# EFFECT OF AUXINS ON ROOT FORMATION IN THE VEGETATIVE PROPAGATION OF *POPULUS ALBA, POPULUS TREMULA, PICEA ABIES* AND *JUNIPERUS COMMUNIS*

**Dr. Adil Al-Kinany***

**Abstract.** *During the course of training in GDR, vegetative propagation of* Populus alba, Populus tremula, Picea abies *and* Juniperus communis *by cuttings using different concentrations of IBA and NAA singly as well as in mixture was studied from February,* 1979 *to June,* 1979 *under glass house conditions at the Department of Biology, Dresden Technical University, Dresden. The choice of the species for this work was predominantly guided by their close similarity in silvicultural behaviour with the economically important species of Iraq.*

*The IBA and NAA treatments of the four experiments were laid in randomized complete block design, each treatment being replicated three times with* 18-20 *cuttings per replication.*

*The results of the study showed that IBA upto* 4000 *ppm alone and upto* 2000 *ppm in mixture with NAA, highly significantly increased the survival percentage of the rooted cuttings of* Populus alba, *while IBA upto* 200 *ppm had a significant effect in terms of increasing the number of branches and leaves, and fresh and dry weight of whole stems as well as roots.*

*The experimental results of* Populus tremula *cuttings indicated that there are bright prospects of boosting their rooting and survival percentage by using higher concentrations than* 2000 *ppm of IBA alone or in mixture with NAA.*

*With* Picea abies, *though IBA at* 4000 *ppm gave better survival percentage and number of roots per plant than* 200 *ppm or control, yet the differences among these treatments were non-significant. However, there are indications of obtaining promising results if higher concentrations than* 4000 *ppm are tried.*

*The work with* Juniperus communis *cuttings showed encouraging results in survival percentage with IBA at* 400 *ppm and pointed to the need for trying higher concentrations than this in order to enhance the survival percentage of rooted cuttings still further.*

**Introduction.** Auxins have been the focus of attention of many researchers because of their marked influence on the root formation of cuttings. It was originally shown by Went (1934), and Thimman and Went (1934) that auxins stimulate adventitious root formation in stem cuttings. Later, Thimman (1935) and Zimmermann (1935) reported

* The author is Head, Department of Forestry, College of Agriculture and Forestry, Mosul University Hamam Al, Alil, Mosul, IRAQ.

that Napthalene acetic acid (NAA) and Indolebutryic acid (IBA) were also active in promoting adventitious root formation of cuttings. The above findings have been extensively substantiated by many scientists within the past three decades or so (Box and Beech, 1968; Mc, Kinnis 1969; Nanda *et al.*, 1969; Ragonese, *et al*, 1969; Ghosh and Bhatnagar, 1977).

Of these two chemical compounds, IBA is probably the best material for general use since it is non-toxic over a wide range of concentration apart from being quite effective in promoting rooting of a large number of plant species (Hartmann, 1968).

Mixtures of root-promoting substances are occasionally more effective than either compound alone. Thus, a mixture of IBA and NAA, when used on a number of widely diverse species, induced a higher rooting percentage in cuttings and more roots per cutting than either compound alone (Evans, 1953; Hitchcock and Zimmermann, 1940; Vanonsem, 1953).

One of the aims of good nursery practices is to possess accurate information regarding the right method of propagation for raising good nursery plants of different species. Besides, it may be equally important to know the effect of auxins on adventitious root initiation in the cuttings of many plant species. The present study was, therefore, undertaken as an attempt to find appropriate answers to the above mentioned aspects of the work in the case of species, *Populus alba*, *Populus tremula*, *Picea abies* and *Juniperus communis*. The selection of the species for this study was predominantly guided by their close resemblence in silvicultural behaviour with the economically important species of Iraq.

**Materials and Methods.** This study was carried out in the glass house maintained by the Forestry Section of the Department of Biology, Dresden Technical University, Dresden (GDR); it was started in April, 1979 and completed by June, 1979 for *Populus alba* and *Populus tremula*, while it extended from February, 1979 to June, 1979 in the case of *Picea abies* and *Juniperus communis*.

*Plant materials and growth regulators:*

1. *Populus alba*. The following treatments were applied to the cuttings which were collected from the root suckers of Populus alba trees found in Graupa (Dresden):

(*i*) IBA 100 ppm (24 hours), (*ii*) IBA 200 ppm (24 hours),
(*iii*) IBA 2000 ppm (5 sec), (*iv*) IBA 4000 ppm (5 sec),
(*v*) IBA+NAA 2000 ppm (5 sec), (*vi*) IBA+NAA 4000 ppm (5 sec) and
(*vii*) Control.

The treated cuttings were then planted in pots containing pure sand and peatmoss (1+1), and placed in the glass house. The experimental work was carried out in three randomized complete blocks with 7 treatments as detailed above and 18 cuttings per replication.

2. *Populus tremula.* The cuttings collected from the mother trees in Graupa/Dresden were subjected to the following treatments:

(*i*) IBA 100 ppm (24 hours), (*ii*) IBA 200 ppm (24 hours),

(*iii*) NAA 100 ppm (24 hours), (*iv*) NAA 200 ppm (24 hours),

(*v*) IBA 2000 ppm (5 sec), (*vi*) IBA 4000 ppm (5 sec),

(*vii*) IBA+NAA 2000 (5 sec), (*viii*) IBA+NAA 400 ppm (5 sec), and

(*ix*) Control.

Of these cuttings, those treated with IBA or NAA at 100 and 200 ppm were stored for one week in moist sand in a dark room having a temperature of about 18° C. The treated cuttings were then planted in pots filled with pure sand and peatmoss (1+1) and placed in the glass house.

The experimental design adopted was a true copy of the one used for *Populus alba.*

3. *Picea abies* and *Juniperus communis.* The cuttings of *Picea abies* were collected from the secondary branches of four years old seedlings, while those of *Juniperus communis* from the adult trees. After treating the cuttings with the following growth regulators these were planted in wooden boxes filled with pure sand (non-washed) and finally placed in the glass house: (i) IBA 2000 ppm (5 sec), (ii) IBA 4000 ppm (5 sec), and (iii) Control.

The experiment were conducted according to the randomized complete block design with the above noted three treatments, each replicated three times. 20 cuttings per replications were used in the case of *Juniperus communis* and 15 cuttings per replication for *Picea abies.*

For each species, data were collected on most of the following attributes at the termination of the experimental work with the exception of survival percentage of rooted cuttings which was recorded after two months from the date of planting the cuttings in the case of *P. alba* and *P. tremula*, and after four months in respect of *Picea abies* and *Juniperus communis:*

(*i*) plant height, (*ii*) number of branches per plant,

(*iii*) number of leaves per plant. (*iv*) fresh weight of leaves+branches+stem,

(*v*) dry weight of leaves+branches+stem,

(*vi*) length of roots, (*vii*) number of roots per plant,

(*viii*) fresh weight of roots per plant, and (*ix*) dry weight of roots.

The average relative humidity, and maximum and minimum temperature during the experimental period in the glass house were as under:

| Month/year | Ralative humidity (%) | Temperature (C°) | | |
|---|---|---|---|---|
| | | Max. | Min. | Mean |
| April, 1979 | 82.8 | 21.1 | 15.7 | 18.2 |
| May, 1979 | 87.6 | 21.7 | 15.3 | 18.6 |
| June 1979 | 87.0 | 24.0 | 18.2 | 21.6 |

After collecting the data analysis of variance and the Duncan's new multiple range test were conducted to detect differences among treatments, using the 5 percent level of significance.

**Results and Discussion.**

1. *Populus alba* cv. Nivea.

(*i*) Survival percentage. The results presented in Table 1 and Fig 1 showed that IBA, as a single substance as well as in mixture with NAA, had a highly significant effect on the survival percentage. The Duncan's new multiple range test indicated that treatments 3 (IBA 2000 ppm), 4 (IBA 4000 ppm) and 5 (IBA+NAA 2000 ppm) gave significantly higher (P 0.05) survival percentage of cuttings compared to the set of all other treatments tested; however, the differences among treatments 3, 4 and 5 were not significant. On the other hand, higher concentration of the mixture of IBA+NAA (4000 ppm) caused a marked decrease in the survival of cuttings. This finding is similar to that of Eliasson (1961) who reported that the application of high concentration of synthetic auxins can inhibit development to the extent that sometimes no shoot growth may take place even though root formation has been adequate.

(*ii*) Plant height. The main stem height of *Populus alba* plants was not affected by any of the treatments. The average plant height ranged from 22.8 to 26.9 cm with the lowest value recorded in the case of plants of treatment 3 (IBA 200 ppm) and the highest one for the plants subjected to treatments 4 (IBA 4000 ppm) and 7 (Control). This finding is in close agreement with the one of Chadwick and Kiplinger (1938) who observed that cuttings treated with root promoting substances are useful in propagating plants but the ultimate size and vigour of such treated plants does not seem to be better than those of the untreated plants.

(*iii*) Number of branches. The cuttings treated with IBA 200 ppm (Table 1 and Fig. 1) produced the largest number of branches (1.53 per plant) which was significantly different from those of plants in treatments 5, 6, 7, 3 and 4. Similarly, treatment 1 (IBA 100 ppm) had significantly more branches as compared with treatment 4 (IBA 4000 ppm) which produced the minimum number of branches; this phenomenon may be attributed to the presence of high density of plants in treatment 4.

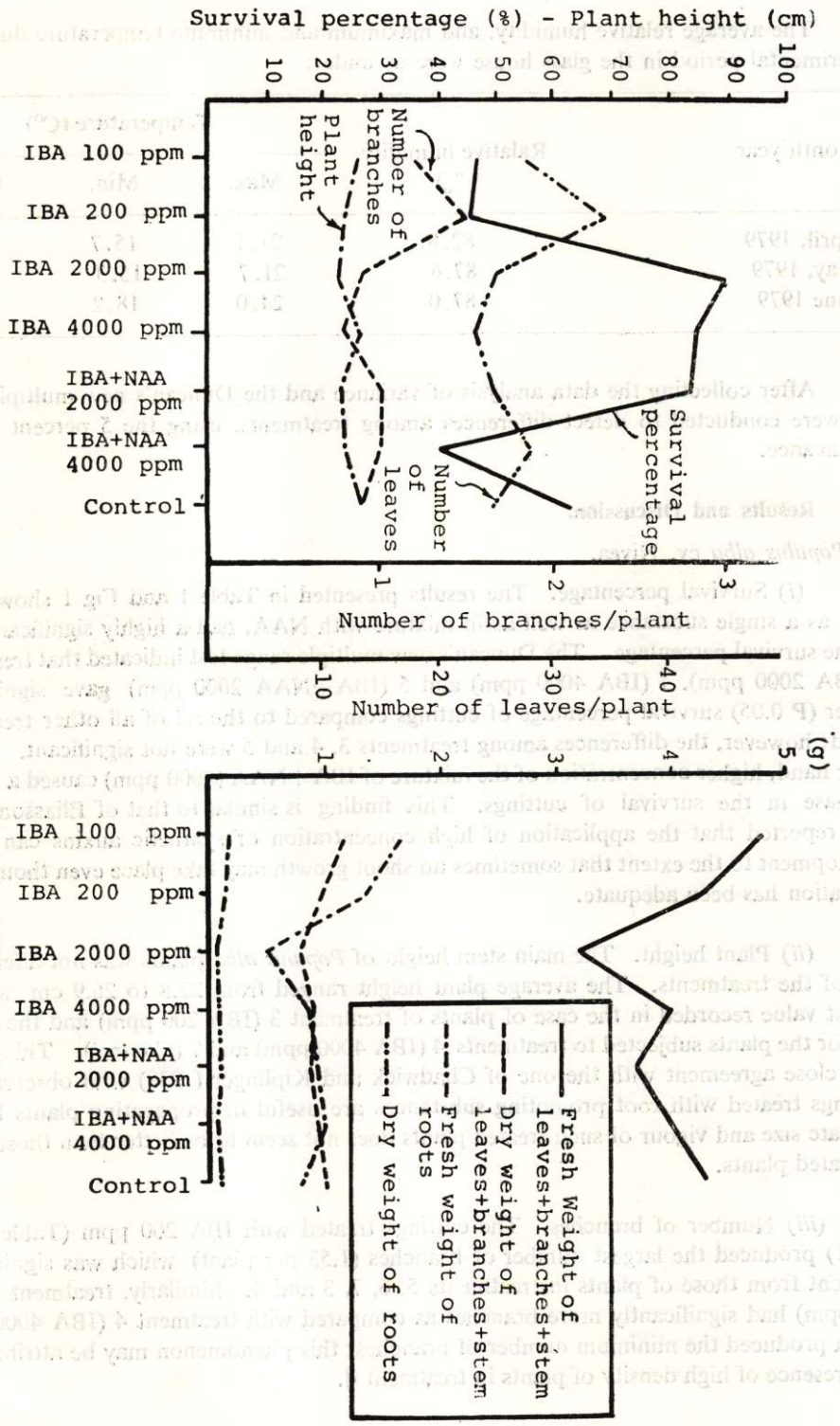


Fig. 1: EFFECTS OF IBA & NAA ON DIFFERENT CHARACTERISTICS OF *Populus alba*.

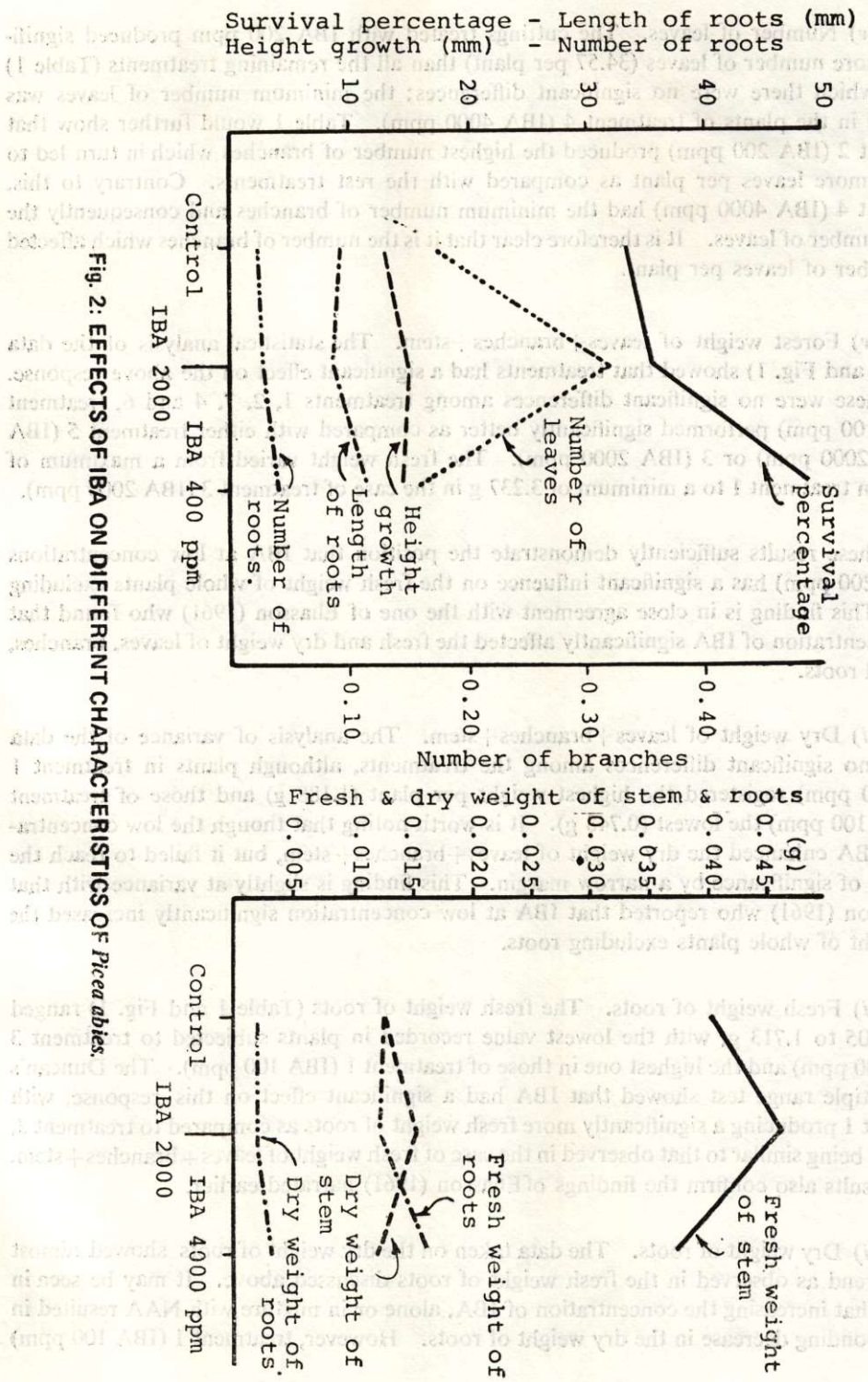


**Fig. 2: EFFECTS OF IBA ON DIFFERENT CHARACTERISTICS OF *Picea abies*.**

(*iv*) Number of leaves. The cuttings treated with IBA 200 ppm produced significantly more number of leaves (34.57 per plant) than all the remaining treatments (Table 1) among which there were no significant differences; the minimum number of leaves was recorded in the plants of treatment 4 (IBA 4000 ppm). Table 1 would further show that treatment 2 (IBA 200 ppm) produced the highest number of branches which in turn led to bearing more leaves per plant as compared with the rest treatments. Contrary to this, treatment 4 (IBA 4000 ppm) had the minimum number of branches and consequently the fewest number of leaves. It is therefore clear that it is the number of branches which affected the number of leaves per plant.

(*v*) Forest weight of leaves+branches+stem. The statistical analysis of the data (Table 1 and Fig. 1) showed that treatments had a significant effect on the above response. While these were no significant differences among treatments 1, 2, 7, 4 and 6, treatment 1 (IBA 100 ppm) performed significantly better as compared with either treatment 5 (IBA +NAA 2000 ppm) or 3 (IBA 2000 ppm). The fresh weight varied from a maximum of 4.836 g in treatment 1 to a minimum of 3.237 g in the case of treatment 3 (IBA 2000 ppm).

These results sufficiently demonstrate the position that IBA at low concentrations (100 or 200 ppm) has a significant influence on the fresh weight of whole plants excluding roots. This finding is in close agreement with the one of Eliasson (1961) who found that low concentration of IBA significantly affected the fresh and dry weight of leaves, branches, stem and roots.

(*vi*) Dry weight of leaves+branches+stem. The analysis of variance of the data showed no significant differences among the treatments, although plants in treatment 1 (IBA 100 ppm) registered the highest weight per plant (1.188 g) and those of treatment 3 (NAA 100 ppm) the lowest (0.748 g). It is worth noting that though the low concentration of IBA enhanced the dry weight of leaves+branches+ stem, but it failed to reach the 5% level of significance by a narrow margin. This finding is slightly at variance with that of Eliasson (1961) who reported that IBA at low concentration significantly increased the dry weight of whole plants excluding roots.

(*vii*) Fresh weight of roots. The fresh weight of roots (Table 1 and Fig. 1) ranged from 0.505 to 1.713 g, with the lowest value recorded in plants subjected to treatment 3 (IBA 2000 ppm) and the highest one in those of treatment 1 (IBA 100 ppm). The Duncan's new multiple range test showed that IBA had a significant effect on this response, with treatment 1 producing a significantly more fresh weight of roots as compared to treatment 3, the effect being similar to that observed in the case of fresh weight of leaves + branches+stem. These results also confirm the findings of Eliasson (1961) narrated earlier.

(*viii*) Dry weight of roots. The data taken on the dry weight of roots showed almost similar trend as observed in the fresh weight of roots discussed above. It may be seen in Table 1 that increasing the concentration of IBA, alone or in mixture with NAA resulted in a corresponding decrease in the dry weight of roots. However, treatment 1 (IBA 100 ppm)

peformed significantly better that either treatment 5, 4, 6 or 3, while there were no significant differences among treatments 1, 2 and 7. This finding is also similar to that of Eliasson (1961).

2. *Populus tremula.* The vegetative propagation of the cuttings of *P. tremula,* using 100, 200, 2000 and 4000 ppm concentrations of IBA and NAA singly or in mixture with the other complementary compound, failed to show any promising results. Most of the treatments had a poor survival percentage (Table 2) except for treatments 7 (IBA+NAA 2000 ppm) and control in which the survival amounted to 45% on average.

Though several responses were measured, the statistical analyses of the data were not attempted because of inadequacy in the data; for the same reasons, the means of various characteristics listed in Table 2 should be interpreted with caution.

3. *Picea abies.* The statistical analysis of the data (Table 3 and Fig. 2) showed that the test treatments failed to produce significant effects on all the characters observed. However, the survival percentage increased with the increasing concentration of IBA; the ranking of treatments in descending order of survival percentage being treatment 3 (IBA 4000 ppm) with 48.9%, followed by treatment 2 (IBA 2000 ppm) with 35.6% and treatment 1 (Control) with 33.3%. As the plants originating from cuttings treated with IBA seem to have a better overall performance as compared with their untreated counterparts, it is quite probable that the survival percentage may increase wth higher concentrations of IBA than the above ones.

A comparison of other characteristics studied (Table 3) would further confirm that the mean values are consistently higher in the case of IBA treatments than those of control. IBA 4000 ppm promoted an increase in 5 characters (survival percentage, length of roots, number of roots, and fresh and dry weight of roots), while IBA 2000 ppm in 4 attributes (height growth, number of branches, and fresh and dry weight of stem) over control plants which often had low values. This finding is rather dissimilar to that of Kalmar (1973) who observed that IBA or NAA 3000 ppm with one minute dipping gave the maximum rooting percentage in the cuttings of Picea abies and several other conifers he worked with.

4. *Juniperus communis.* In Table 4 are presented the results of vegetative propagation of the species by cuttings using IBA at concentrations of 2000 and 4000 ppm (by dipping). By reference to this table it may be seen that IBA 4000 ppm resulted in a higher survival percentage than either treatment 2 (IBA 2000 ppm) or 1 (Control.) It is also interesting to observe that some of the cuttings survived in all the three replications of treatment 3 (IBA 4000 ppm), while they partially succeeded in two out of the three replications of treatment 2, but almost completely failed in all the three replications of control. These results indicate that higher concentrations of IBA than 4000 ppm may possibly increase the survival percentage of rooted cuttings; in future work on the species with this growth regulator, it would be worth considering the possibility of including mist irrigation.

Table 1

*Effect of IBA and NAA on different characteristics of* Populus alba (*values are the means of three replications, each of* 18 *plants*)

| Treatment No. | Particulars | Survival percentage (%) | Plant height (cm) | Number of branches (No.) | Number of leaves (No.) | Fresh weight of stem+ branches+ leaves (g) | Dry weight of stem+ branches+ leaves (g) | Fresh weight of roots (g) | Dry weight of roots (g) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | IBA 100 ppm | 47c* | 26.3a* | 1.2ab* | 27.7b* | 4.836a* | 1.188a* | 1.713a | 0.182a* |
| 2. | IBA 200 ppm | 46c | 23.9a | 1.5a | 34.6a | 4.297ab | 1.022a | 1.404ab | 0.147ab |
| 3. | IBA 2000 ppm | 90a | 22.8a | 0.9bc | 25.0b | 3.237b | 0.748a | 0.505b | 0.070b |
| 4. | IBA 4000 ppm | 85a | 26.9a | 0.8c | 23.3b | 3.962ab | 0.918a | 0.851ab | 0.086b |
| 5. | IBA+NAA 2000 ppm | 84a | 23.6a | 1.0bc | 25.0b | 3.560b | 0.850a | 0.876ab | 0.119b |
| 6. | IBA+NAA 4000 ppm | 40c | 24.4a | 1.0bc | 28.2b | 3.958ab | 0.911a | 1.085ab | 0.082b |
| 7. | Control | 63b | 26.9a | 0.9bc | 24.9b | 4.251ab | 1.003a | 0.811ab | 0.132ab |

* Treatment means followed by the same lower case letters in each column are not significantly different from one another at the 5% level of significance ($P < 0.05$) according to the Duncan's new multiple range test.

Table 2

*Effect of IBA and NAA on different characteristics of* Populus tremula

| | Treatment | Replication No. | Survival percentage (%) | Plant height (cm) | Number of branches (No.) | Number of leaves (No.) | Fresh weight of leaves+branches +stem (g) | Dry weight of leaves+branches +stem (g) | Fresh weigh of roots (g) | Dry weight of roots (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | IBA | 1 | 8 | 34.0 | 2 | 43 | 5.841 | 1.361 | 0.678 | 0.239 |
| | 100 ppm | 2 | — | — | — | — | — | — | — | — |
| | | 3 | — | — | — | — | — | — | — | — |
| 2. | IBA | 1 | 16 | 47.9 | 1 | 25.5 | 5.938 | 1.209 | 0.980 | 0.247 |
| | 200 ppm | 2 | — | — | — | — | — | — | — | — |
| | | 3 | — | — | — | — | — | — | — | — |
| 3. | NAA | 1 | — | — | — | — | — | — | — | — |
| | 100 ppm | 2 | — | — | — | — | — | — | — | — |
| | | 3 | — | — | — | — | — | — | — | — |
| 4. | NAA | 1 | 8 | 4.7 | 1 | 6 | 0.554 | 0.148 | 1.119 | 0.125 |
| | 200 ppm | 2 | — | — | — | — | — | — | — | — |
| | | 3 | — | | — | — | — | — | — | — |
| 5. | IBA | 1 | 8 | 24.1 | 1 | 21 | 1. 939 | 0.335 | 0.213 | 0.062 |
| | 2000 ppm | 2 | — | | — | — | — | — | — | — |
| | | 3 | — | — | — | — | — | — | — | — |
| 6. | IBA | 1 | 8 | 36.1 | 1 | 23 | 3.636 | 0.946 | 0.425 | 0.239 |
| | 4000 ppm | 2 | — | — | — | — | — | — | — | — |
| | | 3 | — | — | — | — | — | — | — | — |
| 7. | IBA+NAA | 1 | 8 | 36 | 2 | 45 | 5.006 | 1.111 | 0.895 | 0.155 |
| | 2000 ppm | 2 | 8 | 26 | 3 | 51 | 5.120 | 1.271 | 0.283 | 0.150 |
| | | 3 | 8 | 19 | 2 | 18 | 1.226 | 0.283 | 0.196 | 0.066 |
| 8. | IBA+NAA | 1 | 8 | 36.7 | 1 | 23 | 3.636 | 0.946 | 0.425 | 0.159 |
| | 4000 ppm | 2 | — | — | — | — | — | — | — | — |
| | | 3 | — | — | — | — | — | — | — | — |
| 9. | Control | 1 | 8 | 9.7 | 2 | 29 | 1.764 | 0.421 | 0.100 | 0.032 |
| | | 2 | 8 | 38.7 | 1 | 28 | 3.270 | 1.459 | 0.762 | 0.112 |
| | | 3 | 8 | 30.8 | 1 | 24 | 1.994 | 0.509 | 0.121 | 0.047 |

Table 3

*Effect of IBA on different characteristics of* Picea abies

| | Treatments | Survival percentage (%) | Height growth (cm) | Number of branches | Length of roots (cm) | Number of roots | Fresh weight of stem (g) | Dry weight of stem (g) | Fresh weight of root (g) | Dry weight of roots (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Control | 33.30 | 12.89 | 0.17 | 9.06 | 2.36 | 0.040 | 0.013 | 0.013 | 0.002 |
| 2 | IBA 2000 ppm | 35.57 | 14.85 | 0.32 | 8.72 | 2.75 | 0.046 | 0.015 | 0.012 | 0.002 |
| 3. | IBA 4000 ppm | 48.87 | 14.25 | 0.16 | 11.20 | 3.97 | 0.037 | 0.012 | 0.016 | 0.003 |

Table 4

*Effect of IBA on different characteristics of* Juniperus communis

| Treatments | Replication No. | Survival percentage (%) | Plant height (cm) | Number of roots | Length of roots (cm) | Fresh weight of stem (g) | Dry weight of stem (g) | Fresh weight of roots (g) | Dry weight of roots (g) |
|---|---|---|---|---|---|---|---|---|---|
| Control | 1 | 5 | 1.8 | 3 | 13 | 0.555 | 0.213 | 0.037 | 0.005 |
| | 2 | — | — | — | — | — | — | — | — |
| | 3 | — | — | — | — | — | — | — | — |
| IBA 2000 ppm | 1 | 10 | 7.8 | 1 | 11 | 0.416 | 0.162 | 0.004 | 0.001 |
| | 2 | 15 | 8.1 | 3 | 19 | 0.542 | 0.214 | 0.065 | 0.009 |
| | 3 | — | — | — | — | — | — | — | — |
| IBA 4000 ppm | 1 | 20 | 7.7 | 2.5 | 10 | 0.441 | 0.168 | 0.025 | 0.004 |
| | 2 | 5 | 7.0 | 1.0 | 3 | 0.451 | 0.194 | 0.002 | 0.001 |
| | 3 | 25 | 7.0 | 2.2 | 33.5 | 0.481 | 0.177 | 0.037 | 0.004 |

**Conclusions.** The following conclusions may be drawn:

1. *Populus alba.* (*i*) IBA had a highly significant effect on the survival percentage of rooted cuttings of *Populus alba* when used in concentrations upto 4000 ppm as a single substance and at 2000 ppm in mixture with NAA.

   (*ii*) IBA had no significant effect on the height of plants originating from the rooted cuttings.

   (*iii*) IBA upto 200 ppm significantly increased the number of branches and leaves in the rooted cuttings.

   (*iv*) IBA upto 200 ppm had a significant effect on increasing the fresh weight of leaves+branches+stem as well as the fresh and dry weight of roots.

2. *Populus tremula.* Increasing the concentration of IBA alone or in mixture with NAA beyond 2000 ppm may give better results in the rooting of cuttings.

3. *Picea abies.* IBA 4000 ppm gave better results in the case of survival percentage and number of roots. Comparing the performance of IBA with that of control the prospects of getting promising results by increasing the concentration to more than 4000 ppm seem highly probable.

4. *Juniperus communis.* IBA gave better results than control in survival percentfage and some other plant characteristics, especially with a concentration of 4000 ppm; using concentrations of more than 4000 ppm are quite likely to yield more favourable effects.

**Acknowledgements.** The author wishes to thankfully acknowledge the facilities liberally extended by Prof. Dr. Tesche, Head of the Department of Biology, Dresden Technical University, Dresden (GDR). The help rendered by Dr. Zentsch in experimental work is deeply appreciated. Thanks are also due to Mrs. Klinder for her assistance in collecting the data and conducting laboratory work.

## References

BOGDANOV, B. 1971. Vegetative propagation of green Douglas Fir Gorsko Stopanstvo (1): 27-33.

BOX, B.H. and L.C. BEECH. 1968. Vegetative propagation trials of eastern Red Cedar and Arizona Cypress in the greenhouse. Tree Plant. Notes 19(3:) 1-2.

CHADWICK, L.C. and D.C. KIPLINGER. 1938. The effect of synthetic growth substances on the rooting and subsequent growth of ornamental plants. Proc. Amr. Soc. Hort. Sci. 36: 809-816.

ELIASSON, L. 1961. The influence of growth substances on the formation of shoots from aspen roots Physiol. Plant, 14: 150-156.

EVANS, H. 1953. Physiological aspects of the propagation of Cacao from cuttings. Rept. 13th Int. Hort. Cong. pp. 1179-1190.

GHOSH, R.C. and H.R. Bhatnagar. 1977. Rooting response of branch cuttings of *Populus gamblei* Dode. Indian Forester, 103: 382-386.

HARTMANN, H.T., W.H. GRIGGS and C.J. HANSEN. 1963. Propagation of own-rooted Old Home and Bartlett pears to produce trees resistent to pear decline. Proc. Amer. Soc. Hort. Sci., 82: 92-102.

HITCHCOCK, A.E. and P.W. ZIMMERMANN. 1940. Effects obtained with mixtures of root-inducing and other substances. Contrib. Boyce Thomp. Inst, 11: 143-160.

KALMAR, S. 1973. Conifer propagation by cuttings. Kertgazdasag 5(4): 67-69.

KOLEVSKA-PLETIKAPIC, B. 1970. Effect of growth substances and anatomical structure on the rooting of *Salix caprea* and *Populus tremula*. Acta Bot. Croat. No. 26 27: 191-211 (Cited from Abs. in Referat Z (10-56: 203) Russ, N.L.L.).

MCKINNIS, G.R. 1969. The effect of DMSO as a carrier for IBA on the rooting of three Juniper species. Plant Propagator Rutgers 15: 4-8 (Cited from Hort. Abstr., 39(4). 1969).

NANDA, K.K., A.N. PUVOLLIT and V.K. KOCHHAR. 1969. Effect of auxins and light on rooting stem cuttings of *Populus nigra*, *Salix tetrasperma*, *Ipomea fistulosa* and *Hibiscus notodus* in relation to polarity. Physiol. Plant., Copenhagen 22(6): 1113-20.

RAGONESE, A.E., F. REAL ALBERTI and V.A. SONOVKO. 1969. Rooting of cuttings of some cultivars of willow and poplar. India. Supl. For. 5: 89-106.

THIMANN, K.V. 1935. On an analysis of activity of two growth-promoting substances on plant tissues. Proc. Kon. Ned. Akad. Wet. 38: 896-912.

THIMANN, K.V. and F.W. WENT. 1934. On the chemical nature of the root forming hormone. Proc. Kon. Ned. Akad. Wet., 37: 456-459.

VANONSEM, J.G. 1953. Synergestic effects of hormone mixtures on the rooting of cuttings. Rpt. 13th Int. Hort. Cong. 506-514.

WENT, F.W. 1934. Method for rhizooaline, the root-forming substance Proc. Kon. Ned. Akad. Wet., 37: 445-455.

ZIMMERMANN, P.W. and F. WILOXON. 1935. Several chemical growth substances which cause initiation of roots and other responses in plants. Contrib. Leyce Thomp. Inst., 1: 209-229.