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Influence of Plant Growth Regulators and Cutting Types on Sprouting and Growth of Henna (*Lawsonia inermis* L.) in Arid and Semi-Arid Regions of Western Rajasthan

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Abstract: The experiment was carried out to observe the effects of plant growth regulators (PGRs) *viz*., indole-3-acetic acid (IAA), indole-3-butyric acid (IBA), and naphthalene acetic acid (NAA) on the vegetative propagation of henna (*Lawsonia inermis* L.) on hardwood, semi-hardwood, softwood, and twigs cuttings. Significant variations were observed in sprouting percentage (%), shoot and leaf growth, root development, and biomass across cutting types and PGR treatments. Hardwood cuttings recorded the highest mean sprouting rate (81.63%), with maximum sprouting (98.14%) achieved under IAA at 1500 and 2000 ppm, followed by IBA 1000 ppm and IAA at 500 and 1000 ppm. Semi-hardwood cuttings showed moderate sprouting (66.79%), best under IAA 1000 ppm (88.33%), while high IAA (2000 ppm) showed reduced sprouting. Softwood and twig cuttings showed relatively lower sprouting rates (48.58 and 46.40%, respectively), with IAA at 500–1000 ppm yielding the best results. In hardwood cuttings, IAA at 500 ppm showed the maximum shoot length (38.33 cm) and leaf number (6.00), while IBA at 1500 and 1000 ppm also enhanced growth significantly. IBA 500-1500 ppm consistently enhanced root number and biomass, especially in hardwood (29.6) and semi-hardwood cuttings (15.6), whereas IAA was more effective in promoting root elongation. NAA generally resulted in lower sprouting and root formation, particularly at higher concentrations. The study highlights the superior effectiveness of IBA and IAA for rooting and growth in henna cuttings, emphasizing the importance of cutting type and auxin concentration for optimizing propagation. These findings provide a valuable basis for developing efficient, sustainable propagation protocols to support large-scale cultivation of henna in arid and semi-arid regions.

Keywords: Henna, *Lawsonia inermis*, Plant Growth Regulators, Vegetative propagation, Stem cuttings

Lawsonia inermis L, is a drought-tolerant shrub belonging to the family Lythraceae, widely cultivated in the arid and semi-arid regions of Rajasthan. It is an important cash crop valued for its natural dye, traditionally used for coloring hair, palms, and feet since ancient times (Singh et al., 2015). Henna cultivation thrives under low rainfall conditions, offering a reliable source of income with minimal input costs, making it well-suited for drought-prone areas. The plant begins yielding economically valuable leaves from the third year, with production continuing for 15 to 30 years. Annual harvesting typically involves cutting shoots 10-15 cm above ground level during October-November (Chand and Jangid 2007). The crop's low fertilizer requirement, high establishment success, and resistance to pests and diseases make it an ideal candidate for promoting economic and ecological development in hot, arid regions. India plays a major role in the global henna market, exporting substantial quantities yearly, with cultivation concentrated mainly in the Pali district of Rajasthan, where Sojat is recognized as the primary processing and trading centre (Chand and Jangid 2007, Jyotshna et al., 2017).

Despite its commercial importance, there has been limited research on the vegetative propagation of henna particularly in semi-arid and arid region of Rajasthan. Generally, henna is propagated through seeds but it exhibits poor germination due to dormancy. The vegetative propagation by stem cuttings is vital for rapid multiplication of genetically uniform plants, which is essential for large-scale cultivation (Hartmann et al., 2002). Rooting success in cuttings is strongly influenced by plant growth regulators (PGRs), particularly auxins, which play a key role in inducing adventitious root formation (Davis and Haissig 1990, Thakur et al., 2021). However, the interaction between different PGRs and the physiological age or size of henna cuttings remains underexplored. Since responses to PGRs vary according to the genetic makeup of the plant species, understanding these species-specific effects is critical to developing efficient propagation methods. While some plants root naturally without treatment, many require exogenous application of auxins such as indole-3-butyric acid (IBA), indole-3-acetic acid (IAA), or naphthalene acetic acid (NAA) to enhance rooting (Syros et al., 2004). Additionally, the physiological maturity of cuttings, which affects endogenous carbohydrate reserves and hormone levels, plays an important role in rooting potential. With this background the present study was undertaken to standardize and optimize suitable type of cutting and to study the effect of different plant growth regulators for better rooting and sustainable propagation method in Henna.

MATERIAL AND METHODS

The study was carried out at Central Arid Zone Research Institute (CAZRI), Regional Research Station, Pali-Marwar (Rajasthan) during February, 2022-23 which is located between 25°47'- 25°49' E and 73°17'-73°18' N at 217-220 m above mean sea level and receives 460 mm annual average rainfall with annual maximum mean temperature 42°C and minimum 7°C. The experiment was conducted at nursery conditions in completely randomized block design with three replications.

To evaluate the effect of three plant growth regulators *viz*., indole-3-acetic acid (IAA), indole-3-butyric acid (IBA) and naphthalene acetic acid (NAA) with a control, across four cutting sizes: hardwood (woody portion of the basal area of stem), semi hard wood (Partially woody portion of the middle area of the stem), softwood (younger portion of upper part of the stem) and twigs (thin or tip of the stem typically less than 10 mm) were considered. Cuttings were collected from healthy, uniform mother plants using one-year-old shoots. Each cutting measured approximately fifteen centimeter in length and included 3-4 nodes. Before treatment, all cuttings were soaked in a Bavistin solution for five minutes to prevent fungal infection. Following this, the treated samples were dipped in different ppm solutions of IAA, IBA or NAA. The control group consisted of cuttings only treated with Bavistin (no PGR application). The plants were planted in each treatments in polybags consisted of a mixture of sand, soil, and farmyard manure (FYM) in a 1:2:1 ratio and kept it in shade net condition.

The sprouting percentage (%) was recorded from 7th day in seven days interval. The seedling growth parameters *viz*., shoot length (cm), number of leaves, leaf length and width (cm) were recorded. At the end of the observation period, five randomly selected cuttings were uprooted without causing any damage to confirm root development and root parameters *viz*., root length (cm) and numbers of root were recorded. Then the shoot and root portions were separated and leaf, shoot and root dry weight (gm) was determined.

RESULTS AND DISCUSSION

The results indicated significant variations based on both the type of cutting and the applied PGR treatment and the differences among treatments were statistically significant.

Sprouting percentage (%): Among all cutting types, hardwood cuttings recorded the highest mean sprouting percentage (81.63%). Maximum sprouting (98.14%) was observed under IAA at 1500 ppm and 2000 ppm, followed by IBA 1000 ppm and IAA at 500 and 1000 ppm (96.29%). NAA at 1500 ppm exhibited the lowest survival rate (35.18%) (Table 1). These findings suggest that IAA, particularly at moderate to high concentrations, is most effective in enhancing sprouting in hardwood cuttings, likely due to its role in promoting cell elongation and root initiation. Quainoo et al., (2014) also observed that hardwood cuttings outperformed semi-hardwood and softwood cuttings of henna across all measured parameters.

Semi-hardwood cuttings exhibited a moderate average sprouting rate of 66.79%. The highest sprouting (88.33%)

Table 1. Effect of plant growth regulators and different types of cuttings on sprouting (%) of Henna (*L. inermis*)

Treatments (Concentrations in ppm)	Cutting type and sprouting (%)			
	Hardwood	Semi hardwood	Softwood	Twigs
IAA 500	96.29	83.33	91.66	63.33
IAA 1000	96.29	88.33	90.00	65.00
IAA 1500	98.14	70.00	75.00	58.33
IAA 2000	98.14	43.33	70.00	35.00
IBA 500	94.44	63.33	76.66	41.66
IBA 1000	98.14	66.66	41.66	55.00
IBA 1500	98.14	73.33	41.66	26.66
IBA 2000	83.33	66.66	55.00	38.33
NAA 500	83.33	50.00	28.33	50.00
NAA1000	74.07	43.33	10.00	60.00
NAA 1500	35.18	75.00	8.333	40.00
NAA 2000	40.74	85.00	21.66	41.66
Control	65.00	60.00	21.66	28.33
Mean	81.63	66.79	48.58	46.40
CD (p=0.05)	9.25	11.87	6.89	8.54

was observed with IAA at 1000 ppm, followed by NAA at 2000 ppm (85.00%) and IAA at 500 ppm (83.33%). Lowest sprouting rate was with the application of IAA 2000 ppm (43.33%) and NAA 1000 ppm (43.33%) (Table 1). These results indicated that semi-hardwood cuttings respond best to lower concentrations of IAA and higher concentrations of NAA. Excessively high levels of IAA, however, may have a detrimental effect, possibly due to hormonal imbalance.

Softwood cuttings recorded a relatively lower mean sprouting percentage (48.58%). The highest sprouting was with IAA at 500 ppm (91.66%) and 1000 ppm (90.00%), while IAA at 1500 ppm yielded a sprouting rate of 75.00%. In contrast, NAA treatments were markedly less effective, with sprouting as low as 8.33% under NAA at 1500 ppm. IBA treatments also resulted in lower sprouting rate (41.66% at 1000 and 1500 ppm). This pattern underscores the superior efficacy of IAA in promoting rooting and survival in softwood cuttings, particularly at lower concentrations.

Twig cuttings showed the lowest average sprouting rate (46.40%) across all cutting types. The best performance was observed under IAA at 1000 ppm (65.00%) and 500 ppm (63.33%). Moderate sprouting was also recorded under NAA 1000 ppm (60.00%). However, sprouting rates declined significantly with higher concentrations of IBA and NAA, with IBA 1500 ppm resulting in only 26.66% sprouting and IAA 2000 ppm in 35.00%. These findings reaffirm the preference for lower concentrations of IAA for softer, less lignified cuttings such as twigs . IBA is widely recognized as the most effective auxin due to its low toxicity and broad efficacy (Hartmann et al., 2002) and the role in enhancing rooting and survival in cuttings has been well-documented (Melgarejo et al., 2000, Henrique et al., 2006, Soundy et al., 2008, Kaur 2024).

Shoot and leaf parameters: In hardwood cuttings of henna, IAA 500 ppm produced the longest shoots (38.33 cm) and a higher number of leaves (6.00), followed by IBA 1500 ppm (28.40 cm) and IBA 1000 ppm (27.40 cm). The enhanced shoot growth under IAA 500 ppm suggests improved apical dominance and nutrient mobilization. Leaf length ranged between 2.20 cm (control) and 3.10 cm (IBA 500 ppm), while the maximum leaf width (1.60 cm) was observed under r IAA 1500 ppm (Table 2). This indicated that lower to moderate concentrations of IAA and IBA improve leaf expansion, likely due to enhanced cell elongation and nutrient uptake in hardwood cuttings. Siva et al., (2018) also reported an increased number of leaves in hardwood cuttings treated with higher concentrations of IBA. This suggests that IBA, at optimal concentrations, enhances shoot vigor by stimulating both cell division and nutrient assimilation. This suggests that hardwood cuttings produce more shoots compared to semi-hardwood and softwood cuttings in henna, likely due to their higher carbohydrate reserves (Dick 2001). Being more physiologically mature, hardwood cuttings also appear to respond more effectively to NAA treatment (Noor Camellia et al., 2009).

Shoot length varied significantly across treatments in semi hard wood cuttings. The longest shoots were under IAA 1000 ppm (19.43 cm), followed by IAA 2000 ppm and IAA 500

Table 2. Effect of plant growth regulators on growth parameters of Henna (*L. inermis*) Hard wood cuttings

Treatments (Concentrations in PPM)	Shoot length (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	No. of roots	Root length (cm)
IAA 500	38.33	6.00	3.0	1.5	29.0	9.33
IAA 1000	25.50	4.33	3.0	1.3	17.3	13.1
IAA 1500	23.56	5.33	2.8	1.6	20.6	5.40
IAA 2000	26.93	6.00	3.0	1.2	22.6	3.00
IBA 500	24.93	5.00	3.1	1.2	25.3	11.4
IBA 1000	27.40	5.00	3.0	1.2	24.6	9.66
IBA 1500	28.40	5.00	2.9	1.3	29.6	5.30
IBA 2000	19.10	8.66	2.3	0.5	17.3	3.86
NAA 500	23.23	6.00	2.7	1.4	28.0	7.63
NAA1000	19.46	3.33	3.0	1.1	17.0	6.46
NAA 1500	19.00	3.66	2.8	1.2	18.0	4.00
NAA 2000	19.00	3.00	2.8	1.1	15.0	3.86
Control	15.06	3.33	2.2	0.9	8.0	2.03
Mean	23.83	4.97	2.8	1.1	20.9	6.54
CD (p=0.05)	2.69	0.57	0.32	0.13	2.25	0.87

ppm in semi hard wood cuttings. The shortest shoot length (7.60 cm) was observed in the control. This suggests that IAA at 1000 ppm is particularly effective in promoting apical growth in semi-hardwood cuttings. The number of leaves per cutting ranged from 2.00 (NAA 1000, NAA 1500, and control) to 3.00 (IBA 500, IBA 1500, and IBA 2000 ppm). While leaf number showed moderate variation, IBA-treated semi hard wood cuttings generally produced more leaves than IAA or NAA treatments. Leaf length ranged from 2.03 cm (control) to 3.00 cm (IBA 1000 ppm), while maximum leaf width (1.56 cm) with IBA 1000 ppm, suggesting that IBA at moderate doses promotes healthier foliage development (Table 3). Soni et al. (2016) also observed improved leaf production in guava cuttings treated with auxins.

Among the treatments in softwood cuttings, IBA at 500 ppm produced the longest shoots with an average length of 21.93 cm, followed by IBA 1000 ppm and IAA 1000 ppm and these showed significant increases compared to the control (5.50 cm). The control treatment had the lowest shoot length, indicating the crucial role of PGRs in stimulating shoot elongation. The number of leaves per cutting ranged from 2.33 to 4.33, with the highest number in IAA 2000 ppm and IBA 500 ppm (4.33 leaves each). Leaf length and width were similarly enhanced by PGR treatments, with IBA 1000 ppm showing the greatest leaf length (3.10 cm) and width (2.10 cm), indicating improved leaf expansion and overall vigor (Table 4).

In twigs, IBA at 1000 ppm resulted in maximum shoot length of 19.63 cm, followed closely by IBA 500 ppm and IAA 2000 ppm. These values were markedly higher than the control group, which showed a shoot length of only 8.70 cm (Table 5). This indicates that moderate concentrations of IBA are effective in stimulating shoot elongation in henna twigs. The number of leaves per cutting was highest in the control (7.00), although the leaves were smaller in size compared to treated cuttings, where leaf length and width were significantly improved by IBA and IAA treatments., IBA 1000 ppm recorded the highest leaf length (2.96 cm) and leaf width (1.40 cm), suggesting that PGRs enhance not just the quantity but also the quality of foliage development. Rao et al. (2020) and Tanwar et al. (2020) also reported that PGRs, particularly auxins, promoted shoot elongation and rooting in pomegranate cuttings. The improved growth observed in these cuttings could also be attributed to auxin-induced histological changes such as callus formation and vascular tissue differentiation, which support shoot and root development (Mitra and Bose 1954, Singh 2014). The overall enhancement of shoot growth and foliage parameters due to IAA and IBA aligns with earlier findings in fig (Pinheiro et al., 1971), lemon (Seran and Umadevi 2011), cape gooseberry (Moreno et al., 2009) and Bougainvillea (Anuradha and Parminder Singh 2024) reaffirming the efficacy of auxins in stimulating vegetative propagation responses across different plant systems.

Root parameters: In hardwood cuttings, the highest number of roots (29.6) were in response to IBA 1500 ppm, closely followed by IAA 500 ppm and NAA 500 ppm. The longest roots (13.13 cm) were observed under IAA 1000 ppm, while

Table 3. Effect of plant growth regulators on growth parameters of Henna (*L. inermis*) Semi hard wood cuttings

Treatments (Concentrations in PPM)	Shoot length (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	No. of roots	Root length (cm)
IAA 500	14.56	2.66	2.56	1.16	15.6	7.36
IAA 1000	19.43	2.66	2.70	1.23	13.3	7.70
IAA 1500	13.76	2.33	2.63	1.40	13.6	7.10
IAA 2000	14.93	2.33	2.70	1.23	11.0	7.53
IBA 500	14.16	3.00	2.76	1.20	15.6	9.86
IBA 1000	14.53	2.66	3.00	1.56	15.0	8.66
IBA 1500	14.73	3.00	2.66	1.33	11.6	9.33
IBA 2000	11.70	3.00	2.13	0.80	15.3	6.53
NAA 500	10.92	2.33	2.33	1.20	14.0	5.66
NAA1000	8.796	2.00	2.26	1.00	11.0	5.53
NAA 1500	8.543	2.00	2.36	1.06	9.10	4.00
NAA 2000	8.223	2.33	2.06	0.93	10.0	3.76
Control	7.600	2.00	2.03	0.86	6.00	2.50
Mean	12.45	2.48	2.47	1.15	12.3	6.58
CD (p=0.05)	1.47	0.28	0.27	0.12	1.41	0.77

the control produced lowest number of roots (8.0) with a mean length of 2.03 cm (Table 2). The results highlight a differential effect of PGRs on root number and root length, where IBA promotes root proliferation, and IAA enhances elongation. Both are crucial for nutrient absorption and overall plant establishment.

Among the treatments in semi hardwood cuttings, the number of roots per cutting were highest with application of IAA 500 ppm and IBA 500 ppm (15.6 each), closely followed by IBA 1000 ppm. IAA and IBA treatments at 500-1000 ppm significantly improved root proliferation compared to NAA and control. The longest roots were observed in IBA 500 ppm (9.86 cm), followed by IBA 1500 ppm and IBA 1000 ppm. The shortest root length (2.50 cm) was in the control. This indicates that IBA, particularly at 500-1500 ppm, is most effective in enhancing root elongation in semi-hardwood cuttings. Furthermore, hardwood cuttings recorded the longest roots followed by semi-hardwood cuttings with

Table 4. Effect of plant growth regulators on growth parameters of Henna (*L. inermis*) Soft wood cuttings

Treatments (Concentrations in PPM)	Shoot length (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	No. of roots	Root length (cm)
IAA 500	19.26	2.66	2.56	1.26	14.3	7.00
IAA 1000	19.86	3.00	2.90	1.33	18.6	6.63
IAA 1500	16.93	4.00	2.60	1.33	13.6	8.16
IAA 2000	19.20	4.33	3.00	1.40	8.33	5.66
IBA 500	21.93	4.33	3.06	1.36	26.6	14.1
IBA 1000	23.46	3.66	3.10	2.10	23.0	6.00
IBA 1500	11.33	3.66	2.30	1.23	19.3	6.36
IBA 2000	11.26	2.33	2.56	1.30	20.6	7.60
NAA 500	11.73	2.66	2.30	1.10	19.0	6.90
NAA1000	11.26	2.33	2.20	1.03	10.3	6.56
NAA 1500	9.400	3.00	2.20	1.10	8.33	4.90
NAA 2000	10.06	3.00	2.06	1.03	7.33	5.90
Control	5.500	3.33	2.36	0.80	6.66	3.80
Mean	14.70	3.25	2.55	1.25	15.0	6.89
CD (p=0.05)	1.81	0.37	0.29	0.14	1.77	0.87

Table 5. Effect of plant growth regulators on growth parameters of Henna (*L. inermis*) Twigs

Treatments (Concentrations in PPM)	Shoot length (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	No. of roots	Root length (cm)
IAA 500	8.466	5.66	2.23	0.80	10.3	7.80
IAA 1000	8.700	3.66	2.20	1.10	11.0	5.36
IAA 1500	9.900	3.66	2.56	1.33	14.6	7.80
IAA 2000	14.60	3.66	2.10	1.10	8.66	19.0
IBA 500	16.36	5.66	2.26	1.10	13.6	9.26
IBA 1000	19.63	3.33	2.96	1.40	10.3	13.7
IBA 1500	14.56	4.33	2.80	1.50	7.00	8.16
IBA 2000	12.00	3.00	1.63	0.80	13.6	3.80
NAA 500	7.466	3.66	2.03	1.16	11.3	3.03
NAA1000	5.733	4.33	1.60	0.96	12.3	6.13
NAA 1500	7.233	3.00	2.13	0.93	17.0	3.26
NAA 2000	5.333	4.33	1.40	0.76	19.6	2.06
Control	8.700	7.00	1.63	0.93	4.66	1.06
Mean	10.66	4.25	2.11	1.06	11.8	6.96
CD (p=0.05)	1.22	0.49	0.22	0.11	1.45	1.00

softwood cuttings with the least root length (Table 3). These increase in root length maybe due to an early initiation of roots at physiologically matured stage of hardwood cuttings and more utilization of the food materials due to early formation of roots.

In softwood cuttings, IBA 500 ppm induced the highest number of roots (26.6), followed by IBA 1000 ppm while the control recorded only 6.66 roots on average. Root length was also greatest (14.10 cm) under IBA 500 ppm, suggesting that this concentration is highly effective in promoting root elongation and development. In contrast, higher concentrations of IBA (1500 and 2000 ppm) and all concentrations of NAA showed a decline in both root number and length, indicating potential inhibitory effects of excessive auxin on root formation in henna softwood cuttings (Table 4).

In twigs, the highest number of roots (14.6) were with IAA 1500 ppm, suggesting that this auxin concentration favors root initiation. Conversely, NAA 2000 ppm resulted in the longest roots (19.6 cm) but minimum roots (7.33), indicating that while NAA may enhance root elongation at high concentrations, may not promote root initiation effectively. IBA treatments at 500 and 1000 ppm resulted in robust root development, with root numbers of 13.6 and 10.3 and root lengths of 9.26 cm and 13.76 cm, respectively (Table 5). These results highlight IBA's strong role in balancing root initiation and elongation, crucial for establishing healthy cuttings.

Among all treatments, IBA especially at 500 to 1500 ppm, consistently promoted the highest number of roots across hardwood, semi-hardwood, and softwood cuttings, confirming its superior rooting efficiency due to low toxicity and stability, as also supported by Hartmann et al. (2002). Hardwood cuttings showed the longest roots, followed by semi-hardwood and softwood cuttings, likely due to early root initiation at a more mature physiological stage and efficient utilization of stored nutrients. These findings were confirmed with the study of Sardoei et al. (2013) and Quainoo et al. (2014) in *L. inermis*.

IAA, in contrast, was more effective in enhancing root length, particularly in hardwood and twig cuttings, suggesting its role in cell elongation and vascular differentiation. Excessive concentrations of IBA and NAA negatively impacted root formation in softwood cuttings, indicating possible auxin overdose. These findings align with earlier study of Singh et al. (2013), emphasizing that optimal auxin concentration is critical for successful root initiation and elongation during vegetative propagation. Similar observations were made by Swamy et al. (2002) in *Grewia optiva* and *Robinia pseudoacacia*, Grewal et al. (2005) in *Dendranthema grandiflora* cv. Snowball, Singh et al. (2010) in *Bougainvillea glabra and* Singh et al. (2013) in *Cestrum nocturnum*..

Biomass parameter: In hardwood cuttings, the highest leaf dry weight was in IBA 1000 ppm (0.85 g), followed by IAA 500 ppm. Leaf dry weight was highest in IBA 500 ppm (0.48 g) in semi hardwood cuttings, followed by IAA 500 ppm, indicating enhanced photosynthetic potential and foliage development. In softwood cuttings, the maximum leaf dry weight was in cuttings treated with IBA 500 ppm (0.48 g), indicating enhanced photosynthetic tissue development. In twigs, the maximum leaf dry weight was observed in cuttings treated with IBA 500 ppm (0.41 g) and IBA 1000 ppm (0.40 g) (Fig. 1).

The shoot dry weight was also highest under IAA 500 ppm (0.78 g) in hardwood cuttings. The control treatment consistently recorded the lowest values across all growth and biomass parameters, confirming the beneficial effect of PGRs on rooting and overall plant vigour. In semi hardwood cuttings, shoot dry weight maximum under IAA 1000 ppm (0.48 g) and IAA 2000 ppm (0.48 g). Shoot dry weight highest at 0.256 g under the same treatment in softwood cuttings. Similarly, shoot dry weight peaked in these treatments (0.10 g and 0.09 g, respectively) in twigs, reflecting enhanced shoot vigor (Fig. 2).

In hardwood, the root dry weight peaked in IAA 1500 ppm (0.10 g), indicating a thicker or more developed root system, despite shorter overall length. Root dry weight was highest in IAA 1500 ppm (0.06 g) and IBA 500 ppm (0.05 g), suggesting well-developed, thick root systems in semi hardwood cuttings. Root dry weight in softwood cutting was also highest in IBA 500 ppm (0.07 g), reflecting better root system development and potential for nutrient uptake. Root dry weight was also higher in these treatments, with IBA 500 ppm

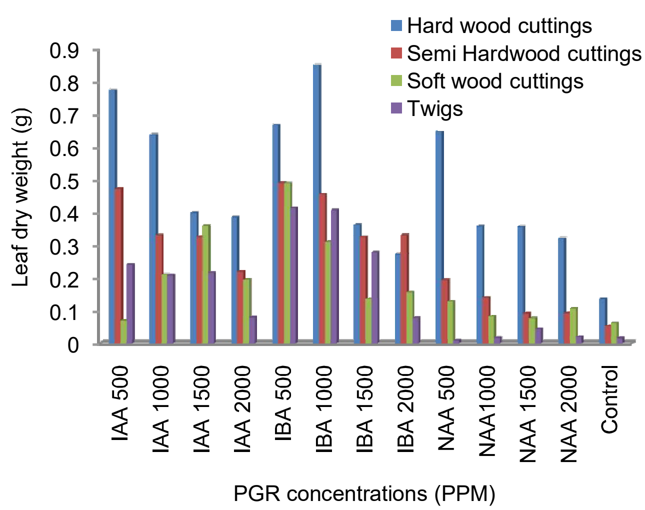

Fig. 1. Effect of plant growth regulators and cutting types on leaf dry weight of Henna (*L. inermis*)

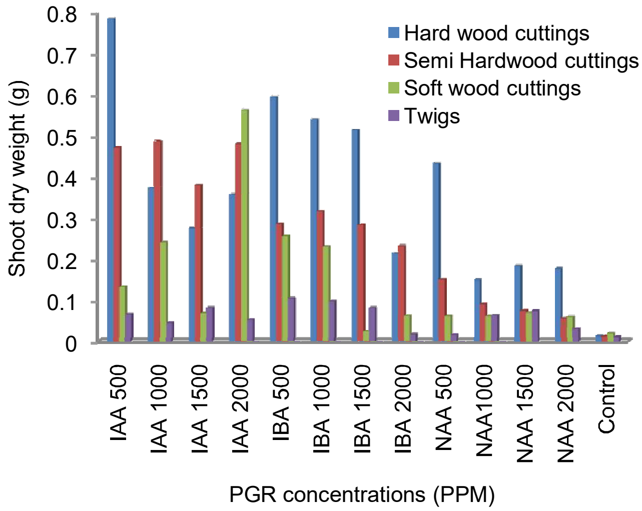

Fig. 2. Effect of plant growth regulators and cutting types on shoot dry weight of Henna (*L. inermis*)

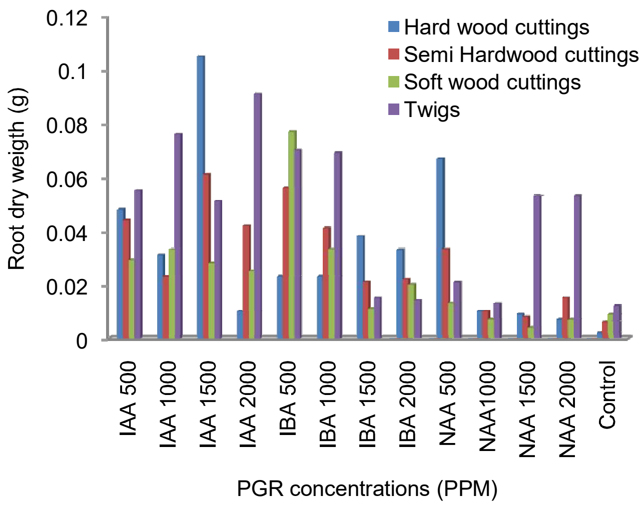

Fig. 3. Effect of plant growth regulators and cutting types on root dry weight of Henna (*L. inermis*)

(0.07 g) in twigs showing significant higher biomass compared to control (0.01 g), highlighting improved root system development (Fig. 3).

The superior dry matter accumulation in hardwood cuttings treated with auxins may be attributed to the higher stored carbohydrate content in these tissues, which, when combined with exogenous auxin application, promoted better root initiation and development. Camellia et al. (2009) in *Jatropha curcus*, reported higher root dry matter due to enhanced root proliferation. Similar outcomes were observed by Deb et al. (2009) in lemon, and Khapare et al. (2012) in fig, where PGR treatments significantly improved biomass accumulation through better root and shoot development.

CONCLUSION

The present study demonstrated that the type of cutting and the concentration of plant growth regulators (PGRs) significantly influence the survival, growth, rooting, and biomass accumulation in henna (*L. inermis*). Among the four types of cuttings evaluated, (hardwood, semi-hardwood, and softwood, and twigs) hardwood cuttings showed superior performance across all parameters, particularly when treated with IAA at 500 ppm or IBA at 1000-1500 ppm. These treatments resulted in the highest sprouting percentage, enhanced shoot length, increased number and size of leaves, maximum root development, and improved biomass accumulation. Semi-hardwood and softwood cuttings responded well to moderate concentrations of IBA (500-1000 ppm), showing satisfactory rooting and shoot growth, though slightly lower than hardwood cuttings. Twig cuttings exhibited the lowest survival and growth performance but still showed improvements under lower concentrations of IAA and IBA. Notably, higher concentrations of NAA were generally less effective or inhibitory, particularly in softwood and twig cuttings. Based on these findings, the use of hardwood cuttings in combination with IAA 500 ppm or IBA 1000 ppm is recommended as the most effective propagation method for henna, offering the best balance between sprouting, vigor, and biomass production. These findings offer a practical strategy to improve henna establishment and productivity in challenging agro-ecological zones.

REFERENCES

Anuradha and Parminder Singh 2024. Auxins treatment of hardwood cuttings of Bougainvillea for inducing rooting. *Indian Journal of Ecology* **51**(6): 1246-1249.

Camellia NA, Thohirah LA, Abdullah NAP and Khidir OM 2009. Improvement on rooting quality of *Jatropha curcus* using indole butyric acid (IBA). *Research Journal of Agriculture and Biological Science* **5**(4): 338-343.

Chand K and Jangid BL 2007. Economic viability of Henna in semi-arid Rajasthan. *Agricultural Economics Research Review* **20**: 137-146.

Davis TD and Haissig BE 1990. Chemical control of adventitious root formation in cuttings. *Plant Growth Regulation Society of America Quarterly* **18**(1): 1-17.

Deb P, Bhowmick N, Ghosh SK and Suresh CP 2009. Effect of different concentrations of naphthalene acetic acid (NAA) and indol butyric acid (IBA) on success and growth of semi hardwood cuttings of lemon (*Citrus limon*). *Environment and Ecology* **27**(3): 1130-1131.

Dick JM 2001. Thirty years of vegetative propagation research on tropical trees in Scotland. *ETFRN News* **34**(01): 26-27.

Grewal HS, Kumar R and Chauhan R. 2005. Effect of IBA and NAA on rooting in chrysanthemum (*Dendranthema grandiflora* Tzevlev) terminal cuttings. *Journal of Ornamental Horticulture* **8**(3): 230-232.

Hartmann HT, Kester DE, Davies FT and Geneve RL 2002. *Plant propagation, principles and practices.* 7th edn. Prentice Hall, New Jersey, 880 pp.

Henrique A, Campinhos EN, Ono EO and Sheila ZP 2006. Effect of plant growth regulators in the rooting of Pinus cuttings. *Brazilian Archives Biology Technology* **49**: 189-196.

Jyotshna, Gaur P, Singh DK, Luqman S and Shanker K 2017. Validated method for quality assessment of henna (*Lawsonia inermis* L.) leaves after postharvest blanching and its cosmetic application. *Industrial Crops and Products* **95**: 33-42.

Kaur Sukhjit 2024. Efficacy of Indole-3-butyric Acid (IBA) on growth performance of terminal stem cuttings of rose-scented geranium [*Pelargonium graveolens* (L.) Herit.]. *Indian Journal of Ecology* **51**(6): 1522-1526.

Khapare LS, Dahale MH and Bhusari RB 2012. Propagational studies in fig as affected by plant growth regulator. *The Asian Journal of Horticulture* **7**(1): 118-120.

Melgarejo P, Martinez J, Amoros A and Martinez R 2000. Study of the rooting capacity of ten pomegranate clones (*Punica granatum* L.). options Méditerranéennes. Série A, *Séminaires Méditerranéens* **42**: 163-167.

Mitra GC and Bose N 1954. Rooting and histological responses of detached leaves to B-Indole butyric acid with special reference to *Boerhavia diffusa* Linn. *Phytomorphology* **7**: 370-374.

Moreno NH, Álvarez-Herrera JG, Balaguera-López HE and Fischer G 2009. Propagación asexual de uchuva (*Physalis peruviana* L.) en diferentes sustratos distintos niveles de auxina. *Agronomia Colombiana* **27**: 341-348.

Noor Camellia NA, Thohirah LA, Abdullah NAP and Mohd Khidi O 2009. Improvement on rooting quality of *Jatropha curcas* using Indole Butyric Acid (IBA). *Research Journal of Agriculture and Biological Sciences* **5**(4): 338-343.

Pinheiro RVR., Conde AR and Filho JBP 1971. The influence of growth substances and of two different cutting beds on the striking, rooting and development of fig cuttings. *Revista Ceres* **18**(97): 210-212.

Quainoo AK, Kabrir K and Mahunu G 2014. Effect of naphthalene acetic acid on rooting and shoot growth of *Lawsonia inermis*. *Biochemistry and Biotechnology Research* **2**(4): 50-52.

Rao GSK, Bisati IA, Sharma A, Kosser S and Bhat SA 2020. Effect of IBA concentration and cultivars on number of leaves, leaf area and chlorophyll content of leaf in Pomegranate (*Punica granatum* L.) cuttings under temperate conditions of Kashmir. *Journal of Pharmacognosy and Phytochemistry* **9**(Special issue 6): 86-90.

Sardoei AS, Sarhadi H, Rahbarian P, Yazdi MR, Arbabi M and Jahantigh M 2013. Effect of plant growth regulators on rooting of henna (*Lawsonia inermis* L.). *International Journal of Advanced Biological and Biomedical Research* **1**(11): 1466-1470.

Seran TH and Umadevi T 2011. Influence of indole acetic acid (IAA) on the establishment of stem cuttings of lemon (*Citrus limon* L.). *Journal of Agrilcultural Research* **49**: 517-524.

Singh DK, Luqman S, Mathur AK 2015. *Lawsonia inermis* L.: A commercially important primeval dying and medicinal plant with diverse pharmacological activity: A review. *Industrial Crops and Products* **65**: 269-286.

Singh KK 2014. Effect of IBA concentrations on the rooting of pomegranate (*Punica granatum* L.) cv. ganesh hardwood cuttings under mist house condition. *Plant Archives* **14**: 1111-1114.

Singh KK, Rawat V, Rawat JMS, Tomar YK and Kumar P 2013. Effect of IBA and NAA concentrations on rooting in stem cuttings of Night queen (*Cestrum nocturnum* L) under sub-tropical valley conditions. *Hort Flora Research Spectrum* **2**(1): 81-83.

Singh N, Singh BP and Singh HK 2010. Effect of different concentrations of indole butyric acid (IBA) on rooting potential and root growth of Bougainvillea stem cuttings. *Journal of Ornamental Horticulture* **13**(1): 41-44.

Siva Prakash M, Rajangam J, Swaminathan V and Venkatesan K 2018. Effect of plant growth regulators on rooting and sprouting of different stem cuttings of Guava (*Psidium guajava* L.) cv. Lucknow-49 under mist chamber condition. *Madras Agricultural Journal* **105**(7-9): 336-340.

Soni N, Pandey S, Singh S, Singh S, Mishra A, Baghel S and Kaurav PK 2016. Propagation of guava through cuttage under net house condition at Jabalpur, Madhya Pradesh, India. *Flora* **22**(1): 36-40.

Soundy P, Mpati KW and Du Toit ES 2008. Influence of cutting position, medium, hormone and season on rooting of fever tea (*Lippia javanica* L.) stem cuttings. *Medicinal and Aromatic Plant Science and Biotechnology* **2**(2): 114-116.

Swamy SL, Puri S and Singh AK 2002. Effect of auxins (IBA and NAA) and season on rooting of juvenile and mature hardwood cuttings of *Robinia pseudoacacia* and *Grewia optiva*. *New Forests* **23**: 143-157.

Syros T, Yupsanis T, Zafiriadis H and Economou A 2004. Activity and isoforms of peroxidases, lignin and anatomy, during adventitious rooting in cuttings of *Ebenus cretica* L. *Journal of Plant Physiology* **161**: 69-77.

Tanwar DR, Bairwa HL, Lakhawat SS and Mahawer LN 2020. Effect of IBA and rooting media on hardwood cuttings of Pomegranate cv. Bhagwa. *International Journal of Environment and Climate Change* **10**: 609-617.

Thakur NS, Hegde HT, Chauhan RS, Gunaga RP and Bhuva DC 2021. Root sucker technique for successful clonal multiplication of *Melia dubia* Cav. without sacrifice of mother tree. *Current Science* **121**(9): 1235-1237.

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