Rooting Medium and Fertilization on the Growth of Chayote (*Sechium edule* J. S.) Planting Material in Nursery

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Abstract

Chayote seedlings in nursery stage were grown in three different rooting media, and three different fertilizers at three different rates were applied to them. Vine length, leaf area, and fresh and dry plant weight were recorded 30 days later. Photosynthetic rate, transpiration rate and ambient parameters were monitored on selected dates. Composite leaf samples were taken for mineral analysis. All three main factors had a statistical impact on biomass accumulation, while their impact on leaf area or vine length was differential. Shortest vines grew in fritted clay, regardless of fertilizer or fertilizer doses. Greatest mean vine length was registered in seedlings grown in peatmoss or lombricompost using urea in the first case and polyfeed in the later. Maximum plant dry weight was observed in plants grown in peatmoss, when using urea. Concomitantly, lowest mean photosynthetic rates were measured in plants grown in fritted clay, regardless of fertilizer or fertilizer doses. Indeed in this case the rates did not exceed 28 or 21% corresponding to plants grown in peatmoss or lombricompost, respectively. Strong differences in leaf temperature among treatments, and an inverse relation between leaf temperature, and photosynthesis and transpiration rates was typical, indicating a tight stomatal control over gas exchange to prevent overheating and desiccation. Mean relative water content in young vines was 90%; mass to surface area ratio on a dry weight basis was estimated at 3.447×10^{-3}; apparent free space in leaves, petioles and vines was estimated at 21, 23 and 33%, respectively, regardless of treatment. Foliar nitrogen was higher in plants grown in lombricompost, while phosphorus and potassium were higher in plants grown in peatmoss. Optimum chayote planting material can be obtained by cultivation of sprouted fruits in peatmoss or lombricompost using urea or polyfeed, respectively, at the rate of 3 g l^{-1} in either case.

1. Introduction

A native of the humid tropical forests of México and Central America, chayote (*Sechium edule*) was known to the indigenous people of this part of the continent long before the arrival of Europeans in the late fourteen hundreds (Newstrom, 1986 and 1991). However, for centuries the species remained practically undisturbed in its natural habitat, the fruit was simply collected while the plant experienced hardly any domestication. In fact, it is only very recently that chayote has been brought out of the forest or home-yard, and its cultivation as a true crop has begun (Flores, 1989). Thus, in spite of a relative abundance of literature on taxonomy (Cruz y Querol, 1985; Lira, 1995; Lira, 1996), there are very few agronomical reports on this gourd, which is closely related to melon, watermelon, squash, cucumber and other extensively documented members of the Cucurbitaceae. The recent success of this exotic gourd in international markets has emphasized the urgent need for studies to improve on the ways in which this natural resource can be best exploited commercially while being preserved at the same time.

In Veracruz, México, chayote is commercially grown from naturally sprouted fruits which are kept in the shade from the time of harvest until planted in pots once the sprout has grown some 40 cm in length and roots have begun to develop. The rooting medium used for potting these seedlings is usually the soil from the same fields where the crop is to be planted. Young potted seedlings are maintained either in an open yard or under some sort of shade for 3 to 6 months until transplanted to the field at densities varying from 100 to 130 plants ha^{-1}. No particular care is exercised to ensure that optimum planting material is obtained. Thus, great loss of seedlings occurs in nurseries for undetermined reasons.

Overall, chayote is currently exploited quite empirically and only very recently has the species become the object of agronomic research.

The paper reports experiments conducted to study the effect of rooting media and fertilization regime on the initial growth of chayote seedlings under a greenhouse environment in order to develop a nursery management strategy to obtain uniform, healthy and vigorous planting material.

2. Materials and Methods

Chayote fruits were obtained from a commercial plantation in Coscomatepec, Veracruz (18° 49´N, 96° 55´W, 1,300 msl) at the end of the harvest season in November 2008. Fruits were selected on the basis of uniformity in size and shape, besides being distinctly free from disease or insect damage. Fruits were overwintered in a dark room at 12±0.5ºC and 85% ambient relative humidity until used for experiments. In April 2009, they were withdrawn from storage and incubated in a controlled environment chamber (Biotronic) at 25/18ºC d/n, 85% relative humidity under 300 $\mu Em^{-2}s^{-1}$ during photoperiod (12/12 h l d^{-1}) until sprouting, which took roughly 5 weeks. After sprouting, seedlings were carefully washed and disinfected by immersion for 5 min in a mixture of Captam 50 (trichloromethyl dicarboximide) and Agrimycin 100 (80% streptomycin and 19% oxytetracycline) at the rate of 30 and 20 g l^{-1}, respectively. The mixture also contained Thiomet 35 (endosulfan) insecticide (3 ml l^{-1}). After this treatment, fruits were thoroughly rinsed under tap water. Plastic bags (37x37 cm^2) were filled with one of the following rooting media: fritted clay, as used by chayote nurseries in the region, peatmoss or lombricompost (*Eisenia foetida*) from various sources including rice, sugar cane and coffee plant residues. The compost was donated by the Microbiology Department at Universidad Veracruzana, Peñuela, Veracruz, México. Twenty seven pots were prepared with each rooting medium for a total of 81 pots. Single seedling of 10±2 cm sprout length was planted in each pot and watered to field capacity immediately with tap water. All pots were watered daily to provide unlimited water availability during 30 days. At this time, when mean sprout length reached 30±5 cm, fertilizer treatments were begun by applying one of the following treatments to groups of 9 pots of each rooting medium prepared and within fertilizer treatment 3 pots received the fertilizer dose treatment: polyfeed (20N-5P-32K) added with micronutrients at 0, 1, 2 or 3 g l^{-1} (polyfeed is a widely used commercial formula in plant nurseries); condensed soluble molasses (CMS) at 5, 10 or 100 ml l^{-1} (CMS is a novel organic fertilizer containing 40% organic matter obtained by evaporation from sugar cane syrups after the industrial production of the aminoacid lysine, and it is also a rich source of some essential minerals such as calcium and manganese); or urea (46-00-00) at 0, 1, 2 or 3 g l^{-1} (urea is the preferred nitrogen source among chayote growers in the region). Fruits were planted in such a way that the apical end pointed upwards while the basal end was buried only slightly to allow root growth while minimizing the risk of fungal or bacterial infection. When the vines reached 40 cm in length they were tutored by vertical lines to prevent lodging.

Growth variables were recorded for analysis of variance 30 days after treatment initiation. Data included vine length, leaf area (portable leaf area meter, Li-Cor 3000A, Nebraska), and fresh and dry weight (Ohaus). Photosynthesis rate, transpiration rate and ambient conditions were recorded using an IRGA provided with a remote leaf chamber (Li-Cor 6400, Nebraska). The instrument was configured as an open system; ambient air was the source of CO_2 after passing through a 20 l container to homogenize ambient air prior to its passage through the remote leaf chamber, thus maintaining a stable ambient CO_2 concentration.

Composite leaf samples were prepared by grinding together at least 5 mature, fully extended leaves from each plant selected per soil-fertilizer treatment combination. These composite leaf samples were used to determine mineral content by atomic absorption spectrophotometry (SpectraAA-200) after Rodriguez et al. (2006). Analytical determinations included foliar: nitrogen, phosphorous, potassium, calcium, magnesium, copper, manganese, iron and zinc.

The experimental design for statistical analysis was a completely randomized block design with three replications laid out in a subplots arrangement. Data were analyzed by a PC version of SAS.

3. Results and Discussion

Nutrient application is best taken advantage of by adequate planting material, promoting better plant growth and productivity (Grunewaldt, 1988). Table 1 summarizes the analysis of variance practiced on three growth variables measured 28 days after treat-

Table 1: Mean squares and statistical significance from ANOVA on growth parameters measured in chayote (*Sechium edule* Jacq. Sw.) plants cultured in a greenhouse environment in three deferent rooting media and Ander three different fertilization regimes

SOV	df	Mean squares and significance					
		Leaf area 1064	F ratio	Vine length	F ratio	Plant height	F ratio
Blocks	2	32415	0.38ns	8.5	0.051ns	5	0.01ns
RM1	2	2814	11.5*	57867	346**	14142	35.9**
Error RM	4	150		167		394	
F	2	340	0.24ns	9542	59.6**	1356	4.52*
SxF	4	625	0.54ns	5456	34.0**	687	2.29ns
Error F	12	1929		160		300	
D	2	2477	0.60ns	5027	2.91ns	6684	6.15**
SxD	4	1199	0.86ns	12231	5.92**	289	0.26ns
FxD	4	3658	0.42ns	972	0.56ns	485	0.44ns
SxFxD	8	2860	1.28ns	4449	2.57*	1165	1.07ns
Error D	36			1728		1086	

RM, F and D stand for rooting medium, fertilizar and doses, respectively; NS=Not significant **p*=0.05, ***p*=0.01

ment initiation. Strong significant effects due to rooting media were evident on leaf area, vine length and plant dry weight. On the other hand, a significant effect by fertilizer product was observed on plant dry weight and vine length but not on leaf area, while fertilizer doses had a statistical effect on plant dry weight only. Thus, independent effects could be observed by all three factors on plant mass accumulation, while their impact on leaf area and vine length seemed differential. Furthermore, among interactions, rooting media by fertilizer product, rooting media by fertilizer dose and rooting media by fertilizer product by fertilizer dose had a significant effect on vine length, but neither on leaf area nor plant dry weight.

In general, the shortest vines grew in fitted clay, regardless of fertilization regime. In this case, the average vine length was 41.7% of the maximum value observed across treatment combinations (Table 2). Mean vine length was maximum in plants grown either in peatmoss or lombricompost using urea for fertilizer in the first case, and polyfeed in the second case. Differences in vine length due to dosage of the same fertilizer were commonly small, but urea worked best when applied to peatmoss, while polyfeed was most effective in lombricompost. CMS did not compete favorably with any of the other fertilizers regardless of root medium. A similar trend could be observed for total leaf area plant^{-1}, in which case plants grown in fitted clay did not exceed 65 cm^2, while average leaf area registered in plants grown in peatmoss was almost twice that value at the end of the experimental period, regardless of fertilizer.

With respect to shoot dry weight, the greatest mean value across treatments was registered in plants grown in peatmoss and fertilized with urea in which case it reached an average value of 93 g plant^{-1}. These observations reflect the intricacy of metabolism and the complex nature of the control of many individual factors of diverse nature on distinct aspects of plant growth.

Young chayote shoots are normally 90% water (Aung et al., 1990) and fully expanded leaves on a 30 day old healthy well watered plant show a very low mass to surface area ratio (3.447×10^{-3} on a dry weight basis, unpublished data) as is the common case in non-fibrous warm climate fast growing species (Poorter and Garnier, 1999). Additionally, this herb develops a hollow pith early on during the elongation of the vines and petioles; while leaves have typically a large volume of intercellular free space. In fact, using a simple technique which relates tissue volume to equilibrium ion simple diffusion, we measured 21, 23 and 33% mean apparent free space in leaves, petioles and vines, respectively, independently of treatment combination. These data were in the same order of magnitude as those determined for wheat by Kylin (1960) using radio label. Clearly, the relatively low apparent density values for chayote leaves, petioles and vines (0.7, 1.01 and 1.00 gfwt.cm^{-3}, respectively) may explain why vine length and leaf area may be statistically affected by the triple interaction tested, without plant dry mass being equally affected; while at the same time, each double interaction seemed to have a differential effect on the same variables.

Table 3 shows mean photosynthesis and transpiration rates recorded on selected plants within the best combinations of root medium and fertilization regime in terms of growth and general vigor. Consistent with the body of evidence presented before this study, the lowest photosynthetic rate was measured in plants grown in fritted clay in which case it amounted to only 28.6 or 21.2% of mean photosynthetic rates typically registered in plants grown in lombricompost or in peatmoss, respectively, regardless of fertilization regime. Concomitantly, despite a similar irradiance at solar noon, there were differences in leaf surface temperature among treatments and an inverse relation between this and rates of photosynthesis and transpiration, confirming a tight environmental control on gas exchange through the response of stomatal aperture to prevent overheating and desiccation (Coria et al., 2009).

Table 2: Mean growth of potted chayote (*Sechium edule* Jacq. Sw.) plants cultured in a greenhouse environment in three different rooting media and under three different fertilization regimes

Treatment combination	Leaf area (cm^2 plant^{-1})	Vine length (cm)	Shoot dry weight (g plant^{-1})
LP1	100.9	196.6	60.1
LP2	54.3	176.1	79.6
LP3	71	192.0	73.6
LC1	89.5	89.9	38
LC2	76.1	119.3	53
LC3	64	136.4	68.6
LU1	61.1	84.7	83.4
LU2	58.3	148.7	41.5
LU3	83.8	159	65
PMP1	94.8	179	84.2
PMP2	135.8	180.1	98
PMP3	96.5	195.5	150
PMC1	104.7	108.3	72
PMC2	126.9	164.4	98.1
PMC3	127.4	166.2	101.7
PMU1	134.6	184.3	90
PMU2	162	187.1	78.3
PMU3	157.2	209.2	110.2
FCP1	63	83.3	45.1
FCP2	34	101.3	59.1
FCP3	32	98.5	89.1
FCC1	40.7	79.5	48.2
FCC2	36	90.7	69.4
FCC3	55	104.9	56.5
FCU1	61	74.3	53.3
FCU2	65.3	79.7	64.7
FCU3	35.6	73.3	33.3

L, PM and FC designate rooting media: L=Lombricompost, PM=Peatmoss and FC=Fritted clay; P, C and U designate fertilizer treatments: P=Polyfeed; C=Condensed soluble molasses and U=Urea; 1, 2 and 3 designate fertilizer doses

Finally, in relation with leaf mineral status, irrespective of fertilizer or fertilizer doses, higher mineral contents were characteristic of leaves from plants grown in either lombricompost or peatmoss (Table 4).

4. Conclusion

This clearly substantiates the observations described above

Table 3: Mean photosynthesis and transpiration rates at solar noon in chayote leaves from intact potted plants grown in a greenhouse environment under the fertilizer regime which best promoted leaf area expansion in each rooting medium

Treatment	Photosynthesis (µmoles m^{-2} s^{-1})	Transpiration (mg m^{-2} h^{-1})	leaf temperature (ºC)	PAR (µmoles m^{-2} s^{-1})
LP1	12.4^{*1}_{a}	6.5_a	26.2_a	520_a
PMU2	16.2_b	7.8_a	25.0_a	550_a
SU2	3.5_c	3.8_b	28.7_a	520_a

*All measurements were taken around solar noon; LP1=Lombricompost, polyfeed at 1 g l^{-1}; PMU2=Peatmoss, urea at 2 g l^{-1} and SU=Soil, urea at 2 g l^{-1}; Means followed by different letters are statistically different (p<0.01)

Table 4: Mineral content in chayote (*Sechium edule* Jacq. Sw.) leaves from plants cultured in a greenhouse environment in three different rooting media and under three different fertilization regimes

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (µmoles.gdwt^{-1}	Cu (%)	Mn (%)	Fe (%)	Zn (%)
LP1	1.52	195.6	1199	1554	430	13.7	3.2	189	1.47
LP2	0.81	155.2	1208	1347	625	14.3	3.8	58.3	2.90
LP3	0.02	170.5	494	1197	882	13.7	3.5	54.7	6.69
LC1	1.40	49.2	871	1362	192	14.7	26.0	72.1	1.27
LC2	1.92	39.9	842	1240	145	7.6	45.2	224	2.o2
LC3	2.26	66.5	920	723	143	7.7	24.2	31.4	1.50
LU1	1.25	107.5	261	1458	217	14.7	76.5	77.9	1.25
LU2	1.52	223.5	1064	1639	367	5.2	5.3	182	2.17
LU3	1.41	263.8	1104	1848	267	8.2	24.4	66.5	1.16
PMP1	2.01	139.3	917	869	294	10.4	19.2	47	1.31
PMP2	1.94	161.1	882	2242	430	12.8	25.2	34.2	0.77
PMP3	2.58	138.2	614	1171	249	10.5	27.6	47	1.37
PMC1	3.94	88.3	312	1223	269	12.4	22.8	10.8	0.63
PMC2	3.11	83.2	386	1199	264	8.6	103.8	59.1	1.00
PMC3	2.56	91.6	291	1594	223	11.4	29.8	719.1	1.18
PMU1	1.48	32.6	107	1979	68	17.9	61.3	56.8	0.74
PMU2	2.33	71.1	109	1145	47	7.7	47.5	0.01	0.62
PMU3	1.46	72.4	99	1624	49	8.8	28.8	374.6	2.04
SP1	0.01	19.4	209	570	136	20.9	23.3	58	1.53
SP2	0.02	18.1	255	1509	233	16.8	26	33.4	1.55
SP3	0.01	28.0	275	1794	125	12.7	50.5	116.7	2.24
SC1	0.81	20.1	155	1539	55	8.8	17.7	272.3	1.75
SC2	0.11	44.6	340	1780	95	16.6	44.9	54	1.49
SC3	1.04	56.5	152	1649	139	18.5	72.2	213.6	1.41
SU1	0.03	11.4	138	1822	153	11.4	66.1	350.3	1.13
SU2	0.01	42.6	147	1409	154	19.2	115	325.8	1.92
SU3	0.01	51.2	165	1374	71	10.8	73.8	90.1	1.32

L, PM and FC designate rooting media: L=Lombricompost, PM=Peatmoss and FC=Fritted clay; P, C and U designate fertilizer treatments: P=Polyfeed, C=Condensed soluble molasses and U=Urea; 1, 2 and 3 designate fertilizer doses

and concludes that either organic rooting media tested here is a better option for chayote planting material growers than conventional practice.

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