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Effect of IAA, IBA and NAA on the vegetative propagation of *Aloe vera* (L.) burm. f. (Ghritakumari)

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Abstract
Aloe vera (L.) Burm. f. is a succulent medicinal herb belonging to the family Aloaceae possesses several medicinal activities and properties. Presence of male sterility and long gestation period of this species, plantlets are the primary and preferable commercial source as propagating material. Therefore, the effect of IAA, IBA and NAA on the vegetative propagation by stem cuttings of the plant was assessed. A total of 13 treatments were applied on the cuttings following the quick dip method and planted in sandy bed. The whole experiment was conducted following completely randomized design. Data were collected at 30, 60 and 90 DAP (Days after planting). The maximum number of roots, length of roots and biomass were observed to be 24.33, 27.17 cm and 122.67 g respectively at 90 DAP in the cuttings treated with NAA 1000 ppm solution (T_8) whereas control (T_{13}) showed minimum rooting and shooting performance. Rooting hormones were performed for number of roots, length of roots and biomass following sequence as NAA> IBA> IAA. The present study concludes that NAA 1000 ppm solution would be considered as the most suitable for producing maximum number of roots, length of roots and biomass in *Aloe vera* (L.) Burm. f. at 90 DAP.

Keywords: *Aloe vera*, vegetative propagation, stem cuttings, rooting hormone, auxins

Introduction

Aloe vera (L.) Burm. f. is a perennial, succulent, xerophytic green medicinal herb belonging to the family Aloaceae popularly known as *Aloe* and Ghritakumari in Bengali. It is widely distributed in dry and hot areas of the Middle East of Asia, the Southern Mediterranean, North Africa and the Canary Islands. *Aloe vera* derives from Arabic word "Alloeh" means "shining bitter substances" and Latin "Vera" means "true". The leaves of the plant are consisted of three layers, the outer thick layer termed as rind, an inner crystalline gel and a yellow sap. The plants commonly grow 60 to 100 cm height in classic rosette shape with entirely arrayed leaves in two or three circles. The leaves are sessile, simple, triangular, thick, succulent, crowed, numerous, 30-60 cm long, 5-12cm wide at the base and 0.8–3cm thick, narrowly lanceolate. Flowers are 2.5–3cm long, yellowish, arranged in clusters on a sole straight stem about 1m long [1-5]. Male sterility is present in flower, which is the main barrier in fast multiplication of this plant by seeds. Fertile seeds are obtained through crosspollination [6] which is involved with the high heterogeneity of the seedlings and expensive due to repeated natural hybridization [7]. Seeded plants have prolonged gestation period (3-4 years) [8]. Therefore, reproduction is substantially by asexual suckers or offshoots or plantlets [9, 10]. The plant used as traditionally to treat skin problems (burns, cuts, eczemas, and insect bites) digestive disorder and dentistry [11]. The plant contains more than seventy five different compounds, including sugars, enzymes (*viz*. amylase, catalase, and peroxidase), minerals (*viz*. zinc, copper, calcium and selenium), hormones (*viz.* auxins and gibberellins), vitamins (*viz.* vitamin A, B12, C and E), anthraquinones (*viz.* emodin and aloin), fatty acids (*viz.* lupeol and campesterol), and others (*viz*. salicylic acid, saponins and lignin) [1, 3, 11]. It has diverse pharmaco-biological properties *viz*. digestive diseases protection [12-14], skin protection [15-17], anti-inflammatory activity [18-20], anticancer [21-24], anti-diabetic [25-28], antioxidant [29-31], bone protection [32-34], cardio protective effect [35-38], antimicrobial and prebiotic activity [39-41]. Recently *Aloe vera* is used as supplemented diet in aquaculture [42] and a promising bio sorbent and coagulant materials in water treatment [43]. The plant have a vast demand in industry [44] with an approximate of $13 billion per year and with annual increasing 20-40% [45, 46]. Bioavailability of plant drugs enhanced due to the recent development of nano-formulation techniques [47, 48].

So far, the literature review is investigated, no specific research has yet been done in the effect of auxin on the vegetative propagation of *Aloe vera* (Ghritakumari) plant in Bangladesh. Therefore the present study was undertaken to assess the effect of IAA (Indole-3-acetic acid), IBA (Indole-3-butyric acid) and NAA (α-Naphthalene acetic acid) on the vegetative propagation (stem cutting) of *Aloe vera* (Ghritakumari).

Materials and Methods

The plantlet of *Aloe vera* (L.) Burm. f. was used as plant material. Plantlets were prepared 4-6 weeks stage having 2-4 leaves. The lower portion cuts of the stems were made slanting below the nodes. IAA/IBA/NAA solution was made by suspending 0.1g analytical auxin hormone into 20 ml alcohol. Subsequently a stock solution of 1000 ppm IAA/IBA/NAA was prepared by including 80 ml purified water to the solution. At last 250 ppm, 500 ppm, 750 ppm and 1000 ppm IAA/ IBA /NAA were prepared by including 75 ml, 50 ml, 25 ml and 0 ml, water to the 25 ml, 50 ml, 75 ml and 100 ml of stock solution respectively. A total of 13 treatments were used, eg. T_1- 250 ppm IAA, T_2- 500 ppm IAA, T_3- 750 ppm IAA, T_4- 1000 ppm IAA, T_5- 250 ppm IBA, T_6- 500 ppm IBA, T_7- 750 ppm IBA, T_8- 1000 ppm IBA, T_9- 250 ppm NAA, T_{10}- 500 ppm NAA, T_{11}- 750 ppm NAA, T_{12}- 1000 ppm

NAA and T_{13}- control or 0 ppm. Cuttings were treated following the quick dip method [49]. Basal ends of the cuttings were dipped in treatment solution for ten seconds and then air-dried and finally treated cuttings were planted in sandy bed. It was done on the 1st week of June, 2019 in rainy season (June-August) which is the proper time of vegetative propagation for maximum plants [50-52]. Watering and mulching were done as when required. Data for number of roots, length of roots and biomass per cutting were collected at 30, 60 and 90 DAP (Days after planting). The whole experiment was done following complete randomized design. Three replications were used for each treatment and statistical analyses were done using MS Excel 2013. DMRT was done by XLSTAT.

Results and Discussion

The results (Table-1, Fig. 5) reveal that the number of roots varied with the change of different treatments. The value of the number of roots of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 30 DAP were found to be 7.67, 8.67, 14.67, 13.33, 10.33, 11.67, 12.67, 13.67, 11.67, 12.33, 15.33, 20.33, and 6.33 respectively and showed the following sequence as $T_{12}> T_{11} > T_3> T_8\geq T_4> T_7> T_{10}> T_6\geq T_9> T_5> T_2> T_1> T_{13}$. Maximum number of roots at 30 DAP were achieved in T_{12} (NAA- 1000 ppm) and minimum in T_{13} (control). The value of the number of roots of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 60 DAP were acquied to be 12.33, 13.33, 16.33, 17.33, 14.67, 16.67, 15.67, 18.67, 15.67, 17.33, 18.67, 22.33 and 8.33 respectively and expressed the following succession as $T_{12}> T_{11}\geq T_8>T_4\geq T_{10}\geq T_6> T_3> T_7\geq T_9> T_5> T_2> T_1> T_{13}$. Maximum number of roots at 60 DAP were observed in T_{12} (NAA- 1000 ppm) and minimum in T_{13} (control). The value of the number of roots of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 90 DAP were obtained to be 16.67, 19.66, 18.33, 21.33, 18.67, 22.33, 19.67, 23.33, 20.33, 23.66, 21.33, 24.33 and 10.33 respectively and appeared following trend as $T_{12}> T_{10}> T_8> T_6> T_{11}\geq T_4> T_9> T_2 \geq T_7> T_5> T_3> T_1> T_{13}$. Maximum number of roots at 90 DAP were determined in T_{12} (NAA-1000 ppm) and minimum in T_{13} (control). ANOVA of number of roots at 30, 60 and 90 DAP indicated significant value (P<0.01) with treatments (Table-3). It is reported that the auxin is used to generate root initiation for the stem cuttings [53-56]. It is worthwhile to mention that maximum number of roots are reported in Ashoka [*Saraca asoca* (Roxb.) De Wilde.], Malary apple [*Syzygium malaccense* (L.) Merr. & Perry] and Carnation (*Dianthus caryophyllus* L.) cuttings treated with NAA [57-59]. These reports are analogous with the present experiment.

The results of length of roots at 30, 60 and 90 DAP are presented in Fig. 2 & 5. The average value of the length of roots of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 30 DAP were attained to be 6.43cm, 7.06cm, 7.53cm, 9.30cm, 9.77cm, 9.93cm, 10.00cm, 10.20cm, 9.67cm, 10.47, 10.77cm, 11.43cm and 5.10cm respectively and indicated the following progression as $T_{12}> T_{11} > T_{10}> T_8> T_7> T_6> T_5> T_9> T_4> T_3> T_2> T_1> T_{13}$. Highest length of roots at 30 DAP were deemed in T_{12} (NAA- 1000 ppm) and minimum in T_{13} (control).

The value of the length of roots of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 60 DAP were measured to be 8.37cm, 12.37cm, 10.33, 12.33cm, 11.57cm, 14.77cm, 12.33cm, 15.33cm, 12.33cm, 14.67cm, 13.67cm, 19.53cm and 7.63cm respectively and confirmed the following magnitude as $T_{12}> T_8> T_6> T_{10}> T_{11}> T_2> T_4\geq T_7\geq T_9> T_5> T_3> T_1> T_{13}$. Highest length of roots at 60 DAP were noticed in T_{12} (NAA- 1000 ppm) and minimum in T_{13} (control).

The value of the length of roots of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 90 DAP were obtained to be 11.51cm, 18.17cm, 13.33cm, 14.67cm, 12.33cm, 20.33cm, 14.50cm, 21.66cm, 16.33cm, 19.50cm, 17.67cm, 27.17cm and 9.66cm respectively and presented the following eminence as $T_{12}> T_8> T_6> T_{10}> T_2> T_{11}> T_9> T_4> T_7> T_3> T_5> T_1> T_{13}$. Highest length of roots at 90 DAP were existed in T_{12} (NAA- 1000 ppm) and lowest in T_{13} (control).

ANOVA of length of roots at 30, 60 and 90 DAP showed significant value (P<0.01) with treatments (Table-3). Maximum length of rooting and shooting performance by NAA were observed in the stem cutting of *Saracus asoca* (Roxb.) De Wilde. and *Morus alba* L. [57, 60]. It was also reported that the highest length of rooting and shooting tendency was observed in the stem cutting of *Rauvolfia sepentina* (L.) Benth. ex Kurz. and *Gymnema sylvestre* L. [61]. These observation are compatible with the present findings.

Table 1: Change of the number of roots in the stem cuttings of *Aloe vera* at 30, 60 and 90 DAP on the effect of IAA, IBA and NAA.

Treatments	30 DAP	60 DAP	90 DAP
T_1 (IAA-250ppm)	7.67 ^{gh} ± 0.58	12.33 ^{g} ± 0.58	16.67 ^{h} ± 0.58
T_2 (IAA-500ppm)	8.67 ^{g} ± 0.58	13.33 ^{f} ± 0.58	19.66 ^{defg} ± 1.53
T_3 (IAA-750ppm)	14.67 ^{bc} ± 0.58	16.33 ^{cd} ± 0.58	18.33 ^{g} ± 0.58
T_4 (IAA-1000ppm)	13.33 ^{cd} ± 0.58	17.33 ^{c} ± 0.58	21.33 ^{cde} ± 0.58
T_5 (IBA-250ppm)	10.33 ^{f} ± 0.58	14.67 ^{e} ± 0.57	18.67 ^{fg} ± 0.58
T_6 (IBA-500ppm)	11.67 ^{ef} ± 1.15	16.67 ^{cd} ± 0.58	22.33 ^{bc} ± 1.15
T_7 (IBA-750ppm)	12.67 ^{de} ± 0.58	15.67 ^{d} ± 0.58	19.67 ^{efg} ± 0.58
T_8 (IBA-1000ppm)	13.67 ^{cd} ± 0.58	18.67 ^{b} ± 0.58	23.33 ^{ab} ±1.15
T_9 (NAA-250ppm)	11.67 ^{ef} ± 1.15	15.67 ^{de} ± 0.57	20.33 ^{def} ± 1.15
T_{10} (NAA-500ppm)	12.33 ^{de} ± 0.58	17.33 ^{c} ± 0.58	23.66 ^{ab} ± 0.58
T_{11} (NAA-750ppm)	15.33 ^{b} ± 1.15	18.67 ^{b} ± 0.58	21.33 ^{cd} ± 0.58
T_{12} (NAA-1000ppm)	20.33 ^{a} ± 1.53	22.33 ^{a} ± 0.58	24.33 ^{a} ± 1.53
T_{13} (Control-0ppm)	6.33 ^{h} ± 0.58	8.33 ^{h} ± 0.57	10.33 i ± 0.58

Legend: In each rows, values with same superscript are non-significant and with different superscript are significant by DMRT (Duncan Multiple Range Test).

Table 2: Change of the total biomass in the stem cuttings of *Aloe vera* at 30, 60 and 90 DAP on the effect of IAA, IBA and NAA.

Treatments	Biomass, g at 30 DAP	Biomass, g at 60 DAP	Biomass, g at 90 DAP
T_1 (IAA-250ppm)	60.67 ^{g} ± 2.08	72.63 ^{i} ±2.15	84.33 ^{g} ±1.53
T_2 (IAA-500ppm)	66.33 ^{f} ±2.31	76.33 ^{h} ±2.52	86.33 ^{fg} ±1.15
T_3 (IAA-750ppm)	75.33 ^{de} ±2.08	83.37 fg ±2.49	92.33 ^{e} ±2.08
T_4 (IAA-1000ppm)	76.33 ^{de} ±2.52	88.17 ^{e} ±1.58	100.33 ^{c} ±3.51
T_5 (IBA-250ppm)	67.67 ^{f} ±1.53	76.37 ^{h} ±1.76	86.33 ^{fg} ±1.53
T_6 (IBA-500ppm)	75.33 ^{de} ±2.08	82.33 ^{g} ±2.08	89.33 ^{ef} ±1.53
T_7 (IBA-750ppm)	77.67 ^{d} ±1.53	86.33 ^{ef} ±2.52	96.33 ^{d} ±1.53
T_8 (IBA-1000ppm)	85.67 ^{c} ±2.52	98.27 ^{c} ±2.05	111.33 ^{b} ±1.15
T_9 (NAA-250ppm)	72.33 ^{e} ±2.52	81.83 ^{g} ±1.76	91.67 ^{e} ±1.53
T_{10} (NAA-500ppm)	82.67 ^{c} ±2.52	91.67 ^{d} ±1.53	99.67 ^{c} ±2.08
T_{11} (NAA-750ppm)	93.33 ^{b} ±2.52	103.17 ^{b} ±2.36	113.33 ^{b} ±2.08
T_{12} (NAA-1000ppm)	97.33 ^{a} ±2.08	109.33 ^{a} ±1.53	122.67 ^{a} ±2.31
T_{13} (Control-0ppm)	40.33 ^{h} ±2.52	45.17 ^{j} ±1.76	51.67 ^{h} ±1.53

Legend: In each rows, values with same superscript are non-significant and with different superscript are significant by DMRT (Duncan Multiple Range Test).

Table 3: Analyses of variance of number of roots, length of roots and biomass on the effect of different concentration of IAA, IBA and NAA at 30 DAP, 60 DAP and 90 DAP of the stem cutting of *Aloe vera* (L.) Burm. f.

Source of variance	Degree of freedom	F-values								
		Number of roots			Length of roots			Biomass		
		30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
Treatments	12	54*	104*	46*	61*	72*	98*	127*	183*	247*

Legend: * denotes significant at 1% level.

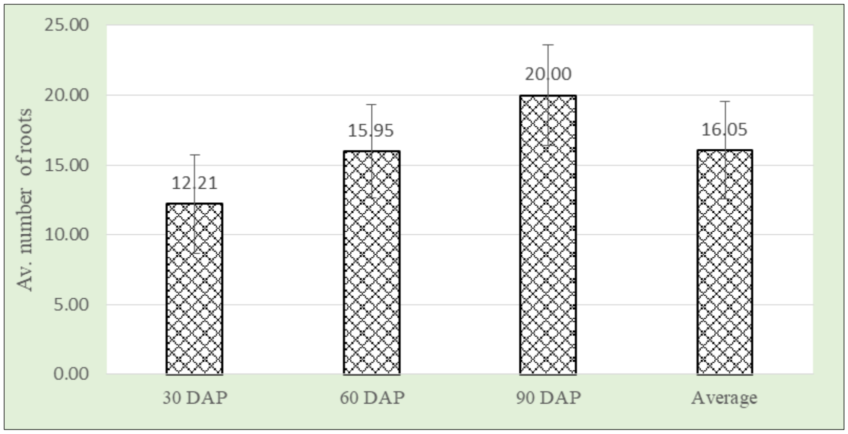

Fig 1: Change of the average number of roots in the stem cuttings of *Aloe vera* (L.) Burm. f. at 30, 60 and 90 DAP on the effect of IAA, IBA and NAA.

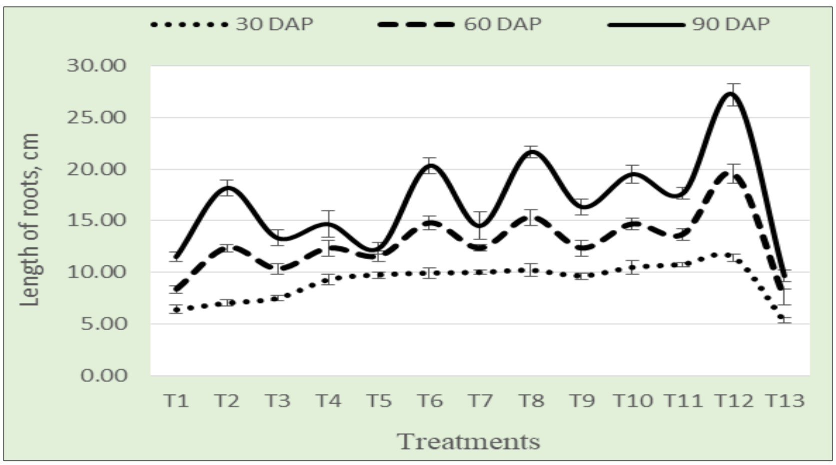

Fig 2: Change of the length of roots in the vegetative propagation of *Aloe vera* (L.) Burm. f. at 30, 60 and 90 DAT on the effect of IAA, IBA and NAA. (T_1: IAA-250ppm; T_2: IAA-500ppm; T_3:IAA-750ppm; T_4: IAA-1000ppm; T_5: IBA-250ppm; T_6: IBA-500ppm; T_7: IBA-750ppm; T_8: IBA-1000ppm; T_9: NAA-250ppm; T_{10}: NAA-500ppm; T_{11}: NAA-750ppm; T_{12}: NAA-1000ppm; T_{13}: Control-0ppm.)

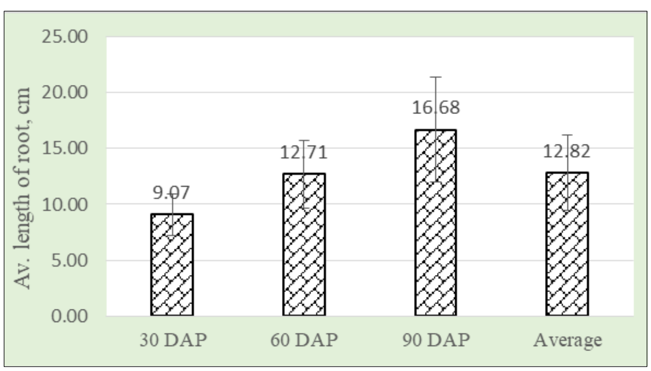

Fig 3: Change of the average length of roots in the stem cuttings of *Aloe vera* (L.) Burm. f. at 30, 60 and 90 DAP on the effect of IAA, IBA and NAA.

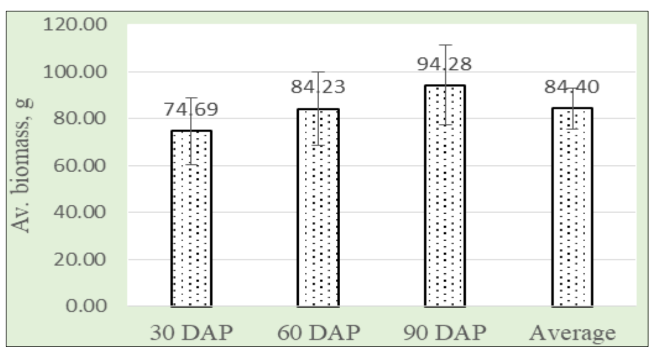

Fig 4: Change of the average production of biomass in the stem cuttings of *Aloe vera* (L.) Burm. f. at 30, 60 and 90 DAP on the effect of IAA, IBA and NAA.

Fig 5: Change of vegetative growth behavior of *Aloe vera* (L.) Burm. f. on the effect of different concentrations of IAA, IBA, and NAA at 90 DAP; A, B and C).

The results of total biomass at 30, 60 and 90 DAP are presented in Table-2 and Fig. 5. The value of the total biomass of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 30 DAP were procured to be 60.67g, 66.33g, 75.33g, 76.33g, 67.67g, 75.33g, 77.67g, 85.67g, 72.33g, 82.67g, 93.33g, 97.33g and 40.33g respectively and pointed the following repercussion as $T_{12}> T_{11}> T_8> T_{10}> T_7> T_4> T_3 \geq T_6> T_9> T_5> T_2> T_1> T_{13}$. Maximum production of total biomass at 30 DAP was determined in T_{12} (NAA- 1000 ppm) and minimum in T_{13} (control). The value of the total biomass of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 60 DAP were earned to be 72.63g, 76.33g, 83.37g, 88.17g, 76.37g, 82.33g, 86.33g, 98.27g, 81.83g, 91.67g, 103.17g, 109.33g and 45.17g respectively and designated the following procession as $T_{12}> T_{11}> T_8> T_{10}> T_4> T_7> T_3> T_6> T_9> T_5> T_2> T_1> T_{13}$. Maximum production of total biomass at 60 DAP was prevailed in T_{12} (NAA- 1000 ppm) and minimum in T_{13} (control). The value of the total biomass of the treatments (*viz*. T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, and T_{13}) at 90 DAP were performed to be 84.33g, 86.33g, 92.33g, 100.33g, 86.33g, 89.33g, 96.33g, 111.33g, 91.67, 99.67g, 113.33g, 112.67g and 51.67g respectively and disclosed the following corollary as $T_{12}> T_{11}> T_8> T_4> T_{10}> T_7> T_3> T_9> T_6> T_2 \geq T_5> T_1> T_{13}$. Maximum production of total biomass at 90 DAP was consummated in T_{12} (NAA- 1000 ppm) and minimum in T_{13} (control). ANOVA of total biomass at 30, 60 and 90 DAP exhibited significant value ($P<0.01$) with treatments (Table-3).

Considering the all treatments the average number of roots, average length of roots and average biomass at 30, 60 and 90 DAP are summarized in Fig. - 1, 3 & 4 respectively. Highest average number of roots, average length of roots and average biomass were detected at 90 DAP whereas lowest in at 30 DAP. It is reported that roots and leaves of the cuttings fresh and dry weight or biomass have been increased in higher concentration of NAA level [57, 59, 62]. These observations are congruence with the present study.

Conclusion

The present study concludes that NAA 1000 ppm solution is suitable for the maximum number of roots, maximum length of roots formation and maximum production of biomass in the vegetative propagation (stem cutting) of *Aloe vera*. Considering the all studied elements NAA 1000 ppm solution is found to be the best concentration for the vegetative propagation (stem cutting) of *Aloe vera* (Ghritakumari) plant.

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