Jump to page
1 2 3 4

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Efficacy of Organic Amendments Used in Plant Production

In this month's Nursery Paper, consultant and Honorary Fellow at Melbourne Universities School of Land and Environment, Dr Sally Stewart-Wade reports on a comprehensive literature review undertaken for NGIA on the science behind whether organic amendments are useful in containerized plant production.

What are organic amendments and what are they good for?

Organic amendments are a broad collection of products sourced from naturally occurring organic materials that can be added to growing media to improve plant growth. It is claimed that, amongst other benefits, they can provide nutrients to plants; stimulate growth and enhance flowering; control diseases and pests; and increase beneficial microbes. But there has been relatively little scientific scrutiny of these claims, particularly in containerized plant production.

While some can improve plant growth, the effects of organic amendments have been generally inconsistent. An organic amendment that improves plant production at one location, may not do so in other regions with different plant materials and cultural conditions, and they may even have negative effects. They need to be compatible with the containerized production system. Synchronizing nutrient release from organic amendments with plant demand is a major challenge. Also, organic amendments can vary depending on season and source, and this can change the characteristics of the growing media. With the nursery, garden and horticultural production industries demanding a consistent, vigorous finished plant on a tight timetable, such variability must not interfere with the uniform rate of growth, plant nutrition or its form and aesthetics.

Some organic amendments can suppress soil-borne diseases; however, inconsistent results have hampered their widespread recommended use. Bonanomi et al. reviewed 2423 studies from 250 papers and found that organic amendments suppressed disease/pathogen populations in 45% of studies, had no effect in 35% of studies and increased disease/pathogen populations in 20% of studies. Furthermore, organic amendments were highly suppressive in only 12% of studies. Compost and organic wastes were most suppressive, each giving effective disease control in more than 50% of studies. The suppressive ability was pathogen-specific, i.e. an organic amendment that suppressed one pathogen, was ineffective or conducive to another. Noble and Coventry found that composts suppressed damping-off, root rots and wilts, and that this effect generally increased with application rate, with a minimum of 20% required, but suppression levels were variable. Factors such as the base substrate (e.g. peat), the feedstock, and the degree of compost decomposition (maturity) may influence suppression, and they recommended that biocontrol agent-fortified compost offer the best commercial opportunity (at about half the cost of a single fungicide drench).

A review examining 28 liquid organic amendments applied to field crops and pasture found no evidence that any of them improved crop yield. Though there was no reference to containerized studies, the author concluded that, when applied as recommended, there were inadequate amounts of nutrients, organic material or plant growth promoting compounds to enhance plant growth; though they may do so if applied at much higher rates. Perhaps this would be the case in containerized production.

Types of Organic Amendments

Locally sourced products that are waste products from other processes and industries would be ideal organic amendments. It is important to get the proportions right17 to deliver plants of equivalent quality and productivity as conventional production methods, though there may be potential trade-offs, such as higher disease incidence. Amendments need to be optimized for individual production systems.

Composts

Compost is produced from the breakdown of organic matter (plant or animal) by microorganisms under aerobic conditions. The starter feedstock; production methods; level of maturity/stability; and the resulting chemical, physical and biological features of compost all affect its ability to improve plant growth and/or suppress disease and make it impossible to draw general conclusions about the positive or negative effects of compost. For example, the suppression of *Verticillium* wilt of eggplant varied among eleven compost amendments, with five composts suppressing disease, three having no effect, and three enhancing disease! Amending with compost, which is generally cheaper than other growth substrates, could make production more cost effective, as long as plant quality was not compromised. If the compost also suppressed disease, unsterilized media could be used and fungicide use could be reduced; and due to slow release of nutrients, fertilizer inputs could be reduced, further decreasing production costs.

Plant Residues

The most promising plant residues for compost production are cotton waste, grape marc, green wastes and spent mushroom waste. Media amended with cotton waste compost at 20-50% generally improved plant growth, though the effect was species-dependent. With Australia's large cotton industry generating ample cotton waste, there is plenty of opportunity to use this inexpensive feedstock. Grape marc, the solid remains of the grape after pressing, is a low cost, widely available, wine-making by-product. Plant species responded variably to different grape marc compost rates, which may be due to different grape cultivars and processing methods, and different composting conditions, but this amendment showed promise. Green waste compost can be produced from any wood and vegetable residues but the composition affects the compost's properties and efficacy. Generally amended at 25-50%, improvement of plant growth is species specific and suppression of disease is disease specific. Soluble salt levels, nitrogen drawdown rate, pH, ammonium concentration, and slumpage need to be monitored. Council collections of green waste provide plentiful feedstock, but the challenge is to produce a reliable, consistent product from such variable material. Spent mushroom compost is the composted organic substrate discarded after mushroom production is complete. Improving plant growth over a range of species, it is essential to optimize the rate to balance improved growth and disease suppression with acceptable levels of soluble salts, pH and media shrinkage. With mushroom growers and production nurseries often in close proximity, the regular turnover of spent mushroom compost could be put to good use.

Animal Manures

While animal manure composts have long been used in the field, their use in container production is less studied. Cattle dung and swine waste composts have improved growth and suppressed disease in some species, and the feedstocks are readily available and inexpensive.

Municipal and Industrial Waste Materials

The most promising municipal and industrial waste materials for compost production are municipal solid waste, sewage sludge and paper mill waste. Municipal solid waste (MSW) compost, made from the organic part of residential kitchen and domestic garden waste, amended at up to 50% has improved the growth of numerous plant species. Levels of soluble salts, pH, heavy metals, organic pollutants, pathogens, sharps (glass, metal, plastic) and odours, as well as the effects of the variable feedstock, need to be monitored. Different plant species can respond differently, so MSW compost should be tested in individual production systems. Australia currently has numerous facilities for the production of MSW compost and continuous feedstock. The cost of commercially produced MSW compost is ~$35-41/m^3 plus transport costs (2006 prices). Sewage sludge compost (made from raw or treated sewage sludge) is rich in plant nutrientsbut the treatment procedure and particle size can influence efficacy. Levels of soluble salts and heavy metals, and manganese binding needs to be monitored, and the response of different species checked. The average cost of dry biosolids is $34 per tonne (2012 prices). Paper mill waste compost, made from the solid waste from effluent treatment from paper mill operations, has shown promise as an amendment but further work on more species is needed. Levels of heavy metals and organic contaminants need to be monitored.

Compost Teas

Compost tea is made by fermenting or 'brewing' compost in water, with or without aeration. Aerated compost tea ferments for only 12-24 hours, usually using an expensive 'brewers'. Non-aerated compost tea usually ferments for 7-14 days, and is cheap to produce. Compost tea contains soluble nutrients and a variety of microorganisms, and aeration seems unnecessary. The effect of compost tea on plant growth and disease suppression depends on the compost feedstock/production; the tea production conditions, such as the ratio of compost to water, duration, temperature and pH; application decisions such as the dilution ratio, application rate, equipment, tank mixing with other inputs, timing, frequency, storage and adjuvants; and the environmental conditions during application and use. It is important to tailor compost tea products to specific production systems.

Meat Blood and Bone Meals

Products derived from animal slaughterhouse wastes are widely used in field applications, but reports of their use in containerized production are scarce. They contain useful nutrients to stimulate plant growth.

Fish Emulsions

Fish emulsions, prepared by modifying the excess liquid from processed fish, provide nutrients for plant growth and act as a nutrient base for plant growth promoting rhizobacteria. Treatment of basil plants with fish emulsion resulted in undesirable flavours, so it is likely that application to edible crops is not acceptable; but there is scope for application to ornamental species and different species should be tested. Emulsions sourced from different fish species should be tested. The cost (adjusted to current prices) is approximately $16-$26/L.

Seaweed Extracts

Seaweeds allegedly enhance germination, root growth, chlorophyll synthesis, general plant vigour, biomass and yield; reduce transplant shock; increase nutrient uptake and plant nutritional quality; induce early flowering and fruit ripening, fruit production and improve marketable qualities of fruit; suppress disease; increase pest resistance; and improve tolerance to salinity and frost. Some effects have been reported only anecdotally by commercial organizations and their value in field production has been questioned. Also, negative results are rarely reported, which creates a bias towards drawing the conclusion from the published scientific literature that they are effective. A liquid seaweed extract, marketed as Maxicrop in numerous formulations, has shown some positive effects on plant growth and pest/pathogen suppression in some studies, but no effect in others. The efficacy of all Maxicrop products was questioned in a legal case in New Zealand. After hearing evidence from more than 40 scientists, the High Court ruled that Maxicrop products did not promote plant growth and provided insufficient nutrients and low levels of plant hormones whose practical significance was doubtful. The judgement was that

Maxicrop (all formulations) 'cannot and does not work', supported by a lack of efficacy in more than 140 field trials. No glasshouse trials were specifically discussed, so there remains the possibility that Maxicrop may have some effect in certain situations. However, there is some evidence that some seaweed extracts improve growth of some plant species in containerized production, probably due to plant growth regulators. Rates; and application method, timing and frequency need to be optimized; and any seasonal differences monitored. The cost (adjusted to current prices) is approximately $11-$32/L.

Bioinoculants
Bioinoculants, particularly mycorrhizal fungi and plant growth promoting bacteria and fungi, can improve plant growth and suppress disease, but the plant response is species-specific. More work is needed on the effect of applying only a single species or consortia; single, dual or multiple applications; and the timing, method and rate of application. The cost (adjusted to current prices) is approximately $11-$80/L.

Biochar
The potential of biochar, charcoal that remains when biomass is heated rapidly without oxygen (pyrolysis), for horticultural field crops has been reviewed recently, and it may be useful in containerized production. Biochar may improve the physical and chemical structure of growing media; provide nutrients; increase fertilizer use efficiency; enhance root growth; and suppress certain diseases. It may also bring environmental, social and economic benefits to growers in terms of carbon trading. But it may decrease efficacy of some pesticides, immobilize nutrients, increase heavy metal content, become water repellent, and promote certain diseases. There have been few studies using biochar in containerized production, and further research is warranted on response of different plant species, different feedstocks and production conditions. However, with the cost of biochar presently at ~$2000-2500/tonne, its use is likely to be uneconomic.

Vermicomposts
Vermicomposts, formed by the breakdown of organic residues by earthworms, have excellent structure, porosity, aeration and drainage properties; good moisture holding capacity; and contain nutrients in plant-friendly form, but vary depending on the feedstock. Vermicompost at 10-40% improved plant growth. Vermicomposts produced from animal manures need to be monitored for pH and soluble salt levels, and human pathogens. The cost of vermicomposts is highly variable depending on the feedstock, but they are (adjusted to current prices)3 approximately $265-$1050/t. Similarly, vermicompost liquid extracts (including tea) vary depending on the feedstock, so should be optimized for individual production systems.

Humic Substances
Commercial humic products are most commonly sourced from brown coals. The effect of humic products on plant growth is variable, so both the source and the rate of humic products should be assessed carefully and optimized for individual production systems.

Uncomposted Plant Parts
The most promising uncomposted plant parts are coir fibre/dust, and pine tree substrate. Coir dust, already widely used in Australia mainly as a replacement for peat due to its excellent physical properties, needs to be monitored for high electrical conductivity, low cation exchange capacity and nitrogen immobilization. Pine tree substrates, though readily available from extensive pine plantations, need to be monitored for phytotoxicity, nitrogen immobilization, shrinkage, and irrigation and nutritional management strategies. In general, plant-based organic amendments should be mixed with growing media at least two weeks before sowing to prevent phytotoxicity and growth inhibition.

Amino Acids and Organic Acids
While there are many products that are based on amino acids and organic acids sold as liquid fertilizers, there are few scientific reports on their effect on plant growth, and even fewer in containerized production, so no recommendations can be given.

Conclusion
While a variety of organic amendments are available to enhance plant growth in containerized production, further research is required to evaluate their efficacy and optimal application rate for a wide range of crops in containerized production for which there is currently very limited information. Further research is needed to determine the optimal base level nutritional benchmarks for all nursery crops so that organic amendments can be identified that can supply, or partly supply, these nutrients. In addition, matching nutrient charting and responsive fertilizer applications to nutrient release from organic amendments to determine the precise application timing of organic amendment products for optimal efficacy is highly desirable. Investigation of the use of blends and sequential application of organic amendments matched to crop requirements for optimal plant production, and studies on the shelf life of organic amendments under normal storage conditions would be useful. This would allow the development of NIASA Best Practice Guidelines for the use of organic amendments in containerized production, promoting consistent quality management within the industry. This would ensure that nursery operators are best equipped to add only useful organic amendments and maximize their production systems.

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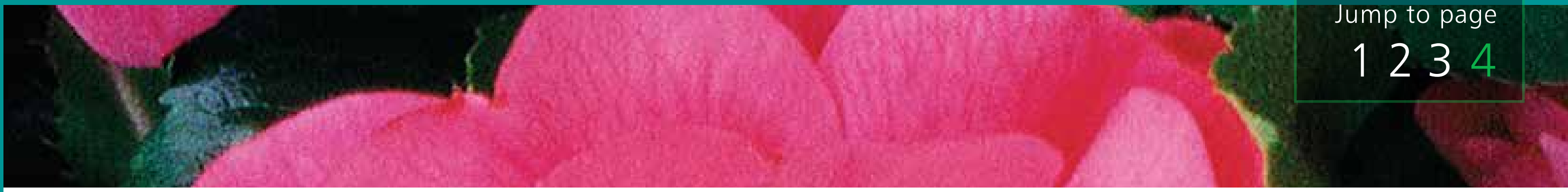
The full review is available online at www.ngia.com.au in addition to an expanded online version of this nursery paper incorporating a full reference list.



Jump to page
1 2 3 4

Table 1. Organic amendments used in containerized production, their features (verified by scientific publications), estimated costs adapted from 3, application rate, potential drawbacks and practical relevance.

Organic Amendment	Feature (verified by scientific publications)	Approximate Costs 2013	Application Rate	Potential Drawbacks	Practical Relevance[a]
Composts	Good nutrient source to plants Stimulates plant growth Suppresses disease Increases beneficial microbial biomass Increases flower and/or fruit set Increases root formation in cuttings Increases yield Improves media structure	Pelletised products: $105-$525/t Non-pelletised products: $7-$840/t	20-50% v/v but varies for different composts and plant species	• Can have detrimental effects on physical and chemical properties of media e.g. animal manures, green waste, MSW, spent mushroom, sewage sludge • Can have variability in properties between batches e.g. green waste, MSW, sewage sludge • Potential human health issues from pathogens and/or sharps e.g. animal manures, MSW • Potential plant health issues e.g. MSW • Unpleasant odours e.g. MSW • Heavy metals/Organic contaminants e.g. MSW, sewage sludge, paper mill sludge • Inconsistent efficacy • Effect can be species-specific	Ease: Variable, generally easy-moderate Costs: Minimal
Compost Teas	Stimulates plant growth Suppresses disease	Cost of compost: $7-$840/t; Then depends on aeration: Non-aerated: negligible Aerated: $250-$2000	A 1:1 to a 1:9 dilution, apply equivalent to 50 L/ha every 14 days; but requires optimization	• Potential human health issues from pathogens e.g. particularly nutrient-amended • Inconsistent efficacy • Need to be made fresh • Effect can be species-specific	Ease: Variable, generally easy-moderate Costs: Minimal-moderate
Meat, Blood and Bone Meal	Good nutrient source to plants Stimulates plant growth	Liquids: $11-$32/L Solids: $840-$1260/t	Liquids: unknown Solids: 1-5% v/v	• Unpleasant odours • Potential human health issues from pathogens? (BSE overseas)	Ease: Easy Costs: Minimal
Fish Emulsions	Good nutrient source to plants Stimulates plant growth Suppresses disease	$16-$26/L	0.5-2% v/v	• Unpleasant odours	Ease: Easy Costs: Minimal
Seaweed Extracts	Stimulates plant growth (hormones) Suppresses disease Increases beneficial microbial biomass	$11-$32/L	0.4-2% v/v (20% v/v for some species)	• Potential human health issues from pathogens e.g. composted seaweed • Inconsistent efficacy	Ease: Easy Costs: Minimal
	Increases flower and/or fruit set Increases root formation in cuttings Increases yield Reduces transplant shock Improves media structure				
Bioinoculants	Stimulates plant growth Suppresses disease Increases beneficial microbial biomass Increases flower and/or fruit set Increases yield Reduces transplant shock	$11-$80/L	Varies; Liquid: 30-60 mL/ 7.6 L container Solid (experimental) - colonized host plant roots, spores, mycelia, substrate): e.g. 2 g/hole of 50 spore/g inocula)	• Effect may be neutral or negative • Effect can be species-specific	Ease: Easy-moderate Costs: Minimal
Biochar	Moderate nutrient source to plants Stimulates plant growth Suppresses disease Increases beneficial microbial biomass Increases tolerance to water stress Improves media structure	$2500/t	1-10% v/v	• May decrease the efficacy of some pesticides • May negatively affect the availability of nutrients • May release bound toxicants such as heavy metals • If allowed to dry out, can become water repellent • Expensive due to lack of large scale production facilities	Ease: Difficult Costs: Minimal
Vermicomposts	Good nutrient source to plants Stimulates plant growth Suppresses disease Suppresses pests Increases beneficial microbial biomass Increases flower and/or fruit set Increases root formation in cuttings Increases yield Improves media structure	Liquids: $1-$21/L Solids: $265-$1050/t	Liquids: A 1-10% solution, applied as drench or spray equivalent to 150-200 mL/25 cm pot every 7 days; but requires optimization Solids: 10-40% v/v but varies for different vermicomposts and plant species	• Can have detrimental effects on physical and chemical properties of media e.g. animal manures	Ease: Variable, generally easy-moderate Costs: Minimal-moderate

Practical relevance concerns issues such as Ease (Ease of sourcing product/materials/equipment) and Costs (Costs to retrofit and/or apply the product)

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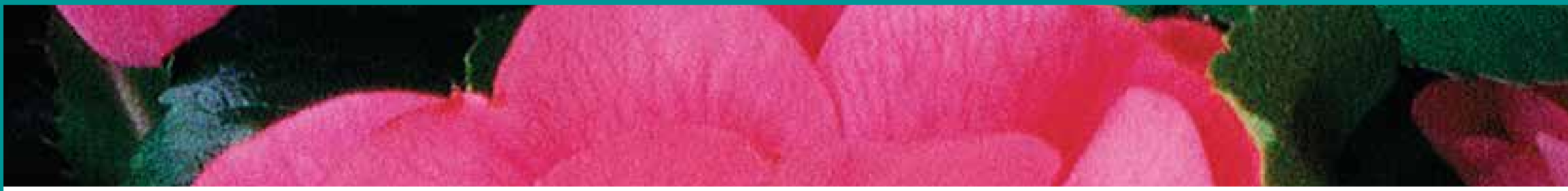

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