

The status of key substitutes to MB and emission reduction strategies are summarised below, and further details are provided in the main document.

Fumigant Substitutes

1,3-D/Pic Products

- Formulations containing 100:0, 65:35, 40:60, and 20:80 mixtures of 1,3-D/Pic are registered for use in soils in Australia.
- Not technically feasible due to inadequate pathogen control at greater soil depths, higher incidences of soil-borne disease in runner crops and subsequent fruit crops, and crop phytotoxicity.
- Not approved for use by the runner Certification authority because formulations of 1,3-D/Pic are less effective in controlling pathogens than MB/Pic. Their use would result in a complete loss to growers because, under the scheme, non-certified runners cannot be sold or distributed.

Chloropicrin (Pic)

- Registered for use in soils in Australia.
- Not technically feasible because it does not control pathogens and weeds as effectively as MB/Pic and it reduces runner yields and subsequent fruit yields.
- Not approved for use by the runner Certification authority. Its use would result in a complete loss to growers because, under the scheme, non-certified runners cannot be sold or distributed.

Pic or 1,3-D co-applied with methyl isothiocyanate (MITC) generators

- The MITC-generators, dazomet, metham sodium and metham potassium, are registered for use in soil in Australia.
- A metham spading rig was imported into Australia from Europe in 2013 for application of MITC in trials, but has proved an ineffective application method on clay soils at Toolangi, Victoria.
- Not technically feasible because application of MITC (as spade injected metham sodium or incorporated dazomet) on its own or co-applied with Pic and 1,3-D/Pic caused significant phytotoxicity in runner crops, and does not control soil-borne pathogens as effectively as MB/Pic.
- Not approved for use by the runner Certification authority. Their use would result in a complete loss to growers because, under the scheme, non-certified runners cannot be sold or distributed.

Pic or 1,3-D/Pic co-applied with herbicides

- The integrated use of the pre-emergent herbicide isoxaben and the post-emergent herbicides phenmedipham and fluazifop-p with Pic or 1,3-D/Pic (20:80) can improve weed control without causing phytotoxicity to runner crops.
- Not technically feasible because these combinations do not control soil-borne pathogens as effectively as MB/Pic.
- Isoxaben and phenmedipham are not yet registered for use in strawberries, but current research is generating efficacy data (residue data) to support their possible registration.
- Fluazifop-p is registered for strawberry, but does not provide adequate weed control unless integrated with the use of phenmedipham, isoxaben and Pic or 1,3-D/Pic (20:80).
- Not approved for use by the runner Certification authority. Their use would result in a complete loss to growers because, under the scheme, non-certified runners cannot be sold or distributed.

Ethanedinitrile (EDN)

- Registered for use in soils in Australia.
- Showing promise, but not yet technically feasible because of inadequate pathogen control compared with MB/Pic, particularly at greater soil depths.
- Not approved for use by the runner Certification authority. Its use would result in a complete loss to growers because, under the scheme, non-certified runners cannot be sold or distributed.

EDN + Pic

- These products are individually registered for use in soils in Australia.
- Co-application of EDN and Pic is showing promise, but is not technically feasible because they do not control pathogens as effectively as MB/Pic at greater soil depths.
- It is not clear whether co-application of these products will require a separate registration for commercial use.
- Not approved for use by the runner certification authority. Its use would result in a complete loss to growers because, under the scheme, non-certified runners cannot be sold or distributed.

Dimethyl Disulphide (DMDS)

- Not registered for use in Australia.
- DMDS and DMDS/Pic were imported into Australia in 2014 for trial purposes.
- Not technically feasible due to inadequate pathogen and weed control compared with MB/Pic, particularly at greater soil depths.

- Registration of DMDS and DMDS/Pic has commenced, but is expected to take a long time. Not available to runner growers.

Methyl iodide

- Application for registration in Australia withdrawn in 2012 by Arysta LifeSciences and not currently available to Victorian runner growers.
- Technically feasible for use in the Victorian runner industry because it has been shown to control soil-borne pathogens and weeds as effectively as MB/Pic without causing crop phytotoxicity.
- The Victorian runner industry has secured registration data and applications from Arysta LifeSciences and aims to achieve technical approval for the product in Australia by 2021, and full commercial use by 2022.
- It is a key component of industry's plan to transition away from MB/Pic.

Recaptured Methyl Bromide from Quarantine Applications

- QPS uses of MB are not restricted under the Montreal Protocol.
- Research has and is examining the amendment of soils with carbon waste containing recaptured QPS MB as an alternative to soil disinfestation with non-QPS MB.
- Recaptured QPS MB on carbon has provided unreliable control of pathogens and weeds due to its inconsistent content of MB.
- Registration of this by-product is required because the properties of recaptured MB on activated carbon must be reviewed compared with the known properties of virgin MB.
- Long way from commercial availability because there is no current commitment from chemical companies to improve the consistency of formulation to support registration.
- Not registered and not available to Victorian runner growers.

Propylene oxide (PPO)

- Not registered for use in soils in Australia.
- Plans were in place to import PPO and PPO/Pic into Australia for trials in the runner industry in 2016/17. However, instability of formulations of PPO in-cylinder prevented this importation. The registrant is conducting studies to improve the stability of PPO in-cylinder before this fumigant can be imported into Australia.
- Not registered and not available to Victorian runner growers. Registration applications for PPO and PPO/Pic could only be prepared when two years of efficacy trials are completed.
- Very long way from potential registration, and not available to runner growers.

Allyl isothiocyanate (AITC) and AITC/Pic

- Dominus® (AITC) and Ally® (AITC/Pic) were imported into Australia in 2018 for trials.
- Not registered and not available to Victorian runner growers.

Non-Fumigant Alternatives

Soil-less Systems

- Already adopted for commercial production of Nucleus, Foundation and Mother stock runners in the multiplication scheme (i.e. first, second and third generations, respectively).
- Partial budget analysis shows that soil-less systems (plug plants) are currently not economically feasible (three times more costly than bare-rooted runners grown in MB/Pic-treated soil) for production of the last generation of runners (Certified stock) (see Part E 16).
- Re-analysis of the economics of soil-less systems for production of Certified stock is underway. The re-analysis is based on actual costs incurred during commercial scale-up of Mother stock production in 2018/19.
- Not technically feasible for Certified runner stock (generation 4) because the subsequent fruit yields from runners produced in soil-less systems are mostly lower than those from bare-rooted runners produced in MB/Pic-treated soil (Part C 8g).

Biofumigation

- Not technically feasible due to inadequate weed and pathogen control.
- Biofumigant crops do not release the same concentration of isothiocyanates into soil as commercial fumigants. Consequently, biofumigants have not resulted in the same level of pathogen and weed control as commercial fumigants (Mattner et al., 2008).
- Integration of biofumigant crops with substitute fumigants does not provide adequate control of soil-borne pathogens in comparison with MB/Pic.

Microwave

- Not currently technically feasible due to inadequate control of soil-borne pathogens compared with MB/Pic. Research is underway to improve the effectiveness of microwave treatment by using different wavelengths to target soil treatment at greater depths.
- Analysis shows that microwave is economically viable if technical issues can be overcome [A31].

Anaerobic Soil Disinfestation

- Pot trials with this method have commenced, but so far have delivered inconsistent pathogen control.
- Long way from commercial trials due to difficulties with implementation on steep slopes, which are common in the Victorian runner industry.

Steam

- Very difficult to implement for soil disinfestation in clay soils containing rocks and on steep slopes at Toolangi for production of the certified generation of runners.
- Preliminary trials with a small prototype unit showed that steam did not control pathogens and weeds at Toolangi.
- Not economically viable compared with MB/Pic and microwave treatment of soil [A31].
- Study tours have been conducted to view steam units in Europe and California, and discussions with experts indicated that these units are currently not economically viable (Stanghellini, 2017).

Emission Reduction Strategies

Lower Dose of Methyl Bromide

- On-going research shows that rates below 25 g MB.m⁻² (see AUS02 CUN15) are not effective in controlling pathogens and weeds in soils at Toolangi, and therefore do not meet the criteria for registration.
- Rates below 25 g MB.m⁻² are not registered and are illegal for Victorian runner growers to use.

Rotation of MB with Alternative Fumigants

- Not currently technically feasible because of lower pathogen control and failure to control volunteer strawberries (see AUS02 CUN18 for details).

Impermeable Barrier Films

- Previous trials demonstrated that impermeable barrier films do not retain MB for longer periods in the high organic soils at Toolangi than standard LDPE films (AUS02 CUN16).
- Currently, impermeable barrier films do not offer a reliable mechanism for reducing application rates of MB because they do not remain in place for long enough in the runner industry (due to high winds).
- Rates below 25 g MB.m⁻² are not registered as they have not demonstrated efficacy and are therefore not available to Victorian runner growers under impermeable barrier films or standard LDPE films.



Figure 1. New rig for applying fumigants in the strawberry runner industry. The design incorporates swept back tynes and small duck-feet for minimising the losses of volatile fumigants like EDN from soil, longer tynes for injecting fumigants at greater soil depths, and a hot-glue system for welding sheets of totally impermeable film.



Figure 2. Demonstration of the prototype microwave rig to members of MBTOC at Toolangi in 2018.



Figure 3. Small-scale steam rig used to treat soils at Toolangi in trials conducted in 2017/18.