Chapter 5

Effect of water movement on phytotoxic activity of water extract from Mexican sunflower leaves in soil

Introduction

Allelochemicals are commonly transferred from living plants and their residues to soil by water leaching (Lovett, 1982; Lovett and Hoult, 1995). Rain water and soil moisture condition have been reported to affect viability and activity of plant phytotoxic compounds in soil (Inderjit, 1996b; May and Ash, 1990; Rice, 1984; Teasdale, 1993). Recently, Inderjit and Dakshini (1994b, 1996) reported that phenolic compounds could be released from the allelopathic plant into soil, and these water soluble compounds could be leached from the soil ultimately to ground water by water leaching. This indicates the role of water movement on the distribution of plant allelochemicals in soil. The study in chapter 4 demonstrated that the water leachates from the green and the senescent leaves of Mexican sunflower obtained by water spray have phytotoxic activity on the growth of rice seedlings in soil. This suggested that phytotoxic compound(s) could be released from both the green and the senescent leaves of Mexican sunflower to soil by rain and have the potential to inhibit growth of other plants under its canopy. In the natural field conditions, several heavy rainfall events commonly occur during the rainy season in Mexican sunflower infested areas in Thailand. Water leaching due to rain could influence the release of phytotoxic compound(s) contained in Mexican sunflower leaves, as suggested in chapter 4 and may affect the phytotoxic activity of Mexican sunflower leaf leachates in soil. The objective of the study in this chapter was to investigate the effect of downward movement of water in soil on the phytotoxic activity of Mexican sunflower leaf water extract. This was also done in order to obtain basic information about the phytotoxicity of Mexican sunflower under natural conditions.

Materials and Methods

To determine the downward mobility of Mexican sunflower leachate in dry soil condition by the first rain, Mexican sunflower leaf extract from the air-dried green leaves powder at the concentration of 20 mg DME/ml was applied into a soil column. Seven hundred and fifty grams of air-dried Kannondai soil was put into a column consisting of 10 pieces of plastic ring (10.5 cm in diameter and 1 cm height). Five hundred ml of water extract was poured onto the top of soil column to the maximum water holding capacity (MWHC). After 3 hr, the treated soil columns were divided into 10 layers, and 17 grams of soil from each layer was put into small glass bottles (8 cm in height and 4 cm in diameter) and bioassayed with germinated rice seeds as described in chapter 2. The soil-water from each soil layer was separated by centrifugation as described in chapter 2 and bioassayed with germinated rice seeds in sea sand as the same procedures described in chapter 1. Shoot and root length of the rice seedlings were measured at 4 days after planting. To investigate the downward movement of Mexican sunflower leaf extract in wet soil, a similar experiment was conducted using the soil columns which had been pre-moistened with distilled water by sub-irrigation to be the MWHC (hereinafter referred as wet soil column). The wet soil column was treated with 500 ml of water extract from Mexican sunflower leaf powder at the concentration of 20 mg DME/ml. After 3 hr, the treated soil column was divided into 10 layers. The soil and its soil-water in each layer were bioassayed with germinated rice seeds in the same procedure as described above. To determine the effect of rain on the mobility of phytotoxic substance(s) from Mexican sunflower leachate previously existing in the top soil, 250 g of soil previously applied with 175 ml of Mexican sunflower leaf extract at the concentration of 40 mg DME/ml was placed on the top of the wet soil column. The thickness of the treated soil was 3.3 cm. The soil column was applied with 600 ml of distilled water at 24 hr after the placement of the treated soil on the top and allowed the applied water to completely move to the bottom for 3 hr. The treated soil was removed and the soil and its soil-water in each layer were bioassayed in the same procedures as described above. All experiments were carried out twice with three replications each time.

Results and Discussion

The phytotoxic activity of water extract from Mexican sunflower leaves applied in dry and wet soil conditions on shoot and root growth are shown in Fig. 5.1 and 5.2. The phytotoxic activity of the soil-water separated from each of the soil layers are shown in Fig. 5.3 and 5.4. The effect of downward movement of water on the phytotoxic activity of phytotoxic substance(s) previously adsorbed on the top soil was simulated by placing the soil previously treated with the water extract from Mexican sunflower leaves onto the top of the wet soil column, and the phytotoxic activity of each soil layer and of its separated soil-water on rice seedling growth are shown in Fig. 5.5 and Fig. 5.7, respectively.

When the leaf extract was applied onto the dry soil columns, the shoot and root growth of rice in the upper layers was inhibited more remarkably than those in the deeper layers (Fig. 5.1), whereas in the wet soil column, the shoot and root elongation of rice in the 5-6 cm layer was inhibited more than the seedlings in the upper or lower layers (Fig. 5.2). The results indicated that the phytotoxic activity of Mexican sunflower extract applied in soil differed among the soil layers and was affected by the moisture condition of the soil before the application.

Fig. 5.3 shows that the shoot and root growth of rice seedlings grown in sea sand, treated with soil-water separated from each soil layer of the dry soil column previously applied with Mexican sunflower leaf extract, was inhibited in the same pattern as those grown directly in the soil layers of the dry soil column (Fig. 5.1). Similarly, the result in Fig. 5.4 also shows that the shoot and root growth of rice seedling in sea sand, treated with the soil-water separated from each soil layer of the wet soil column previously applied with Mexican sunflower leaf extract, was inhibited in a similar extent as those grown directly in the soil layers of the wet soil column (Fig. 5.2). These results demonstrated that the phytotoxic activity of Mexican sunflower leaf extract in soil correlated well with that of the soil-water.

Fig. 5.5 shows that the most remarkable inhibitory effect on the growth of rice was found in the 4-6 cm layer. The inhibitory activity in the treated soil which was placed on top of the soil column was clearly decreased by the application of water compared to the activity before the water application (Fig. 5.6). This suggested that phytotoxic substance(s) previously adsorbed on soil could be leached down from the treated soil to the lower layers of the soil column by water movement after the adsorption.

Shoot and root elongation of rice seedlings in sea sand treated with soil-water from each soil layer were inhibited in the same manner as those grown directly in the soil layers (Fig. 5.7). The results also demonstrated that the phytotoxic activity of Mexican sunflower leachate in soil correlated well with that in soil-water.

The application of Mexican sunflower extract into dry and wet soil columns simulated the movement of phytotoxic substance(s) released from the plant under natural field conditions during the first and later rainfall events of the season. The first rainfall begins when the top soil layer is dry, and the soil profile is kept moist at various levels up to its field water holding capacity by the following rains. The application of water onto the soil treated with Mexican sunflower extract, which was placed on the wet soil column, mimicked the effect of rain on the downward movement of phytotoxic compound(s) previously existing in the top soil into the lower soil layers during the rainy season. Therefore, it is suggested that the phytotoxic substance(s) in Mexican sunflower leaves could be eluted by rain, reach onto the soil surface, and then move down with water to the lower soil layer, at least to the top 5 cm where most of the weed seeds are commonly located. The phytotoxic compound(s), which have been previously released from the leaves onto the soil surface by the first rainfall, could be further mobilized into the lower soil layers by the succeeding rains. The reason for the differing effect of water movement on the phytotoxic activity between dry and wet soil might be due to soil adsorption, but this should be further investigated.

Similar response patterns of shoot and root growth of rice seedlings to the soil containing the leachate and to its soil-water in the study in this chapter suggested that the phytotoxic activity of water leachate in soil was actually induced by the concentration of phytotoxic substance(s) in soil-water. This confirmed the previous findings in chapter 2, chapter 3, and chapter 4, that the phytotoxic activity of Mexican sunflower in soil depends on the concentration of phytotoxic compound(s) in soil-water.

Little information is known about water leaching or the mobility of plant allelochemicals in soil. However, it is believed that environmental factors affecting the mobility of plant phytotoxins in soil are similar to the factors influencing herbicide movement (Cox *et al.*, 1996; Inderjit, 1996b; Pool and Toit, 1995). Precipitation is the main factor involved in the downward movement of chemical substances after application. Weidenhamer (1996) noted that, like herbicides, allelochemicals can be bound and made unavailable by soil organic matter and clays and that, unlike herbicides which are applied one or two times with a given rate and subsequently decrease in concentration with time, allelochemicals are continually being added to the soil and removed from the soil associated with the downward movement of water. Thus, it is likely that the phytotoxicity of allelochemicals is a function of both static availability and dynamic availability based on the total amount of chemical moving in and out the system over a period of time (Williamson and Weidenhamer, 1990). The maximum concentration of allelochemical in soil will be reached when the amount of rainfall is not sufficient to cause runoff or deep drainage (May and Ash, 1990). This study suggested that the phytotoxicity and the mobility of substance(s) released from Mexican sunflower in soil are affected by water movement and soil moisture condition. Under natural field conditions, thus the phytotoxic activity of Mexican sunflower in soil may vary depending on the amount of rainfall in that area.

Summary

1) Shoot and root growth of rice seedlings grown in each soil layer of the dry and wet soil columns previously treated with water extract from Mexican sunflower leaves was inhibited.
2) The degree of inhibition on rice seedling growth varied among the soil layers and differed between the dry soil column and the wet soil column.
3) The inhibitory activity on rice seedling growth found in the soil layers was well correlated with that in the soil-water of each soil layer.
4) Growth of rice seedlings in the soil layers of the soil column

which was placed with the soil previously applied with Mexican sunflower leaf extract was inhibited and the pattern of rice seedling growth in response to the soil was similar to its soil-water.

5) These results suggested that phytotoxic substance(s) in Mexican sunflower leachate by rain could be moved down from the upper soil layers to the lower layers of the soil profile. The downward movement of phytotoxic compound(s) in soil is affected by water movement and soil moisture conditions in addition to adsorption by soil.

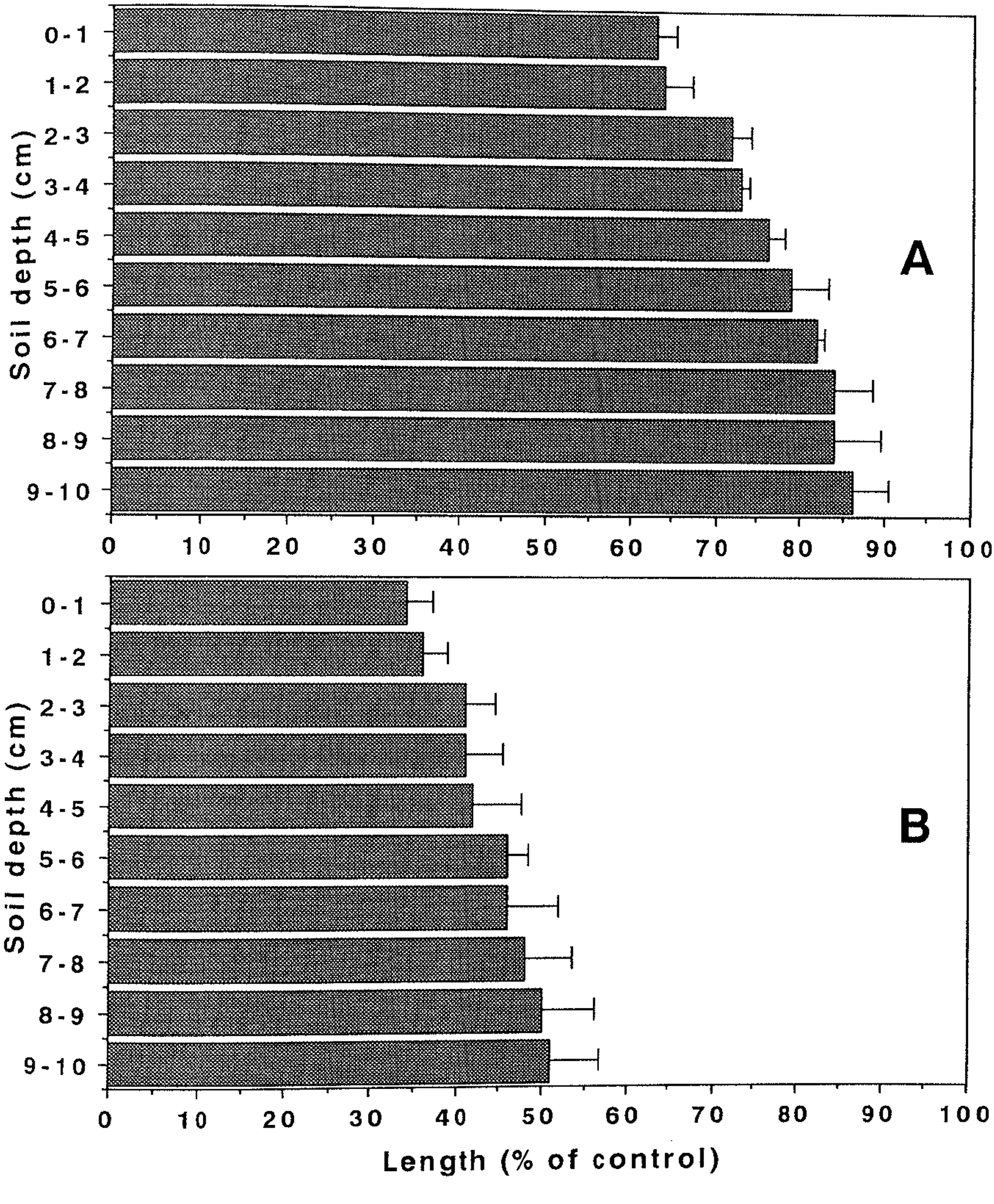

Fig. 5.1 Shoot growth (A) and root growth (B) of rice seedlings in each soil layer of dry soil column applied with water extract from Mexican sunflower leaves. Shoot and root length of the control were 37 ± 3 mm and 63 ± 4 mm, respectively.

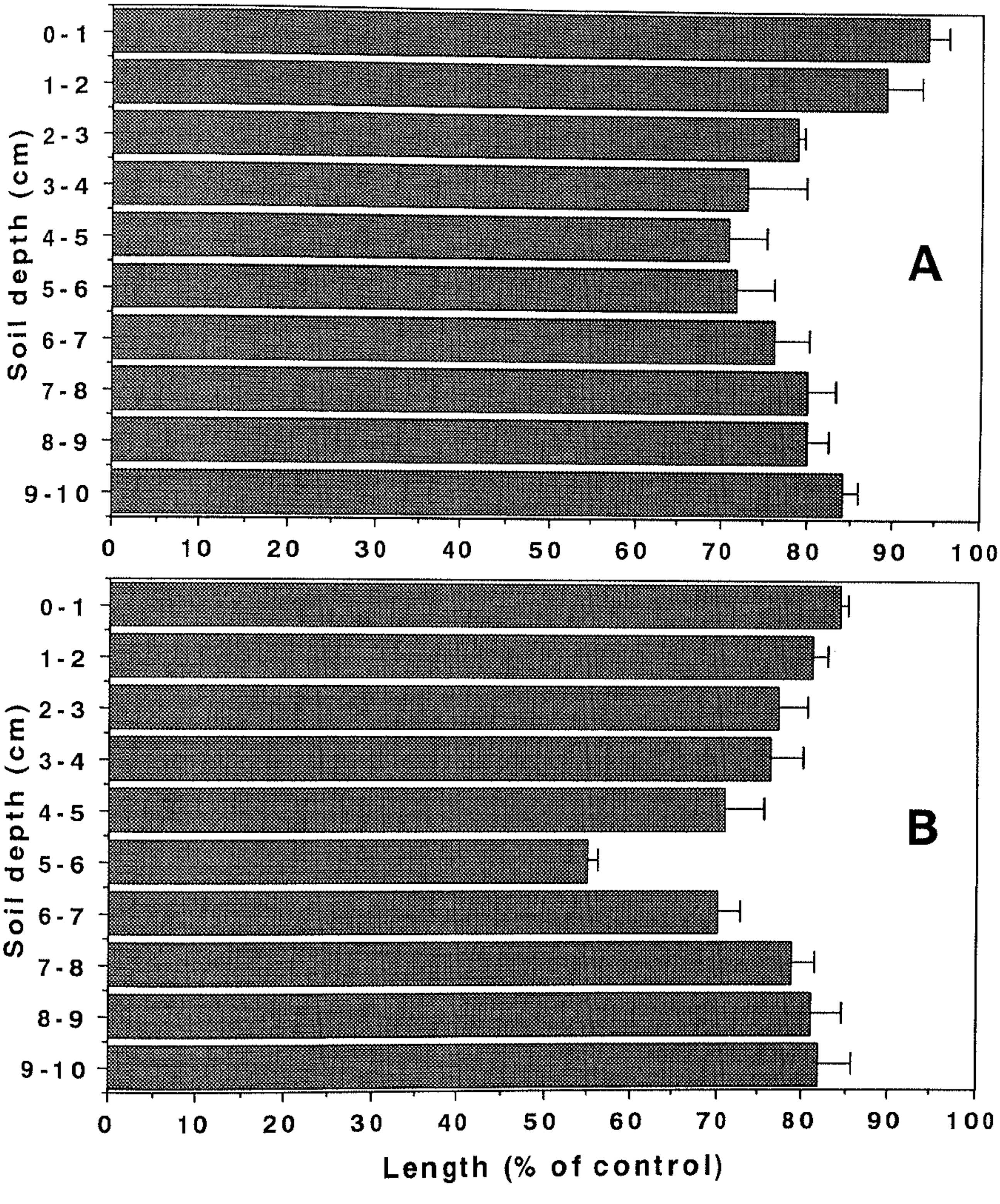

Fig. 5.2 Shoot growth (A) and root growth (B) of rice seedlings in each soil layer of wet soil column applied with water extract from Mexican sunflower leaves. Shoot and root length of the control were 37 ± 3 mm and 63 ± 4 mm, respectively.

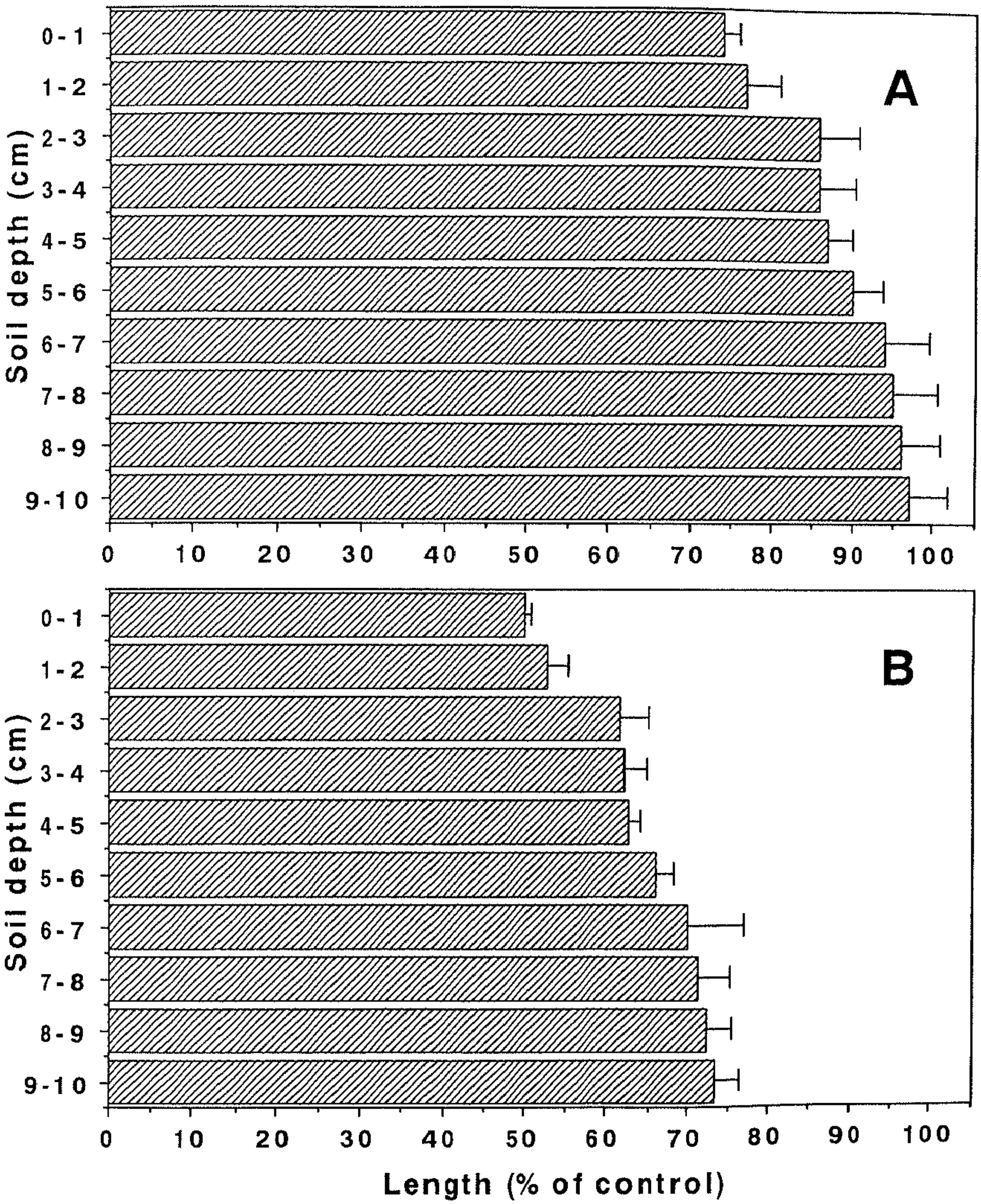

Fig. 5.3 Shoot growth (A) and root growth (B) of rice seedlings in sea sand treated with soil-water from each soil layer of dry soil column treated with water extract from Mexican sunflower leaves. Shoot and root length of the control were 26 ± 2 mm and 38 ± 2 mm, respectively.

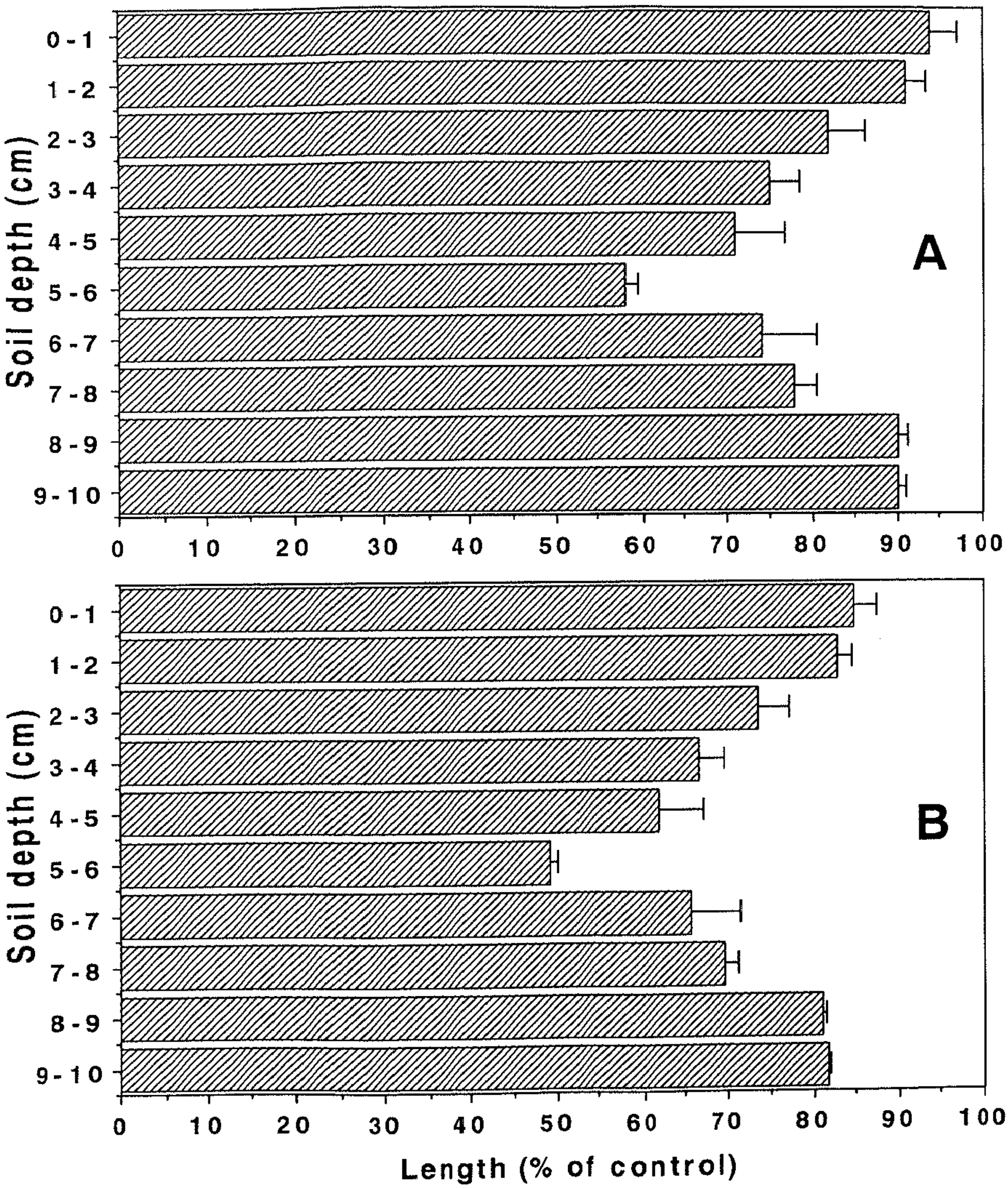

Fig. 5.4 Shoot growth (A) and root growth (B) of rice seedlings in sea sand treated with soil-water from each soil layer of wet soil column treated with water extract from Mexican sunflower leaves. Shoot and root length of the control were 26 ± 2 mm and 38 ± 2 mm, respectively.

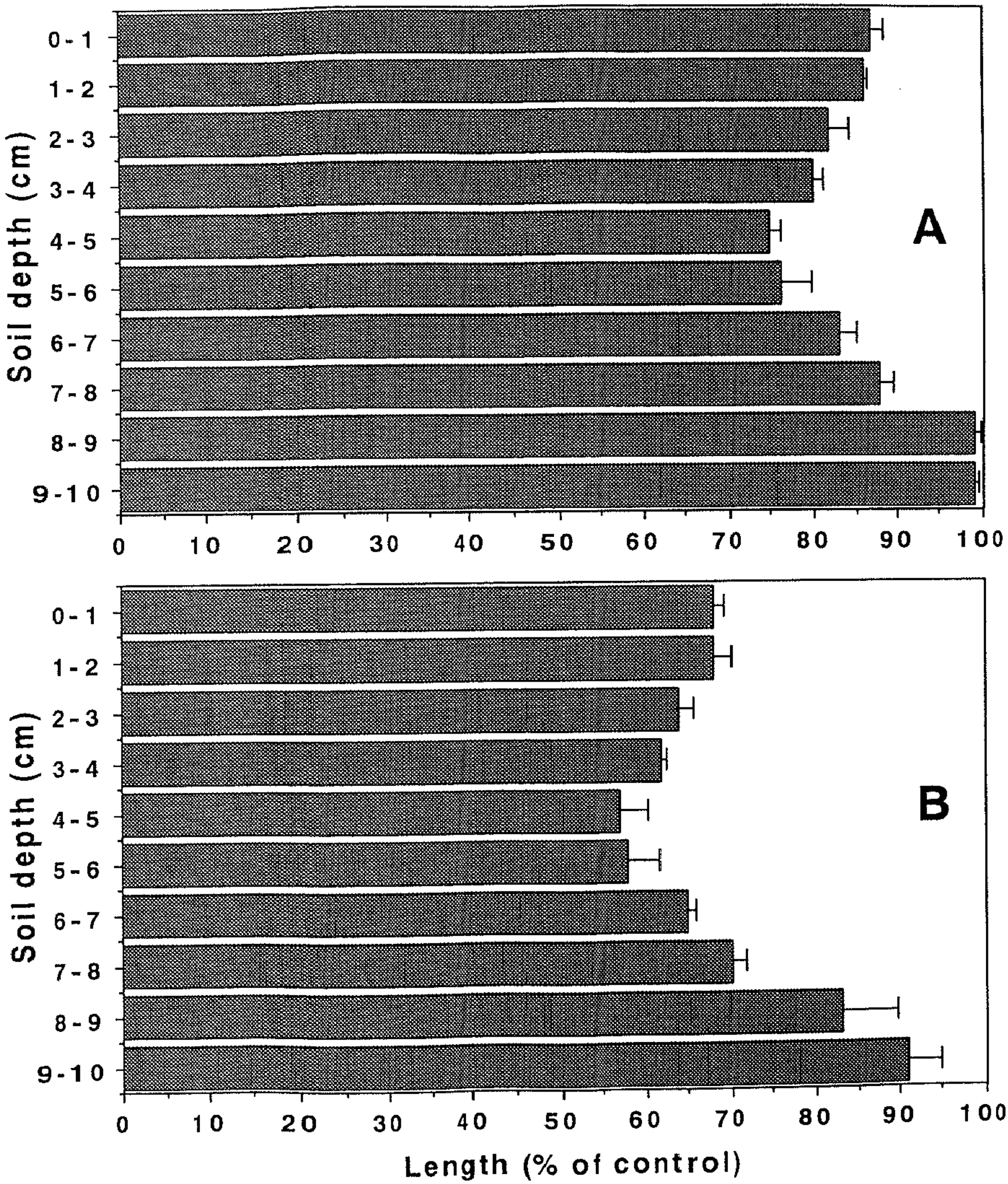

Fig. 5.5 Shoot growth (A) and root growth (B) of rice seedlings in each layer of wet soil column topped with soil treated with water extract from Mexican sunflower leaves for 24 hr before water was applied. Shoot and root length of the control were 37 ±3 mm and 63 ±4 mm, respectively.

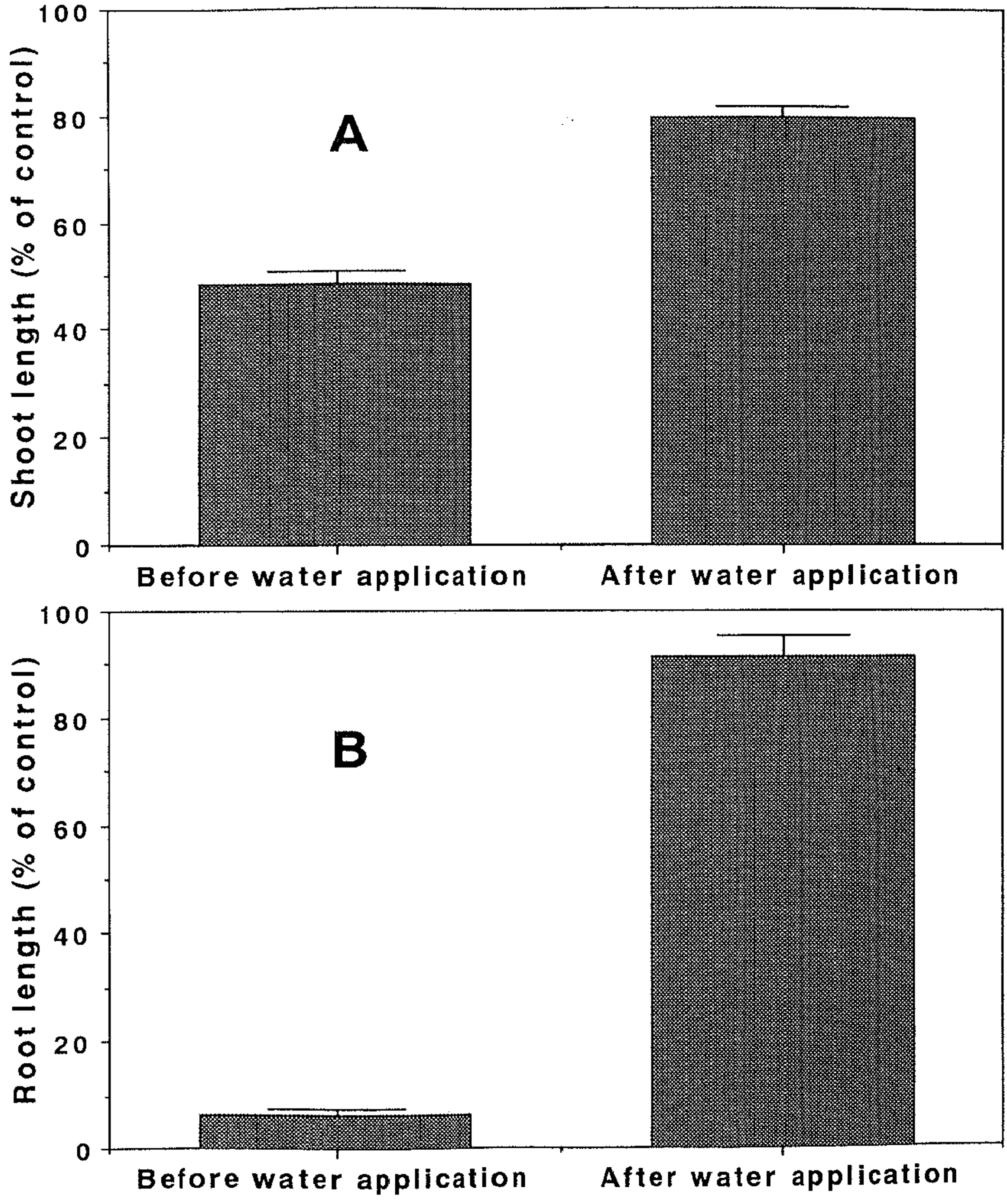

Fig. 5.6 Shoot growth (A) and root growth (B) of rice seedlings in soil treated with water extract from Mexican sunflower at the concentration of 40 mg/ ml, which was placed on the soil column before and after applied with water. Shoot and root length of the control were 26 ± 2 mm and 38 ± 2 mm, respectively.

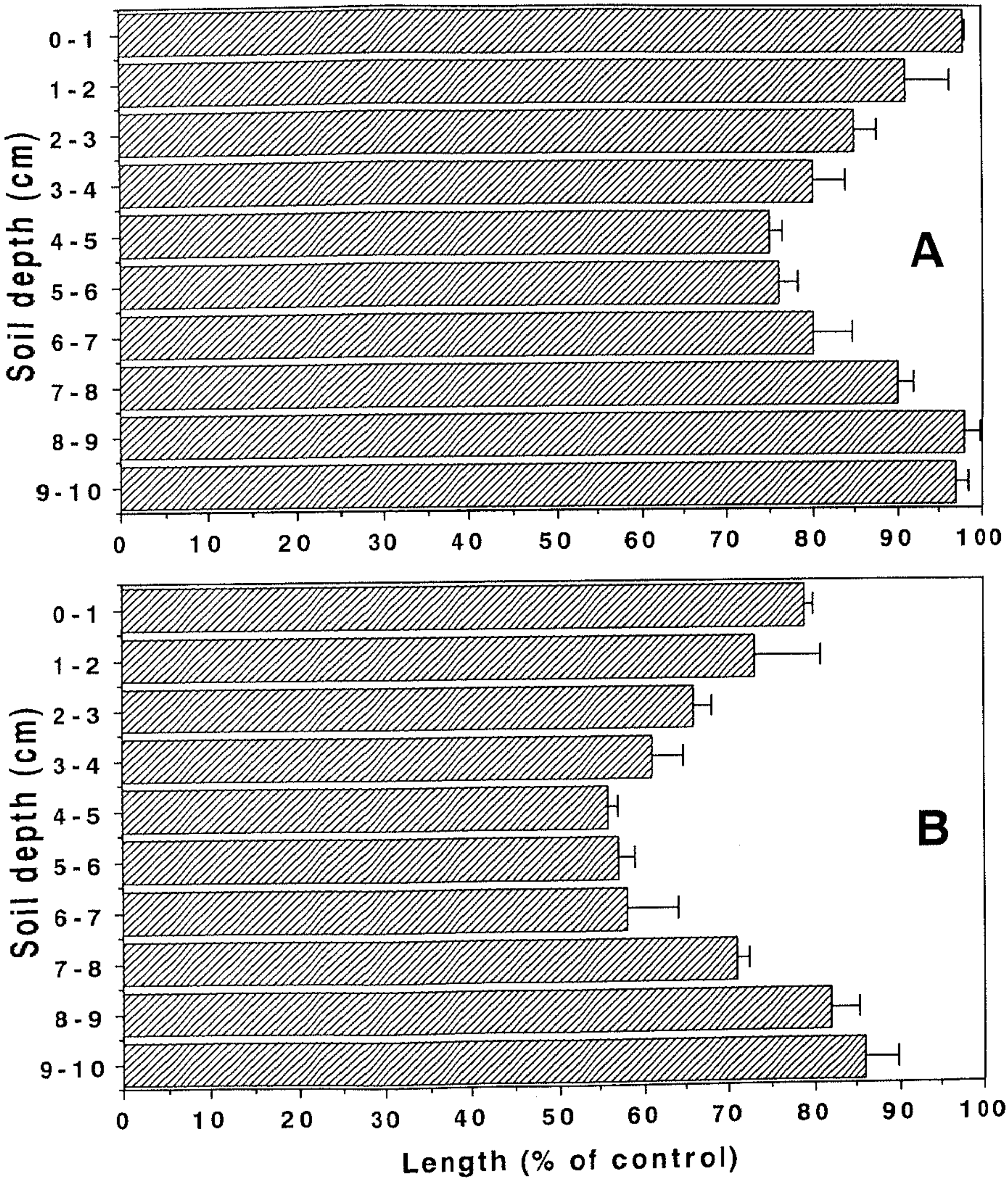

Fig. 5.7 Shoot growth (A) and root growth (B) of rice seedlings in sea sand treated with soil-water from each soil layer of wet soil column topped with soil treated with water extract from Mexican sunflower leaves for 24 hr before water was applied. Shoot and root length of the control were 26 ±2 mm and 38 ±2 mm, respectively.