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DIRECT LEACHING OF SPENT MUSHROOM COMPOST (SMS) FOR SEEDLING CULTURE

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ABSTRACT: Seedling culture in chemically active media presents challenges due to phytotoxicity associated with high contents of soluble salts. A greenhouse study was conducted to investigate the effect of direct leaching on the suitability of spent mushroom substrate (SMS) as a seedling nursery media. Germination, growth and nutrition characteristics of cucumber and hot pepper were compared among leached SMS (SMSL), unleached SMS (SMSU) and promix (PM) in a factorial design with three replicates. Seedling media significantly affected germination of hot pepper seeds, which was reduced to < 30% for the SMSU. Cucumber seeds showed > 90% germination across all media used. Across both crops, over the growing period, plants grown in SMSL showed consistently, and in most cases significantly ($P< 0.05$) greater heights and stem diameters than those in the SMSU and PM. Chlorophyll index (CI) was greatest for the unleached SMS and lowest for promix. At no time was there a significant difference in CI between the leached and unleached treatments. A similarly lower dry matter was shown for the unleached treatment compared to that of the others. Leached SMS resulted in either better or equal growth responses to PM, with the added advantage of not having to be fertilized.

Keywords: spent mushroom substrate, seedling growth, chlorophyll index, incubation media

INTRODUCTION

Nursery production of important horticultural crops has been a common practice and continues to play a major role in providing vigorous, disease-free plants towards sustainable crop production. Root medium's physical and chemical properties affect seedling quality and hence field performance. Nappi and Barberis (1993) indicated that an ideal potting medium should be free of weeds and diseases, heavy enough to avoid frequent tipping over and yet light enough to facilitate handling and shipping. The media should also be well drained, yet retain sufficient water to reduce frequent watering. Other parameters to consider include cost, availability, consistency, and stability over time. Special attention should also be given to media chemical properties such as pH, electrical conductivity (EC), cation exchange capacity (CEC), carbon to nitrogen (C:N) ratio as they all play vital roles in seedling survival.

Commercial peat and peat-based products have dominated the market for seedling media due to their desirable properties including high water holding capacity (WHC), high porosity and low bulk density (BD) allowing developing roots ease of penetration into the medium as well as ease of removal from the seedling tray at transplanting. Such media are only limited by poor fertility, which traditionally would be supplemented. In recent times, because of increasing demand and rising cost for peat, as well as questionable availability related to environmental constraints (Abad et al., 2001), the search for alternative high quality, low cost substrates is increasing.

Selection of appropriate media components is critical to successful production of transplants. Spent mushroom substrate (SMS) has been proposed as a stable organic based material with great potential as a seedling media substrate or component (Ahlawat and Sagar, 2007). Romaine and Holcomb (2001) indicated that fresh SMS properly sized by sieving, leached of salts and blended with vermiculite acts as an ideal growth medium for plants and offers exceptional aeration, porosity, WHC and nitrogen (N). It acts as a conceivable alternate to peat in soilless media. SMS and other composts possess phytotoxic properties that may limit and affect seedling growth. Electrical conductivity has been identified as potentially the most significant of these properties (Eudoxie and Alexander, 2011; Sanchez-Monedero et al., 2004). It has been shown that salts decline substantially and have no detrimental effect on plant growth within a week after planting with regular watering (Romaine and Holcomb, 2000). However, the response may vary dependent on crop type. Additionally, leaching of salts also reduces SMS fertility, which may cancel a most significant advantage this seedling media possesses over peat-based products. The extent to which direct leaching influences seedling germination and response remains mostly unanswered. This paper reports on a trial that sought to determine the potential for direct leaching of SMS (in trays) and its effects on seedling germination and growth in unfertilized culture.

MATERIALS AND METHODS

Spent mushroom substrate was obtained from a local commercial mushroom operation, with the major substrates being sugarcane bagasse and poultry litter. The SMS was air dried and along with the commercial peat (Premier Promix BX, Premier Horticulture Inc., Quakertown, PA), screened to pass a 6.25 mm mesh. Spent mushroom substrate and PM were added to 72-well seedling trays to make three treatments; PM, SMSU and SMSL. The latter was prepared by supplying water to the trays until drainage EC was < 2 dS/m. Media treatments were seeded to two crops (cucumber and hot pepper) in a 3×2 factorial design with three replicates.

The treatments were laid out in a completely randomized pattern in an unheated Perspex covered greenhouse. Germination was performed under ambient conditions protected under shade cover allowing 60% sunlight. Trays were exposed to natural sunlight 72 hrs after germination. Seedling trays were irrigated daily with a pressurized spray bottle. Additionally, the peat treatments were fertigated once weekly with water containing a soluble fertilizer (Bayfolan Forte) at 50 mg N/L. Germination percentage was determined by counting the number of germinated seeds after 72 hrs and 14 days for cucumber and hot pepper, respectively. Plant growth and quality parameters; plant height, diameter and CI were measured from the first week after germination and at weekly intervals throughout the study. Plant height was measured with a ruler, diameter with a digital caliper, 1 cm from the base of the stem (only for cucumber), and CI with a field scout chlorophyll meter (CM 1000 Spectrum Technologies, Inc. Plainfield, IL). Upon attaining commercial transplanting size, four and five weeks for cucumber and hot pepper respectively, 20 plants, including roots, were removed from the middle of the tray, excess media washed off and weighed to determine fresh weight. Plants were further dried in a force draft oven at 65° C for 48 hrs to determine dry weight.

Electrical conductivity and pH of the media were measured in a water extract (media: distilled water ratio of 1:5) (TMECC, 2001). For water soluble nutrients, phosphorus (P) and total available nitrogen (TAN) were determined colorimetrically. Potassium (K) was measured by atomic absorption spectrophotometry. Total N was determined by the Kjeldahl method according to

Bremner (1996) and total organic carbon (TOC) by loss on ignition at 430° C for 24 hrs (Navarro, et al., 1993). The C/N ratio was determined mathematically from the percentages of its components. Physical properties of each treatment were determined by using procedures described by TMECC (2001). Porosity (TPS) was determined by saturation under zero tension. The mass of water at saturation was divided by the bulk volume. Aeration porosity or air space (AS) was similarly measured after saturation. Samples were left to drain at 4 kPa on a tension table for 48 hrs. Bulk density (BD) was determined by dividing the oven dried weight of each substrate by its bulk volume. Water holding capacity (TWHC) was measured gravimetrically, after saturating and allowing substrates to drain naturally under the influence of gravity.

Media evaluation was subjected to repeated measures ANOVA (GenStat Discovery Edition 4), with means separated by Fisher's protected LSD test at $p < 0.05$.

RESULTS AND DISCUSSION

Media Properties

Spent mushroom substrate pH changed slightly after leaching, increasing from 6.32 to 6.40 (Table 1). The SMS media was slightly acid, whilst the peat was moderately acid and outside the ideal media range (Abad et al., 2001). The low pH posses a fertility concern, as macronutrients are not readily available at this pH (Jones and Jacobsen, 2005). However, peat products are generally devoid of nutrients as indicated in Table 1 and require supplemental nutrition to ensure vigorous healthy transplants, a cost that potentially can be alleviated through the use of composts including SMS. Leaching resulted in a large reduction in the EC of the SMS, although the value remained outside the upper acceptable range. A target EC of < 2 dS/m was used as Brady and Weil (2008) indicated that most plants can tolerate salt concentration in that EC range without growth limiting effects. The commercial peat product was the only media that satisfied the acceptable criteria. Leaching also reduced the primary nutrient concentrations in the SMS, but the values remained well above the acceptable range. In this case the fertility of the SMSL was still superior to that of the PM. Carbon to Nitrogen ratio was higher for the PM compared to that of the SMS treatments. The values for the SMS treatments suggest that this media may still be active and may continue to decompose during use. Bernal et al. (1998) indicated that a C:N ratio of < 12:1 indicates maturity and such compost shows little further active decomposition. However, decomposition should be minimal because of small quantities used and short incubation period.

Physical properties were similar across all three media with only BD being in the acceptable range. Air space was very low for all media, whilst WHC was moderate. The two latter properties are not expected to present a limitation because the root volume is very small allowing for gaseous exchange throughout the root zone, and the watering regime ensured that seedlings were adequately watered.

Germination and growth parameters

Seed germination was non-significantly ($P > 0.05$) different across the three media for cucumber but SMSU resulted in a significantly ($P < 0.05$) lower germination for hot pepper (Figure 1). Germination was reduced to < 30% for the SMSU, although it continued after the 14 day cut off period. The seeds were inhibited by phytotoxic properties in the SMS. This was alleviated in the

SMSL media, which supports the hypothesis that EC was the main source of phytotoxicity. Medina et al. (2009) reported reduced seed germination with increased compost composition in the media, with the reason being high salinity. Leaching not only alleviated the salinity but also apparently stimulated seed germination, with the SMSL treatment recording a higher germination percentage. Tomati et al. (1993) showed that composted materials favour rooting, rooting initiation and root biomass development. Visually, germination of hot pepper seeds occurred first in the SMSL media, one to two days before those in the PM.

Seedling diameter increased with time for all media. There was no significant ($P > 0.05$) difference between PM and SMSL, whilst the SMSU showed significantly lower plant diameters at two and three weeks after germination (Figure 2). Compost phytotoxic effects were evident and restricted plant growth and development. Seedling growth rate was lower only for SMSU. Eudoxie and Alexander (2011) reported similar effects for unleached SMS sown to tomatoes. A similar trend was observed for plant height for both crops (Figure 3). The performance of the SMSL compared to that of the SMSU supports the hypothesis that salinity was the main phytotoxic property and reducing media EC to < 2 dS/m resulted in alleviating that limitation. Additionally, the SMSL was not fertilized, indicating that inherent fertility was satisfactory for the seedling incubation period. This is a significant advantage which would save the grower not only fertilizer but labour and operational costs.

Chlorophyll index, which is strongly correlated to tissue N content (Wood et al., 1992), showed an opposite pattern to the plant growth indices across seedling media. Unleached SMS resulted in the highest CI in cucumber, but the values were non-significantly different from SMSL (Figure 4). Table 1 shows that both SMSL and SMSU contained high levels of primary nutrients including N, which would have improved plant nutrition status. At week 4 the fertilized PM recorded the same CI as the SMSU, the former media showing an increasing trend, whilst the latter decreasing. Weekly fertilizer applications eventually increased CI for the PM treatments whilst fertility was gradually reduced in the two SMS media, because of plant uptake and also leaching associated with watering. Unleached SMS resulted in significantly lower CI for hot pepper than the other media. The lower readings may be attributed to stunted growth and phytotoxic effect associated with the SMSU media. For hot pepper, SMSL showed the highest CI, but the value decreased with time similarly to that of cucumber.

Dry matter showed similar variation among the three media for both crops. Unleashed SMS resulted in significantly ($P < 0.05$) lower dry matter than PM and SMSL, the latter two being non-significantly different.

CONCLUSION

Direct leaching lowered SMS media EC, whilst retaining adequate fertility. Germination percentage as well as growth indices were similar for SMSL and the fertilized PM, both being significantly higher than the SMSU. Seedling growth, especially hot pepper, was affected by SMSU media, although chlorophyll index was higher for the SMS treatments in both crops. Leached SMS was shown to produce similar or better quality seedling than fertilized PM. Additionally, EC was shown to be an effective diagnostic measure of compost suitability as seedling media.

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Table 1 Selected properties of seedling media

Property	PM	SMSU	SMSL	IM[a]
pH	5.15	6.32	6.40	5.3 - 6.5
EC (dS m^{-1})	0.43	9.53	1.84	< 0.5
C:N Ratio	123	27.3	28.5	20 - 40
TAN (mg kg^{-1})	17.3	608	211	100 - 199
P (mg kg^{-1})	106	660	379	6 - 10
K (g kg^{-1})	0.26	4.73	1.36	0.15 - 0.25
BD (g cm^{-3})	0.15	0.25	0.25	< 0.40
AS (%)	7.79	8.18	8.18	20 - 30
WHC (%)	42.5	48.5	48.5	60 - 80

PM = promix, SMSU = unleached spent mushroom substrate, SMSL = leached spent mushroom substrate, IM = ideal media, EC = electrical conductivity, TAN = total available nitrogen, BD = bulk density, AS = air space, WHC = water holding capacity

[a] Ideal media according to Abad et al. (2001)

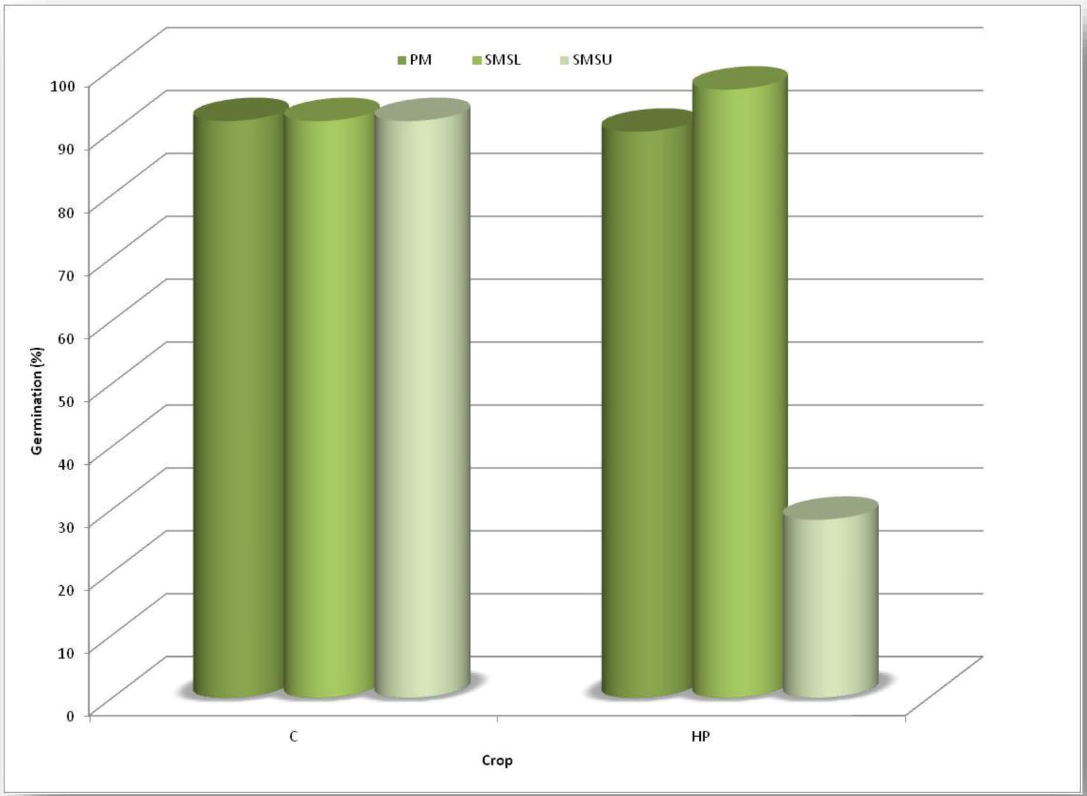


Figure 1. Seedling germination for cucumber (C) and hot pepper (HP) planted in promix (PM), leached SMS (SMSL) and unleached SMS (SMSU)

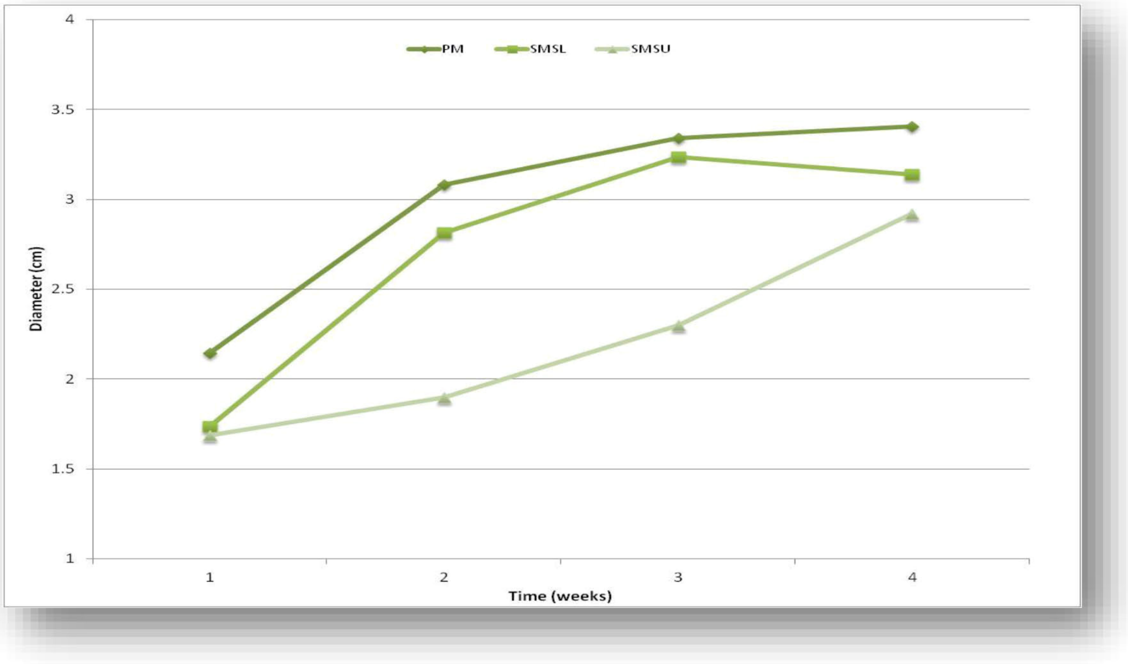


Figure 2. Influence of seedling media on cucumber plant diameter.

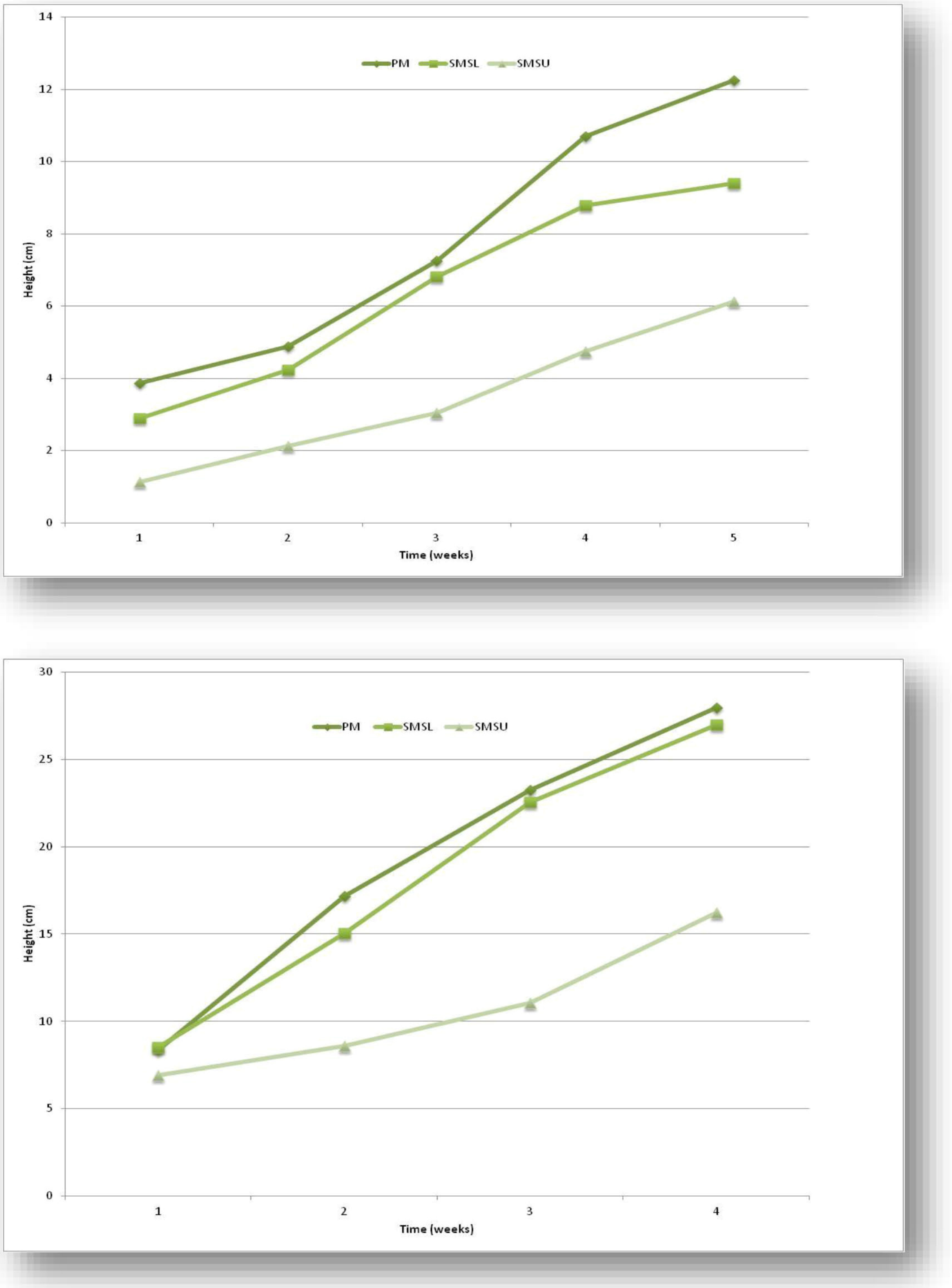
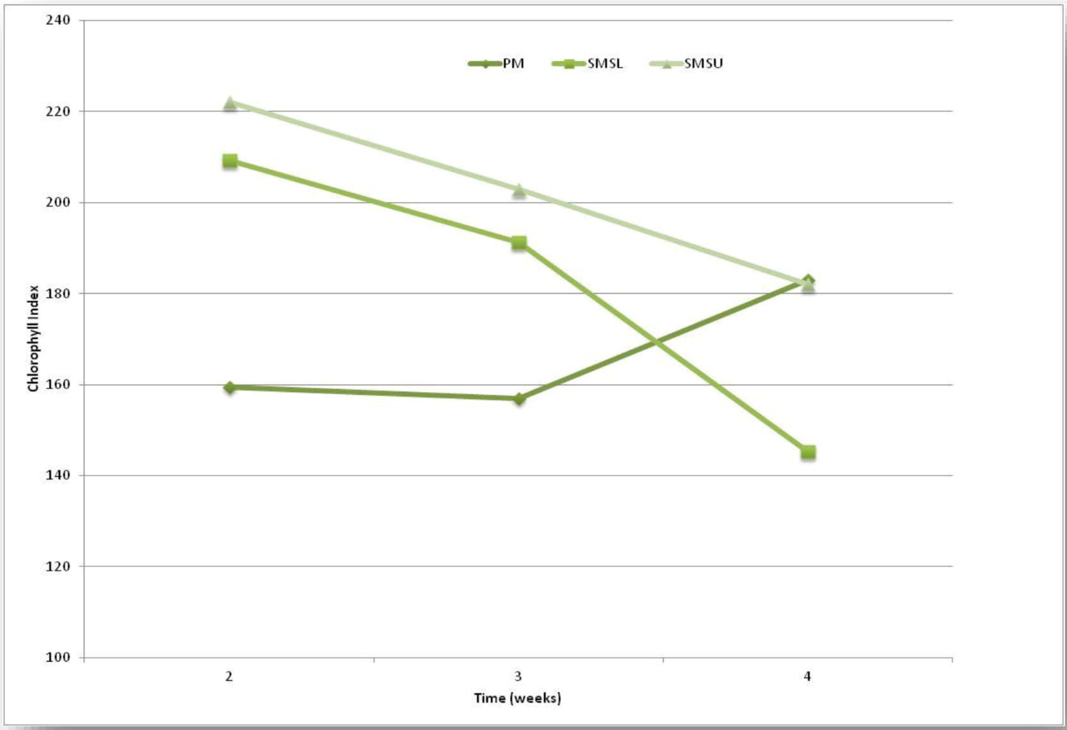


Figure 3. Influence of seedling media on hot pepper (A) and cucumber (B) plant height.



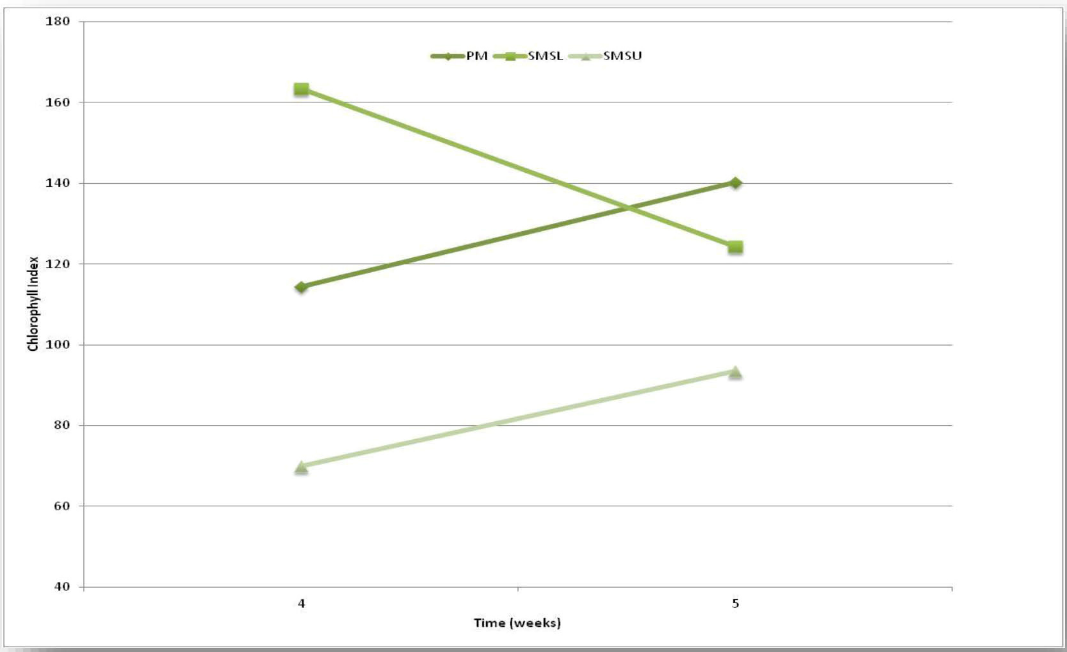


Figure 4. Influence of seedling media on cucumber (A) and hot pepper (HP) chlorophyll index.

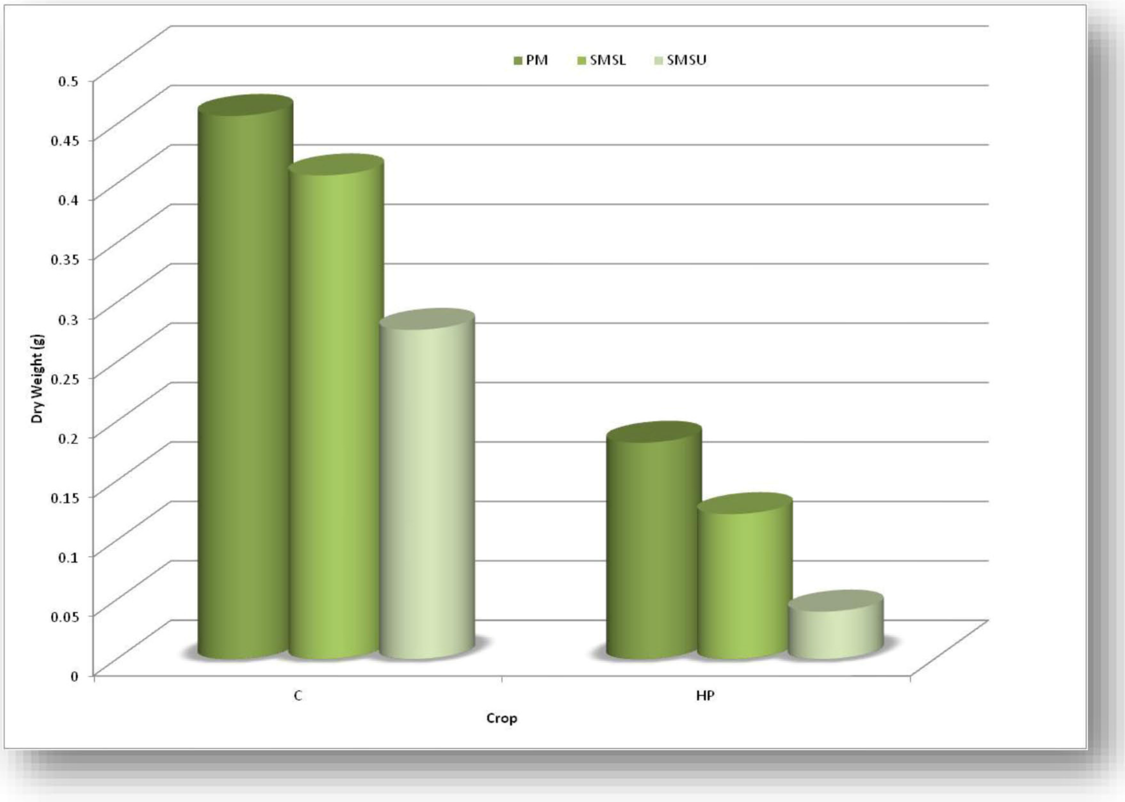


Figure 5. Influence of seedling media on cucumber(C) and hot pepper (HP) dry weight.