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Effects of different inorganic mulches on seed germination, weed biomass and plant growth

(Kesan beberapa jenis sungkupan bukan organik terhadap percambahan biji benih, biomas rumpai dan pertumbuhan tanaman)

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Keywords: inorganic mulch, seed germination, annual multi species

Abstract

This study investigated the effects of several types of inorganic mulch such as sand, gravel and quarry dust on seed germination of annual multi species and weed growth through direct sowing technique in the urban landscape. Results showed that sand, gravel and quarry dust gave significant effect on the percentage seed germination of annual multi species such as *Catharanthus roseus* (70%), *Coreopsis tinctoria* (20%), *Cosmos sulphureus* (95%), *Gomphrena haageana* (70%) and *Impatiens balsamina* (60%). The total weed biomass per quadrat was significantly less in the plots treated with gravel (15.12 g), quarry dust (21.56 g) and sand (30.45 g) mulches compared to the control, without mulch (64.41 g). The use of inorganic mulches inhibited germination of weed seeds in the soil which often competes with sown seeds in creating an annual multi species plant community through direct sowing. Multi species grown on various mulch types produce flowers at different time and period depending on the species which resulted in prolonging flowering (4 – 5 months) and attractive plant combination in the garden.

Introduction

The planting of annual multi species in the garden is a new approach needed to be explored in Malaysia. This planting concept is still in the introductory stage and faces challenges in terms of species selection, planting techniques and maintenance to suit Malaysia's climate (Zabedah et al. 2009). Current research that has been conducted at MARDI using direct seed sowing technique produced an attractive multi species community which flowered up to 4 months in the garden area. This will save cost of planting and require less maintenance (Hanim et al. 2010).

In general, at the early growing stage, a problem that often occurs is the competition of seed sown with existing weeds in the soil (Hitchmough et al. 2004; Hanim et al. 2010). Frequently, new emergence competes with the existing weeds during the germination stage. This will affect the survival and growth of the germinants/emergents. They eventually fail to survive due to competition. Similarly, self-sowing for the second generation shows an unattractive view during seed germination. To overcome this issue, the use of mulching materials, which inhibit the growth of weeds at the early stages of

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germination and at the same time allowing the sown seeds to survive, is necessary.

At present, the use of inorganic mulch materials such as gravel, sand and pebble for plantings has not been studied in Malaysia. Most of these materials are only used as materials for hard landscape, as a surface material for plant nursery, pedestrian elements and garden ornament elements (Cushnie 2009). Such characteristics can be used in the context of creating an annual multi species plant community which are sustainable, giving a longer flowering period and involving a number of life cycle growths in landscaping area.

In a landscape-horticulture perspective, some annual multi species plant community that are created through ecological approach (Dunnett and Hitchmough 2004) will produce flowers and seeds after approximately 1 – 2 months sowing such as *Zinnia elegans* (Hanim et al. 2010). This plant community will give an attractive visual impact with a wide range of flower colours blooming at different times and periods. However, after 4 – 5 months of planting, the established plant communities will look less attractive and should be cut, cleaned and removed (Hanim et al. 2013). Typically, the plant species community will regenerate by natural germination or 'self-sowing' of seeds which were produced by matured plants. During the period of germination, the landscape area often looks unattractive, monotonous and with less vegetation (Dunnett and Hitchmough 2004). Theoretically, the use of aesthetic inorganic mulches such as gravel, sand and quarry dust can provide interesting views of the community during the regeneration process or forming new community of plants.

This study was conducted to determine the effects of different inorganic mulch materials on seed germination and plant growth. These involved investigating different types of inorganic mulch materials include sand, gravel and quarry dust on the germination, emergence and growth of multi species annual plant communities in urban landscapes.

Materials and methods

The experiment was conducted at the Ornamental Garden, MARDI, Serdang from January 2011 to May 2011. The site was flat and exposed to full sunlight. During site preparation, in January 2011, weeds were sprayed with a glyphosate herbicide and removed manually to achieve plant free conditions. Soil surfaces were then mowed to a depth of 300 mm and levelled.

A total of 16 treatment plots, 60 cm x 60 cm each were set up using four different treatment mulches, i.e. T1 = Soil (without mulch) as the control, T2 = Sand mulch, T3 = Gravel mulch and T4 = Quarry dust mulch. A 30 mm layer of treatment mulch was distributed in each treatment plot. A fully randomised complete block design involving four replicates of each treatment, arranged randomly in four rows and four columns was set up. A total of nine species of annuals were selected on the basis of their attractiveness when blooming, bloom duration and adaptation to urban tropical climate in Malaysia (*Table 1*).

The seeds were collected locally from experimental landscape plots between July and September 2010 at MARDI, Serdang. Seeds which were not available naturally were obtained from commercial nursery. These included *Cosmos bipinnatus* and *Gomphrena haageana*. In this study, annual seeds with five seeds of each species were mixed and sown in each treatment plot (125 seeds/m^2) to create a multi species community. Watering was carried out using mist irrigation system.

Permanent quadrates (50 x 50 cm) were established for data collection. Within each quadrate, seedling emergence, plant numbers, day to first flowering, peak flowering and biomass data were collected. The number of each species within each quadrate was recorded in February 2011. In all quadrats, the weed biomass was harvested in March 2011. At the end of full

Table 1. Species in the sowing mix

Species	Family	Plant type/habitat*	Flower colour
Catharanthus roseus	Apocynaceae	Annuals/dry to wet areas	Pink
Celosia argentea	Amaranthaceae	Annuals/dry areas	Pink
Coreopsis tinctoria	Asteraceae	Annuals/wet to dry areas	Yellow with maroon centres
Cosmos bipinnatus	Asteraceae	Annuals/dry to wet areas	White, pink
Cosmos sulphureus	Asteraceae	Annuals/dry to wet areas	Yellow
Gomphrena haageana	Amaranthaceae	Annuals/dry to wet areas	Orange
Impatiens balsamina	Balsaminaceae	Annuals/wet areas	Red
Zinnia elegans	Asteraceae	Annuals/dry to wet areas	Yellow
Zinnia linearis	Asteraceae	Annuals/dry to wet areas	Golden yellow

*Under typical garden condition

growing season (when most of the species were at their peak bloom), all plants of each species were harvested from each quadrat to provide dry weight of individual species. Soil-mulched moisture was recorded using moisture meter (Takemura DM-15) field equipment.

Statistical analysis

Numbers of seedling emergence from the experiment were converted to percentages (seeds germinated/emerged as a percentage of those sown). Kolmogorov-Smirnov tests indicated that the count data were not normal and could not be adequately improved by transformation, thus the analysis was undertaken using non-parametric tests (Dytham 2003). The Kruskal-Wallis test was used to compare the significant differences between the mulch treatments. When a Kruskal-Wallis test gave a significant result ($p < 0.05$), a Mann-Whitney *U*-test was undertaken to allow comparison and ranking of means. Statistical analysis was undertaken using SPSS version 15.

Results and discussion

Effect of mulching on seed germination

The species varied in their emergence patterns. In general, most of the annual species germinated both in sand and gravel mulches (with the exception of *Coreopsis tinctoria* and *Zinnia linearis*), quarry dust (with the exception of *Coreopsis tinctoria* and *Impatiens balsamina*) and soil without mulching (*Table 2*). Maximum germination was achieved in sand mulch (*Cosmos sulphureus*, 95%; *Gomphrena haageana,* 70%) and gravel (*Catharanthus roseus*, 70%).

In this study mulching had a significant influence on seed germination. In general, the seeds of annuals had high germination percentage, especially on sand mulch compared with other treatments. High percentage of germination in sand was due to its physical characteristics such as high water holding capacity, low resistance to root penetration and also efficiently holding the sown seeds from penetrating too deep (Hitchmough et al. 2001; Tobe et al. 2005). A similar study found that forbs and grasses seeds, which were sown on sand, resulted the highest in germination but lowest on brick rubble (Hitchmough et al. 2001).

The use of gravel and quarry dust mulches caused a low germination percentage of small size seeds or species that are sensitive to moisture stress such as *Coreopsis tinctoria* and *Zinnia linearis* (Winkel et al. 1993). These mulching layers may have caused seed sown to stick on the surface and reduce seed-soil contact for germination. Observation showed that some of the seedlings germinated under gravel mulch were etiolated. This could have been

Table 2. Maximum percentage emergence of annual plants on the different mulches

Species	Soil (without mulch)	Sand mulch	Gravel mulch	Quarry dust mulch	*p value*
Catharanthus roseus	30.0a	30.0a	70.0b	30.0a	0.028*
Celosia argentea	40.0a	10.0a	30.0a	25.0a	0.419^{ns}
Coreopsis tinctoria	5.0ab	20.0bc	0.0a	0.0a	0.016*
Cosmos bipinnatus	20.0a	55.0a	30.0a	0.0a	0.059^{ns}
Cosmos sulphureus	65.0b	95.0c	50.0a	35.0a	0.007**
Gomphrena haageana	30.0bc	70.0c	20.0a	5.0a	0.012*
Impatiens balsamina	20.0bc	60.0c	10.0a	0.0a	0.014*
Zinnia elegans	20.0c	15.0a	5.0a	10.0a	0.056^{ns}
Zinnia linearis	5.0c	5.0a	0.0a	5.0a	0.392^{ns}

Different letters within rows indicate significant differences (Kruskal-Wallis test) between mulch type
*p = 0.05; **p = 0.01, ns = not significant

due to lack of light as a result of being obstructed by a thick layer of gravel.

Effect of mulching on weed biomass
As a result of the early invasion of some individual weeds in soil and suppressed by mulch treatment, the weeds were harvested (March 2011) as a total biomass to generate growth data. As shown in *Figure 1,* mean total dry weight of weeds per quadrat (0.25 m^2) was significantly different between treatments (p = 0.043, Kruskal-Wallis test).

In general, sand, gravel and quarry dust mulches could inhibit weed growth when compared to control plots. Gravel mulch gave the lowest weed biomass compared to sand and quarry dust mulches (*Figure 1*). It also inhibited small size seeds and weeds to germinate. It has been reported earlier that using inorganic mulching in a sufficient depth such as gravel layer (1 – 5 cm) prohibits emergence of weeds (Winkel et al. 1993; Chalker-Scott 2007; Nagase et al. 2013). In landscape practice, direct seed sowing without mulch may not be suitable because the seeds will compete with weeds during germination process. This requires more labour and high maintenance cost (Hitchmough 2011). Therefore, the use of inorganic mulch will inhibit weed invasions and reduce the cost of weeding in the garden spaces.

Effect of mulching on plant growth
Flowering times Flowering of multi species (*Figure 2*) commenced at different times and the peak flowering period ranged from about 35 – 81 days. *Gomphrena haageana* and *Cosmos bipinnatus* started to flower earlier; *Celosia argentea, Cosmos sulphureus* and *Zinnia linearis* were the late flowering species. *Coreopsis tinctoria* took longer time to bloom. These data verified that the annual multi species community could extend the flowering period in urban landscapes.

Plant height Mulch types had no significant effect in many annual plants in terms of plant height (*Figure 3*). However, between species, the highest plant was recorded for *Celosia argentea* in all mulch treatments although plant height of each individual species was not significantly influenced (p <0.05, Kruskal-Wallis test) by the treatments. The plant height of *Catharanthus roseus, Cosmos bipinnatus* and *Zinnia elegans* were greater on gravel mulch compared on the sand mulch, quarry dust mulch and control plots at the final growing stage.

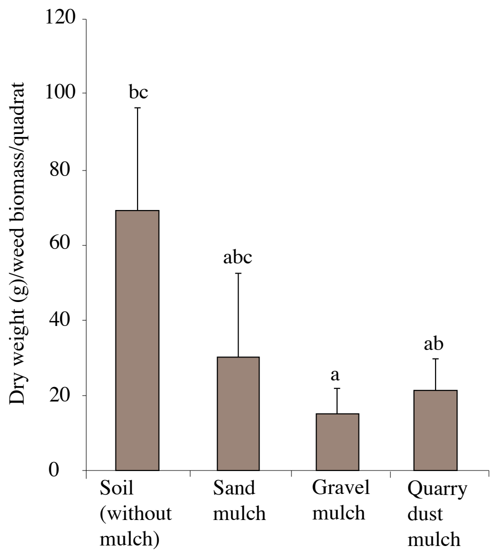

Figure 1. Mean total dry weight of weeds between mulch treatment. Bars labelled with different letters are significantly different at p = 0.05 (Kruskal-Wallis test, pairwise Mann-Whitney U-tests). Error bars represent 1 S.D.

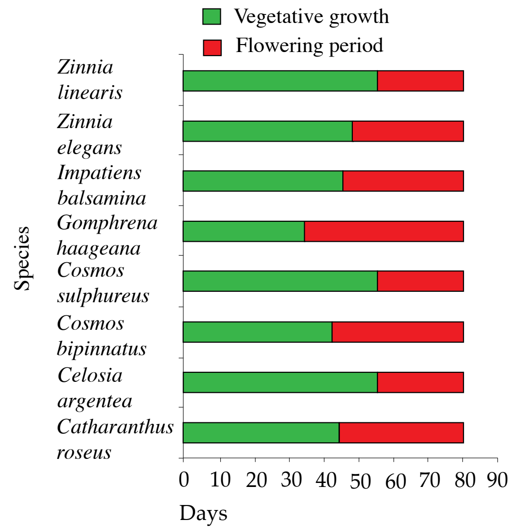

Figure 2. Vegetative growth and time of flowering of each species

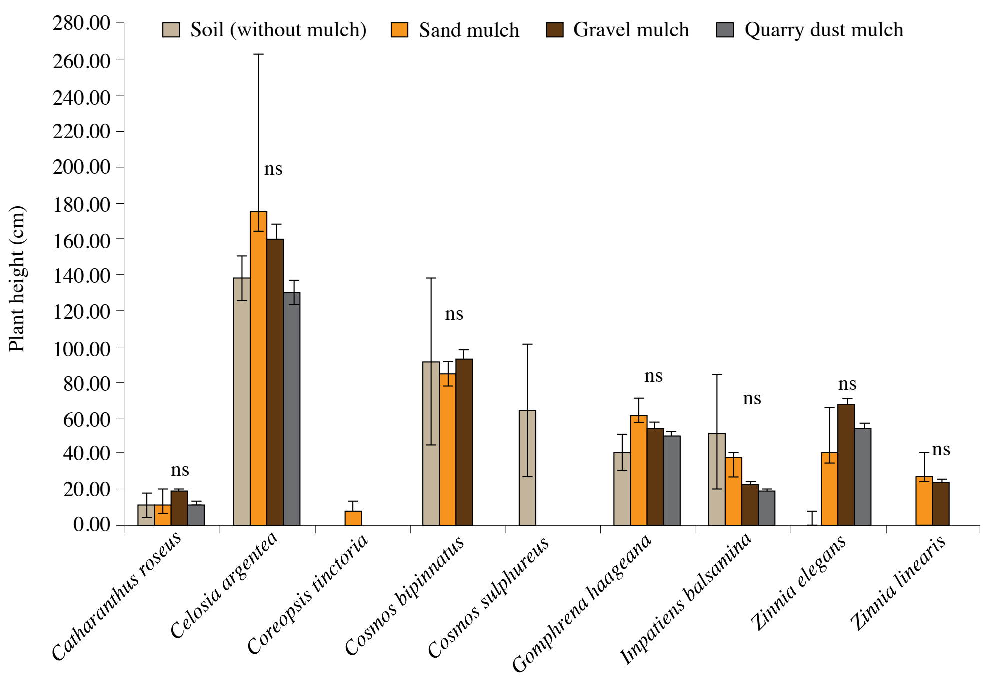

Figure 3. Effect of mulch type on plant height of individual species in May 2011. Error bars represent 1 S.D. Significant differences (Kruskal-Wallis test) between mulching types are indicated by: ns, not significant. Coreopsis tinctoria and Cosmos sulphureus were excluded from analysis due to insufficient data

Plant biomass Mulching had no marked influence on the total mean dry weights of annual species ($p = 0.229$; Kruskal-Wallis test) as shown in *Figure 4*. Total dry weight (as total mean of all species) was greater on gravel mulch (144.26 g) and quarry dust mulch (143.57 g) compared on the sand mulch (56.04 g). The effect of mulching type on plant biomass was also analysed in terms of individual species, as shown in *Table 3* using the Kruskal-Wallis test. All species (with the exception of *Coreopsis tinctoria*) did not show any significant difference in production of biomass at $p = 0.05$. The biomass of *Celosia argentea* was the highest in all mulch treatments as compared to other species.

In general, sowing of multi species on different mulch types produced flowers at different periods and time depending on the species. Mixing of multi species produced diverse plant heights with interesting structure in the experimental plot (*Figure 3*). However, mulch types gave different effects on the biomass of each individual species. For example, *Celosia argentea* and *Zinnia elegans* had the largest dry weight on quarry dust mulch while *Gomphrena haageana* on gravel mulch. However, *Catharanthus roseus* did not show a significant difference in plant height.

In terms of plant growth as expressed by total plant dry weight, mulch types did not have a significant effect on growth of multi species plant community. Plant growths were greatest on gravel mulch and quarry dust mulch than those growing on sand mulch and without mulch. This may be due to low seed germination and their

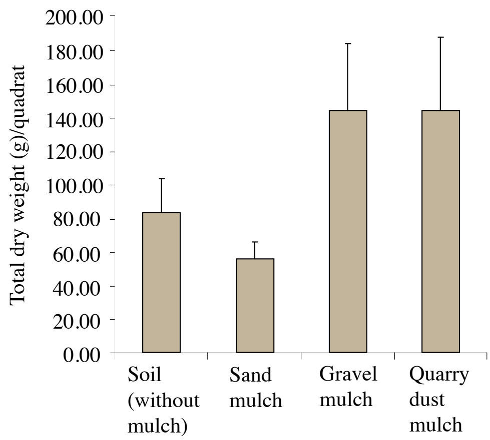

Figure 4. Effect of mulching on total mean dry weight of annuals (g) at final harvest. Error bars represent 1 S.D. They are not significantly different at p = 0.05 (Kruskal-Wallis tests)

Table 3. Dry weight (g) of individual species of annual plants on the different mulches

	Soil (without mulch)		Sand mulch		Gravel mulch		Quarry dust mulch		*p* value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Catharanthus roseus	0.86	0.51	0.30	0.26	1.16	0.68	0.66	0.31	0.096 ns
Celosia argentea	61.54	72.30	113.10	56.55	122.06	69.45	176.89	122.15	0.214 ns
Coreopsis tinctoria	0.00	0.00	0.95	0.89	0.00	0.00	0.00	0.00	0.017 *
Cosmos bipinnatus	18.81	13.30	14.32	6.11	17.38	8.73	2.48	1.24	0.058 ns
Cosmos sulphureus	7.48	3.74	0.00	0.00	0.00	0.00	0.00	0.00	0.392 ns
Gomphrena haageana	1.56	1.01	8.58	1.09	9.54	8.70	8.16	4.08	0.097 ns
Impatiens balsamina	4.93	3.94	2.36	1.49	2.91	1.46	0.26	0.13	0.492 ns
Zinnia elegans	1.04	1.17	3.04	1.76	9.97	4.99	15.04	10.76	0.805 ns
Zinnia linearis	0.00	0.00	0.51	0.26	0.12	0.06	0.00	0.00	0.542 ns

Significant differences between mulch type (Kruskal-Wallis test) are indicated by asterisks; ns = not significant; $*p = 0.05$

response to the below ground competition (Brenda and Robert 1997) for nutrient, water and light to increase their size (Grime 2001). This highlights that the seedlings were able to respond to some degree to the soil below the mulch where weed competition was prohibited by gravel or quarry dust mulches.

Conclusion

This study has shown that inorganic mulching had significant effect on germination in 5 of 9 annual species studied: *Catharanthus roseus, Coreopsis tinctoria, Cosmos sulphureus, Gomphrena haageana* and *Impatiens balsamina*. This finding showed that mulch can give a different response and significant effect on percentage of germination in annual seeds. It also demonstrated that inorganic mulches gave an aesthetical value to the garden in urban landscapes. Sand/gravel proved to be successful mulch for seed germination, suppressed weed and at the same time did not inhibit the growth of annual multi species. In this case, inorganic mulches acted as physical barriers by suppressing weeds, which allowed the emerged seedlings to access the sub-surface, less weed competition and allow the plants to grow profusely with less maintenance. As a counterpoint to this, using inorganic mulch is a practical approach during seed germination and plant growth of annual multi species in urban landscapes.

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Abstrak
Kajian ini menilai keberkesanan beberapa jenis sungkupan bukan organik iaitu pasir, batu kelikir dan batu kuari terhadap percambahan biji benih tanaman bunga semusim dan pertumbuhan rumpai melalui teknik penyemaian terus di kawasan landskap bandar. Keputusan kajian mendapati pasir, batu kelikir dan batu kuari memberi kesan signifikan ke atas peratus percambahan biji benih spesies bunga-bungaan semusim seperti *Catharanthus roseus* (70%), *Coreopsis tinctoria* (20%), *Cosmos sulphureus* (95%), *Gomphrena haageana* (70%) dan *Impatiens balsamina* (60%). Jumlah biomas rumpai per kuadrat adalah kurang, berbeza secara signifikan dalam plot yang dirawat dengan sungkupan batu kelikir (15.12 g), sungkupan batu kuari (21.56 g) dan sungkupan pasir (30.45 g) jika dibandingkan dengan kawalan, tanpa sungkupan (64.41 g). Penggunaan sungkupan bukan organik telah menghalang percambahan biji benih rumpai di dalam tanah yang sering bersaing dengan biji benih yang disemai untuk mewujudkan komuniti pelbagai spesies tanaman bunga-bungaan semusim melalui penyemaian terus. Pelbagai spesies yang ditanam dengan pelbagai jenis sungkupan mengeluarkan bunga-bungaan pada masa dan tempoh yang berbeza-beza bergantung kepada spesies dan ini memberi tempoh pembungaan yang panjang (4 – 5 bulan) dan kombinasi tumbuhan yang menarik dalam taman.

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