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RESPONSE OF JOJOBA (*SIMMONDSIA CHINENSIS*) CUTTINGS TO VARIOUS CONCENTRATIONS OF AUXINS

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Abstract

Semi-hardwood cuttings of 6 promising strains of jojoba were treated with auxins (IBA, IAA and NAA) solutions each @ 0, 1250, 2500, 5000 and 10000 mg l^{-1} and planted during October in sand:silt medium (1:1) under humid conditions maintained by polyethylene sheet tunnel till the end of March. Data on growth parameters regarding root, shoot and survival of the cuttings were recorded. The cuttings from PKJ-3 were the most responsive of all other strains as they took minimum time for rooting, gave maximum number of roots and leaves per cutting, length and diameter of primary root and shoot, and resulted in maximum rooting, sprouting and survival percentages. IBA significantly enhanced the root growth and increased survival of the cuttings, while IAA significantly promoted shoot growth. The highest level of each auxin was the most effective.

Introduction

Jojoba [*Simmondsia chinensis* (Link) Schneider] is a dioecious drought-tolerant perennial shrub. Its seeds contain about 50% oil (liquid wax) which has been proved as a good substitute to the sperm whale oil. Jojoba plantations are established *via* seeds, seedlings, rooted cuttings, or plantlets from tissue culture. Generally the male plants outnumber the female plants when raised from seeds (Harsh *et al*., 1987). Being dioecious, a seeded plantation of jojoba has genetic heterogeneity and low average yields (Benzioni, 1997). Vegetative propagation enables the establishment of plantations with the desired proportion of male to female plants from pre-selected superior clones (Benzioni, 1997). It also creates uniformity, high yields, early bearing and reduced cost of cultural and harvesting operations (Hogan & Palzkill, 1983). Attempts have been made to propagate jojoba vegetatively through air-layering (Reddy, 2003; Bashir *et al*., 2005), graftintg (Shah & Bashir, 2000; Bashir *et al*., 2006), stem cuttings (Bashir *et al*., 2001, 2007a) and tissue culture (Bashir *et al*., 2007b, c & d; Bashir *et al*., 2008). Although jojoba is a difficult to root plant, yet propagation through cuttings is the most commonly used asexual method with limited success (Palzkill & Feldman, 1993).

Successful rooting of jojoba cuttings can be achieved by the use of different auxins. The rooting rates of cuttings treated with IBA, NAA and IAA (each at 100 mg l^{-1}) were 82, 80 and 76%, respectively and the rooting time for cuttings ranged from 125 to 261 days (Zhou, 2002). The rooting ratio of semi-hardwood cuttings was increased by IBA @ 1000 mg l^{-1} and the rooting ratio of young individuals was higher than the mature ones (Cao & Gao, 2003). Clonal differences for rooting capability of semi-hardwood cuttings treated with 2000 mg l^{-1} IBA under intermittent mist were evident among 12 clones of jojoba (Lee & Palzkill, 1984). Marked differences in the rooting of cuttings from different genotypes of jojoba were reduced by IBA + wounding (Howard *et al.*, 1984). Thomson (1982) reported 30 to 70% rooting in terminal cuttings treated with 4000 mg l^{-1} IBA using intermittent mist in a partially shaded greenhouse. Feldman *et al.*, (1983) rooted the cuttings of 20 different male jojoba plants by treating with 4000 mg l^{-1} IBA for 15 seconds, misting intermittently for 8 seconds every 4 minutes. Creating an atmosphere of 100% humidity at the leaf surface of jojoba stem cuttings, without saturating the rooting medium, had contributed to a high degree of rooting (Brown & Campbell, 1985). Abramovich *et al.*, (1985) improved the rooting percentage of jojoba cuttings by adding a mixture of 0.5 mg l^{-1} boric acid + 500 mg l^{-1} NAA or 1000 mg l^{-1} vitamins C to 15000 mg l^{-1} Potassium Indole-butyrate solution. Arce & Jordan (1988) found that IBA and NAA could induce approximately 56 and 26% root formation in jojoba cuttings, respectively. Benzioni (1997) recorded rooting of jojoba cuttings within three to five weeks in a greenhouse with substrate temperature of 30^{o}C and mist applied for 10 second every 8-10 minutes. Bashir *et al.*, (2001) recorded 61% rooting in semi-hardwood cuttings of jojoba just dipped in 4000 mg l^{-1} IBA solution under partially shaded polyethylene sheet tunnel having 90 to 95% humidity with mean temperature of 15 - 30^{o} C. The cuttings did not respond to 500 mg l^{-1} IBA even increasing the dipping time. Singh *et al.*, (2003) conducted studies to determine the effect of IBA (at 500, 1000, 2500, 3000, 4000, 5000, 6000, 8000, 10000 and 15000 mg l^{-1}) with boric acid (at 31 mg l^{-1}) on adventitious rooting of jojoba stem cuttings. The quick dip (20-30 seconds) method of IBA (5000 mg l^{-1}) with boric acid effectively caused rhizogenesis in young sprouts of 1- to 2-year-old branch.

Since jojoba was introduced in Pakistan during mid 1980's, it could not flourish due to problems in propagation to get true-to-type plants. Multiplication of superior genotypes *via* rooted cuttings will help in multiplication of the future varieties of jojoba that might solve the male and female plant ratio problems in the fields, and ultimately increase the yield per plant compared to the average yield from seedlings. The aim of the present study was to develop a cheaper and accessible technique for rooting the jojoba cuttings by using a suitable auxin with its optimum concentration, ultimately to multiply true-to-type uniform, desirable selections to establish jojoba plantations in Pakistan.

Materials and Methods

The 15 year old female plants of promising jojoba strains i.e., PKJ-1, PKJ-2, PKJ-3, PKJ-4, PKJ-5 and PKJ-6 as characterized by Bashir *et al.* (2005), were tried to propagate through stem cuttings. Semi-hardwood cuttings (about 1-year-old with brownish green bark) 20-30 cm long and 0.25-0.50 cm in diameter having 4-6 pairs of leaves were taken from each strain in the month of October. The leaves from basal 1/3rd portion of the cuttings were trimmed off. The whole cuttings first were fully dipped in Topsin-M (fungicide @ 2.5 g l^{-1} water) solution for 2 hours, taken out and dried completely in shade. Then the basal 1/3rd portion of the cuttings was dipped for 5 minute in IBA (Indole butyric acid), IAA (Indole acetic acid) or NAA (Naphthalene acetic acid) solution with a concentration of 0, 1250, 2500, 5000 and 10000 mg l^{-1}.

The treated cuttings were planted in polyethylene bags filled with the soil medium composed of sand and silt (1:1) and kept under polyethylene sheet tunnel where high humidity was maintained. The bags were arranged in Randomized Complete Block Design

(RCBD) with three factors in three replications, each replication containing 450 bags. The first factor was strains, the second one auxins and the third concentrations of auxins. The bags were watered with a sprinkler at fortnightly interval depending upon the prevailing temperature and humidity, and kept covered with polyethylene sheet for about 5 months till the end of March. Five cuttings of each strain were treated with a single concentration of an auxin in each replication and only one cutting was planted in each bag. A total 1350 cuttings of six strains were planted during the first year and the same number of cuttings during the second year. Data were recorded on the following parameters; number of days to root, rooting percentage, number of roots per cutting, length of primary root, diameter of primary root, sprouting percentage, number of leaves per cutting, length of primary shoot, diameter of primary shoot and survival percentage. The rooting/sprouting/survival percentage of cuttings was calculated by the given formula:

$$\text{Rooting/sprouting/survival percentage} = \frac{\text{Number of cuttings rooted/sprouted/ survived}}{\text{Number of cuttings planted}} \times 100$$

Data in number, having values 0 and 100 and the data in percentage were transformed by logarithmic transformation and arcsin (angular) transformation, respectively prior to statistical analysis. The data of both years were combined and analyzed for pooled analysis by using Analysis of Variance technique. Treatment means were compared by employing Duncan's Multiple Range test at $\alpha = 5\%$ (Steel & Torrie, 1984).

Results

Although IBA @ 1250 mg l^{-1} proved effective to cause rooting on some of the cuttings but none of them survived. The same level of IAA/NAA was not effective to cause rooting of cuttings. The untreated cuttings (control, without any auxin treatment) did not root at all. Hence, these treatments i.e. control and each auxin @ 1250 mg l^{-1}, were excluded from statistical analysis of all the root parameters and survival percentage of cuttings for convenience in data presentation.

Effect of strains: Root parameters as well as shoot parameters and survival percentage of the cuttings were significantly affected by the strains. The cuttings from PKJ-3 strain rooted the earliest; excelled the other strains with maximum rooting, sprouting and survival percentages; produced maximum roots and leaves per cutting; and attained longer primary root and shoot with maximum diameter. The cuttings from PKJ-2 strain rooted at the last and resulted in the minimum values for all the growth parameters of the cuttings (Table 1).

Effect of auxins: All the cuttings treated with IBA rooted earlier than those treated with the other two auxins which were almost similar in effect. IBA led with maximum rooting and survival percentages, number of roots per cutting, length and diameter of primary root. It was followed by IAA for all the root parameters studied. However, shoot parameters comparatively better responded to IAA. The cuttings treated with NAA though were statistically similar to IAA in rooting time and survival percentage, yet NAA gave minimum rooting and sprouting percentages with minimum roots and leaves per cutting and shortest primary root with minimum diameter. However, the effect of NAA and IBA on the length of primary shoot and that of NAA and IAA on the diameter of primary shoot was statistically similar (Table 1).

Table 1. Growth parameters of jojoba cuttings as affected by strains, auxins and their concentrations.

Factors	No. of days to root	Rooting (%)	No. of roots per cutting	Length of primary root (cm)	Diameter of primary root (mm)	Sprouting (%)	No. of leaves per cutting	Length of primary shoot (cm)	Diameter of primary shoot (mm)	Survival (%)
Jojoba strains										
PKJ-1	107.15c*	38.94c	20.13d	5.79c	0.67c	33.78d	6.43d	5.42e	1.51d	35.86c
PKJ-2	128.53a	34.00d	16.11e	4.80d	0.53d	30.89e	5.82e	5.07f	1.45e	30.27e
PKJ-3	86.70e	49.41a	28.93a	7.22a	0.87a	50.67a	9.73a	8.25a	1.94a	45.66a
PKJ-4	109.14c	39.66c	22.04c	6.24b	0.69c	37.11c	7.98c	6.84c	1.68c	36.81c
PKJ-5	120.50b	37.87c	19.78d	4.98d	0.55d	35.78cd	6.52d	5.67d	1.55d	33.39d
PKJ-6	100.46d	44.74b	25.41b	6.46b	0.74b	45.78b	8.89b	7.42b	1.82b	41.90b
Auxins										
IBA	91.00b	44.64a	34.38a	7.20a	0.87a	39.00b	7.57a	6.35b	1.60b	39.96a
IAA	117.22a	41.30b	17.72b	5.42b	0.60b	42.22a	7.80a	6.58a	1.70a	38.57b
NAA	118.03a	36.37c	14.09c	5.10c	0.56c	35.78c	7.31b	6.40b	1.68a	33.42b
Concentrations (mg l^{-1})										
0	-	-	-	-	-	26.30e	5.65e	4.98e	1.46e	-
1250	-	-	-	-	-	32.41d	6.41d	5.67d	1.55d	-
2500	124.17a	34.31c	16.18c	4.87c	0.54c	38.15c	7.34c	6.33c	1.65c	31.72c
5000	107.47b	40.67b	22.19b	6.00b	0.68b	44.63b	8.39b	7.13b	1.75b	37.76b
10000	94.25c	47.34a	27.83a	6.88a	0.80a	53.52a	10.03a	8.11a	1.88a	42.47a

*Means sharing similar letters under each parameter are non-significant at $\alpha = 5\%$ (DMR test).

Table 2. Growth parameters of jojoba cuttings as affected by strains and auxins (interaction).

Strains X Auxins	No. of days to root	Rooting %	No. of roots per cutting	Length of primary root (cm)	Diameter of primary root (mm)	No. of leaves per cutting	Length of primary shoot (cm)	Diameter of primary shoot (mm)
PKJ-1 x IBA	90.36f*	42.31cd	29.44de	6.88c	0.88c	5.87e	4.83hi	1.35j
PKJ-2 x IBA	116.6bcd	35.59ef	27.83e	5.68e	0.65ef	5.20f	4.58i	1.33j
PKJ-3 x IBA	69.82h	57.02a	44.94a	8.70a	1.16a	10.27a	8.68a	1.98a
PKJ-4 x IBA	90.16f	41.67cd	33.33c	8.01b	0.92bc	8.13c	7.00cd	1.68ef
PKJ-5 x IBA	104.23e	40.97cd	32.39cd	6.29d	0.70e	6.20e	5.27gh	1.46i
PKJ-6 x IBA	82.22g	50.32b	38.33b	7.76b	0.95b	9.77a	7.73b	1.82bc
PKJ-1 x IAA	119.67bc	38.92de	16.28gh	5.00fgh	0.55ghi	7.03d	5.82ef	1.58gh
PKJ-2 x IAA	136.77a	35.65ef	11.56ij	4.17ij	0.46jk	5.87e	5.05h	1.47i
PKJ-3 x IAA	90.36f	48.27b	23.33f	6.84c	0.76d	9.87a	8.32a	1.99a
PKJ-4 x IAA	121.06b	42.31cd	18.44g	5.67e	0.59fg	8.27c	6.78d	1.65efg
PKJ-5 x IAA	129.42a	39.04de	15.44gh	4.62gh	0.51hij	7.17d	6.10e	1.62fgh
PKJ-6 x IAA	112.20cd	43.59c	21.28f	6.23d	0.70e	8.63bc	7.42bc	1.88b
PKJ-1 x NAA	113.76bcd	35.59ef	14.67hi	5.47e	0.60fg	6.40e	5.60fg	1.61fgh
PKJ-2 x NAA	133.66a	30.78g	8.94j	4.56hi	0.49ijk	6.40e	5.58fg	1.55h
PKJ-3 x NAA	103.51e	42.95cd	8.50g	6.10d	0.68e	9.07b	7.75b	1.85b
PKJ-4 x NAA	119.40bc	35.00ef	14.33hi	5.03fg	0.57gh	7.53d	6.73d	1.72de
PKJ-5 x NAA	129.72a	33.60fg	11.50ij	4.03j	0.44k	6.20e	5.63fg	1.56h
PKJ-6 x NAA	110.15de	40.32cd	16.61gh	5.41ef	0.58g	8.27c	7.12cd	1.77cd

*Means sharing similar letters under each parameter are non-significant at α = 5% (DMR test).

Table 3. Growth parameters of jojoba cuttings as affected by auxins and their concentrations (interaction).

Auxins X Concentration (mg l^{-1})	No. of days to root	Rooting %	No. of roots per cutting	Diameter of primary root (mm)
IBA x 2500	112.20cd*	36.58e	27.14c	0.71c
IBA x 5000	90.78f	44.04cd	34.75b	0.89b
IBA x 10000	73.96g	53.32a	41.25a	1.02a
IAA x 2500	128.53a	35.23e	12.03g	0.49e
IAA x 5000	118.85b	42.02d	17.36e	0.60d
IAA x 10000	105.68e	46.63bc	23.69d	0.70c
NAA x 2500	133.05a	31.10f	9.36h	0.43f
NAA x 5000	115.08bc	35.94e	14.36f	0.56d
NAA x 10000	107.15de	42.08d	18.56e	0.68c

*Means sharing similar letters under each parameter are non-significant at α = 5% (DMR test).

Effect of auxin concentrations: All the growth parameters of cuttings were significantly affected by the concentrations of auxins. The highest concentration (10000 mg l^{-1}) of auxins significantly reduced the time for rooting; increased rooting, sprouting and survival percentages to the maximum; produced maximum roots and leaves per cutting and caused the longest primary root and shoot both with the maximum diameter. The lowest values of all root parameters as well as survival were recorded by the concentration (2500 mg l^{-1}) of auxins, while the lowest values of all shoot parameters by the control (Table 1).

Effect of strains x auxins (interaction): Two-way interaction between the jojoba strains and the auxins was significant for all the root parameters as well as for number of leaves per cutting and length and diameter of primary shoot. The cuttings of PKJ-3 treated with IBA took the minimum time to root, got maximum rooting percentage, number of roots and leaves per cutting, length and diameter of primary root and shoot. However, shoot parameters of PKJ-3 under the influence of IAA were at par with those of PKJ-3 in response to IBA. The cuttings of PKJ-2 treated with NAA took maximum time to root and gained minimum values for most of the root parameters, while the cuttings of the same strain got minimum values for most of the shoot parameters under the effect of IBA (Table 2).

Effect of auxins x concentrations (interaction): The interaction between auxins and their concentration significantly affected only the root parameters except the length of primary root. The cuttings treated with the highest concentration (10000 mg l^{-1}) of IBA took the minimum time to root, got maximum rooting percentage, number of roots per cutting and diameter of primary root. While the cuttings treated with NAA @ 2500 mg l^{-1} took the maximum time to root and got minimum values for all root parameters under study (Table 3).

Effect of strains x auxin concentrations (interaction): The interaction between strains and the auxin concentrations remained statistically significant for diameter of primary root, number of leaves per cutting and the length of primary shoot. The maximum values for these parameters were obtained by the cuttings of PKJ-3 strain at the highest concentration of auxins. The cuttings of PKJ-2 got the minimum diameter of primary root at 2500 mg l^{-1} concentration of auxins, while minimum number of leaves and length of primary shoot at 0 mg l^{-1} (control). However, it remained statistically at par with the cuttings of PKJ-5 for these parameters at the same set of concentrations (Table 4).

Table 4. Growth parameters of jojoba cuttings as affected by strains and auxin concentrations (interaction).

Strains X Concentrations (mg l^{-1})	Diameter of primary root (mm)	No. of leaves per cutting	Length of primary shoot (cm)
PKJ-1 x 0	-	4.78op	4.28pq
PKJ-1 x 1250	-	5.33mno	4.83nop
PKJ-1 x 2500	0.55ij	6.28jkl	5.44klm
PKJ-1 x 5000	0.69efg	7.22ghi	5.92ijk
PKJ-1 x 10000	0.79cd	8.56ef	6.61fg
PKJ-2 x 0	-	4.22p	3.80q
PKJ-2 x 1250	-	5.00nop	4.44op
PKJ-2 x 2500	0.43k	5.78klmn	5.17lmn
PKJ-2 x 5000	0.54j	6.56ijk	5.75jkl
PKJ-2 x 10000	0.63gh	7.56gh	6.19ghij
PKJ-3 x 0	-	7.56gh	6.61fg
PKJ-3 x 1250	-	8.00fg	7.25ef
PKJ-3 x 2500	0.68fg	9.11de	7.86cd
PKJ-3 x 5000	0.88b	10.56c	9.00b
PKJ-3 x 10000	1.03a	13.44a	10.53a
PKJ-4 x 0	-	6.11jklm	5.44klm
PKJ-4 x 1250	-	6.89hij	5.97hijk
PKJ-4 x 2500	0.56ij	8.00fg	6.75fg
PKJ-4 x 5000	0.70ef	8.89e	7.61de
PKJ-4 x 10000	0.83bc	10.00c	8.42c
PKJ-5 x 0	-	4.33p	3.86q
PKJ-5 x 1250	-	5.56lmno	4.97mno
PKJ-5 x 2500	0.44k	6.33jkl	5.56klm
PKJ-5 x 5000	0.56ij	7.28ghi	6.42ghi
PKJ-5 x 10000	0.65fgh	9.11de	7.53de
PKJ-6 x 0	-	6.89hij	5.89ijk
PKJ-6 x 1250	-	7.67gh	6.58gh
PKJ-6 x 2500	0.61hi	8.56ef	7.19ef
PKJ-6 x 5000	0.75de	9.83cd	8.06cd
PKJ-6 x 10000	0.87b	11.50b	9.39b

Means sharing similar letters under each parameter are non-significant at $\alpha = 5\%$ (DMR test).

Effect of strains, auxins and their concentrations (interaction): Three-way interaction for all growth parameters of cuttings under study was found statistically non-significant.

Discussion

Large differences occur in growth parameters of cuttings due to mother plants (Thomson, 1982) and clones (Lee & Palzkill, 1984). Literature indicates that cuttings of jojoba start to root within 2-8 weeks (Benzioni, 1997). The delay in rooting and the other differences among growth parameters of cuttings in the present study could be attributed to the differences among the genotypes, auxin concentrations, infrastructure (polyethylene sheet tunnel) used in this experiment, environmental conditions in these infrastructure and nature of cuttings. Zhou (2002) related the rooting rates of jojoba cuttings to age of mother plant, temperature and humidity as the rooting rates of cuttings from young and old female jojoba shoots were 60 - 64 and 3-5%, respectively at a temperature of 19-23°C and 80-85% R.H. The results obtained by Cao & Gao (2003) also indicated that the rooting ratio of young jojoba individual was higher than mature individuals. Previously, Lee & Palzkill

(1984) reported that clones with a high rooting percentage also tended to produce an increased number of roots per cutting. In the present study, the cuttings from PKJ-3 survived to the maximum and that of PKJ-2 did to the minimum among the strains, indicating their differential behavior for different growth parameters.

Treatment of cuttings with an auxin, usually enhances rooting efficiency. In the present study, rooting started earlier in response to IBA and the cuttings had much time to increase number of roots and length and diameter of primary root. The rooting percentage of cuttings was increased by auxins treatment, especially treatment by IBA. The findings are partially in line with Arce & Jordan (1988) who found that IBA and NAA could induce approximately 56 and 26% root formation in jojoba cuttings, respectively. In the present study, survival percentage of jojoba cuttings showed a positive response to IBA as it resulted in high rooting percentage. As the rooting percentage increased, survival percentage also showed a gradual increase. Similar findings were reported by Luqman *et al*., (2004) in semi-hardwood cuttings of guava. Singh (2004) stated that IAA in plant tissue is the principal native auxin. IBA is a synthetic auxin which is chemically similar to IAA with similar physiological activity. NAA is also a synthetic auxin which is not chemically similar to IAA, but still similar in physiological activity. The auxin having indole group generally produce a more fibrous root system than the naphthalene group. That is why IBA is preferred to NAA for rooting of cuttings. The results are also in accordance with the findings of Ahmad *et al*., (1998) who reported better rooting response and the highest rooting percentage with IBA than NAA in guava cuttings. However, auxins being root promoting growth regulators, had no direct impact on sprouting percentage of buds (Luqman *et al*., 2004) as bud sprouting is mainly attributed to the stored carbohydrate in the cuttings (Wahab, 1999). In fact, sprouting depends on physical status and food reserves of cuttings as the cuttings utilize the reserved food when temperature rises and start sprouting earlier than callus formation (Mabood *et al*., 1996).

Auxin concentrations applied to the cuttings also play an important role in formation of adventitious roots and subsequent survival of rooted cuttings. In the present study, the maximum values of root parameters of cuttings were recorded at the highest concentration of IBA. This was possibly because of the early rooting of cuttings at the highest concentration of IBA and sparing more time to increase length and diameter of primary root and number of roots per cutting. However, the minimum values of these parameters at 2500 mg l^{-1} of NAA were probably due to maximum time to root by this treatment. The results do not support the findings of Palzkill (1988) who accounted that root length was little affected by the concentration of IBA, but, are in conformity with his findings that root number increased dramatically at the higher concentrations of 15000 and 20000 mg l^{-1} of IBA. This is probably because of the fact that higher concentration of auxins promoted the cell division which increased the number of roots. The findings of the present study are also in line with him that rooting percentage increased steadily as IBA concentration increased from 0 to 15000 mg l^{-1}. Bashir *et al*., (2001) recorded 55% rooting in semi-hardwood cuttings of jojoba when treated with 2000 mg l^{-1} IBA and further increased to 61% at 4000 mg l^{-1}. The results contradicted to Zhou (2002) who recorded very high rooting percentage of cuttings at very low concentrations of auxins i.e., 82, 80 and 76% rooting in jojoba cuttings treated with IBA, NAA and IAA (each at 100 mg l^{-1}), respectively. However, in his experiment, he used young semi-lignified shoots of jojoba to prepare cuttings and appropriate temperature and humidity control for rooting. According to Singh (2004), a high ratio of carbohydrates to nitrogen compounds in the plant tissue as well as an optimum supply of auxin contribute to best rooting of cuttings. Often other factors such as shade and high moisture content of the air around the tops of the cuttings are more important than auxin treatment. Singh *et al*., (2003) stated that the quick dip (20-30 seconds) method of IBA (5000 mg l^{-1}) with 31 mg l^{-1} boric acid effectively caused rhizogenesis in young sprouts of 1 to 2-year-old branches of jojoba. In the present study, as the highest concentration of IBA caused maximum rooting and produced more number of roots, so it helped in survival of the cuttings to the maximum. The trend of survival of the cuttings was the same as was noted in case of rooting percentage and number of roots. Similar findings were reported by Luqman *et al*., (2004) in semi-hardwood cuttings of guava. Similarly, buds sprouted earlier at the highest concentration of auxins sparing more time to increase length of primary shoot and number of leaves per cutting.

Conclusion

The cuttings of PKJ-3 strain were the most responsive to the various levels of auxins, followed by those of PKJ-6. Hence, both strains are the most suitable for multiplication through cuttings. IAA significantly promoted shoot growth, and IBA significantly enhanced the root growth and increased survival of cuttings. The highest level of each auxin was the most effective. Therefore, IBA @ 10000 mg l^{-1} could be applied to jojoba cuttings for mass multiplication from a selected strain/clone/plant. The use of polyethylene sheet tunnel for jojoba cuttings propagation is a successful cheaper technique in lieu of costly greenhouse or mist propagation chambers. The outcome of this study surely will not only help in multiplication of elite selections as cultivars, but it is also expected that jojoba will firmly establish as a valuable new crop in areas of Pakistan with limited water.

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