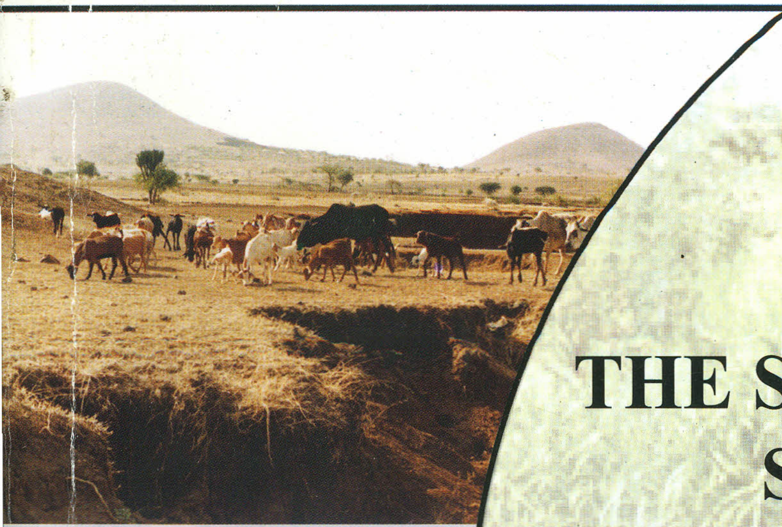

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Capacity Building for Land Resource Management to Meet the Challenges of Food Security in Africa

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NURSERY MEDIA EFFECTS ON TAMARINDUS INDICA SEEDLING ESTABLISHMENT

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ABSTRACT

Trees are an important component of farming systems and contribute to human needs both directly through tree products and indirectly through their influence in soil fertility. Efforts by small-scale farmers to increase trees of high value in their farms are hampered by poor quality of seedlings with low survival and slow growth rate. One reason for poor seedling development is inappropriate chemical and physical properties of the growing media used. This study attempted to find out the effect of these chemical and physical properties of the growing media used by farmers on the seedlings of *Tamarindus indica (L.)* and the appropriate levels for the species. Therefore, samples of the growing media used in 6 on-farm tree nurseries in two agro-ecological zones in Mount Kenya region - main coffee and marginal coffee zones - were collected and tested in an on-station experiment at ICRAF headquarters, Nairobi, Kenya. The media were analyzed for chemical (nitrogen, phosphorus, calcium, magnesium) and physical (pH, total pore volume, aeration pore volume and water holding capacity) properties. The root diameter, seedling height and root and shoot dry weights of seedlings raised in the media were measured periodically. Data were analyzed for variance (ANOVA) using Genstat 4.1 release and treatments compared using Students-Newman-Keuls test. Aeration pore volume, total pore volume and wet bulk density were the physical properties that had greatest influence on seedling quality parameters especially during initial period of growth (up to 75 days). Chemical properties, on the other hand, affected seedling growth and quality parameters at later stages of growth. Important nutrients were observed to be nitrogen, organic carbon, magnesium and calcium. From the findings of this study, farmers can curtail nursery period of *Tamarindus indica (L.)* from 130 days to as little as 75 days.

INTRODUCTION

Trees are important component of farming systems but efforts to increase their component in small scale farmers' fields is hampered by sub optimal physical and chemical properties that lead to low seedling quality (Wightman 1999). Such growing media quite often affect seedling physical quality and survival in the field (Jaenicke 1999) and the effects vary from one farmer to another. Balanced physical properties and supply of nutrients in growing medium are needed for healthy and vigorous plant growth while ensuring adequate root development and plant hardiness (Mason and Aldhous 1994).

The demand for *Tamarindus indica* has resulted in increased seedling production but often without sufficient knowledge to assure high quality. This demand, resulting from the current upsurge in high value agroforestry trees need to be matched with diffusion of knowledge on modern techniques for raising high quality agroforestry seedlings. The knowledge gap stems from the fact that few studies have tested the growing media used to raise seedlings by the farmers themselves and given feedback to these farmers. The result of insufficient farmer knowledge is high seedling mortality and seedlings produced may exhibit mineral deficiency symptoms. Further several studies on contributions towards optimizing seedling quality have focused on temperate species and provenances with less focus on tropical species.

According to Wightman (1999), medium for raising seedlings should ideally possess the optimal chemical properties such as fertility, acidity and cation exchange capacity. Growing media quality is determined by the mix ratio (Awang and Taylor 1993; Wightman 1999). Weber (1977) notes that good results have been achieved by mixing plain sand with sieved cattle manure at a ratio of 1:1. Tiwari and Barholia's study (1994) on some fruit and forest species recorded better growth with 4:2:4 ratios of soil: sand: compost. An unevenly mixed growing medium may result in irregular seedling growth (Awang and Taylor 1993).

Growing media used vary from place to place depending on availability of the ingredients such as manure, compost, vermiculite, perlite and peat. These differ in nutrient availability and release as well as in their structure. Different nursery mixtures possess these qualities in differing proportions and are affected by their origin and organic matter content. Organic matter is particularly important due to its effect on nutrients and physical properties of the soil and is an appropriate option given its low-cost availability to small-scale farmers compared to inorganic fertilizers. The optimal growing medium should have an appropriate balance of the various components for optimal growth.

This study aimed at determining the effects of small scale farmers' growing media properties on seedlings and propose the properties appropriate for the generation of quality seedlings of *Tamarindus indica*.

RESEARCH METHODOLOGY

Study areas

This on-station experiment was carried out at ICRAF headquarters tree nursery located in Nairobi at 01° 14′ 14′′S and 36° 49′ 02′′E, with mean annual rainfall of 937mm recorded and mean monthly temperature of 23.8°C.

Sampling procedure

The growing media were classified according to whether they were primarily farm soil, compost, sand or forest soil as shown in Table 1 based on their percent soil, compost (or forest soil) and sand proportions. A growing medium was classified as compost when the level of organic component added exceeded 20% or if forest soil, as sand when the proportion of sand in the medium exceeded 20% and farm soil when the level of organic matter used or its sand content did not exceed 20 %.

Table 1: Growing media and their farm soil, sand and compost percentage.

Substrate	Nursery Name	Farm soil	Compost	Sand	Forest soil	Category
ICRAF standard (C:Fs;1:2)	ICRAF	0	33	0	66	Standard
Medium 1 (100% F)	Umoja	100	0	0	0	Farm soil
Medium 2 (100% Fs)	Njuri	0	0	0	100	Forest soil
Medium 3 (F:C:S; 6:2:1)	Ntomba	67	22	11	0	Forest, Compost and Sand (FCS)
Medium 4 (F:C, 3:1)	Njaina	75	25	0	0	Forest and Compost (FC)
Medium 5 (F:C:S; 2:1:4)	Kinoti	29	14	57	0	Sand

F=farm soil; Fs= Forest soil; C= Compost; S= Sand

Experimental design

The experimental design was a randomized complete block design (RCBD) with six treatments (substrates) replicated three times. Each treatment, with 20 seedlings (one seedling per 4″×6″ polythene bag), was watered on alternate days during germination and thereafter every morning. Weeds were removed out immediately they were noticed. The seedlings were planted in September 2000 and after emergence were monitored for 130 days until the conclusion of the study in February 2001. The experiment was conducted for one season only.

Seedling growth

Systematically randomly selected seedlings were fortnightly measured for root collar diameter (0.1mm accuracy) using root calipers and height (1mm accuracy) using a measuring ruler up to 130 days of growth. Root and shoot dry weights were determined destructively every 6 weeks. The carefully separated roots and shoots were oven dried at 60°C for 24 hours (Duryea 1985) and their respective weights taken using an electronic weighing balance (0.0001 g accuracy).

Physical and chemical analyses of the growing media

Soil physical properties were determined following a modification of the International Society for Horticulturae Science (ISHS) reference method (Gabriels and Verdonck, 1991) while pH was determined using a standard method (ICRAF 1997) that uses a soil/water ratio of 1:2.5. Similarly, standard methods were used in chemical determination. Exchangeable Calcium and Magnesium were determined using 1 N KCl extractant at 10:1 soil solution ratio and their concentration values (me/ 100g of soil) determined using an atomic absorption spectrophotometer (Buck scientific, 200A). Total organic carbon was determined colorimetrically by the modified Mebius method (Heanes 1984) using wet oxidation by acidified dichromate (Anderson and Ingram 1993). Nitrogen was determined by wet oxidation based on Kjeldahl digestion method while modified Olsen method was applied for phosphorus determination (Anderson and Ingram 1993).

RESULTS AND DISCUSSIONS

Characteristics of the growing media

The physical properties of the growing media used varied as shown in Table 2. The observed aeration pore volume for forest soil, FCS and the sand medium deviated from the recommendations for forest tree seedlings by Landis et al. (1990). FCS had the highest bulk density and also the lowest water-holding capacity (WHC), total pore volume (TPV) and aeration pore volume (APV) and demonstrated an inappropriate balance between APV and WHC (0.40 ratio). Good aeration pore volume for container seedlings is 20- 35% of total volume (Bilderback 1982; Landis *et al.* 1990). The differences reflect the different proportions and properties of the medium components. For example, although FCS is classified as compost based, its high density could be resulting from farm soil component. Nevertheless, other compost-based media had higher TPV and better balance of APV and WHC and it can be concluded that compost provides a better combination of physical properties as compared to sand.

Table 2: Physical properties observed from different growing media used by different farmers

Substrate	Name	Wet Bulk Density	Water Holding capacity	Total pore Volume	Aeration Pore Volume	APV/WHC ratio
Standard (C:Fs;1:2)	ICRAF	1	47	76	29	0.62
Medium 1 (100% F)	Umoja	1.2	42	67	26	0.62
Medium 2 (100% Fs)	Njuri	1.2	43	67	24	0.56
Medium 3 (F:C:S; 6:2:1)	Ntomba	1.4	45	63	18	0.40
Medium 4 (F:C, 3:1)	Njaina	1.1	41	71	30	0.73
Medium 5 (F:C:S;2:1:4)	Kinoti	1.2	44	68	24	0.55
SD		0.13	2.16	4.41	4.3	
Recommended (Landis et al. 1990)			***25 - 45***	***50 - 80***	***25 - 35***	

Though the Standard medium had higher water holding capacity than the recommended, it still maintained high aeration pore volume due to its high total pore space resulting from high level of organic matter. FC with farm soil and compost in a 3:1 ratio however had the highest APV/WHC ratio (0.73) and also the lowest wet bulk density (WBD).

Farm soil (Medium 1) recorded the lowest level for all main nutrients (Table 3) due to low level of the inherent organic matter and lack of organic incorporations. All media apart from FC had at least one of their nutrients deviating from the recommendations of Landis et al. (1990) (Table 3). Sand medium (F:C:S; 2:1:4), which had only 1/7 of organic (chicken manure) incorporation, had highest nitrogen content demonstrating the ability of chicken manure to improve nitrogen content in tree nursery growing medium.

Table 3: Chemical properties of growing media observed

Substrate	Name	pH	K	Mg	Ca	P* (mg/kg)	Organic C (g/kg)	N*
			- mg/100g -					
Standard (C:Fs;1:2)	ICRAF	7.0	4.4	35.2	13.0	18.6	54.9	171.1
Medium 1 (100% F)	Umoja	5.3	0.4	8.8	3.6	10.6	14.1	11.3
Medium 2 (100% Fs)	Njuri	7.0	1.3	37.0	11.6	26.4	38.0	85.5
Medium3 (F:C:S; 6:2:1)	Ntomba	8.0	4.4	21.0	5.2	287.2	17.4	122.5
Medium 4 (F:C, 3:1)	Njaina	7.1	4.6	21.2	7.0	39.5	26.4	67.4
Medium 5 (F:C:S;2:1:4)	Kinoti	7.5	5.3	27.4	12.0	127.0	31.5	186.2
Recommended (1990) (Landis *et al.*	2.5-11.5	30-60	1.5-20.0	35.0-95.0		50.0-150.0		
SD		1.01	2.02	10.4	3.97	107.8	14.9	66

Effect of growing media on germination

The observed germination percentage was within the range of 30% to 75% reported for tamarind by Gunasena and Hughes (2000). The standard, forest soil and FC, all of which had high organic matter and low bulk density, achieved higher germination percentage (Table 4). These media provided good aeration enabling high germination percentage (R^2=0.6). Gunasena and Hughes (2000) have suggested the use of cow dung in germination medium to enhanc germination of tamarind.

Table 4: The effect of growing media on germination of Tamarindus indica

Growing medium	Germination (%)
Standard (C:Fs;1:2)	76
Medium 1 (100% F)	67
Medium 2 (100% Fs)	72
Medium 3 (F:C:S; 6:2:1)	37
Medium 4 (F:C, 3:1)	71
Medium 5 (F:C:S;2:1:4)	35

Seedling heights, root collar diameter and sturdiness quotient

Seedlings from FC, which had the best range of all nutrients and physical properties, were taller and had greater sturdiness quotients consistently for the last half of the growth period while those from sand medium had greatest diameter during the same period (Figure 1 and Table 5). Seedlings produced in farm soil (Medium 1) and FCS had the least recorded height, root collar diameter (RCD) and sturdiness quotient (SQ) due to the fact that, of all growing media, farm soil only medium had the least levels of all nutrients (Table 3 and 5) while FCS had inappropriate physical properties (Table 2). Lowered growth in the standard medium from day 71 is possibly due to low phosphorus content in media. P controls root colonization through its effect on host carbon metabolism (Singh et al., 1997).

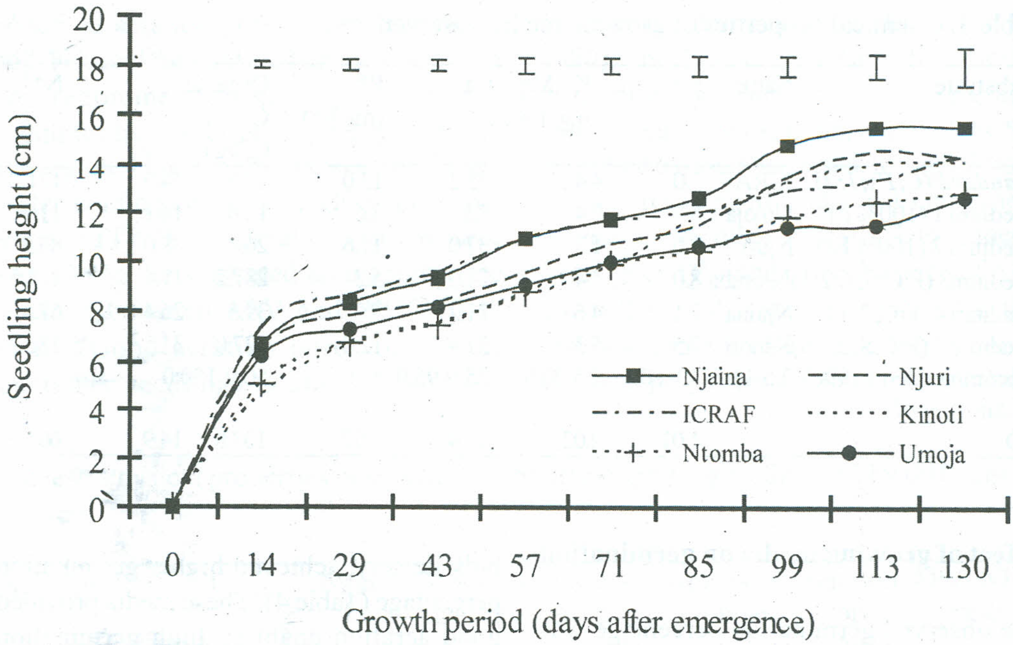

Figure 1. Tamarindus indica seedling height growth curves using six different growing media at ICRAF tree nursery

Analysis of variance showed that seedling heights were significantly different (P = 0.05) throughout the experiment period apart from days 85 and 130 (Figure 1). Insignificance at day 85 corresponds to the end of the great influence of physical properties on growth and the beginning of more influence from chemical properties. Comparison of means using Students-Newman-Keuls test showed that the standard growing medium produced significantly taller seedlings than the heavy media consistently up to 71 days of growth (Figure 1). Significant differences were also observed between the standard and other media for RCD, shoot dry weight (SDW) and root dry weight (RDW) (Table 5). SQ did not change widely with nursery period indicating proportionate distribution of photosynthates in *Tamarindus indica.*

Table 5: Shoot and root dry weights and Shoot/root ratio at different growth periods

Growth period	Treatment	RCD (mm)	SQ	SDW (gms)	RDW (gms)	S:R ratio
29 days	Standard	1.94	4.46	0.32	0.08	4.00
	Kinoti	2.12*	3.17	0.26	0.06	4.73
	Njaina	1.95	4.39	0.35	0.11	3.17
	Njuri	1.99	3.93	0.33	0.09	3.91
	Ntomba	1.95	3.48	0.26	0.11	3.30
	Umoja	1.83	4.04	0.29	0.06	4.79
	sed	0.06	0.17	0.03	0.03	1.01
71 days	Standard	2.98	3.93	0.62	0.24	2.59
	Kinoti	2.93	3.53	0.43*	0.27	1.69**
	Njaina	2.94	3.94	0.62	0.29	2.15*
	Njuri	2.74	3.91	0.62	0.27	2.28
	Ntomba	2.85	3.49	0.44*	0.21	2.14*
	Umoja	2.62*	3.80	0.55	0.23	2.31
	sed	0.13	0.22	0.07	0.03	0.19
113 days	Standard	3.65	3.65	1.05	0.63	1.68
	Kinoti	3.85	3.74	1.08	0.54	1.91
	Njaina	3.60	4.32	1.07	0.54	1.98
	Njuri	3.61	4.03	1.13	0.66	1.74
	Ntomba	3.64	3.42	0.72	0.51	1.42
	Umoja	3.22*	3.57	0.74	0.52	1.48
	sed	0.19	0.22	0.20	0.12	0.20
130 days	Standard	3.71	3.86	1.06	0.72	1.52
	Kinoti	4.14*	3.46	1.06	0.68	1.54
	Njaina	3.80	4.09	1.20	0.79	1.55
	Njuri	3.90	3.65	1.34	0.93	1.49
	Ntomba	3.83	3.32	0.97	0.79	1.29
	Umoja	3.57	3.52	0.90	0.63	1.47
	sed	0.19	0.35	0.21	0.09	0.21

* Significant at 95% ** significant at 99%, as compared to the standard medium
RCD – Root collar diameter, SQ – Sturdiness quotient, SDW – Shoot dry weight, RDW – Root dry weight, S:R – Shoot: Root ratio

Effect of media physical properties on seedling height, root collar diameter and sturdiness quotient

APV and TPV had significant positive influence on initial growth of seedlings that was more pronounced up to day 85 (Figure 2). At the same period, WBD had a negative effect and it is possible that at this growth period oxygen requirement by the roots was very high which was reduced by increased bulk density and hence suppressed seedling growth. A good combination of physical properties also provide good root environment for appropriate nutrient uptake. Tamarind is sensitive to low levels of oxygen just like Alleppo pine (Borelli and Shirone, 1988). Reduced growth due to increased bulk density is similar to the finding of Bukhari (1998) who found it to reduce growth of *Acacia seyal* seedlings.

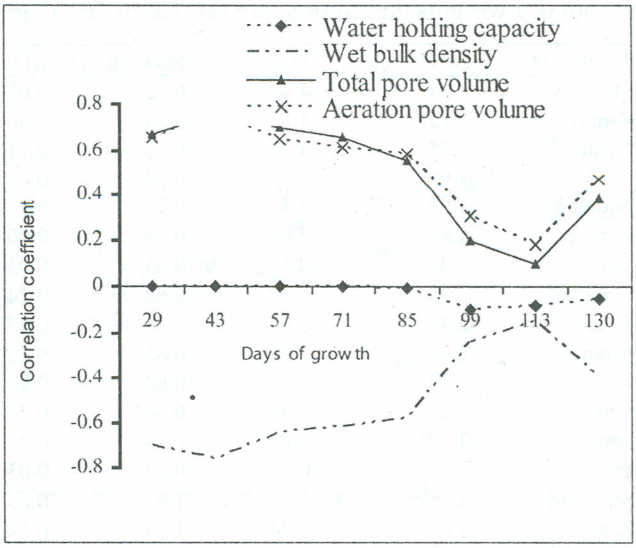

Figure 2: Correlation coefficients of media physical properties and seedling height over time

Effect of media chemical properties on seedling growth

Positive additive effects on seedling growth were observed with potassium, calcium, nitrogen, carbon and magnesium up to the end of the experiment (Table 6). At the initial growth period both FCS and sand medium, which had the highest P levels of 287 and 127 respectively, maintained the lowest height and largely contributed to the negative correlation coefficients. Accelerated growth of the sand medium towards the end of the study, however, could coincide with reduced P concentration due to reduced concentration by uptake but this requires further corroboration. Other researchers have observed decreased seedling growth due to higher levels of phosphorus and attributed this to either decreased use efficiency of P in the absence of N or reduced colonization by mycorrhizae (Prasad and Rawat 1991; Newton et al. 1992a and 1992b; Chauhan and Sharma 1995 and Arahou et al.1996).

Table 6. Correlation coefficients of some chemical properties with seedling height for six different types of growing media at different growth periods

Growth period (days)	P	Organic C	K	Total N	Ca	Mg
29	-0.45	0.35	0	0.35	0.13	0.1
43	-0.48	0.33	0	0.3	0.065	0.06
57	-0.29	0.32	0.04	0.3	0.08	0.06
71	-0.46	0.38	0.04	0.36	0.16	0.11
85	-0.23	0.35	0.23	0.4	0.22	0.34
99	-0.1	0.15	0.17	0.2	0.2	0.2
113	0.005	0.14	0.16	0.19	0.28	0.23
130	-0.14	0.27	0.18	0.3	0.24	0.25

Nitrogen had favourable effect on seedling growth, agreeing with the findings of Kannan and Paliwal (1995) who worked with *Cassia siamea* and attributed the response to better utilization of P and K in presence of adequate N levels. Nitrogen is used in chlorophyll synthesis and its deficiency leads to reduced photosynthesis and carbohydrate assimilation and thus to reduced seedling growth (Anoop et al. 1998).

The effects of K, Ca and Mg on seedling height were not significant though their deficiency or depletion as nursery period extends could affect carbohydrate and protein metabolism (Ogbonnaya 1994) that could reduce seedling growth as observed in 100% farm soil medium.

Effect of growing media on shoot and root dry weights

As observed with seedling height, compost media recorded the largest shoot and root oven dry weight compared to the pure farm soil and the sand based media (Table 5). Sand and FCS had significantly smaller shoot dry weight and S/R than the standard at day 71. A combination of good aeration and high availability of nutrients could contribute to higher growth of shoot relative to root as observed in the standard medium. Wet bulk density which related inversely with SDW, RDW and S/R could impact higher root penetration resistance and hence reduced growth as also observed by Borelli and Schirone (1988) for Aleppo pine (*Pinus halepensis*), Bhukari (1998) for *Acacia seyal* seedlings and Akinnifesi et al. (1999) for *Enterolobium cyclocapum* and *Leucaena leucocephala*.

There were no significant effects of chemical properties on shoot and root dry weights and shoot/root ratio. Only additive positive influence was observed with magnesium and nitrogen on dry weights and could be attributed to their role in production of photosynthates (Agboola and Kadiri 1999) and of protein and nucleic acid synthesis (Ogbonnaya 1994) respectively.

CONCLUSIONS AND RECOMMENDATIONS

The physical properties of the different media were found to affect seedling growth rate mostly up to 71 days. On the other hand, substrate chemical properties influenced seedling growth during the mid and late growth phases (57 to 130 days after germination) with organic carbon, nitrogen and magnesium having greater effect on seedling height and RCD.

Germination percentage was higher in compost-based media compared to sand and farm soil-based growing media due to higher percentage of organic matter that provided higher TPV and APV and low WBD. These physical properties also positively influenced seedling height, root collar diameter, sturdiness quotient and shoot dry matter of *Tamarindus indica* during initial growth period (0 - 85 days), after which, the effect was not significant.

From the foregoing, this study concludes that physical and chemical properties of the growing media influence seedling growth and play an important role in reducing nursery period. The nursery period of *Tamarindus indica* seedlings can be curtailed by up to 55 days for more economic benefits using farm soil compost in a ratio of 3:1. For example, Umoja and Ntomba growing media achieved the height achieved by Njaina at 85 days of growth 45 days later. Farmers and nursery operators raising *Tamarindus indica* seedlings should avoid using pure farm soil and incorporations of sand.

Drawing on the results from this study, it is recommended that *Tamarindus indica* seedlings be raised in a light substrate with at least ¼ organic matter. Feeding with a weak liquid fertilizer may start 6-10 weeks after germination. However, these recommendations could be corroborated through a study carried out for 2 or 3 seasons in varied conditions.

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