECENT DEVELOPMENTS IN THE PROPAGATION AND ESTABLISHMENT OF PLANTS FROM SEED.

TONY BIGGS

Horticulture Department, Hawkesbury Agricultural College, Richmond, New South Wales

Investigations dealing with horticultural seeds continue to occupy growers, researchers, educationalists, and others all over the world. The range of topics being investigated becomes wider each year and over the last four years more than 2000 abstracts on seeds have been cited in Horticultural Abstracts. This review paper looks at some of the recent work in the areas of dormancy and germination inhibition, and also considers developments in seed treatment.

DORMANCY AND GERMINATION INHIBITION

The effects of low temperatures during seed stratification on breaking dormancy have been investigated extensively with many fruit and ornamental plants. Work with peaches (27) has confirmed the effect of the endocarp (stone) and testa on dormancy. Stratification for 12 weeks at 4.4°C was required to break dormancy of seeds within uncracked endocarps, whereas removal of the stone before cold treatment reduced the period to 4 weeks. Cold treatment of excised peach embryos overcame dormancy in only 2 weeks. Leaching unstratified excised embryos in water stimulated germination even more rapidly. The endocarp inhibits germination by preventing water uptake and also interferes with the leaching of inhibitors from the testa and embryo.

Indian workers (9) demonstrated that lignins extracted from the bark of a number of trees will inhibit germination of lettuce very effectively. On the same topic, workers in Japan (10) isolated and identified phenolic compounds as germination inhibitors in beetroot seed clusters.

There has been increased interest in the effect of saline soil conditions on seed germination of vegetable crops in particular. Work with brassicas, capsicums, onions, and tomatoes has shown that germination percentages fall with increasing sodium chloride concentrations in the soil solution. Concentrations between 0.05% and 0.5% NaCl significantly reduced germination in these vegetables. On the other hand, it was found that soaking seeds in sodium chloride solutions of up to 3% for 12 hours before sowing into non-saline soils had no affect on germination. Further work demonstrated that cultivars differ in their behavior in saline soils.

Work with pecans (11) showed the interaction between abscisic acid (ABA) and gibberellic acid (GA) in germination inhibition. Before cold stratification at 4°C there were low levels of GA-like substances and high levels of ABA. During stratification the positions were reversed, with GA reaching the highest level after 6 weeks of stratification. Soaking seed in water for 24 hours after 2 to 3 weeks of stratification caused more rapid disappearance of ABA, while soaking in GA, at 1000 ppm for 24 hours after 6 weeks of stratification improved germination significantly. Work in Germany with mustard seeds (21) has reinforced the importance of abscisic acid as a germination inhibitor. It was shown that ABA reversibly stopped embryo development at the brink of radical growth initiation by inhibiting the water uptake which accompanies embryo development. Subsequent removal of the ABA allowed seeds to take up water rapidly and continue to germinate.

SEED TREATMENTS

Aeration and oxygenation. Tomato seeds were aerated for 24 hours with air or oxygen in water at 20° to 25°C before sowing (22). This treatment converted complex storage chemicals into simple utilisable materials and improved germination from 77% to 92%. Similar improvements have been obtained with melon seeds (19) following a 24 hour soak in aerated water. Russian workers (14) soaked tomato seeds in 0.2% to 0.6% solutions of hydrogen peroxide for 2 to 4 days and then held them for 6 to 18 hours in temperatures alternating between +21°C and -1°C. The composite treatment advanced emergence by 7 to 8 days when seed was sown in the field and crop yield was increased by approximately 25% over controls.

Seaweed extract soaking (30). Beetroot seeds soaked in a 1% (v/v) solution of seaweed extract prepared from various species within the families Laminariacae and Fucuceae showed superior germination to seeds soaked in water. The improvements were attributed to the cytokinin-like properties of the extract.

Organic solvent soaking. (26). Surrounding layers of seeds frequently contain and exude germination inhibitors and germination may be improved by totally or partially removing these layers. Manual removal may not be practical, however, and benefits have been demonstrated with cashew by soaking seeds for 2 hours in chloroform or acetone. The solvents removed the waxy pericarp layers and facilitated water imbibition and phenol exudation. The treatments hastened and partially synchronised germination and advanced field emergence.

Growth substances. Germination improvements have been demonstrated with a large number of species following treatments with gibberellic acid (GA) and cytokinins. Frequently there are interactions between the growth substance treatments and species/environment factors.

Work with celery (4) demonstrated that gibberellic acid and cytokinin treatments, separately, allow seeds to germinate at higher temperatures. Mixtures of GA with ethephon (Ethrel) or some cytokinins [especially benzylamino purine (BA)] produced even more effective germination promotion.

Low temperature treatment (1.5°C for 4 weeks) and/or GA_3 treatment (500 mg./litre for 24 hours) were compared on freshly harvested (27 species) and stored (23 species) seeds (2). Low temperature and GA treatments both improved germination in all fresh seed but GA treatments were more effective on stored samples. Species varied in behavior but it was recommended that a combined treatment of 24 hours in 500 mg./litre of GA_3 followed by 4 weeks at 1.5°C could be successful when exact requirements are not known. Work in California with Valencia orange (7) confirmed that seed taken from fruit harvested early in the season did not germinate. Storage of those seeds at 3°C to 4°C for 21 days produced 100% germination. Similar germination improvements were shown by seeds from fruits which remained on trees and received approximatley 100 hours below 3°C to 4°C. Gibberellic acid (GA_3) treatments overcame the cold requirement to some extent and produced 55% germination in seeds which received no low temperature treatments.

Germination of sour orange seed in Texas was delayed and reduced when seed was air-dried for more than 24 hours (8). GA_3 seed soaks reversed these effects of air drying and also produced taller seedlings. The adverse effects of air drying were not reversed by either stratification or water soaking treatments.

Other interactions with gibberellic acid were shown in treatments of sour orange, rough lemon, and *Poncirus trifoliata* seed used for producing citrus rootstocks (1). GA soaks for 16 to 30 hours gave best results with seed of low vigour. With P. *trifoliata*, the best results were obtained when seeds were extracted just before treatment from fully ripe fruit.

Gibberellic acid and kinetin have been compared on scarified apricot stones and on lime seeds *(Citrus aurantifolia)* (3). GA at 500 ppm or kinetin at 5 or 10 ppm gave the best results with apricot, but a lower (100 ppm) concentration of GA was most successful on lime. Gibberellic acid and kinetin treatments also improved seedling growth.

Germination of Alexandra palm *(Archontophoenix alexandrae)* seed was shown to be accelerated by soaking for 24 to 72 hours in water before sowing and further accelerated by soaking for 72 hours in 100 ppm or 1000 ppm solutions of gibberellic acid (18).

The effect of gibberellic acid on excised embryos was demonstrated by work with *Camellia japonica* (13). Untreated fresh seed gave 48% germination after 12 days, but treatment with 1000 ppm GA for 24 hours increased germination to 84%. Treatment of excised embryos with a solution of 1000 ppm GA for 24 hours gave 100% germination in 6 days.

Germination of fresh, untreated seed of American horn beam *(Carpinus caroliniana)* was only 24%, but this was improved by stratification for up to 21 months (5). Further improvements resulted from combined treatments of stratification and gibberellic acid soaks, but the best results were obtained following scarification and GA soak treatments (up to 500 ppm) when good germination was obtained without stratification.

General germination stimulation has also been reported for medicinal plants (15), where 24 hour soaks of GA_3 at 100 to 1000 ppm gave improvements with *Lavendula spica, Atropa belladonna*, and Hyoscyamus niger, and Primula × polyantha (16), where a soak of 250 ppm GA_3 stimulated germination to 88% compared with 55% for untreated seeds. In this case there was no improvement to seeds of *Primula vulgaris*.

Irradiation with gamma rays. Gamma ray irradiation has been used on seed for many years in attempts to induce genetic mutations, but more recently the effects on germination have been studied.

Work .with cucurbits has shown crop yield increases following irradiation of seed at 300 and 500 rad. (33). These increases were demonstrated in the crops grown immediately from irradiated seed and also in the following season with crops grown from seed saved from the first plants. Higher levels of irradiation (500 to 100 rad.) on cucumbers also accelerated plant development, increased the number of female flowers and produced yield increases (6).

Ghanian workers (31) irradiated oil palm seeds with levels between 1 and 140 K.rad. The highest rates produced high germination percentages within 2 to 5 weeks of the treatment but untreated seeds did not germinate. Unfortunately the irradiation treatments retarded further plant growth.

Irradiation of poppy seeds with 150 to 10,000 rad. reduced the morphine content of seed capsules, with the highest irradiation levels causing the greatest reduction (20).

Further work with carrots (24) using seed irradiation of 2000 rad. produced crop yield increases of 17% to 20%, more uniform plant stands, and improved root quality. Higher irradiation rates on calendula seed (5000 to 10,000 rad.) caused advancement of flowering, increases in the number of double flowers, and productivity improvement (25). Finally, there are indications that onion plants produced from gamma-irradiated seeds showed less infection by white rot *(Sclerotium cepivorum)* (28).

Osmotic pre-treatment. Soaking carrot seed in a mixed salt solution of KNO_3 and K_2HPO_4 at -5 bars reduced the time between sowing and emergence from 16.6 days to 11.3 days (29). Microscopic examination showed good correlations between embryo length in the seed and earliness of emergence. Osmotic pre-treatment with polyethylene glycol (PEG) allowed carrot seed to be stored up to 20 months without any reduction in seedling emergence.

Treatment of impatiens seeds with polyethylene glycol at −7.5 bars for 10 days resulted in 80% germination within 24 hours of subsequent sowing. Seedlings were more advanced after 5 days and flowering occurred earlier (23).

Anti-bacterial treatments. Previous seed treatments to eliminate brassica black rot *(Xanthomonas campestris)* have had mixed results. Hot water treatments often do not eliminate the pathogen but do reduce germination. Low concentration thiram soaks (0.2% w/v) are more successful and also eradicate canker *(Phoma lingam)* without reducing seed germination. Bactericide soaks using 500 μg/ml. of terramycin or streptomycin solutions for 1 to 2 hours, followed by a water rinse and a 30 minute soak in 0.5% (w/v) sodium hypochlorite, have eradicated black rot with no phytotoxicity to developing plants (12). Non-use of the water rinse and hypochlorite soak did cause subsequent phytotoxicity.

Bacterial spot of pumpkin *(Xanthomonas cucurbitae)* was eliminated from seed taken from infected plants by soaking for

60 minutes in a 1 : 20 solution of commercial hydrochloric acid in water with 1% non-ionic spreader added (17). Hot water or sodium hypochlorite treatments only reduced the incidence of bacterial spot and the disease developed rapidly on seedlings and young plants.

Biological control of soil-borne diseases (32). Moist tomato seeds coated with *Trichoderma viride, Streptomyces griseus,* or *Bacillus subtillis* were sown in soils infected with *Phytophthora parasitica, Pythium debaryanum* or *Fusarium oxysporum.* The antagonistic activities of the bacteria significantly reduced the incidence of damping-off diseases.

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