Effect of early spring planting on the number of tillers, height, diameter and yield of sugarcane stems

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Abstract :

Two-experiment research study were conducted on the sugarcane crop in 2024. The first was conducted in a greenhouse affiliated with the Directorate of Agriculture in Diyala Governorate, and the second experiment was conducted in the field on sugarcane planted at the research station of the Iraqi Center of Sugarcane Research, affiliated with the University of Diyala. Three varieties were planted.: CP72-2086, CP89-2143, and CP81-325.These are American varieties introduced to Iraq and planted in the fields of the General Sugar Company/Sugar Cane Factory and Farm in Maysan Governorate in 2004. Then, some stems of each of these varieties were transferred and planted in a number of areas in Diyala Governorate in 2016, and in 15 Iraqi governorates until 2025.

The first experiment was implemented according to a Completely Randomized Design inside the greenhouse, and included 9 experimental units resulting from three varieties and three replicates, with the aim of evaluating the response of sugarcane varieties to the transplanting cultivation technique and determining the extent of their success when planted early in the spring season.The second experiment was applied according to a Complete Randomized Block Design with a split-plot arrangement and three replications. The first factor included the varieties that represented the main plots, while the second factor included the planting technique (one-month-old seedlings and the traditional planting method) that represented the sub plots with the aim of knowing the extent of the effect of early spring planting on early maturity and the reflection of this effect on the stem yield (tons.h̄¹.(

The results of the study showed the following:

.1Significant differences were found between the varieties in the mean of the studied traits. The CP89-2143 variety achieved the highest germination percentage, root length, stem length,number of leaves, number of tillers and seedling dry weight, reaching 99.34%, 17.8 cm, 11.9 cm,5 leaves, 3.1 tillers and 22.6 g, respectively .

..2Using the transplanting technique for the CP89-2143 variety resulted in the highest increase in mean stem height, tillering period, total stem number, and no.of extractable stems , reaching 290.6 cm, 41.1 days, 50.7 stems/m², and 48.2 stems.m̄², compared to the traditional planting method for the same variety, which recorded 242.0 cm, 29.3 days, 29.1 stem.m̄², and 26.9 stem.m̄² respectively.

.3The traditional planting method with the CP81-325 variety recorded the highest number of non-extractable stems, reaching 4.8 stems.m̄², and with the CP72-2086 variety, the highest mean stem diameter was recorded, reaching 3.5 cm, compared to the transplanting technique for the same variety, which recorded 3.5 stem.m̄² and 2.6 cm respectively.

..4The transplanting technique for the CP89-2143 variety achieved the highest mean stem yield of 85.8 tons.hā¹, a 67% increase compared to the traditional planting method for the same variety, which recorded 51.4 tons.hā¹ .

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We conclude from the current study that it is possible to plant sugarcane setts early and transfer it to the permanent field early, as this leads to early maturity and increased stems yield.

Keywords: Sugarcane, transplanting technique, varieties, early spring planting.

Introduction:

Sugarcane Saccharum officinarum L. is an important strategic agricultural and industrial crop, cultivated in all countries between 35° north and south of the equator. Countries' interest in cultivating this crop stems from its economic importance, derived from the sugar industry, biofuel, and secondary industries produced from its waste, both in the field and in the factory [5.[

The cessation of the sugarcane factory and farm in Maysan Governorate and all factories that depend on raw materials resulting from its waste did not stand in the way of researchers in conducting research and studies on it, but rather increased interest in its cultivation in 14 Iraqi governorates to determine the extent of the suitability of natural factors in the growth and production of the crop [6.[

Sugarcane varieties vary in their ability to record the highest number of tillers, the number of extractable stems, the height and diameter of the stem, and the weight of one stem. They also vary according to environmental conditions, as a loss in yield was observed in some varieties under these conditions [20.[

The transplanting technique has been used on sugarcane crop in Egypt to reduce the production cost per hectare of cuttings [9]. Indonesia has also shown interest in developing sugarcane crop by using the transplanting cultivation technique [19]. India has achieved a significant increase in stem yield per hectare by using the transplanting cultivation technique by ensuring 100% germination rate and increasing the number of branches per seedling [12.[

The idea of using the seedling technique in spring planting came about by planting the crop in mid-February (early planting) instead of the recommended planting in mid-March.

The aim is to evaluate the extent to which the varieties used in the study can tolerate environmental changes and their ability to influence the number of tillers, plant height, and stem diameter, and the reflection of this effect in the crop reaching the early maturity stage, increasing the number of extractable stems, and raising the stem yield compared to the traditional planting method.

Materials and Methods:

A two-experimental research study were conducted on sugarcane crop. The first was conducted in a greenhouse affiliated with the Directorate of Agriculture in Diyala Governorate, and the second was conducted in the field on sugarcane planted in 2024 at the research station of the Iraqi Center of Sugarcane Research affiliated with the University of Diyala. Three varieties, CP72-2086, CP89-2143 and CP81-325, which are American varieties introduced to Iraq and planted in the fields of the General Sugar Company/Sugarcane Factory and Farm in Maysan Governorate in 2004, were planted with stems of each of these varieties and planted in a number of areas in Diyala Governorate in 2016, and in 15 governorates until 2025 [5.[

Greenhouse Experiment

An experiment was conducted using a Completely Randomized Design within a greenhouse. It included nine experimental units produced from three varieties and three replicates. The aim was to evaluate the

response of sugarcane varieties to the transplanting technique and determine their success when planted early in the spring. 300 single-bud setts of each sugarcane variety were planted 5 cm below the soil surface on 15/1/2025. Buds emerged 8-10 days after planting , to obtain one-month-old seedlings with 4-6 leaves (Figs.1,2 and 3(

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Fig. 1: Sugarcane seedlings varieties CP72-2086, CP89-2143 and CP81-325

Fig.2: Sugarcane seedlings before being transferred to the permanent field

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Fig.3: Sugarcane setts roots one month after planting and before transferring them to the permanent field.

Before transferring the seedlings to the permanent field on 15/2/2025.the following characteristics were studied:

-Bud germination rate(%)
-Root length (cm(
-Stem length (cm(
-Number of tillers
-Number of leaves
-Dry weight of seedlings (g(

Field Experiment :

A factorial experiment was conducted according to a Completely Randomized Block Design with three replicates. The first factor included the varieties (CP72-2086, CP89-2143, and CP81-325), which represented the main plots, while the second factor included the transplanting technique (one-month-old seedlings and traditional planting methods), which represented the sub plots. The goal was to determine the extent to which early spring planting affects early maturity and the reflection of this effect on stem yield (tons.h̄¹.(After soil treatment operations such as plowing, loosening and leveling, the field was divided into several plots with an area of 9 m² per plot and a distance of 1 m between each plot and 2 m between replicates. The plot included three rows, each 3 m long, and a distance of 1 m between each row. 15 seedlings were placed in 1 m in the treatments using the transplanting technique and 5 setts (each sett consisting of three buds) in 1 m at a depth of 5 cm in the treatments using the traditional method (control treatment) (Fig. 4.(

Fig.4:Transferring seedlings to the permanent field and their sustainability

Data were recorded for a number of important growth traits in plants growing in the midline of each experimental unit and averaged as follows:

-Stem height (cm): Measured using a tape measure from the soil surface to the last node for ten plants taken from the midlines of each experimental unit.

-tillering stage duration: Calculated by calculating the number of days from the start of the tillering stage to the start of the elongation stage for each experimental unit. The start of the elongation stage was determined when the temperature reached approximately 30°C. [17.[

-Total number of stems: The stems were counted per square meter of each experimental unit.

-Number of extractable and non-extractable stems: The stems were counted per square meter of each experimental unit at the end of the final maturity stage.

-Stem diameter (cm): It was measured using a Vernia measuring machine from three locations, the base, middle and top of the stem, and was divided by 3 to obtain the mean of this trait for ten plants that were taken to measure the stem height trait from each experimental unit at the end of the final maturity stage.

-Stem yield (tons.hā¹): Stem yield was calculated from the weight of plants within one square meter taken from the center line of each experimental unit. It was converted to tons per hectare.

The data of the greenhouse experiment were analyzed according to the analysis of variance method for a factorial experiment with a Completely Randomized Design , and the data obtained from the field experiment were analyzed according to the analysis of variance method for a factorial experiment with a Completely Randomized Block Design with split plot arrangement using the ready statistical program (SPSS). The Least Significant Difference (LSD) test was chosen to compare the means, at a probability level of 0.05.

Results and Discussion:

Greenhouse Experiment:

buds germination percentage:(%)

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The results of Table (1) indicate that there were significant differences between the varieties in the mean germination percentage of buds. The varieties CP89-2143 and CP81-325 recorded an mean germination percentage of 99.34 and 98.00%, respectively, while the variety CP72-2086 gave the lowest germination percentage of 96.67% . This may be due to the inherent characteristic of each variety [8] and this is consistent with [14], which indicated that the highest germination percentage was recorded in the variety CoI 64 (65.5%), while the lowest germination percentage was recorded in the variety CoH 128 (48.5%.(

Root length (cm:(

The results of Table (1) indicate significant differences between varieties in mean root length. The CP89-2143 variety recorded the highest mean for this trait, at 17.8 cm. Meanwhile, the CP81-325 variety recorded the lowest germination percentage, at 15.0%, and did not differ significantly from the CP72-2086 variety. The reason for the increased mean root length of the CP89-2143 variety was that it produced greater quantities of food, some of which was transferred to the roots, which may have led to the increased root length. The reason for the increase in the CP89-2143 variety is due to a characteristic inherent in the variety itself.

Stem length (cm:(

The results of Table (1) also indicate significant differences between varieties in mean stem length. The CP89-2143 variety produced an mean increase in this trait of 11.9 cm, while the CP72-2086 variety produced the lowest stem length of 10.2 cm, and did not differ significantly from the CP81-325 variety , which recorded 10.5 cm. The reason for the CP89-2143 variety recording the highest mean stem length is probably due to its effective role in giving the highest mean root length (Table 1), as a number of studies have indicated the presence of a highly significant positive correlation between stem height and root length [18]. The ability of the variety to produce food through photosynthesis, which allows for the storage of some of the nutrients in other plant organs such as the stem and root, has led to increased growth and has been positively reflected in the increased length of the stem.

Number of leaves. Seedling $^{-1}$:

The results of Table (2) indicate no significant differences between the varieties.

Number of tillers. Seedling^{-1}

The formation of tillers in sugarcane is important because of its contribution to increasing yield through its role in creating a large reservoir of nutrients stored in specialized tissues [15]. Furthermore, the tillering capacity and subsequent growth efficiency determine the yield of the variety.

The results of Table (2) indicate significant differences between the varieties in the mean number of tillers. CP89-2143 variety gave the highest mean for this trait, reaching 3.1 tillers . CP72-2086 variety gave the lowest number of tillers , reaching 2.3 tillers , it did not differ significantly from CP81-325 variety.

The significant effect of the CP89-2143 variety may be due to the high ability of this variety to exploit all environmental factors in its favor, which caused this clear increase in the mean of this trait.

Seedling dry weight (g(

The results of Table (2) indicate significant differences between varieties in mean seedling dry weight. The CP89-2143 variety yielded an mean increase of 22.6 g in this trait, while the CP72-2086 variety recorded the lowest seedling dry weight, at 19.0 g. This is due to the increase in the mean root length and the

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mean stem length (Table 1), the mean number of leaves and the mean number of tillers (Table 2). This means that the seedlings have caused a clear increase in vegetative growth, which has been positively reflected in their average dry weight.

Table (1): The effect of varieties on the mean percentage of bud germination (%), root length (cm), and stem length (cm) for the sugarcane crop inside the greenhouse.

varieties	Bud germination rate (%)	Root length (cm)	Stem length (cm)
CP89-2143	99.34	17.8	11.9
CP81-325	98.00	15.0	10.5
CP72-2086	96.67	15.6	10.2
L.S.D 0.05	0.288	0.657	0.338

Table (2): The effect of varieties on the mean of some vegetative characteristics of the sugarcane crop inside the greenhouse.

Varieties	Number of leaves.seedling	Tillering no.	dry weight of seedling (gm)
CP89-2143	5.0	3.1	22.6
CP81-325	4.9	2.5	20.4
CP72-2086	4.8	2.3	19.0
L.S.D 0.05	N.S	0.303	0.287

Field Experiment:

Stem height (cm(

The data in Table (3) indicate significant effects between the transplanting technique and the varieties, as well as their interaction with each other, on the mean stem height. The transplanting method recorded a significant increase, reaching 283.3 cm, compared to the traditional planting method, which recorded 227.0 cm. The increase in the mean stem height coincided with the end of the tillering stage and the entry into the Boom stage of growth , which is the stage during which growth and elongation accelerate due to the availability of suitable environmental conditions, especially the rise in temperature that reached approximately 30°C [5] . This environmental factor provided a greater scope for the crop to accumulate temperature for growth and elongation.

The variety CP89-2143 recorded a significant increase in the average of this trait, as it reached 266.3 cm compared to the varieties CP72-2086 and CP81-325 which recorded a stem height of 251.0 and 248.2 cm, respectively, while the transplanting technique for the CP89-2143 variety achieved the highest increase in mean stem height, which reached 290.6 cm, compared to the traditional planting method for the same variety, which recorded 242.0 cm..

The superiority of the CP89-2143 variety in the mean of this trait, by giving the highest mean stem height, is evidence that it is the most efficient in exploiting its genetic and physiological capabilities, as it gave the highest mean of this trait at the end of crop growth,as plant height is affected by genetic factors and the surrounding environmental factors [2]. The difference in the mean of this trait among the varieties was consistent with the results of [4] and [10] , who found a significant difference in the mean plant height among the studied genetic compositions .

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Table (3): The effect of transplanting technique and varieties on the mean stem height (cm) of sugarcane crop.

Planting method	Varieties			Mean planting method
	CP72-2086	CP89-2143	CP81-325	
Transplanting technique	281.3	290.6	277.9	283.3
Traditional	220.7	242.0	218.4	227.0
Varieties mean	251.0	266.3	248.2	
L.S.D 0.05	For planting method 1.993	for varieties 2.041	for interaction 3.885	

Tillering stage duration (days(

The data in Table (4) show significant effects between the transplanting technique and the varieties, as well as their interaction during the tillering stage. The transplanting technique resulted in a significant increase in the mean duration of this trait, which reached 40.0 days, compared to the traditional planting method, which reached 28.3 days.

The CP89-2143 variety had a significant increase in the mean of this trait, reaching 35.2 days, compared to the CP81-325 and CP72-2086 varieties, which recorded 33.7 and 33.6 days, respectively.

The superiority of the seedling technique in achieving the longest period for the tillering stage is perhaps due to the long period of exposure of the plants or seedlings to climatic factors, especially temperature and lighting, which contributed to the emergence of buds before transferring them to the field while they are still in the greenhouse (Figure 1) , Which took advantage of the longest period for the emergence and formation of tillers compared to the traditional cultivation method (planting setts), which caused the period from planting until the emergence of buds to be extended, which took about 15 days, which led to a reduction in the period of the tillering stage [3],[13] reported that tillers grow best at a daily temperature of 18-35°C with an average temperature of 26°C, while tiller growth decreases when the temperature rises above 35°C and falls below 18°C. These results are consistent with what was observed by both [11] and[7.[

Table (4): The effect of the transplanting technique and varieties on the mean period of the tillering stage (number of days from the beginning of the tillering stage until the beginning of the elongation stage) for the sugarcane crop.

Planting method	Varieties			Mean planting method
	CP72-2086	CP89-2143	CP81-325	
Transplanting technique	39.7	41.1	39.3	40.0
Traditional	27.5	29.3	28.0	28.3
Varieties mean	33.6	35.2	33.7	
L.S.D 0.05	For planting method 0.716	for varieties 0.841	for interaction 1.662	

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Total number of stems:

The results of Table (5) show significant differences between the transplanting technique and the varieties, as well as their interaction in the mean total number of stems per square meter. A significant increase was observed with the transplanting technique, which recorded 45.8 stems.m̄² , compared to the traditional planting method, which recorded 25.8 stems.m̄² .

The main reason for the increased number of tillers of the seedlings, which led to an increase in the number of stems later on, is the increase in the period of the tillering stage (Table 4), which led to their exposure to light in the early stages of their growth (the beginning of the tillering stage), while the setts planted in the traditional way were still in the germination and emergence stage, which started the tillering stage after about 14 days (Table 4), as [3] indicated that the early improvement in light penetration at the beginning of the tillering stage of sugarcane plants causes a significant increase in the number of tillers at the end of the growth stage .

The CP89-2143 variety recorded a significant increase in the mean of this trait, reaching 39.9 stems.m̄², compared to the CP72-2086 and CP81-325 varieties, which recorded 34.2 and 33.4 stems.m̄², respectively.

Table (5): The effect of transplanting technique and varieties on the mean number of total stems,m̄² of sugarcane crop.

Planting method	Varieties			Mean planting method
	CP72-2086	CP89-2143	CP81-325	
Transplanting technique	44.8	50.7	42.0	45.8
Traditional	23.5	29.1	24.8	25.8
Varieties mean	34.2	39.9	33.4	
L.S.D 0.05	For planting method 1.077	for varieties 1.112	for interaction 2.006	

Number of extractable and non-extractable stems

The results of Table (6) show the mean number of extractable and non-extractable stems according to the effect of the planting method and sugarcane varieties. There are significant effects between the two planting methods. The transplanting technique recorded an increase in the mean number of extractable stems, amounting to 42.6 stems.m̄², with an increase rate of 128% , compared to the traditional planting method, which recorded a number of extractable stems of 22.0 stems.m̄², and a significant decrease in the mean number of non-extractable stems, which recorded 3.5 stems.m̄², a decrease of 28% compared to the traditional planting method, which recorded a number of non-extractable stems of 3.9 stems.m̄² .

Regarding the varieties, the CP89-2143 variety had a significant superiority in the mean number of extractable stems over the other two varieties, as the mean number was 37.6 stems.m̄², while the CP81-325 variety had the lowest mean number of stems, amounting to 29.3 stems.m̄².

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As for the interaction, the transplanting technique for the CP89-2143 variety achieved the highest significant increase in the number of extractable stems, 48.2 stems.m̄², with an increase rate of 111% compared to the traditional planting method, which recorded 26.9 stems.m̄², and the lowest significant decrease in the mean number of non-extractable stems, 2.5 stems.m̄², with a decrease rate of 44% compared to the traditional planting method, which recorded 2.2 stems.m̄² .

The increase in the number of extractable stems and the decrease in the number of non-extractable stems using the transplanting technique may be due to the increase in the mean number of tillers since the beginning of the tillering stage and continued until harvest (Table 4), it has allowed the newly formed tillers to grow and develop later and form stems that can be extracted this is to improve the absorption of both water and food, and to provide the appropriate place for the growth of tillers on the one hand, and to provide sufficient light for the process of photosynthesis on the other hand. This in turn has caused the storage of sufficient quantities of sugars that accumulate in the stems of crop plants.

Table (6): Effect of transplanting technique and varieties on the mean number of extractable and non-extractable stems. m̄² of sugarcane crop .

Number of extractable stems				
Planting method	Varieties			Mean planting method
	CP72-2086	CP89-2143	CP81-325	
Transplanting technique	41.0	48.2	38.5	42.6
Traditional	19.2	26.9	20.0	22.0
Mean varieties	30.1	37.6	29.3	
L.S.D 0.05	For planting method 1.298	for varieties 1.622	for interaction 2.583	
Number of non-extractable stems				
Planting method	Varieties			Mean planting method
	CP72-2086	CP89-2143	CP81-325	
Transplanting technique	3.8	2.5	3.5	3.5
Traditional	4.3	2.2	4.8	3.9
Mean varieties	3.7	2.3	4.0	
L.S.D 0.05	For planting method 1.225	for varieties 1.318	for interaction 2.103	

1.225 1.318 2.103

Stem diameter (cm:(

Data in Table (6) indicate significant effects between the transplanting technique and the interaction between the transplanting technique and the variety . However, varieties had no significant effect on the mean stem diameter. The traditional planting method recorded the highest mean for this trait, 3.3 cm, compared to the transplanting technique, which recorded an mean of 2.5 cm.

The fact that the traditional farming method achieved the highest mean stem diameter may be due to these treatments achieving the lowest stem height (Table 3). Perhaps the nutrients represented by the photosynthesis process were used to increase the diameter instead of investing them in increasing the

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stem height, [16] indicated that there is a negative and highly significant correlation between plant height and stem diameter.The decrease in the mean stem diameter in the transplanting techniq treatment may be due to the increase in the mean stem height (Table 3) and the increase in the mean number of total stems (Table 5), which increased competition for nutrients between the stems and contributed in turn to the depletion of large quantities of nutrients for growth, which was negatively reflected in the mean stem diameter.

Regarding the interaction, the traditional planting method treatment achieved the highest increase in the mean stem diameter for all varieties, and the CP72-2086 variety for the same treatment achieved the highest mean of 3.5 cm.

Table (6): The effect of transplanting technique and varieties on the mean stem diameter (cm) of sugarcane crop.

Planting method	Varieties			Mean planting method
	CP72-2086	CP89-2143	CP81-325	
Transplanting technique	2.6	2.5	2.3	2.5
Traditional	3.5	3.0	3.3	3.3
Varieties mean	3.1	2.8	2.8	
L.S.D 0.05	For planting method 0.532	for varieties N.S	for interaction 0.911	

Stem yield (tons.hā¹:(

From the results of Table (7), it is evident that there are significant differences between the transplanting technique and the varieties, as well as their interaction in the mean stem yield. The use of the transplanting technique resulted in a significant increase in the mean yield of this trait, reaching 81.3 tons.h̄¹, an increase of 58% compared to the traditional cultivation method, which recorded 50.5 tons.h̄¹, The increased competition for the necessary growth requirements that appeared early in favour of the seedlings may have increased the size of the resource, as it increased the ability of the vegetation to intercept and penetrate a large amount of light, thus increasing the products of photosynthesis, which was positively reflected in the mean yield of stems per unit area.

As for the varieties, the CP72-2086 and CP89-2143 varieties significantly outperformed the CP81-325 variety, with a production of 68.6 tons.h̄¹ for each of them, compared to the CP81-325 variety, which produced 65.5 tons.h̄¹ , this can be attributed to the fact that there are a large number of genes that control the quantitative trait and its manifestation, and this trait is more affected by environmental factors. These genes may have been previously inactive in a certain environment, but their effect may be evident in another environment with factors suitable for the gene to express itself [1]. This is consistent with the two varieties that showed superiority in most vegetative traits, which was reflected in the stem yield per unit area.

Regarding the interaction , the transplanting technique for the CP89-2143 variety achieved the highest mean of 85.8 tons.hā¹, an increase of 65%, compared to the

traditional cultivation method for the same variety, which recorded 51.4 tons. hā¹ .

The increase in stem yield achieved by using the seedling technique may be attributed to the role of seedlings in increasing stem height (Table 3) and the number of extractable stems (Table 6), which increased competition for growth factors and contributed to the availability of building products in greater quantities, and improved light interception by crop plants, in addition to improving water absorption and transferring part of the food to meet the requirements of the growth of the new tillers to invest the time needed for growth and development, which led to the exploitation of this food being equal between the tillers to be more homogeneous compared to the traditional planting method, Consequently, these tillers eventually become heavier, more extractable stems.

Therefore, stimulating the production of these tillers from the beginning of the crop growth stage has led to the storage of larger quantities of photosynthesis products in these tillers and these have produced stems that can be extracted, which has been positively reflected in the mean yield of the stems.

Or the reason for the increase in the yield of sugarcane stems as a result of using the transplanting technique may be due to a significant decrease in the mean number of stems that cannot be extracted, this explains that sugarcane plants have become satisfied with the nutritional elements due to the presence of an excess of these elements stored in the main stem, which is considered a storehouse of carbohydrates, as the products of photosynthesis are used by the crop plants in growth and formation, while the excess of them that do not have an outlet is stored in the secondary stems of the crop in the late stages of growth. .

Table (7): The effect of transplanting technique and varieties on the mean stem yield (tons.hā¹) of sugarcane crop.

Planting method	Varieties			Mean planting method
	CP72-2086	CP89-2143	CP81-325	
Transplanting technique	78.0	85.8	80.2	81.3
Traditional	49.2	51.4	50.8	50.5
Varieties mean	68.6	68.6	65.5	
L.S.D 0.05	For planting method 1.057	for varieties 1.222	for interaction 1.983	

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