

Effect of Substrates on Germination and Seedling Emergence of Sunflower (*Helianthus annuus* L.) at the Yongka Western Highlands Research/Garden Park, Bamenda-Cameroon

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Summary

A study was carried out at the Yongka Western Highlands Research Garden Park, Nkwen-Bamenda in Cameroon to evaluate the effect of substrates on the germination and seedling emergence of sunflower (*Helianthus annuus* L.). Seeds of African Giant variety were used with six substrate media (sawdust, sand, soil, sawdust-sand, sawdust-soil and sand-soil). The experiment was laid out in a Randomized Complete Block Design in three replications. Germinated seeds were counted daily for a 15 days period. To estimate seedling emergence from two Weeks After Sowing (WAS) up to four WAS, data on seedling height and number of leaves were recorded. The results showed that germination started 8 days after sowing for all substrates. Germination rate was significantly affected by the substrates but the rates were less than 80%. The highest germination rate was recorded on the soil substrate (75%) while the lowest rate (25%) was recorded on the sawdust substrate. Seedlings on the sawdust substrate were also less vigorous and had less leaves (12.67 cm height and 4.7 leaves) than those on other substrates at four WAS (50–63 cm and 12.6–15.3 leaves). Based on the results, it is recommendable to use the soil substrate to nurse African Giant seeds.

Résumé

Effet des substrats sur la germination et l'émergence des plantules de tournesol (*Helianthus annuus* L.) au Yongka Western Highlands Research/Garden Park, Bamenda-Cameroun

Une étude a été menée au Yongka Western Highlands Research Garden Park, Nkwen-Bamenda au Cameroun, pour évaluer l'effet de différents substrats sur la germination et l'émergence des plantules de tournesol (*Helianthus annuus* L.). La variété African Giant a été utilisée avec six substrats (sciure, sable, sol, sciure-sable, sciure-sol et sable-sol). L'essai a été installé selon un dispositif en blocs aléatoires complets avec trois répétitions. Les graines germées étaient comptées tous les jours pendant 15 jours. Pour l'émergence des plantules entre deux Semaines Après Semis (SAS) et quatre SAS, des données ont été collectées sur leur hauteur et leur nombres de feuilles. Les résultats ont montré que la germination a débuté après huit jours pour tous les substrats. Les substrats ont significativement affecté les taux de germination qui étaient tous inférieurs à 80%. Le taux le plus élevé a été enregistré sur le substrat constitué de sol (75%) contre 25% pour le substrat constitué de sciure. De même, les plantules cultivées dans la sciure étaient moins vigoureuses avec moins de feuilles (12,67 cm de hauteur et 4,7 feuilles) que les autres à quatre SAS (50–63 cm et 12, 6–15,3 feuilles). De ce fait, il est recommandé l'utilisation d'un substrat composé de sol pour faire germer les graines de la variété African Giant.

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Introduction

Vegetable oils are an important source of calories in the human diet providing 38 kJ/g compared to 17.8 kJ/g for proteins and carbohydrates (32). In addition to the traditional oil plants such as groundnuts, soybean, coconut and sesame, it is necessary to develop other new oil crops such as sunflower (*Helianthus annuus* L.) in Africa. Sunflower is an important oil seed crop which can be adapted to different agroecological conditions of the world (32). Sunflower oil is the fourth important vegetable oil seed in world trade at present with an annual production around 9 million tons (32). The cultivated area is over 22 million hectares, mainly concentrated in the Russian Federation, Ukraine, India and Argentina, who have more than 50% of sunflower acreage worldwide (32). Sunflower is considered to be one of the most promising oil crops that can meet the oil needs because it is characterized by high unsaturated fatty acids and vitamin E contents (10). It is rich in oil content (38-50%) and the oil cake contains higher amounts of protein (40-44%) and balanced amino acids compared to other oil crops (20).

Sunflower is cultivated in the rainy season (March to October), but it has been found to be more or less drought resistant (20). For the establishment of a good crop stand and uniform and maximum germination of seeds, an emergence of strong and sturdy seedlings are necessary as they are able to survive under stress conditions. For a better germination and growth of plants, fertile soils are necessary (12). To grow the largest sunflowers, it is essential to sow seeds that have attained maturity and are viable directly into the garden rather than start them in pots of any kind. This is because sunflowers have long tap roots that grow quickly and become stunted if confined (20).

With time, deep soil tillage, application of high amounts of inorganic fertilizers and herbicides, burning of crop residues and continuous cropping, result in a progressive deterioration of soil fertility (6), degradation of soil aggregate stability (15), increased soil compaction (30), nitrate losses and gravitational water pollution (28), and thus have negative consequences not only on the soil

properties, but also on the environmental quality. As such, it is necessary to use sustainable agricultural practices (16). Soil degradation has become one of the most important problems facing agriculture. Erosion, salinization, compaction and loss of organic matter are the main forms of soil deterioration. Addition of organic matter could be a way to improve soil structure and aeration, creating a better environment for plant growth. The growth and distribution of the roots depends to a great extent on the soil environment. Soil aggregation can provide physical protection of organic matter against rapid decomposition (25) and the aggregate formation seems to be closely linked with soil organic matter storage in soils (8). Microorganisms too are the fundamental component of soils, playing a key role in essential processes such as organic matter nutrient cycling dynamics, degradation of residues, development of soil structure and aggregation.

Literature on the soil environment for the cultivation of this crop is scarce in Cameroon. Though, it has been reported that direct seeding is preferred to nursing of seedlings in pots prior to transplantation into the field, due to problems of low germination rates with some sunflower seeds, it was necessary to test the behaviour of *Helianthus annuus* in varying substrates likely to cover the range of soil properties which would be conducive for its cultivation in the field. This study was undertaken to find out the effect of using soil, sand, sawdust, sawdust-sand, soil-sand and soil-sawdust substrates on the seed germination and seedling growth of sunflower in polyethylene bags.

Materials and methods

The study was conducted at the Yongka Western Highlands Research Garden Park Nkwen-Bamenda located in the Western Tropical Highlands region of Cameroon from the months of July to August 2011. It receives monomodal rainfall with a peak in August and having a mean annual precipitation of 2500 mm (33).

The African Giant variety constituted the planting material of the experiment. To examine the effects of substrate media on germination and seedlings development of sunflower over four weeks, six

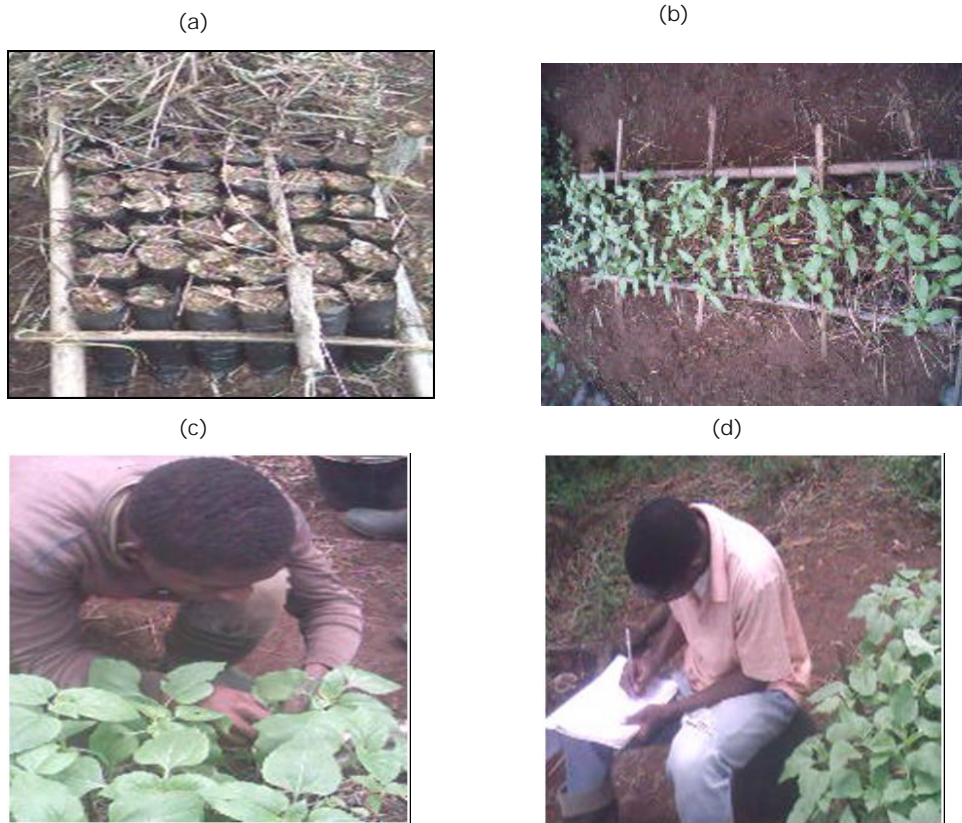


Figure 1: Lay out of one replicate (a), Experiment eight days after sowing (b), Seedling height measurement (c), Data recording in the field (d).

different substrates were used: (i) sawdust; (ii) sand; (iii) soil; (iv) sawdust-sand; (v) sawdust-soil; and (vi) sand-soil. They were chosen based on their porosity, water retention capacity and nutrient potential. Sand was collected from the Yongka Park German trench which constitutes colluvium regularly brought down by runoff from the adjoining road. A dark-colored organic matter-rich silty clay loam soil was collected from the Ap horizon of a Cambisol in the Yongka Park. The sawdust was obtained in town. Heaps of sand, soil, and sawdust cones were made, and a spade was used to homogenize them. Two-component substrates were well mixed using a 1/1 proportion. Ten cups of poultry manure were added to all treatments. After leveling and delimitating a 150×30 cm panel with bamboo, the nursery was laid out in a Randomized Complete Block Design with 3 replicates and 6 pots per treatment in the block (Figure 1a). Before sowing, a viability test was carried out to detect the seeds having the embryo. Three seeds were sown per pot at 2 cm depth as

recommended by guidelines for sunflower growing (22). The planting time coincided with the period of high rainfall intensity and thus no additional water through irrigation was applied.

To study seed germination, the germination rate was measured (Figure 1b); this test gives an idea of the viability of seeds. It expresses in percent the number of seeds that germinate in a short period (15 days) of time. This test is important to the farmer who can then estimate the number of seeds able to constitute a homogenous lot of seeds. Data collection on plant height (cm) and number of leaves was initiated two WAS (Weeks after Sowing) (Figure 1 c and d). Leaves were counted daily while plant height was recorded every two days. Data collection was discontinued four WAS as it was observed that the seedlings were vigorous and ready to be transplanted into the field. Germination rates, plant height and number of leaves were analyzed using the analysis of variance at p 0.05 (9) and means were compared with the Duncan Multiple Range Test.

Based on data on germination rate and plant height, the evolution of germination and seedlings development with time on the different substrates was graphically represented (21). Correlation relationships were studied between the percent substrate components and the selected seedling parameters. Regression equations were developed for those parameters that showed significant correlations (21).

Results

Effect of substrate on seed germination

For all the substrates, the germination rates were below 80% two WAS. Results showed that substrates of soil (soil, sawdust-soil and sand-soil) had the highest germination rates (Figure 2). However, seeds sown in sawdust had a constant and low germination rate (25%) after the two WAS in contrast to those sown on sawdust-soil where the maximum rate of 75% was reached 9 days after sowing. Substrates thus had a significant effect ($p < 0.05$) on the germination of seeds of *Helianthus annuus* (Table 1).

Germination performed significantly better on soil and sand-soil substrates than on sawdust. On sand, sawdust-sand and sawdust-soil substrates, intermediate germination rates of 66.67, 58.33 and 66.67%, respectively were observed (Figure 2). Based on germination rate, the substrates are classified as follows soil sand-soil > sand sawdust-soil > sawdust-sand > sawdust. Therefore, the African giant variety has a germination rate of 75% when sown on a dark colored, organic matter -rich silty clay loam soil.

Effect of substrate on emergence of sunflower seedlings

In general, parameters of vegetative seedlings development (seedling height and number of leaves) evolved differently over time on the six substrates. Two WAS, significant differences among the treatments were observed for seedling height but the substrates had no statistical effect on the number of leaves. The seedling heights at two WAS, reported on the sand, soil, sand-soil, sawdust-sand substrates were all statistically similar, but higher than that on sawdust.

Sawdust-soil occupied an intermediate position. At four WAS, the number of leaves and seedling height showed similar relative performances on the different substrates. Vegetative development was less in sawdust than in the other substrates (Table 1). Over time, sand had the highest seedling height of 16.50 and 63.16 cm, respectively for two WAS and four WAS. Sand is closely followed by soil, sand-soil, sawdust-soil and sawdust-sand substrates. For number of leaves, seedlings on the soil substrate performed best developing 3 leaves two WAS and 15.3 leaves four WAS, respectively followed by sand and other substrates. A general increase of the seedling height was observed (Figure 3) as the initial heights which were between 10 and 20 cm 16 days after sowing increased to 50-60 cm 31 days after sowing. Growth curves of sand and soil coincide from 20 days after sowing up to 29 days after sowing. The same situation is observed between sawdust-soil and sawdust-sand from 26 to 31 days after sowing. The curves showed that the variation from none to significant difference between sawdust and sawdust-soil over time, observed in table 1, started 26 days after sowing. Except for sawdust-soil and sawdust, the substrates maintained uniform growth tendencies over time. Thus, sand and soil are the best substrates in terms of vegetative development.

Regressions between percent substrate components and selected seedling parameters

There is a significant, strongly negative correlation between the rate of sawdust present in the substrate (0, 50 and 100%) and the number of germinated seeds (Table 2). As such, when the sawdust quantity increases, the germination rate decreases. Linear regression relationships between germination rate and sawdust percentage (Figure 4a) indicate a high correlation ($R^2=0.82$). The percentage of sawdust present in the substrate thus explained 82% of the variance in germination rates. There is a non-significant positive trend towards higher germination rates with increased soil percentages in the substrate (Table 2).

Regression equations between sawdust percentage and selected vegetative development parameters (Figure 4b, c) indicate that the relationship of

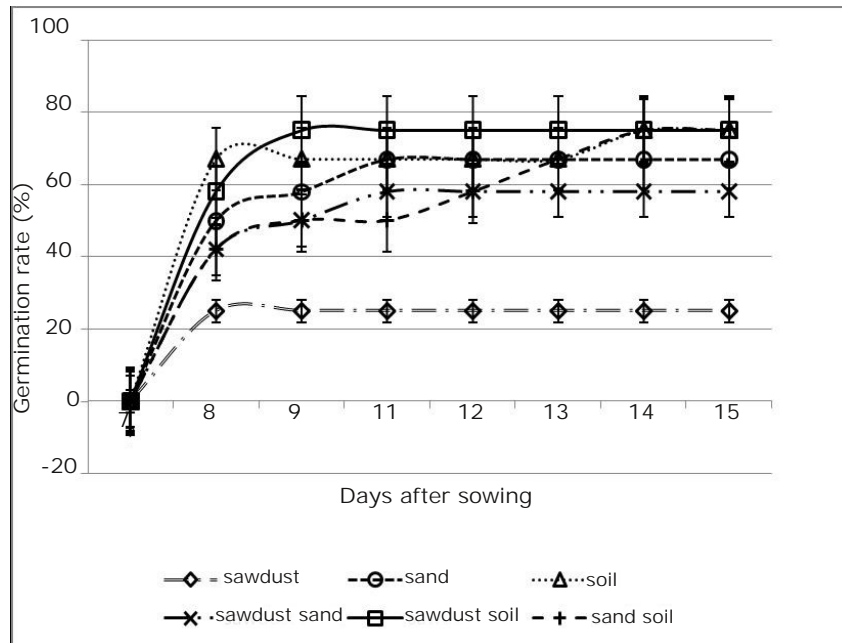


Figure 2: Effects of substrates on germination of *H. annuus* seeds 2 WAS. Each point is the mean of three replicates.

Table 1

Analysis of variance of the germination and vegetative development of sunflower on 6 different substrates.

Data are means of three replicates. Means with same letter are not significantly different at $p < 0.05$.

Variables	Substrates	Weeks after sowing (WAS)	
		2 WAS	4 WAS
Average germination rate (%)	sawdust	25.0±14.1a	-
	sand	66.6±14.1ab	-
	soil	75.0±14.1b	-
	sawdust-sand	58.3±14.1ab	-
	sawdust-soil	66.6±14.1ab	-
	sand-soil	75.0±14.1b	-
Average plant height (cm)	sawdust	4.4±2.6a	12.7±8.5a
	sand	16.5±2.6b	63.2±8.5b
	soil	15.0±2.6b	58.8±8.5b
	sawdust-sand	13.1±2.6b	50.5±8.5b
	sawdust-soil	12.5±2.6ab	51.3±8.5b
	sand-soil	14.6±2.6b	54.7±8.5b
Average number of leaves per seedling	sawdust	2.0±0.5a	4.7±1.4a
	sand	2.6±0.5a	14.6±1.4b
	soil	3.0±0.5a	15.3±1.4b
	sawdust-sand	2.6±0.5a	12.6±1.4b
	sawdust-soil	2.3±0.5a	14.6±1.4b
	sand-soil	2.3±0.5a	14.6±1.4b

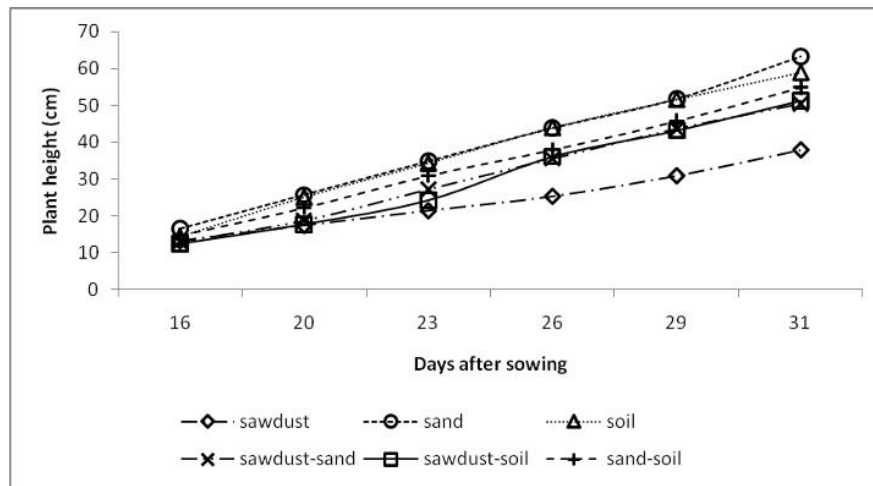


Figure 3: Effects of substrates on plant height of *H. annuus* seedlings during 4 WAS. Each point is the mean of three replicates.

Table 2

Correlation coefficient (r) between the substrate components and selected plant parameters.

Variables n= 6	Percent Sawdust	Percent Sand	Percent Soil
Germination rate	-907 (a)	290	617
Plant height 2WAS	-931 (b)	569	362
Plant height 4 WAS	-901 (a)	505	397
Number of leaves 2 WAS	-687	166	521
Number of leaves 4 WAS	-869 (a)	331	538

(a), (b): Significant at the 0.01 and 0.05 levels, respectively; WAS = Weeks After Sowing

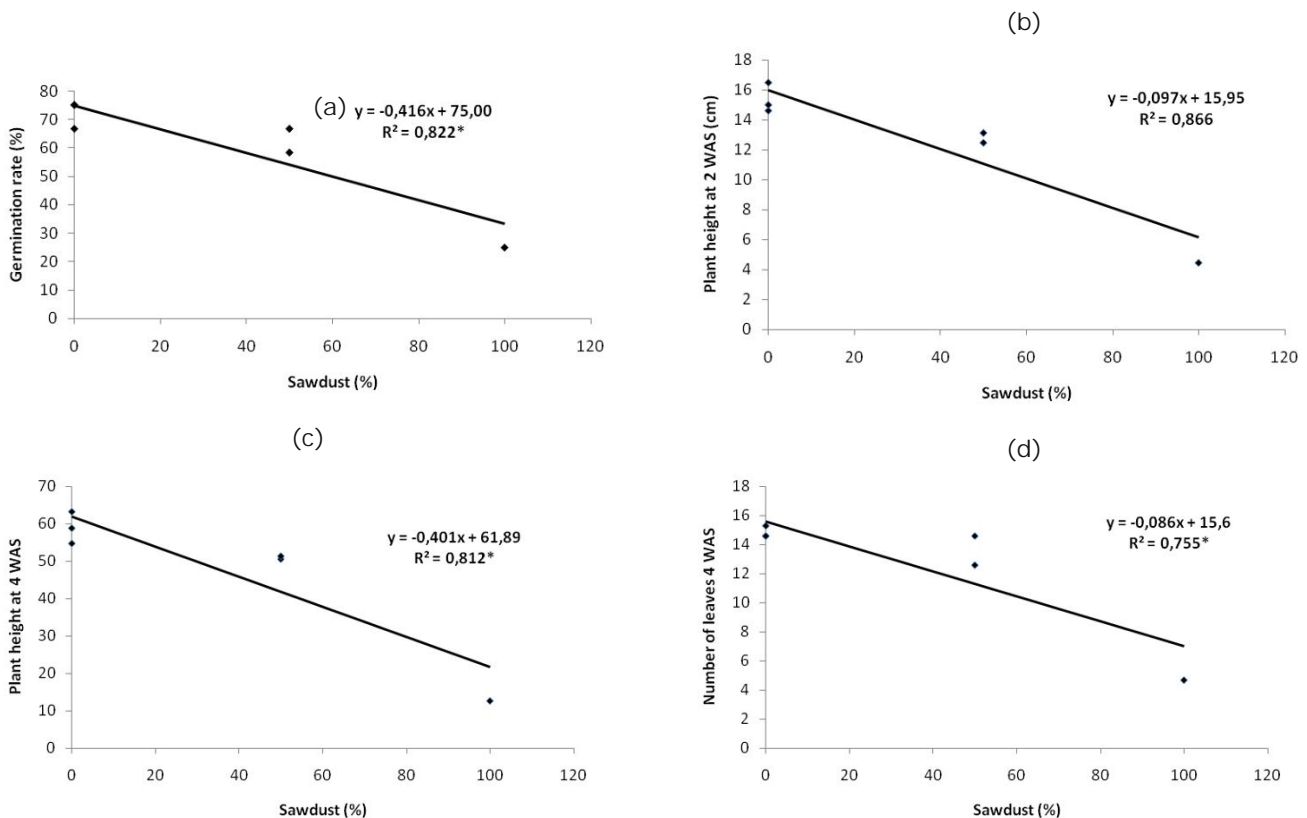


Figure 4: Relation of the percent sawdust with germination rate (a), plant height at 2 WAS (b), plant height at 4 WAS (c), and number of leaves (d).

sawdust percentage in substrate vs. plant height two WAS and sawdust percentage in substrate vs. plant height four WAS accounted for 86% and 81% of the variance, respectively. The above relationships appear linear. This indicates that the increase of sawdust in the substrate leads to the slowing down of seedling growth. The same result is obtained with number of leaves 4 WAS with an R^2 of 0.755 as shown in figure 4d. Correlations were significant at 5% and 1% levels of significance for seedling height, number of leaves four WAS and seedling height two WAS, respectively. The correlation of sand percentage in substrate vs. plant height and number of leaves overtime was positive but not significant. As the proportion of sand increases in the substrates, plant height and number of leaves also tend to increase over time (Table 2). However, this correlation was relatively higher for plant height than for number of leaves where they were very low (Table 2, $r=0.166$ and $r=0.331$, respectively for 2 and 4 WAS). Soil proportion was not highly correlated with plant height over the weeks (Table 2, $r=0.362$ and $r=0.397$, respectively for 2 and 4 WAS). However, the correlation coefficients were quite high when the proportion of soil was correlated with the number of leaves with r values of 0.52 and 0.54, respectively for 2 and 4 WAS. Hence, the increases in vegetative development parameters are well explained by the increase of sand substrate in the substrates for plant height and soil substrate for a number of leaves.

Discussion

It is hardly possible to attain a maximum seed yield without successful seedling establishment. The period of germination and seedling emergence prior to establishment is the most vulnerable stage in a crop life (24). Poor seedling emergence results in yield reductions. This may be due to poor soil water content (7), seed-soil contact (31), inaccurate seed placement, low and high soil temperatures (7), soil insects or soil-borne disease, soil compaction or smearing (23), and surface crusting after sowing and poor quality seeds (1). Seiler (27) suggested that optimal seedbed conditions are needed for successful seedling emergence in sunflower.

Sunflower, like other crops, requires proper seedbed conditions for optimum plant establishment. A suitable seedbed condition for germination and seedling emergence depends on soil physical properties (24). The soil organic matter is an important component of the soil. It has a profound impact on soil physical, chemical and biological properties (5, 29). The results indicate that the effects of substrates on germination were significant. They also indicate that, under unfavourable conditions, there would be a seedling emergence problem in substrates containing larger quantities of sawdust, possibly because of the unsuitable sawdust physical and biological properties. These results also indicate that substrates having soil in their composition were better media for good germination and emergence of seedlings. Good seedling emergence could reflect the quality of the soil physical properties (14, 24, 27). Based on the proportion of organic matter, the biological part of the soil is known to enhance seedbed conditions for desired seed emergence (2). Germination of sunflower seeds is often difficult, resulting in poor field seedling emergence. The problem of poor emergence under field conditions is even more pronounced in varieties characterized by large seeds and a thick pericarp (26). This may indicate why the germination rates in this study were less than 80%. However, some results support the hypothesis that the low germination rate is not only due to the mechanical barrier imposed by the seed coat, but to low embryo vigor (26). Seed germination and seedling emergence result from a sequence of biological events initiated by water imbibitions followed by enzymatic metabolism of stored nutrients (18). All these processes are regulated by the environment and the quality of the seed (13). Both suboptimal soil temperature and lack of soil moisture delayed and reduced the germination rate and seedling emergence (4). Apparently, substrates promoting optimal temperatures (around 15 °C) and having high water content such as those with a good proportion of organic matter and dominant particles less than 2 mm (soil, sand-soil, and sand) would give good germination and seedling emergence rates.

The efficiency of substrates with sand may be attributable to the addition of organic matter through manure. Regarding emergence, seedling growth is linked to root elongation and nutrient uptake, while growth and elongation of roots are a function of the type of substrates, water content, oxygen concentrations and gas exchange (19). Hence, substrates having higher amounts of these physical properties would give better seedling emergence and growth. The non statistical effect of substrates on the number of leaves can be attributable to the fact that in the early stage of growth, the seedlings still depended on nutrients in the seeds reserves.

The results of this study indicate that as the amount of sawdust increases the percent germination decreases. Sawdust has a high C/N ratio. In the sawdust-soil substrate, sawdust is considered as a residue to improve soil aeration, but does not decompose easily because it provides less surface area for moisture retention. Studies by Henriksen and Breland (11) indicate that contact between soil and residues have a major effect on the fate of carbon decomposition in soil. The extent of contact between residues and the soil matrix as determined by the method of residue incorporation, affects decomposition dynamics both under natural and experimental conditions associated with the amounts of water retained and the microbial activity

enhanced by the moisture content. An increase in germination rate was observed for all treatments except on sawdust between 8–14 days after sowing. Apparently the low surface area associated with sawdust limited the amount of moisture that would be required for germination. According to Myers (22), in guidelines for sunflower cultivation, if the soil is kept moist, seed germination will appear within 5-10 days.

Conclusions

Differences in morphological and physiological quality of seedlings produced on the six substrates evaluated were largely due to differences in the amount of water and nutrient retention capacities of the different substrates assuming other environmental variables that could influence germination and emergence of seedlings are similar. The seeds showed greater performance in some substrates than others. Seedling quality was significantly higher when grown on soil substrates than other substrates. The sand substrate with inherently low organic matter contents and low water and nutrient retention capacities had a similar performance to soils, when poultry manure was added to it. This indicates that addition of organic matter to poor or sandy soils would improve not only good seedling emergence, but also optimum plant growth at later stages.

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