EFFECT OF GROWTH REGULATORS ON *IN VIVO* BUDDING IN ROSES (*Rosa hybrida* L.)

Dissertation

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
in
FLORICULTURE AND LANDSCAPING
(Minor Subject: Botany)

By

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(L-2013-A-31-D)

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LUDHIANA – 141 004

2017

CERTIFICATE I

This is to certify that the dissertation entitled, **"Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida* L.)"** submitted for the degree of **Doctor of Philosophy**, in the subject of **Floriculture and Landscaping (Minor subject: Botany)** of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Prabhjit Kaur (L-2013-A-31-D)** under my supervision and that no part of the dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the dissertation entitled, **"Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida* L.)"** submitted by **Prabhjit Kaur (L-2013-A-31-D)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Ph.D.** in the subject of **Floriculture and Landscaping (Minor subject: Botany)** has been approved by the Student's Advisory Committee along with the Head of the Department after an oral examination on the same, in collaboration with an external examiner.

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ACKNOWLEDGEMENT

With all humility and sincerity, I bow my head with reverence and accord my gratitude to the '**ALMIGHTY**', whose grace and blessings gave me courage and wisdom to accomplish this important task of my life.

The precious debt of learning is difficult to pay only gratitude can be felt. I feel highly elated to express my deep sense of gratitude and indebtedness to my esteemed major advisor, **Dr. H. S. Grewal**, Senior Floriculturist and Head, Department of Floriculture and Landscaping, for his meticulous guidance, keen supervision, and untiring efforts during the tenure of present investigation and preparation of manuscript.

I extend my gratitude to other respectable members of my advisory committee **Dr. Premjit Singh,** Senior Plant Pathologist, **Dr. (Mrs.) K.K. Dhatt, Senior Floriculturist,** Department of Floriculture and Landscaping, **Dr. (Mrs.) Nirmaljit Kaur, Senior Botanist**, Department of Botany and **Dr. R.K. Dubey**, Assistant Professor of Landscaping, Department of Floriculture and Landscaping (Dean PGS nominee) for their help, guidance and critical appraisal of manuscript.

I owe my special thanks to **Mr. Ranjit Singh**, Assistant Professor, Dr. **Parminder Singh**, Associate Professor, Dr. **H.S. Mukker,** Retired Professor, Dr. (Mrs) Madhu Bala, Assistant Floriculturist, Department of Floriculture and Landscaping, for timey help, judicious and valuable guidance and for being there every time I needed, during my tenure of work and for encouragement throughout the research.

Perhaps no language exists in which I can express my indebtness and obligation to my beloved Father **S. Dalip Singh** and mother **Smt. Jasbir Kaur,** who spent their life in making my life. I am extremely obliged to my brothers **Ranbir Singh, Rajbir** Singh, bhabi **Sharanvir Kaur** and little angels of family **Agamvir** and **Harniwaz** for their indelible help, perceptive inspiration, moral support and immense love at every stage of this research work right from the conception to the execution.

I express cheerful acknowledgement to my friends **Nasir, Zahoor, Harwinder, Priya, Jagriti, Neha, Tanya, Ravneet, Raman** and **Jashan** for their moral support, encouragement and cheerful company which helped me in achieving my goal and making it a golden period of my life.

I am thankful to the **Mr. Mahavir ji** and **Mr. Ram Surat ji** for their timely help throughout my research. It is not possible to give a mention to everybody by words but I am gratified to everyone who had been a source of moral support and inspiration directly or indirectly during the course of present study.

I am also grateful to **Mr. Gurdeep Singh (ALPS)** for typing this manuscript neatly and correctly.

Date:

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Title of the Dissertation	**:**	Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida* L.)
Name of Student the and admission No.	:	Prabhjit Kaur L-2013-A-31-D
Major Subject	**:**	Floriculture and Landscaping
Minor Subject	**:**	Botany
Name and Designation of major Advisor	:	Dr. H.S. Grewal Senior Floriculturist-cum-Head
Degree to be Awarded	**:**	Ph.D. (Floriculture and Landscaping)
Year of Award of Dissertation	**:**	2017
Total Pages in Dissertation	**:**	119 + VITA
Name of the University	**:**	Punjab Agricultural University, Ludhiana – 141 004, Punjab, India

ABSTRACT

The present investigations entitled "Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida* L.)" were carried out on the Research Farm, Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana, during 2014-16. The experiments were conducted to study the effect of auxin on the rooting of the budded cuttings and cytokinin on bud take in *Rosa hybrida* L. in two different cultivars, *viz*. First Red and Grand Gala. The mature shoots (>1 yr old) of rootstocks, *viz. R. indica* var. *odorata, R. multiflora* and *R. bourboniana* were used for making the stem cuttings. In Experiment I, rootstock cuttings (8-9 inches long, pencil thickness) were treated with different concentrations of IBA for rooting and budded with the scion of rose cvs. First Red and Grand Gala in December-February. In Experiment II, the rootstock cuttings were treated with IBA 1500 mg L^{-1} for rooting and budded with the scion of rose cvs. First Red and Grand Gala after treating with BAP concentrations in December- February. The type of rootstock and growth regulators treatments significantly ($p<0.05$) affected the plant growth and flowering of two rose cultivars. The per cent sprouting, survival, shoot length, plant height, number of leaves and flowers per plant were observed the highest in rootstock *R. indica* var. *odorata*, whereas, per cent rooting and number of branches were at par in *R. indica* var. *odorata* and *R. multiflora.* The IBA treatment T4 (2000 mg L^{-1}) was found the best regarding per cent sprouting (85.00, 81.67) and rooting of cuttings (91.67, 96.67) survival (68.34, 65.00), shoot length (13.64 cm, 16.29 cm), plant height (20.60, 20.66 cm), number of branches (3.20, 2.84), leaves (9.61, 10.94) and flowers per plant (3.08, 2.07) in rose cv. First Red and Grand Gala, respectively. The best BAP treatment for per cent sprouting (91.66, 88.34), survival (86.67, 86.67), shoot length (15.01 cm, 17.94 cm), plant height (23.01 cm, 24.15 cm), number of branches (3.53, 3.39), leaves (9.95, 11.31) and flowers per plant (2.21, 2.50) was in T4 (BAP 20 mg L^{-1}) in rose cv. First Red and Grand Gala, respectively. It was concluded that the rootstock *R. indica* var. *odorata* performed better for First Red and Grand Gala among the different rootstocks tested. The auxin and cytokinin improved the vegetative growth and flowering of the rose plants. The treatment of cuttings with IBA @ 2000 mg L^{-1} and scion bud with BAP @ 20 mg L^{-1} were the best for the plant growth and flowering of cv. First Red and Grand Gala budded on *R. indica* var. *odorata* rootstock.

Keywords: Auxin, cytokinin, rose, rootstocks

Signature of the Major Advisor **Signature of the Student**

ਖੋਜ ਗ੍ਰੰਥ ਦਾ ਸਿਰਲੇਖ	:	ਗੁਲਾਬ (*ਰੋਜ਼ਾ ਹਾਈਬ੍ਰਿਡਾ* ਐਲ.) ਵਿੱਚ ਇੰਨ-ਵਿਟਰੋ ਅੱਖ-ਚੜ੍ਹਾਉਣ ਉਪਰ ਪੌਦੇ ਦੇ ਵਿਕਾਸ ਨੂੰ ਵਧਾਉਣ ਵਾਲੇ ਕਾਰਕਾਂ ਦਾ ਪ੍ਰਭਾਵ
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ਡਿਗਰੀ	:	ਪੀ.ਐਚ.ਡੀ.
ਡਿਗਰੀ ਨਾਲ ਸਨਮਾਨਿਤ ਕਰਨ ਦਾ ਸਾਲ	:	2017
ਖੋਜ ਗ੍ਰੰਥ ਵਿੱਚ ਕੁੱਲ ਪੰਨੇ	:	119 + ਵੀਟਾ
ਯੂਨੀਵਰਸਿਟੀ ਦਾ ਨਾਮ	:	ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ-141 004, ਪੰਜਾਬ, ਭਾਰਤ

ਸਾਰ-ਅੰਸ਼

ਮੌਜੂਦਾ ਅਧਿਐਨ "ਗੁਲਾਬ (*ਰੋਜ਼ਾ ਹਾਈਬ੍ਰਿਡਾ* ਐਲ.) ਵਿੱਚ ਇੰਨ-ਵਿਟਰੋ ਅੱਖ-ਚੜ੍ਹਾਉਣ ਉਪਰ ਪੌਦੇ ਦੇ ਵਿਕਾਸ ਨੂੰ ਵਧਾਉਣ ਵਾਲੇ ਕਾਰਕਾਂ ਦਾ ਪ੍ਰਭਾਵ" ਸਿਰਲੇਖ ਅਧੀਨ ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਫਲੋਰੀਕਲਚਰ ਅਤੇ ਲੈਂਡਸਕੇਪਿੰਗ ਵਿਭਾਗ ਦੇ ਖੋਜ ਫਾਰਮ ਵਿਖੇ ਸੰਨ 2014-2016 ਦੌਰਾਨ ਕੀਤਾ ਗਿਆ। ਗੁਲਾਬ ਦੀਆਂ ਦੋ ਵੱਖੋ-ਵੱਖਰੀਆਂ ਕਿਸਮਾਂ ਫਸਟ ਰੈੱਡ ਅਤੇ ਗ੍ਰੇਂਡ ਗਾਲਾ ਵਿੱਚ ਬੱਡ ਕਲਮਾਂ ਦੀਆਂ ਜੜ੍ਹਾਂ ਉਪਰ ਓਗਜ਼ਿਨ ਦੇ ਪ੍ਰਭਾਵ ਅਤੇ ਅੱਖ ਉਪਰ ਸਾਈਟੋਕਾਇਨਿਨ ਦੇ ਪ੍ਰਭਾਵ ਦਾ ਮੁਲਾਂਕਣ ਕਰਨ ਲਈ ਤਜ਼ਰਬਾ ਕੀਤਾ ਗਿਆ। ਕਲਮਾਂ ਤਿਆਰ ਕਰਨ ਲਈ *R. indica, R. multiflora* ਅਤੇ *R. bourboniana* ਨਾਮਕ ਜੜ੍ਹ-ਮੁੱਢ ਦੀਆਂ 1 ਸਾਲ ਤੋਂ ਵਧੇਰੇ ਉਮਰ ਵਾਲੀਆਂ ਟਹਿਣੀਆਂ ਲਈਆਂ ਗਈਆਂ। ਪਹਿਲੇ ਤਜ਼ਰਬੇ ਵਿੱਚ, ਦਸੰਬਰ ਤੋਂ ਫਵਵਰੀ ਦੌਰਾਨ, ਜੜ੍ਹ-ਮੁੱਢ ਕਲਮਾਂ (8-9 ਇੰਚ ਲੰਬੀਆਂ, ਪੈਂਸਿਲ ਜਿੰਨੀਆਂ ਮੋਟੀਆਂ) ਨੂੰ ਜੜ੍ਹਾਂ ਲਈ ਆਈ.ਬੀ.ਏ. ਦੀਆਂ ਵੱਖੋ-ਵੱਖਰੀਆਂ ਘਣਤਾਵਾਂ ਨਾਲ ਸੋਧਿਆ ਗਿਆ ਅਤੇ ਗੁਲਾਬ ਦੀਆਂ ਕਿਸਮਾਂ ਫਸਟ ਰੈੱਡ ਅਤੇ ਗ੍ਰੇਂਡ ਗਾਲਾ ਦੀਅ ਅੱਖਾਂ ਨਾਲ ਇਹਨਾਂ ਦੀ ਅੱਖ ਚੜ੍ਹਾਈ ਗਈ। ਦੂਜੇ ਤਜ਼ਰਬੇ ਵਿੱਚ, ਦਸੰਬਰ ਤੋਂ ਫਰਵਰੀ ਦੌਰਾਨ, ਜੜ੍ਹ-ਮੁੱਢ ਕਲਮਾਂ ਨੂੰ ਜੜ੍ਹਾਂ ਲਈ ਆਈ.ਬੀ.ਏ. ਦੀ 1500 mg L^{-1} ਘਣਤਾ ਨਾਲ ਸੋਧਿਆ ਗਿਆ ਅਤੇ ਗੁਲਾਬ ਦੀਆਂ ਕਿਸਮਾਂ ਫਸਟ ਰੈੱਡ ਅਤੇ ਗ੍ਰੇਂਡ ਗਾਲਾ ਦੇ ਅੰਕੁਰਾਂ ਨਾਲ ਇਹਨਾਂ ਦੀ ਅੱਖ ਚੜ੍ਹਾਈ ਗਈ। ਦਸੰਬਰ ਦੇ ਅੰਤ ਤੋਂ ਮੱਧ ਅਕਤੂਬਰ ਤੱਕ ਗੁਲਾਬ ਦੇ ਪੌਦਿਆਂ ਦੀ ਛੰਗਾਈ ਕੀਤੀ ਗਈ ਅਤੇ ਕਟਾਈ ਮਗਰੋਂ, ਟਹਿਣੀਆਂ ਨੂੰ ਡਾਈ ਬੈਕ ਬਿਮਾਰੀ ਤੋਂ ਬਚਾਉਣ ਲਈ ਬੀਲੋਟੈਕਸ ਪੇਸਟ ਨਾਲ ਸੋਧਿਆ ਗਿਆ। ਪੌਦਿਆਂ ਨੂੰ ਰੂੜੀ ਖਾਦ ਅਤੇ ਹੋਰ ਖਾਦਾਂ ਦੀ ਸਿਫਾਰਿਸ਼ ਮਿਕਦਾਰ ਪਾਈ ਗਈ। ਵੱਖੋ-ਵੱਖਰੀਆਂ ਜੜ੍ਹ-ਮੁੱਢ ਕਲਮਾਂ ਉਪਰ ਟੀ-ਬਡਿੰਗ ਲਈ ਗੁਲਾਬ ਦੇ ਪੌਦਿਆਂ ਦੀਆਂ ਤੰਦਰੁਸਤ ਟਹਿਣੀਆਂ ਤੋਂ ਅੱਖਾਂ ਲਈਆਂ ਗਈਆਂ। ਜੜ੍ਹ-ਮੁੱਢ ਅਤੇ ਵਿਕਾਸ ਨੂੰ ਵਧਾਉਣ ਵਾਲੇ ਕਾਰਕਾਂ ਦੇ ਉਪਚਾਰ ਦਾ ਗੁਲਾਬ ਦੀਆਂ ਦੋਨਾਂ ਕਿਸਮਾਂ ਦੇ ਪੌਦਿਆਂ ਦੇ ਵਿਕਾਸ ਅਤੇ ਫੁੱਲ ਪੈਣ ਦੀ ਸਮਰੱਥਾ ਉਪਰ ਅਰਥਪੂਰਨ ($p<0.05$) ਪ੍ਰਭਾਵ ਪਿਆ। *R. indica* ਜੜ੍ਹ ਮੁੱਢ ਵਿੱਚ ਅੰਕੁਰਣ, ਹਰੇ ਰਹਿਣ ਦੀ ਸਮਰੱਥਾ, ਟਹਿਣੀ ਦੀ ਲੰਬਾਈ, ਪੌਦੇ ਦੀ ਉਚਾਈ, ਪ੍ਰਤੀ ਪੌਦਾ ਪੱਤਿਆਂ ਅਤੇ ਫੁੱਲਾਂ ਦੀ ਗਿਣਤੀ ਸਭ ਤੋਂ ਵਧੇਰੇ ਪਾਈ ਗਈ ਜਦੋਂਕਿ *R. indica* ਅਤੇ *R. multiflora* ਵਿੱਚ ਜੜ੍ਹ ਆਉਣ ਦੀ ਪ੍ਰਤੀਸ਼ਤਤਾ ਅਤੇ ਟਹਿਣੀਆਂ ਦੀ ਗਿਣਤੀ ਇੱਕ ਸਮਾਨ ਸੀ। ਗੁਲਾਬ ਦੀਆਂ ਕਿਸਮਾਂ ਫਸਟ ਰੈੱਡ ਅਤੇ ਗ੍ਰੇਂਡ ਗਾਲਾ ਵਿੱਚ ਅੰਕੁਰਣ ਪ੍ਰਤੀਸ਼ਤਤਾ (85.00, 81.67) ਅਤੇ ਕਲਮਾਂ ਦੀ ਰੂਟਿੰਗ (91.67, 96.67), ਹਰੇ ਰਹਿਣ ਦੀ ਸਮਰੱਥਾ (68.34, 65.00), ਟਹਿਣੀ ਦੀ ਲੰਬਾਈ (13.64 ਸੈ.ਮੀ. ਅਤੇ 16.29 ਸੈ.ਮੀ.), ਪੌਦੇ ਦੀ ਉਚਾਈ (20.60, 20.66 ਸੈ.ਮੀ.), ਟਹਿਣੀਆਂ ਦੀ ਗਿਣਤੀ (3.20, 2.84), ਪ੍ਰਤੀ ਪੌਦਾ ਪੱਤਿਆਂ (9.61, 10.94) ਅਤੇ ਫੁੱਲਾਂ (3.08, 2.07) ਦੀ ਗਿਣਤੀ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਆਈ.ਬੀ.ਏ. ਉਪਚਾਰ T4 (2000 mg L^{-1}) ਸਭ ਤੋਂ ਵਧੀਆ ਪਾਇਆ ਗਿਆ। ਗੁਲਾਬ ਦੀਆਂ ਕਿਸਮਾਂ ਫਸਟ ਰੈੱਡ ਅਤੇ ਗ੍ਰੇਂਡ ਗਾਲਾ ਵਿੱਚ ਅੰਕੁਰਣ ਪ੍ਰਤੀਸ਼ਤਤਾ (91.66, 88.34), ਹਰੇ ਰਹਿਣ ਦੀ ਸਮਰੱਥਾ (86.67, 86.67), ਟਹਿਣੀ ਦੀ ਲੰਬਾਈ (15.01 ਸੈ.ਮੀ. ਅਤੇ 17.94 ਸੈ.ਮੀ.), ਪੌਦੇ ਦੀ ਉਚਾਈ (23.01, 24.15 ਸੈ.ਮੀ.), ਟਹਿਣੀਆਂ ਦੀ ਗਿਣਤੀ (3.53, 3.39), ਪ੍ਰਤੀ ਪੌਦਾ ਪੱਤਿਆਂ (9.95, 11.31) ਅਤੇ ਫੁੱਲਾਂ (2.21, 2.50) ਦੀ ਗਿਣਤੀ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਬੀ.ਏ.ਪੀ. ਉਪਚਾਰ T4 (BAP 20 mg L^{-1}) ਸਭ ਤੋਂ ਵਧੀਆ ਸਿੱਧ ਹੋਇਆ। ਅਧਿਐਨ ਦੇ ਨਤੀਜਿਆਂ ਦੇ ਅਧਾਰ ਤੇ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਫਸਟ ਰੈੱਡ ਅਤੇ ਗ੍ਰੇਂਡ ਗਾਲਾ ਲਈ ਤਜ਼ਰਬੇ ਦੌਰਾਨ ਵਰਤੀਆਂ ਗਈਆਂ ਵੱਖੋ-ਵੱਖਰੀਆਂ ਜੜ੍ਹ ਮੁੱਢਾਂ ਵਿੱਚੋਂ *R. indica* ਜੜ੍ਹ ਮੁੱਢ ਸਭ ਤੋਂ ਵਧੀਆ ਸੀ। ਓਗਜ਼ਿਨ ਅਤੇ ਸਾਈਟੋਕਾਇਨਿਨ ਨਾਲ ਗੁਲਾਬ ਦੇ ਪੌਦਿਆਂ ਵਿੱਚ ਬਨਸਪਤਕ ਵਿਕਾਸ ਅਤੇ ਫੁੱਲ ਪੈਦ ਦੀ ਸਮਰੱਥਾ ਵਿੱਚ ਸੁਧਾਰ ਹੋਇਆ। *R. indica* ਜੜ੍ਹ ਮੁੱਢ ਉਪਰ ਫਸਟ ਰੈੱਡ ਅਤੇ ਗ੍ਰੇਂਡ ਗਾਲਾ ਕਿਸਮਾਂ ਦੇ ਵਿਕਾਸ ਅਤੇ ਫੁੱਲਾਂ ਦੀ ਸਮਰੱਥਾ ਲਈ ਕਲਮਾਂ ਨੂੰ IBA @ 2000 mg L^{-1} ਨਾਲ ਅਤੇ ਅੱਖ ਨੂੰ BAP @ 20 mg L^{-1} ਨਾਲ ਸੋਧਣਾ ਸਭ ਤੋਂ ਵਧੇਰੇ ਅਸਰਦਾਰ ਸੀ।

ਮੁੱਖ ਸ਼ਬਦ: ਓਗਜ਼ਿਨ, ਸਾਈਟੋਕਾਇਨਿਨ, ਗੁਲਾਬ, ਜੜ੍ਹ ਮੁੱਢ

ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER – I

INTRODUCTION

Rose is a woody perennial of the genus *Rosa* in the family Rosaceae, having diverse growth habit, color, fragrance and blooming period. The superiority of rose over the other flowers is mainly due to its elegant flower shape and color availability suitable for use in decoration. In ancient Rome and India, roses were widely used by the royal and affluent people as well as by the saints. Ayurveda has also a mention of the different uses of roses for the benefits of the mankind. More than 2500 years ago, the poetess Sappho addressed the rose as 'The Queen of Flowers' (Muhammad *et al* 1996). Roses have deep relationship with human sentiments being symbol of love, adoration, innocence and have a high demand in international markets on account of their use in almost every event. Approximately 20,000 varieties of use are available in different shape, hue and sizes resulting in their extensive demand world over. In India, area under rose cultivation was 30.87 thousand hectare producing 96.09 thousand tonnes loose flowers and 166.47 thousand tonnes cut stems (NHB, 2014). There are nearly 200 different species of rose and all the species are growing naturally in the temperate zones of the northern hemisphere along with sub temperate and sub tropical areas. The important commercial species are *Rosa indica* L., *R. bourboniana* Desp., *R. chinenesis* Jacq., *R. macrophylla* Lindl., *R. multiflora* Thunb. and *R. damascaena* Mill. Although some of the varieties and species are suitable for specific location, however, many of the Hybrid Tea and Floribunda (Hybrid Tea x *Rosa multiflora* or Polyantha) are well suited to the Indian conditions. The main rose growing states of India are Tamil Nadu, Karnataka, Maharashtra and West Bengal.

Rose is cultivated all over the world for various purposes. Currently, major cut rose producers are the Netherlands, Colombia, Kenya, Israel, Ecuador and Japan. In the countries of northern hemisphere, due to the development of rose cultivation under greenhouse conditions and marketing, there has been an increase in the cost of its production. The use of climate controlled green houses for the heating and cooling system and high labour wages resulted in high production cost. As a result, the cultivation of cut roses increased in the countries of southern hemisphere such as Columbia, Mexico, Kenya and Zimbabwe. Further, the development of rose varieties suitable for cultivating under high temperature brightened their prospect for expansion of area under open conditions. The new centres of rose production under low cost plastic green houses have developed in the countries of southern hemisphere for export to the countries of northern hemisphere. Due to the above developments there has been an increase of interest in production of cut roses in green houses in India also. The greenhouse varieties, having good quality flowers, long stem length and vase life, are in great demand in the market for making bouquets and flower arrangements e.g.

First Red, Grand Gala, Dallas, Noblesse, Sonia Meilland, Konfetti, etc. The demand of plants for greenhouse varieties is always increasing, as more and more greenhouses are being established to meet the demand of flowers of retail florists and therefore, have a very good potential under Indian conditions. Since, the demand of high quality roses is increasing tremendously, it is essential to produce more number of plants locally for planting in the greenhouses under protected conditions. The protected cultivation (i.e. controlled temperature, humidity and light) of roses has many advantages for producing high quality flowers free of diseases with long stem length and uniform pigment development resulting in good price of cut stems.

In India, roses are grown from ancient times mainly for beautification of dwelling houses and temples. However, during the last four or five decades, an increased awareness, recognition of high returns, rapid growth rate, improved lifestyle, increased desire to live and work in an environment friendly atmosphere and increase in hotel and restaurant business has led to more demand of flowers. The commercial cultivation of roses is becoming popular for the demand of long stemmed roses, loose flowers for garland making and worship purposes.

Rose can be propagated sexually through seeds and asexually through vegetative means. The conventional methods of propagation are cutting, budding, grafting and layering. The hardwood cuttings and budding are the commercial methods to multiply the desirable rose varieties. Plant propagation by grafting is one of the oldest practices and involves high propagation cost besides more chances of failure resulting in very low number of saleable plants. Roses are usually propagated by T- budding, which has advantage for producing uniform plants, low chances of failure, low disease incidence and labour cost etc. The conventional method of rose propagation involves budding on one year old field established rootstock plants. In the North Indian conditions, T- budding is done in December- March and plants become saleable in October–November, almost after two year of planting the rootstock. This method is laborious as plants need to be taken care for two years and lot of space is required for propagation. The method of simultaneous budding i.e. cuttage-buddage method, has been reported successful for large scale propagation in one year to meet the demand of high quality rose plants.

The present day commercial roses being grown in the tropics and subtropics have been evolved by interspecfic hybridization. Apart from the genetic potential of the varieties so developed, their performance is governed by a number of factors such as available light intensity, temperature, nutrition and the rootstock used in the commercial propagation. Assessment of response of different rootstocks used for propagation of commercial varieties is equally important as that of the scion varieties used for budding. The rootstock used in rose influences the scion growth and development in various aspects. The most important soil factors are adaptation to pH values and drainage conditions, climatic factors, disease resistance, plant longevity, compatibility, productivity and flower quality. The effect of use of rootstocks could be highly positive as compared with their own rooted plants. The differences in flower quality as influenced by rootstock have been reported earlier, while differences in color due to rootstock were found by De Vries and Dubois (1988). The rootstock used for propagation of roses varies according to region and the climate. The most commonly used rootstock includes *R. canina inermis*, Dr. Huey, *R. multiflora*, *R bourboniana, R. laxa, R. manetti,* etc. Wholesale rose growers select rootstock based upon various characteristics, including ease of use and rate of success for field grown roses. However, *R. indica* var. *odorata* was the best rootstock due to resistance to powdery mildew, vigorous growth of scion buds, floriferousness, better rooting of cuttings, bud take and longer plant life. Sharma (1979) reported *R. indica* var. *odorata* was better than other rootstocks used with respect to rooting of cuttings and bud take under Hisar conditions.

The most preferred rootstock for colder climate is *R. multiflora* and for warmer climates Dr. Huey. In the plain areas of India, *R bourboniana* is one of the most popular rootstock for standard roses because it provides the straight stem length suitable for budding up to one meter height for developing standard plants. In Punjab conditions, *R. indica, R. bourboniana* and *R. multiflora* are commonly used as rootstock for commercial propagation in roses.

The rootstock is prepared from cuttings, however, root formation failed in some rootstocks being woody in nature. The problem can be overcome by treatments of cuttings with the growth regulators. The hormone widely used for rooting are auxins i.e. IBA and NAA. The treatment with growth regulators influenced the performance of plants with respect to growth and flowering.

The rose plants for green house production are either imported or procured from unreliable sources these days. Since, only little work on propagation of greenhouse varieties through simultaneous budding i.e. cuttage-buddage method, has been reported so far, therefore, the present investigations were undertaken to study the various factors affecting *in vivo* budding through cuttage-buddage method.

Objectives

1. To study the effect of different growth regulator treatments on rooting of budded cuttings
2. To study the effect of growth regulator treatments on bud take of cuttings

CHAPTER – II

REVIEW OF LITERATURE

The proposed research has been undertaken to study the effect of rootstocks and growth regulators for production of greenhouse varieties of rose plants by simultaneous budding for extending their market availability under Punjab conditions.

The relevant literature pertaining to the present investigations has been reviewed as under:

2.1 Rootstock

2.2 Propagation

2.3 Growth regulators for rooting of cuttings

2.4 Growth regulators for bud take and budding

2.1 Rootstock

In roses, rootstock significantly influenced performance of scion genotype with respect to plant growth and flowering. *R. indica*, *R. bourboniana* and *R. multiflora* have been extensively used as rootstock for commercial propagation of roses. The rose plants budded on *R. multiflora* and *R. canina* rootstock produced vigorous growth with more flower yield (Rowley 1961).

Singh (1972) observed that the scion bud take of cv. Picadily, Monetezuma and Super Star performed better on *R. multiflora* and *R. bourboniana* than rootstock *R. moschata*. Aslam and Khan (1973) reported that the highest rooting percentage (80.10) was observed in edouard rose in Delhi area. The rose plants when budded on rootstock *R. multiflora* resulted in vigorous growth and high flower yield (Tillage 1974).

Swarup and Malik (1974) concluded that the type of rootstock affected the bud take of dfferent scion varieties. The bud take was the highest in Super Star (100.00 %), Dr Homi Bhaba (88.00 %) and Pusa Sonia (80.00 %) when budded on *R. indica* var *odorata*, however; in Queen Elizabeth bud take was the highest (96.00 %) on *R. multiflora.* Some of the cultivars gave equally good results on two different rootstocks McGredys Sunset on Edouard and *R. multiflora,* McGredys Yellow on Edouard and *R. indica* var. *odorata* and Happiness on *R. indica* var *odorata* and *R. multiflora.* However, *R. indica* var. *odorata* was the best rootstock due to resistance to powdery mildew, vigorous growth of scion buds, floriferousness, better rooting of cuttings, bud take and longer plant life.

Goujan (1974) reported that cvs. Carina, Lara, Super Star and Zorina produced more flowers per plant on *R. indica* var. *major* than on their own rootstock. *R. multiflora* has also been reported the best rootstock for cv. Montezuma (Pandey and Sharma 1976). Similarly, *R. multiflora* was also found to be the best rootstock for Charlesmaller (Singh, 1977).

Sharma (1979) reported that *R. indica* var. *odorata* was the best rootstock than *R. bourboniana* and *R. muliflora* with respect to rooting of cuttings and bud take under Hisar conditions.

Malik (1980) observed that the *R. indica* var. *odorata* was better rootstock than *R. bourboniana* and *R. muliflora*. Further, it was reported that rose cv. Sonia produced more number of marketable blooms when budded on *R. indica* var. *odorata* rootstock than own rooted plants.

Mukhopadhyay and Banker (1982) studied the effect of rose cv. Happiness, Queen Elizabeth and Super Star on *R. multiflora* and *R. indica* rootstock. It was concluded that the non significant difference of the rootstock with respect to weight of pruned wood, shoot length, flower number, plant spread and number of export quality flowers, although rootstock *R. multiflora* performed better than *R. indica* in Hessaraghatta conditions.

Likewise, Randhawa and Mukhopadhyay (1986) also reported that *R. indica* var. *odorata* was better rootstock due to resistance to powdery mildew and better suitability to North Indian conditions. Miller (1986) observed that rose cultivar Sonia produced more number of marketable blooms when budded on *R. indica* rootstock than own rooted plants.

Mukhopadhyay and Bankar (1986) reported that thornless rootstock produced maximum number of flowers followed by *R. multiflora* and *R. indica*. Miller (1986) observed that cv. Sonia on *R. indica* var. *major* produced more marketable blooms than on their own rooted budded plants and therefore recommended it as the best rootstock for increasing overall production, especially for winter production.

Balakrishnamurthy and Rao (1988) reported that the cuttings of *R. bourboniana* showed the highest rooting (49.38 %), largest number of primary roots (29.60) and secondary roots (39.80). Dubois *et al* (1990) found that the *R. indica* var. *manetti, R. indica* var. *major* and the seedling rootstock *R. multiflora* produced the maximum flowers. It was reported that in rootstock *R. multiflora,* the bud take was 83.33 % in scion cv. Smokey, followed by cv. Piccadily 70.00. Further, sprouting of buds was the maximum in cv. Smokey and the tallest plants (14 cm) were obtained in cv. Piccadily (Ishtiaq and Jehangir 1994).

Khan *et al* (2004) used two rootstocks *R. bourboniana* and *R. gruss an teplitz* and three rose cultivars, i.e. Kardinal, Gold Medal and Whisky Mac. These cultivars showed maximum growth and flowering when budded on *R. gruss an teplitz* as compared to *R. bourboniana.*

The performance of rose cultivars may depend much on the rootstock used; however, the performance of cultivars on particular rootstock may be suitable for a particular locality and may not perform well in another (Karadi and Patil 2006). Further, it was reported that among the three different rootstocks used, *R. multiflora* performed the best for bud take percentage, plant height, plant girth, number of branches and minimum number of days taken for flower bud initiation.

Balaj and Zogaj (2011) studied the level of compatibility for hybrid tea and climbing roses using the rootstock of *R. canina* var. *laxa*, in Kosovo. The grafting was done in August, in the form T-budding, on a same rootstock of *R. canina* var. *laxa*. The parameters like number and diameter of roots, length of flower stems, diameter of shoots and number of flowers were recorded. The level of compatibility between rootstock with all varieties was tested. The rootstock significantly influenced the commercial varieties regarding length and diameter of the flowering shoots, flower diameter and the dry matter of both rootstock and scion part.

Singh *et al* (2011) observed stionic effect of rootstocks (*R. multiflora*, *R. indica* var. *odorata*, *R. witchuriana* and *R. bourboniana*) on different rose cultivars and *R. indica* var. *odorata* was found superior with respect to days to root initiation, percentage of rooted cuttings, number of roots per cutting and length of root.

2.2 Propagation

McFadden (1963) reported a technique for propagating roses by combining cutting and grafting by using *R. fortuneana* as rootstock. Nanjan *et al* (1971) budded the rose scion on briar cuttings for simultaneous bud union and rootstock rooting. It was observed that the plants were ready for sale after 5-6 months compared with 12-16 months by the usual method and also the mean successful bud take was 78.00 % compared with 68.00 % for the normal budding method.

Rojas (1972) shield budded various rose cvs. on *R. multiflora japonica* cuttings and planted them in polythene bags in field and as well as in the green house. The bud take exceeded 90 % and first flowers were obtained within 8 weeks of budding. Davis and Fann (1983) found that the cuttage buddage success on *R. multiflora* cuttings was 93.00 % for Climbing White American Beauty and 67 % for blaze.

In the Netherlands, another technique was developed and introduced for Dutch conditions using *R. indica* var. *major* as a rootstock (Pol and Vliet, 1979) and called "stenting" which is derived from Dutch words "stekken" (to strike a cutting) and "enten" (to graft), thus the plant developed by this technique are called "stentling".

Ohkawa (1980) observed that cutting – Grafts of Sonia on *R. multiflora* K-1, *R. indica* var. *major*, *R. wichuraiana* produced flowers of the same number and quality when budded on to *R. multiflora* seedling rootstock. It was suggested that the best factors for obtaining successful graft union and rooting were tongue grafting, softwood scions with 1 or

2 leaves, dormant stock cuttings with all buds removed before graftings, 10-15 cms length of stock cutting, IBA quick dip treatment before rooting and mist equipment.

Pol and Breukelaar (1982) found that bench grafting and stenting gave similar results. *R. chinensis* proved to be a better rootstock for the cv. Cocktail, while *R. inermis* was better for Motrea. Fann *et al* (1983) noted that for bench-chip budding the rootstock auxiliary buds were necessary for initial root system establishment but should be removed early to maximize scion development and reduce field production time.

Davies and Fann (1983) reported that 93.00 % and 67.00 % success in cuttage buddage method in variety Climbing White American Beauty and Blaze on rootstock *R. multiflora* when one year old mature cuttings were taken to raise plants in less than one year.

Gill (1984) reported that direct budding on cuttings i.e. cuttage-buddage method was useful for quick propagation in December-January in North India. In rose, T budding done directly (simultaneous budding) on the one year old mature cuttings have been reported successful for raising plants in less than one year.

Ohkawa (1984) in Kanagawa, Japan, observed that for scion cv. Sonia, *R. multiflora* gave the best percentage of graft unions, whereas, *R. indica* var. *major* gave the poorest results. It was observed that whip and tongue grafting were better than veneer grafting and also suggested paraffin coating of scion and union along with a basal quick dip in 0.40 % IBA.

Gill (1984) reported that cuttage- buddage method was highly successful in December – January under Ludhiana conditions. Pol *et al* (1986) found that within 12 days from whip grafting cv. Ilona on *R. chinensis*, 100.00 % of grafts formed xylem vessel connection and after 15 days 75.00 % grafts were rooted.

Hanan and Grueber (1987) obtained the best results when scion of cv. Royalty was grafted on cuttings of *R. odorata.* However, cv. Samantha and Cara Mia scion on *R. manetti* rootstocks suffered from leaf drop and rooted poorly.

Marczynski and Michleewlcz (1988) carried out a trial in which cvs. Bingo, Mercedes, Red Success and Sonia were stented on *R. multiflora* and *R. rubiginosa.* These cuttings were inserted in 3:1 perlite and peat at 20-25 °C under glasshouse. *R. multiflora* proved to be the best rootstock with an average of 83.00 % rooted cuttings after grafting in August. Kromwijk *et al* (1990) also reported high percentage of success with side grafting cv. Sonia on *R. canina.*

Davies (1991) conducted propagation trials in Texas and reported that chip budding on the dormant rootstock cuttings was successful. Pandey *et al* (1991) reported that in cv.

Snow Girl, the budding success was the greatest (27.00) when it was carried out in the first week of January.

Singh (1998) reported that the method of propagation as cuttage-buddage method in rose cv. Rakatgandha after treating with growth regulators for quick bud union, bud break and shoot growth.

2.3 Growth regulators for rooting of cuttings

The uses of auxins have been reported for the rooting of hardwood and softwood cuttings of roses by many research workers. De Souza and Inforzato (1958) reported that in *R. canina* and *R. chinensis,* the roots were vigorous and the foliage was better in the IBA and NAA treated cuttings than in the untreated cuttings.

Tognonl (1964) recorded that the average rooting in untreated *R. canina* cuttings was only 4.50 %. The enhanced rooting of cuttings in *R. indica* var. *major* treated with 500 ppm IAA or 2000 ppm NAA had been reported by Papandreou (1972).

Maiti (1972) treated the scion buds of HT roses with 500, 1000, 1500 ppm IBA and *R. multiflora* with Seradix B3. It was observed that 51.60 % of treated cuttings produced root and 46.70 % developed into successful grafts in six months.

Bhujbal and Kale (1973) reported that *R. multiflora* produced the maximum percentage of rooted cuttings (90.00), maximum number and length of rooted cuttings in mixture of 1000 ppm IAA and IBA, whereas, *R. moschata* showed better rooting and development with IBA 1500 ppm and IAA + IBA 500 ppm. *R. bourboniana* performed relatively poorly throughout, with best response in IBA 1000 ppm treatment.

Azimi and Bisgrove (1975) observed greater root dry weight per cutting in *R. multiflora* than *R. canina* with 750 ppm IBA, whereas, *R. canina* rooted the best with 3000 ppm IBA treatment.

Shafie *et al* (1976) studied the effect of combined application of different growth regulators on rooting of rose. The increase in rooting of cv. Perle Vol Aalsmeer was found when dipped for 4 hours in NAA solution, with or without kinetin spray before and after planting. It was observed that dipping of cuttings in 50 mg L^{-1} of NAA produced the best rooting and foliar sprays with kinetin improved rooting. The application of kinetin without dip treatment of cuttings with NAA improved root growth as compared to the control.

Ivanicka *et al* (1977) observed that rooting of rose rootstock cuttings was better with IBA 2500 ppm as compared to IBA 1500 ppm. Das *et al* (1978) reported that *R. multiflora* rooted better with IBA 1000 ppm.

Mukhopadhyay and Bankar (1982) reported that quick dip application of IBA 2000 ppm on cuttings exhibited the highest rooting in roses. Rusmini (1982) observed that application of IBA also improved root quality of the cuttings in roses.

Thomson (1984) reported that IBA increased root number and length as compared to IAA or NAA and 92.00 % rooting was induced by using IBA 1000 ppm as quick dip application.

Singh and Lal (1985) tried different concentrations of IAA ranging from 250 ppm to 1000 ppm on cvs. Montezuma and Grand Moughel budded on *R. bourboniana.* It was observed that the days to bud break were minimum in both the cultivars and percentage of bud break, rooting, length of sprout, numbers of leaves per sprout were greatest with 1000 ppm IAA treatment.

Randhawa and Mukhopadhyay (1986) observed 1000-10,000 ppm quick dip treatment of cuttings with auxins resulted in better rooting. Balakrishnamurthy and Rao (1988) reported that stem cuttings of *R. bourboniana* produced 51.25 % rooting and 65.51 % survival in glass house by quick dip treatment of IBA 1000 ppm for 5-10 seconds. Stoltz and Anderson (1988) observed the difference of rooting response between the cultivars and IBA concentrations (125, 250, 550 and 750 ppm) using single node cuttings. It was found that the per cent rooting, number of roots and root length improved with 750 ppm of IBA.

Wu (1988) observed that a mixture of 0.1 ppm lanthanum and 1 ppm indole propionic acid (IPA) stimulated rooting, doubled root length and increased the dry matter of roots.

Sutapradja (1988) treated *R. multiflora* with different concentrations of IBA and NAA ranging from 0-75 ppm and it was observed that both the hormones increased root length in 42 days. Root number per cutting was the maximum (9.28 and 9.64) with the application of 75 ppm IBA and NAA, respectively.

Hartmann and Kester (1989) reported that treatment with 50-10,000 ppm auxin (dissolved in 50% alcohol) for quick dip of basal ½ to 1 cm cuttings for 3 seconds increased rooting of budded cuttings, hastened root initiation, increased number of roots per cutting, improved quality of roots and uniformity of rooting of cuttings.

Chu (1990) treated the single internode of *R. multiflora* with IBA solution at 2000 ppm after budding with a scion of cvs. Christian Dior, Landora and Romantica having a dormant bud and a leaf on this scion. The budded cuttings were rooted in perlite medium and after 1 month rooting of the budded cuttings were observed satisfactory.

Nautiyal *et al* (1991) observed in *Tectona grandis* that the cuttings produced the best rooting when treated with IBA (100 ppm) for 24 h dipping and planted in soil/sand mixture (2:1) in the pots.

Harris and Singh (1991) reported that the cutting of bougainvillea cvs. Shubra, Refulgence, Formosa, Mangnifica, dipped in IBA (100 ppm) for 12 h and placed under mist chamber, resulted in the highest per cent rooting and maximum number of roots per cutting in all the cultivars.

Cong (1991) reported that *Prunus triloba* cuttings resulted in the maximum survival in treatment with IBA (500 ppm) and planted in earthen pots containing garden soil.

Jhon and Paul (1991) reported that in difficult to root *Euonymus japonica* that the highest per cent survival of cuttings resulted in treatment with IBA (6000 ppm) and planted in washed coarse sand bed, covered with transparent polythene sheets.

Carpentar and Cornell (1992) observed Hibiscus cv. Pink cuttings had maximum rooting with IBA (10,000 ppm) treatment. However, in *Coriaria nepalensis*, the cuttings resulted in best rooting with IBA (100 mg L^{-1}) treatment (Joshi *et al*, 1992).

Bhattacharjee and Balakrishana (1992) observed in *Hamelia patens* that IBA treatment at 4000 ppm significantly increased rooting and number of roots per cutting.

Nath (1992) obtained the highest percentage of rooting (90.00 %), number of primary root (25 per cutting), length of the longest root (12cm) and percentage survival (90.00 %) with IBA (2000 ppm) in *Mussaenda phillipica.*

Eltroky and El- sennawy (1993) reported in *Ficus deltodiea* that the maximum rooting percentage was in the cuttings taken in February and treated with IBA (3000 ppm) before planting in peat under intermittent mist conditions. Gupta *et al* (1993) reported that *Dalbergia sisoo* cuttings dipped for 24 h resulted in the best rooting (80-90%) with IBA (100 and 200 ppm) treated before planting in earthen pots in river sand/soil (2:1).

Paul and Jhon (1993) reported in *Ligustrum lucidum* that the stem cuttings dipped in IBA (500 ppm) resulted in the maximum rooting (90.00%), root length (10.9 cm), number of roots/cutting (3.88) and survival of plant (76.66%).

Singh (1993a) reported in *Bougainvillea* cv. Thimma that the cuttings resulted in more number of root /cutting in treatment with IBA (3000 or 4000 ppm) regardless of the season.

Singh (1993b) studied the effect of various concentrations of auxin (0, 1000, 2000, 3000 or 4000) in *Callistemon lanceolatus* and reported that auxin treatment improved survival, growth and development of cutting but high concentration inhibited the branching.

Wen *et al* (1993) examined the single-node cuttings of rose (*R. hybrida* L.) cv. Royalty for the relationship between adventitious root formation, bud break, and ethylene synthesis. IBA 200, 400, 600, 800, 1000, and 1200 mg L^{-1} were applied to the cuttings. IBA 600 mg L^{-1} application increased rooting and inhibited bud break of cuttings.

Sun and Bassuk (1993) observed that IBA application increased rooting and inhibited bud break of cuttings in roses, however, root initiation and root elongation of cuttings promoted bud break afterwards.

Gupta (1994) reported that IBA 4000 ppm (10 sec.) induced the best rooting (91.70%) with maximum survival (88.98%), number of roots per cutting (24.66) and root length (12.71cm) in semi hardwood cutting of *Sambucus nigra.* The treatment of *Nerium oleander* cuttings with 1000 ppm IBA or NAA for 10 sec. also improved rooting (Standardi and Mariani 1994).

Raju *et al* (1994) reported that IBA promoted rooting in *Coriaria nepalensis, Debregeasia hypolenca* and *Woodfordia floribunda* cuttings as compared to the untreated cuttings.

El- Shazly and Sabrout (1994) reported in pear that the best rooting percentage (32.75%), number of roots per cutting (2.03%), number of leaves per cutting (19.13), average shoot length (17.63 cm) were observed in treatment with IBA (4000 ppm).

El- Shazly *et al* (1994) observed that the cutting of lemon treated with IBA (1000) ppm and planted in sand and peat moss medium (1:1) under mist resulted in the maximum number of roots/cutting, whereas, 400 ppm resulted in maximum number of roots/cuttings. In loquat that treatment with IBA (4000 ppm) resulted in the highest rooting percentage, average root length and number of roots per cutting.

Masoodi *et al* (1994) reported in *Glycyrrhiza glabra* that the cuttings treated with IBA (0.5 mg L^{-1}), before planting in sand under mist chamber, resulted in the highest sprouting (96.67 %) and rooting (90.00 %).

Aminah *et al* (1995) studied that the application of auxin (indole butyric acid) significantly increased the rate of root emergence in single node leafy stem cuttings of *Shorea leprosula.* A range of IBA doses (0, 20, 40, 60 and 80 µg IBA per cutting) were tested and 20 µg per cutting was found to be the best with 70% of cuttings rooted within 12 weeks. Higher doses resulted in less rooting success. IBA application also enhanced the number of roots developed on each cutting. The mean accumulated number of roots per rooted cutting in week 10 on cuttings treated with 20, 40, 60 and 80 µg IBA was 5.05, 5.26, 4.82 and 4.80 respectively compared with 3.11 for cuttings treated with only a 50% ethanol and water mixture.

Chovatia *et al* (1995) reported in *Bougainvillea* var Mary Palmar the highest root initiation (88.55%), longest roots (51.47 cm), longest shoot (36.78 cm) and the highest number of root/cutting (6.08) in treatment of cuttings with IBA 4000 ppm (15 sec.) before planting in pots containing garden soil.

Sunil *et al* (1995) reported in *Dalbergia sisso* that IBA (100 mg L^{-1}) was the most effective; however, the higher concentration inhibited rooting. Fouda and Schmidt (1994) reported that IBA treatment of cuttings improved rooting percentage, number roots and root length. Arnold *et al* (1995) reported that rooting of roses was obtained with high IBA and NAA concentrations.

Chezhiyan *et al* (1996) observed the highest rooting and survival of cuttings dipped in IBA (2000 ppm) for 12 h in the cuttings of clove (*Syzygium aromaticum*).

Kumar and Forooqi (1996) reported in *Rula graveolens* that stem cuttings treated with IBA (300 ppm) resulted in the maximum number of roots (32.38), number of sprouts (5.68), length of largest sprout (6.33 cm) and number of leaves (6.75).

Kumar *et al* (1996) reported that in Kanpur conditions, the scions of hybrid tea rose cultivars Montezuma and June Bride when budded on rootstocks *R. borboniana*, *R. indica* var. *odorata* and *R. multiflora*, the rootstocks took 21-28 days for root initiation. The highest rooting was with IBA (2000 ppm), the quickest in *R. indica* and slowest in *R. multiflora.* Further, it was observed that per cent rooting and bud break take was highest in *R. indica.*

Menon and Nybe (1996) reported in *Plumbago rosea* that treatment of cuttings with IBA (500 ppm) for 60 sec. resulted in the highest number of roots per cutting with average length, whereas, survival of rooted cutting was the maximum in treatment with IBA at 500 ppm for 30 sec followed by IBA (500 ppm) for 60 seconds.

Rana (1996) reported in five cultivars of plum that the maximum rooting (40.25%) occurred in treatment with IBA (2000 ppm). The cutting of *Pongamia pinnata* resulted in 100% rooting and maximum number of roots in treatment with IBA 800 ppm (Palanisamy *et al* 1998).

Rossal and Kersten (1997) observed that the cutting of triangular and cylindrical *Valenica organge* treated with IBA (3000 ppm), before planting in sand or rice husk ash under intermittent mist, resulted in highest rooting percentage.

Sambyal (1997) reported that the treatment of rose buds with BAP, IBA and GA_3 resulted in increase in sprout length, per cent bud take and per cent plant survival. However, the maximum number of primary roots and root length was observed with the cuttings treated with IBA 1000 ppm, whereas, the maximum sprout length and per cent survival was observed with combination of NAA and IBA.

Palanisamy *et al* (1998) reported in *Azadirachta indica* that the cuttings treated with IBA (1000 ppm), before planting in coarse sand under intermittent mist, resulted in the maximum rooting (70.00 %). Number, length and dry weight of roots was 23.00 % as compared to control.

Montarone *et al* (1999) reported that shoot cuttings of *Protea* rooted the best (>40%) in treatment with IBA (2000 ppm) as compared to 500 ppm (<15%), whereas, the low IBA levels required longer treatment (60 sec.) to improve rooting of cuttings.

Pivetta *et al* (1999) reported that in rose cv. Red Success that apical and intermediate cuttings treated with IBA 0, 1000, 2000, 4000 ppm failed to root. Further, it was observed that in rose cv. Dallas rooting percentage was higher (95.32 %) with IBA treatment than untreated cuttings (80.44 %). The rooting percentage was the highest in sand (98.00), followed by vermiculite (90.00). Further it was observed that the number of roots increased at weekly intervals.

Choi *et al* (2000) observed the effect of root promoters viz. IAA, NAA and IBA on rooting of cuttings of cvs. Noblesse and Red Velvet. The rooting of Red Velvet cuttings was better with treatment IAA, NAA and IBA up to 1000 mg ml^{-1}. Rooting was the highest in cv. Noblesse with treatment of IAA (1000 ppm), NAA and IBA up to 500 ppm. The number of roots, length and weight in cv. Noblesse were the highest with 500-2000 ppm IBA treatment.

Singh (2000) reported in *Hamelia patens* that hard wood cuttings treated with IBA (500 ppm) resulted in significantly more sprouting (77.50 %), rooting (60.00 %), number of shoots per cutting (3.93), number of leaves per cutting (69.33), average shoot length (19.28 cm) and establishment of plant (50.80 %) than all other treatments, irrespective of duration (12, 24 h) of treatment and method of planting. Likewise in *Bougainvillea peruviana* cv. Shubra, the treatment of cutting with IBA (500 ppm) resulted in significantly more sprouting (71.67 %), rooting (57.5 %), number of shoots per cutting (1.37), number of leaves per cutting (41.4), average shoot length (128.86 cm) and establishment of plant (51.67 %) than all other treatments, irrespective of duration (12, 24 h) of treatment and method of planting.

Akhtar *et al* (2002) reported in roses that the maximum length of shoots, number of branches and number of roots were obtained in the cuttings treated with IBA. The treatment of cuttings with IBA (1000 ppm) was found promising with respect to vegetative growth and rooting and *R. bourboniana* proved better for plant height as compared to *R. gruss-an-teplitz* among the two *Rosa* species (Hussain and Khan 2004).

Khan *et al* (2004) found 1000 ppm IBA gave rise to more number of roots, length of root and branches in rose. Pati *et al* (2004) reported that IBA was better than NAA or IAA for promoting rooting in rose cuttings. Further, the performance of rooting of cuttings, root number, root length and bottom break was better with IBA. Auxin, the root-promoting growth regulator was applied to the basal portion of cuttings using a liquid or talc formulation and quick-dip method was preferred for commercial use (Blythe *et al* 2004).

Khan *et al* (2004) observed the effects of two hormones viz. IBA and Seradix-A on growth and rooting percentage of *R. bourboniana* cuttings. Seradix-A exhibited best results for different parameters of *R. bourboniana* followed by 1000 ppm of IBA and 500 ppm of IBA, respectively while control showed the minimum results which indicates positive effect of rooting hormones to increase sprouting and rooting percentage.

It was reported that in miniature rose cuttings IBA concentrations between 10^{-3} and 10^{-1} M, were better for root formation and IBA at 10^{-4} to 10^{-3} M for axillary bud growth, whereas, time to flowering and plant height increased by increasing the IBA concentration (Niels *et al* 2004).

Gupta *et al* (2005) reported that in semi-hardwood cuttings of *Bougainvillea* cv. Pallavi, root length was more when the cuttings were treated with IBA (4000 ppm) than all other lower concentrations of IBA and NAA. It was concluded that in semi-hardwood cuttings of cvs. Pallavi and Mahara variegata, the treatment with IBA (4000 ppm) was the most effective for large scale vegetative propagation.

Bhatt *et al* (2008) observed in *Lavendula officinalis* that the cuttings treated with IBA resulted in callusing (86.66 %), early root emergence (21.66 days), maximum rooting percentage (86.66), number of roots (7.00), length of roots (10.30 cm) and field survival (93.33 %) of plants.

Hussein (2008) reported that stem cutting of *Thunbergia grandiflroa* Roxb. treated with IBA (6000 ppm) for 30 seconds showed the highest value for rooting percentage, root length, number of root per plant and fresh and dry weight of rooted plants than the other treatment. The treatment with IBA (6000 ppm) also resulted in the highest positive effect on plant height, fresh and dry weight of branches per plant, number of leaves per plant and dry weight of leaves per plant as compared to the other treatment, however, the cuttings treated with IBA (1500 and 3000 ppm) showed higher per cent rooting.

Kumar *et al* (2008) reported in *Arribidaea magnifica* that the cutting treated with IBA (2000 ppm) resulted in significantly higher percentage of rooting (72.75 %) followed by IBA 1500 ppm (61.96 %) and IBA+ NAA 2000 ppm (58.57 %). The number of primary roots per cutting was the maximum in treatment with IBA 2000 ppm (12.50) and also the highest length of longest primary root (11.20 cm).

Nazari (2009) evaluated the performance of four *R. hybrida* L. cultivars (African Dawn, Ilios, Maroussia and Soprano) grown either on their own roots or grafted (stenting) onto *R. canina* L. *Inermis* rootstock in hydroponics system. Fresh weight of flowering stem and diameters, flower fresh and dry weight, flower diameter and length, petal number, leaf chlorophyll content and quality index were higher in grafted plants as compared to those propagated by cuttings. However, the highest flowering stem length and number were observed in the plants propagated by cutting, although it was non significant as compared with stenting method.

Karami and Salehi (2010) observed that Rohida (*T. undulata*) cuttings harvested in the late winter resulted in better rooting than the cuttings harvested in the late autumn and response to auxin was uneven between the seasons, however, both NAA and IBA had significant effect on rooting. During the first period, the application of NAA at the concentration of 0.3 % resulted in 82.92 and 89.37 % rooting of semi-hardwood and hardwood cuttings, whereas, IBA at the concentration of 0.4 % resulted in 80.61 % and 81.65 % rooting of semi-hardwood and hardwood cuttings, respectively.

Parmar *et al* (2010) reported that IBA (4000 mg L^{-1}) was the best with respect to number of days taken for sprouting, percentage of rooted cuttings, number of roots per cutting, length of root, number of shoots per cutting, length of shoot and survival per cent of rooted cuttings in *Bougainvillea peruviana* cv. Torch Glory. The treatment of cuttings with IBA (3000 mg L^{-1}) and IBA (2000 mg L^{-1}) + NAA (2000 mg L^{-1}) were better with respect to root and shoot characters as well as survival percentage of rooted cuttings.

Riberio *et al* (2010) reported that in *Prunus spp.* IBA application significantly increased rooting of cuttings planted in early spring. With IBA rooting was significantly higher (67.00 % to 80.00 %) and the highest number of roots (27.20 roots per cutting) was obtained with 7500 ppm of IBA and mean root length (24.76 mm) with 1000 ppm of IBA.

Yatoo *et al* (2010) observed that in *Myratus commnunis* interaction between IBA (4000 ppm) and August planting proved the best and resulted in minimum number of days taken to rooting (60.42), maximum rooting (88.80 %), number of primary branches (20.26), length of primary branches (12.22 cm) and field survival (93.71 %) of plants.

Singh and Singh (2011) studied the effect of IBA on rooting potential of hardwood cuttings of different varieties of Bougainvillea *i.e.* Louise Wathen, Thimma, Mrs. Butt and Shubhra. The IBA concentration and variety both had significant effect on sprouting, rooting, callusing and establishment of cuttings. The cuttings treated with 1000 ppm IBA exhibited more per cent sprouting (85.39 %), rooting (75.46 %), callusing (80.78 %) and establishment of plants (100.00 %).

Singh *et al* (2011) obtained the maximum rooting and sprouting (100.00 %) of cuttings in IBA in *Bougainvillea glabra* var. Torch Glory, however, the maximum length of sprout per cutting (18.77 cm) and number of roots per cutting (21.22) were obtained in IBA (3000 mg L^{-1}), whereas, length of roots per cutting was maximum (15.32 cm) in IBA (5000 mg L^{-1}).

Singh *et al* (2011) studied the stionic effect on rooting attributes of four rootstocks of rose (*R. multiflora*, *R. indica* var. *odorata*, *R. witchuriana* and *R. bourboniana*) and four scion cultivars (Montezuma, Nazneen, June Bride and Raktagandha). The days to root initiation (24.13 and 24.34), percentage of rooted cutting (85.23 and 85.59), number of roots per cutting (28.43 and 29.96), length of root (6.99 and 6.92 cm), diameter of root (0.18 and 0.17 cm), fresh weight of root (2.27 and 2.37 g) and dry weight of root (1.35 and 1.35 g) were significantly improved by using the rootstock *R. indica* var. *odorata* followed by the rootstock *R. bourboniana*.

Adekola and Akpan (2012) reported that in *Jatropha curcas* the stem cuttings treated with growth hormone performed better than untreated cuttings (control). However, significant effects of treatment on rooting behaviors as observed and the cuttings treated with IBA were found to root better than those of NAA.

Izadi *et al* (2012) investigated vegetative propagation method of *R. canina*, mainly used as rootstock for hybrid tea scion varieties. A mixture of cocopeat and perlite was found effective for rooting on stem cuttings (10 cm long) with two leaves. The treatment of IBA with 5000 ppm with in stentling method showed higher graft success (68.70 %) and root number (2.09) in cv. Dolcevita.

Alshammary and Shahba (2013) reported that in *Hamelia patens* IBA (500 ppm) treatment resulted in the highest bud break percentage with an increase of 70.50 %, rooting percentage (65.60 % and 69.40 %), number of roots per cutting (30.50 and 29.80), roots per cutting (36.6 and 9.2 mm), number of branches per cutting (8.8) number of leaves per cutting (65.30 and 48.30 %) and establishment of plants (68.30 and 53.30 %) after 12 and 24 h of treatment, respectively. At twelve-hour soaking time, IBA (500 ppm and 300 ppm) resulted in longer branches (159.2 and 151.3 mm).

Alshammary *et al* (2013) reported in *Bougainvillea peruviana* cv. Shubra and *Hamelia patens* that IBA (2000 ppm) resulted in higher bud break percentage (73.90 % and 59.20 %), rooting percentage (53.60 % and 28.40 %) , number of roots per cutting (15.50 and 24.80), root length per cutting (31.60 mm and 27.20 mm) establishment percentage (60.30 % and 42.30 %), number of branches per cutting (3.60 and 5.40), longer branches (139.20 mm and 139.23 mm) and number of leaves per cuttings (59.00 and 50.10).

Dawa *et al* (2013) evaluated the effect of indole butyric acid (IBA) and naphthalene acetic acid (NAA) applied @ 500, 1000 and 1500 ppm on rooting of four commercial cut flower cultivars of rose viz. Grand Gala, First Red, Naranga and Noblesse. The rooting was significantly improved with auxin treatments. The minimum days to root appearance (22.55) maximum rooting (76.67 %), primary root number (12.57), root length (5.87 cm) and field survival (73.13 %) was obtained in cuttings treated with IBA @ 1500 ppm. The rooting was improved with IBA in comparison to NAA application. Among the genotypes, First Red exhibited the maximum rooting (66.67 %), primary root number (11.29), root length (4.98 cm) and field survival (76.28%). The minimum days to root appearance (21.61) and the maximum percentage of cuttings (13.81) with new leaf growth were observed in cv. Noblesse.

Grewal and Singh (2013) studied the effect of auxin and cytokinin on rooting and bud union by using *R. indica* var. *odorata* as rootstock and Raktagandha as scion. The treatment of budded cuttings with IBA 2000 mg L^{-1} resulted in significantly more plant survival (77.96 %) as compared to the control (64.44 %) however; the treatment of budded cuttings with IBA 2000 mg L^{-1} and IBA 3000 mg L^{-1} were at par with respect to plant survival. The plant survival was significantly more (77.76 %) in bud treatment with BA 50 mg L^{-1} as compared to the control (74.81 %). The rooting of cuttings and bud take was significantly more under protected condition as compared to the open conditions resulting in higher plant survival.

Kumari *et al* (2013) reported in *Jatropha curcas* that IBA (200 ppm) resulted in early emergence of shoots (25.92 days), the maximum number of shoots per cutting (5.58), shoot length (10.57 cm), average number (38.95), sprouting (81.10 %) and rooting (49.83 %).

Shahba and Alshammary (2013) reported in *Bougainvillea peruviana* cv. Shubra that IBA (500 ppm) treatment resulted in the highest rooting (55.60 % and 59.40 %), more number of roots per cutting (20.50 and 19.80), higher root length per cutting (46.60 and 49.20 cm), the highest bud break percentage with an increase of 69.50 % compared to the control and achieved the highest number of shoots per cutting (2.80), higher number of leaves per cuttings (49.00 and 40.00), higher fresh and dry weight of roots after 12 h and 24 h treatment, respectively. The treatment of cuttings with IBA at 500 ppm also resulted in the highest establishment (68.30 and 53.30 %) after 12 and 24 h of treatment time, respectively, however, 12 h soaking time and IBA at 500 ppm and 300 ppm resulted in longer branches (129.20 and 121.30 mm). The treatment of IBA at 500 ppm was recommended for effective rooting of hardwood cuttings of Shubra white shrub and effect of time of soaking (12 - 24 h) was inconsistent.

Susila and Reddy (2013) reported in *Adathoda vasica* that IBA (1500 ppm) resulted in the maximum rooting (67.50 %) and longest root length (22.18 cm), whereas, the treatment with NAA (1500 ppm) resulted in the maximum roots per cutting (40.89), root fresh (3.22 g) and dry weights (1.12 g).

Yeshiwas *et al* (2015) observed that the auxin was significantly influenced by environmental conditions, types of stem cuttings softwood, semi-hard and hard wood cuttings and rooting media used and IBA concentrations (0, 1000, 1500, 2000, 2500 and 3000 ppm) on growth and development of stenting-propagated roses in environmental conditions of Bahir Dar and varieties Natal Break and Acpinc were used as rootstock and scion, respectively. Grafted healthy rose-cuttings with 2-3 leaves were treated with quick dip method in solution containing the respective IBA-concentrations. After air drying, six stem cuttings were planted in pots (90 x 150 mm) filled with coco peat (3.5 cm deep). Number of roots per cutting, root length, root dry weight, root fresh weight, shoot length, leaf number, shoot fresh weight and shoot dry weight of rose stem-cuttings were considered as performance indicator. The different concentrations of IBA deciphered significant effects on growth parameters of grafted rose cuttings sourced from different developmental stages of rootstock stems. Rose cuttings treated with 1000 ppm of IBA had shown significant positive effects on most of the root and shoot parameters including root length, number of roots per cutting, root fresh weight, root dry weight, shoot fresh and dry weight, leaf number and shoot length.

Pirola *et al* (2016) evaluated the size of cuttings and IBA concentration on mini-cutting rooting of rose variety Mary Rose. Cuttings were obtained from mother plants grown in gardens, with sizes of 3, 5 and 7 cm of length, 1.0 cm in diameter and treated with IBA (0; 500 and 1000 mg L^{-1}). After 60 days, rooted cuttings (%), cuttings with callus (%), primary sprouting, leaves and roots numbers, length of the three major roots (cm) and mortality (%) were evaluated. It was recommended to propagate roses by the use of mini-cuttings with 7 cm treated with 500 mg L^{-1} of IBA.

2.4 Growth regulators for bud take and budding

Wickson and Thimman (1958) observed that the cytokinins helped in promoting lateral bud break and it overcame apical dominance. Zielsin and Halevy (1976) reported an increase in axillary bud break with the use of BAP 100 ppm and 250 ppm in rose cv. Baccara. Further there was an increase in the number of flower buds with BAP treatment.

De Vries and Dubois (1988) studied the combined effect of BAP (0, 62.5, 125, 250, 500, 1000 or 2000 mg L^{-1}) and IBA (potassium salt, 0, 312.5, 625, 1250, 2500 or 5000 mg L^{-1}) in relation to the sprouting of auxiliary buds and adventitious root formation of 21-day-old Amanda rose softwood cuttings. Time and frequency of sprouting were inhibited as IBA concentration increased; BAP had no significant effect on time of sprouting. Sprout length decreased as BAP concentration increased; IBA increased sprout length, particularly at low concentrations. BAP promoted the occurrence of more than one sprout per axil and IBA inhibited multiple breaks.

Singh (1998) observed that cytokinins play an important role in budding through quick bud union, bud break and shoot growth. The plant survival was maximum (57.33 %) when buds of cv. Rakatgandha were treated with BAP (100 ppm) followed by control (51.98 %) in cuttage-buddage method.

CHAPTER III

MATERIALS AND METHODS

The present investigations entitled "Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida* L.)" was carried out for two years at Research Farm of Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana during season of 2014-16. The detail of the material used and the methods followed are presented in this chapter.

3.1 Geographical location:

Ludhiana, situated at 30°54′ North latitude and 75°48′ East longitude with an altitude of 247 metres above the mean sea level, is placed in the central plain region of Punjab under Trans-Gangetic agro-climatic zone of India.

3.2 Climate

It represents sub-tropical and semi-arid climate with very hot and dry summer from April to June, hot and humid conditions from July to September, cold winters from November to January and mild climate during February and March. Seventy five per cent of the average annual rainfall is received during July to September. The normal data with respect to various weather parameters averaged for the period of February to June over the last 30 years reveal that normal value of total rainfall during February to June is 162.3 mm, constituting 22.1 % of annual rainfall. Normal maximum and minimum temperatures vary from 21.6°C and 7.2°C in February, respectively. The corresponding figures for March, April and May are 26.6°C and 11.3°C; 34.2°C and 16.9°C; and 38.6°C and 21.9°C, respectively. The normal relative humidity is 69.0 % in February and 49.0 % in June through 63, 47 and 39 % in the months of March, April and May, respectively.

3.3 Chemical properties

The composite soil samples were collected before planting the cuttings in the polythene bags and analyzed for initial soil reaction, electrical conductivity and fertility status. The values so obtained are presented in Table 1.

Table 1: Chemical properties of soil of the experimental field

Characters	Values	Method used
pH	8.3	1:2 soil:water suspension (Jackson 1967)
EC (dSm^{-1})	0.260	1:2 soil:water supernatent Solubridge conductivity meter (Jackson 1967)
Organic carbon ($g\ kg^{-1}$)	5.40	Walkley and Black's rapid titration method (Walkley and Black 1934)

3.4 Details of Experiment

3.4.1 Plan of work

The experiments of the research entitled "Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida a* L.)" were carried out as follows:

Location of work: Research Farm, Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana.

Experimental material: The experimental material comprised of genotypes of Rose as mentioned below:

Name of the cultivar

1. First Red – Red colour
2. Grand Gala – Red colour

Name of the rootstocks

1. *Rosa indica* var. *odorata*
2. *Rosa multiflora*
3. *Rosa bourboniana*

3.4.2 Experiments

Experiment 1: Effect of growth regulators on rooting of budded cuttings of greenhouse varieties

Treatments

1. T1: IBA 500 mg L^{-1}
2. T2: IBA 1000 mg L^{-1}
3. T3: IBA 1500 mg L^{-1}
4. T4: IBA 2000 mg L^{-1}
5. T5: Control

The mature shoots (>1 yr old) used for making the stem cuttings for using as rootstock. The cuttings (8-9 inches long, pencil thickness) of rootstocks treated with different concentrations of IBA for rooting as per the experiment and budded with the scion of rose cvs. First Red and Grand Gala in December- February. These cuttings were planted in pots after treatment.

Number of genotypes: 2

Number of rootstocks: 3

Number of replications: 3

Number of plants per replication: 10

Number of treatments: 5

Total number of plants: 2x3x3x10x5= 900

Design: Factorial CRD (Factorial Completely Randomized Design)

Experiment II: Effect of growth regulator treatment on bud take of cuttings of greenhouse varieties

Treatments

1. T1: BAP 5.0 mg L^{-1}
2. T2: BAP 10.0 mg L^{-1}
3. T3: BAP 15.0 mg L^{-1}
4. T4: BAP 20.0 mg L^{-1}
5. T5: Control

The mature shoots (>1 yr old) used for making the stem cuttings for using as rootstock. The cuttings (8-9 inches long, pencil thickness) of rootstocks treated with IBA 1500 mg L^{-1} and then budded with scion buds of rose cvs. First Red and Grand Gala after treating with BAP as per experiment in December- February. The cuttings were planted in pots after treatment.

Number of genotypes: 2
Number of rootstocks: 3
Number of replications: 3
Number of plants per replication: 10
Number of treatments: 5
Total number of plants: 2x3x3x10x5= 900
Design: Factorial CRD (Factorial Completely Randomized Design)

3.4.3 Methodology

The rose plants cvs. First Red and Grand Gala (the commercial cultivars), pruned at end September to mid October and fertilized with decomposed FYM and recommended doses of fertilizers. The cut ends pasted with Blitox paste to control the incidence of die back disease. The scion bud taken from the plant for budding on different rootstocks. The mature shoots (>1 yr old) used for making the stem cuttings for using as rootstock. The cuttings (8-9 inches long, pencil thickness) of rootstocks treated with different concentrations of IBA and BAP as per the experiment and budded with the scion of rose cvs. First Red and Grand Gala in December- February.

3.5 Observations

The growth and flowering parameters of plants were recorded as per the following observations:

3.5.1 Per cent sprouting of budded cuttings- the number of cuttings sprouted, indicated by the visibility of bud swelling.

3.5.2 Per cent rooting of cuttings – the number of cuttings having roots, corresponding to the total number of cuttings in particular treatment.

3.5.3 Per cent survival of budded cuttings – per cent of survival of cuttings was recorded in each treatment by counting the total number of surviving plants out of total number of treated cuttings.

3.5.4 Shoot length - The shoot length (cm) was measured after 3 months of planting of the budded cuttings.

3.5.5 Plant height - The plant height (cm) was measured after 3 months of planting of the budded cuttings.s

3.5.6 Number of branches - The number of branches were counted per plant after 3 months of planting of the budded cuttings.

3.5.7 Number of leaves per plant - The number of leaves were counted per plant after 3 months of planting of the budded cuttings.

3.5.8 Days to flower bud emergence -Days taken to appearance of flower buds were recorded from the date of planting.

3.5.9 Days to full bloom - Days taken for full bloom were recorded from date of planting.

3.5.10 Number of flowers per plant – The number of flowers were calculated per plant.

3.6 Statistical Analysis

The experiments were conducted as per treatments in factorial completely randomized design (CRD) with three replications comprising ten polythene bags per replication. The observations were recorded during the two years (2014-16) and the data was pooled. The statistical analysis was performed using SAS software and treatment means were compared using Duncan Multiple Range Test (DMRT) at 5% level of significance (Duncan 1955).

CHAPTER IV

RESULTS AND DISCUSSION

The present investigations entitled "Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida* L.)" were carried out to study the effect of rootstocks and growth regulators on vegetative growth and flowering parameters of two greenhouse varieties viz. First Red and Grand Gala. The salient findings of present investigations are presented in this chapter under the following headings:

4.1 Effect of rootstocks and auxin treatments on growth and flowering of different genotypes of rose

4.2 Effect of rootstocks and cytoknin treatments on growth and flowering of different genotypes of rose

4.1 Effect of rootstocks and auxin treatments on growth and flowering of different genotypes of rose

The plant growth regulators (auxins) play an important role in improving the rooting of cuttings. The effect of auxin treatments on rootstocks cuttings on sprouting of budded cuttings, rooting of cuttings, survival of budded cuttings, plant height, shoot length, number of primary branches, leaves per plant, days taken to emergence, days to taken to full bloom and number of flowers per plant were recorded.

4.1.1 Sprouting of the budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The stem cuttings of the rose rootstocks *R. indica* var. *odorata, R. multiflora* and *R. bourboniana* after budding with scion bud of cvs. First Red and Grand Gala, were treated with Indole-3 butyric acid (IBA) concentrations and planted in the pots. The sprouting of the cuttings was significantly influenced by the IBA treatments (Table 2a, 2b and Fig. 1, 2).

The treatment T4 (IBA 2000 mg L^{-1}) was the best for sprouting in both the genotypes. On averaging across the years and genotypes, the maximum sprouting 73.34 % (i.e. 75.00 % in cv. First Red and 71.67 % in cv. Grand Gala) was observed in treatment T4 (IBA 2000 mg L^{-1}). The minimum sprouting was observed as 43.06 % (i.e. 46.11% in cv. First Red and 40.00% in cv. Grand Gala) in T5 (control). The sprouting of the budded cuttings differ significantly among the genotypes. In cv. First Red, the sprouting of the budded cuttings was 58.89 % which was significantly higher than cv. Grand Gala 56.11 % (Table 2a).

On averaging across the years, genotypes and treatments the maximum sprouting (65.83 %) observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum sprouting across the years, genotypes and treatments was found in *R. bourboniana* (47.50%). However, among treatments the maximum

Table 2a: Effect of growth regulator treatment on sprouting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock	First Red		Mean	Grand Gala		Mean	Grand Mean
		Year			Year			
		2014-15	2015-16		2014-15	2015-16		
	Rosa indica var. *odorata*	60.00	63.33		53.33	56.67		
T1	*Rosa multiflora*	53.33	56.67	52.78d	50.00	53.33	49.44d	51.11d
	Rosa bourboniana	40.00	43.33		40.00	43.33		
	Rosa indica var. *odorata*	60.00	66.67		60.00	63.33		
T2	*Rosa multiflora*	56.67	60.00	55.56c	56.67	60.00	54.46c	55.01c
	Rosa bourboniana	43.33	46.67		43.33	43.33		
	Rosa indica var. *odorata*	76.67	80.00		73.33	76.67		
T3	*Rosa multiflora*	63.33	66.67	65.00b	66.67	70.00	65.00b	65.00b
	Rosa bourboniana	50.00	53.33		50.00	53.33		
	Rosa indica var. *odorata*	83.33	86.67		80.00	83.33		
T4	*Rosa multiflora*	73.33	76.67	75.00a	70.00	73.33	71.67a	73.34a
	Rosa bourboniana	63.33	66.67		60.00	63.33		
	Rosa indica var. *odorata*	50.00	53.33		43.33	46.67		
T5	*Rosa multiflora*	46.67	50.00	46.11e	40.00	40.00	40.00d	43.06e
	Rosa bourboniana	40.00	36.67		33.33	36.67		
Mean		57.33	60.45	58.89a	54.67	57.55	56.11b	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

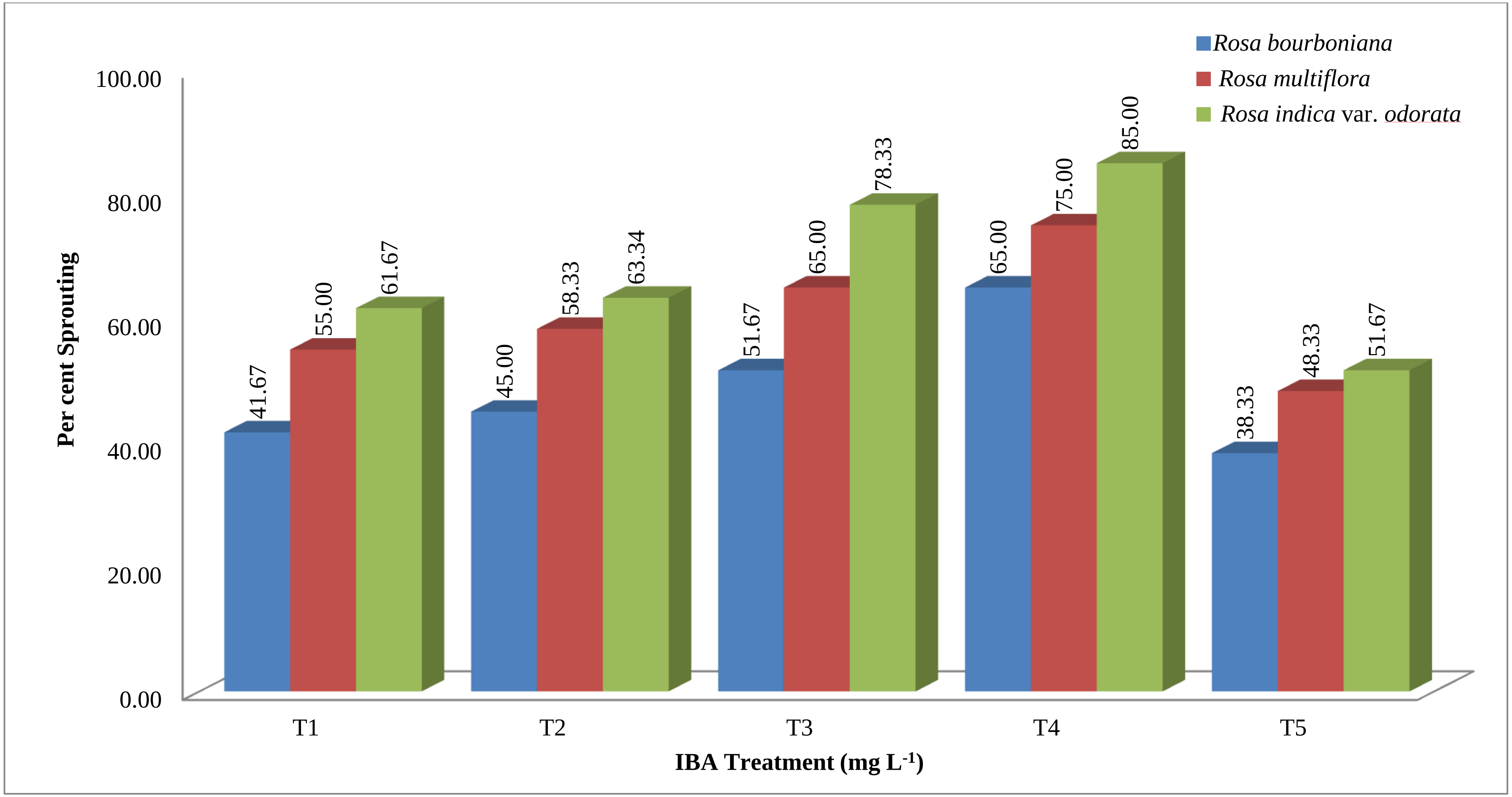

Fig. 1: Effect of growth regulator treatment on per cent sprouting in budded cuttings in *Rosa hybrida* L. cv. First Red

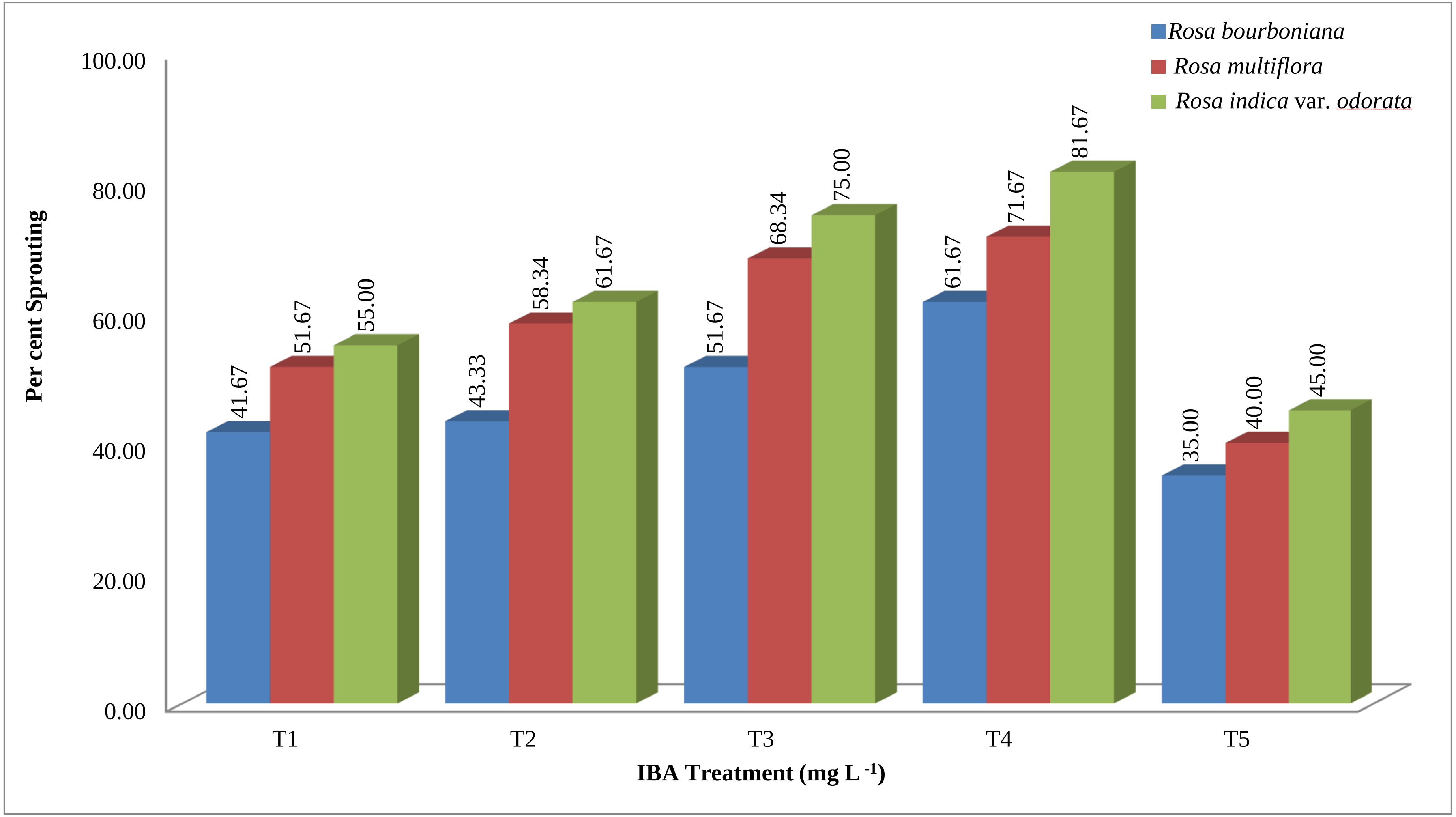

Fig. 2: Effect of growth regulator treatment on per cent sprouting in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 2b: Effect of growth regulator treatment and rootstock on sprouting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	
T1	58.34	53.33	41.67	51.11d
T2	65.62	58.34	44.17	55.01c
T3	76.67	66.67	51.67	65.00b
T4	83.33	73.33	63.33	73.34a
T5	48.33	44.17	36.67	43.06e
Mean	65.83a	59.17b	47.50c	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

sprouting (73.34%) was in treatment T4 (IBA 2000 mg L^{-1}) in rootstock *R. indica* var. *odorata* (Table 2b). These findings were in agreement with Swarup and Malik (1974) where *R. indica* var. *odorata* was found the best rootstock due to resistance to powdery mildew, vigorous growth of scion buds, floriferousness, better rooting of cuttings, bud take and longer plant life. The results are in conformity with Sharma (1979) who concluded that *R. indica* var. *odorata* was better than other rootstocks with respect to rooting of cuttings and bud take under Hisar conditions.

In cv. First Red, on averaging across the years the maximum sprouting (85.00 %) was observed in T4 (IBA 2000 mg L^{-1}) in *R. indica* var. *odorata*, whereas, the minimum sprouting (38.33 %) was observed in T5 (control) in *R. bourboniana* (Fig 1). Similarly, in Grand Gala, on averaging across the years the maximum sprouting (81.67 %) was observed in T4 (IBA 2000 mg L^{-1}) in *R. indica* var. *odorata*. The minimum sprouting was observed as 35.00 % in T5 (control) in *R. bourboniana* (Fig 2).

Similarly, Swarup and Malik (1974) observed that the bud take varied with the type of rootstock used. The percentage of bud take on *R. indica* var. *odorata* was the highest in Super Star (100), Dr Homi Bhaba (88) and Pusa Sonia (80) while bud take of Queen Elizabeth was the highest (96) on *R. multiflora.* Some cultivars gave equally good results on two different rootstocks, McGredys Sunset on Edouard rose and *R. multiflora*, McGredys Yellow on Edouard rose and *R. indica* var. *odorata* and Happiness on *R. indica* var. *odorata* and *R. multiflora.*

4.1.2 Rooting of the budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The different rootstocks and IBA concentrations have significant impact on rooting of the cuttings (Table 3a, 3b and Fig. 3, 4). The treatment T4 (IBA 2000 mg L^{-1}) was the best treatment for rooting in both the genotypes. On averaging across the years and genotypes, the maximum rooting 92.78 % (i.e. 93.34 % in cv. First Red and 92.22 % in cv. Grand Gala) was observed in treatment T4 (IBA 2000 mg L^{-1}). The minimum rooting was observed as 53.60 % (i.e. 56.11 % in cv. First Red and 51.11 % in cv. Grand Gala) in T5 (control). Similarly, Tognan (1964) recorded that the average rooting in untreated rootstock cuttings was only 4.50 %. Pirola *et al* (2016) evaluated the IBA concentration (0, 500 and 1000 mg L^{-1}) on mini-cutting rooting of rose variety Mary Rose. After 60 days rooted cuttings (%), cuttings with callus (%), primary sprouting, leaves and roots numbers, length of the three major roots (cm) and mortality (%) were evaluated and recommended that the better results the mini-cuttings (7 cm) should treated with 500 mg L^{-1} of IBA. Auxin treatment resulted in better rooting because auxins, natural or artificially applied, are required for the initiation of adventitious roots on stem (Hartmann and Kester, 1989).

The rooting of the budded cuttings was also differing significantly among the genotypes. In cv. First Red the rooting of the budded cuttings was 75.33 % which was significantly higher than cv. Grand Gala where the rooting was 72.68 % (Table 3a).

In table 3b, on averaging across the years, genotypes and treatments the maximum rooting (79.53 %) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum rooting percentage across the years, genotypes and treatments was found in *R. bourboniana* (68.95 %). Likewise, Bhujbal and Kale (1973) reported that *R. bourboniana* performed relatively poor. However, among treatments the maximum rooting (92.78 %) was in treatment T4 (IBA 2000 mg L^{-1}) and 96.67 % in rootstock *R. indica* var. *odorata* T4 (IBA 2000 mg L^{-1}). These findings were in agreement with Swarup and Malik (1974) where *R. indica* var. *odorata* found the best rootstock due to resistance to powdery mildew, vigorous growth of scion buds, floriferousness, better rooting of cuttings, bud take and longer plant life. The results are in conformity with Sharma (1979) who concluded that *R. indica* var. *odorata* was better than other rootstocks with respect to rooting of cuttings and bud take under Hisar conditions.

In cv. First Red, on averaging across the years the maximum rooting (96.67 %) was observed in T4 (IBA 2000 mg L^{-1}) in *R. indica* var. *odorata*, whereas, the minimum rooting (55.00 %) was observed in T5 (control) in *R. bourboniana* (Fig 3). Similarly, in Grand Gala, on averaging across the years the maximum rooting (96.67 %) was observed in T4 (IBA 2000 mg L^{-1}) in *R.indica* var. *odorata*. The minimum rooting was observed as 45.00 % in T5(control) in *R. bourboniana* (Fig 4). Likewise, Singh *et al* (2011) observed stionic effect of

Table 3a: Effect of growth regulator treatment on rooting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock	First Red		Mean	Grand Gala		Mean	Grand Mean
		Year			Year			
		2014-15	2015-16		2014-15	2015-16		
T1	*Rosa indica* var. *odorata*	76.67	73.33	66.11d	63.33	66.67	61.11d	63.61d
	Rosa multiflora	63.33	66.67		63.33	63.33		
	Rosa bourboniana	56.67	60.00		53.33	56.67		
T2	*Rosa indica* var. *odorata*	86.67	83.33	78.90c	80.00	83.33	75.00c	76.94c
	Rosa multiflora	80.00	76.67		76.67	80.00		
	Rosa bourboniana	73.33	73.33		63.33	66.67		
T3	*Rosa indica* var. *odorata*	90.00	93.33	87.22b	86.67	90.00	83.95b	85.59b
	Rosa multiflora	90.00	86.67		83.33	86.67		
	Rosa bourboniana	80.00	83.33		76.67	80.33		
T4	*Rosa indica* var. *odorata*	96.67	96.67	93.34a	96.67	96.67	92.22a	92.78a
	Rosa multiflora	93.33	96.67		90.00	93.33		
	Rosa bourboniana	90.00	86.67		86.67	90.00		
T5	*Rosa indica* var. *odorata*	60.00	56.67	56.11e	56.67	56.67	51.11e	53.60e
	Rosa multiflora	53.33	56.67		50.00	53.33		
	Rosa bourboniana	53.33	56.67		46.67	43.33		
Mean		75.22	75.45	75.33a	71.56	73.80	72.68b	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

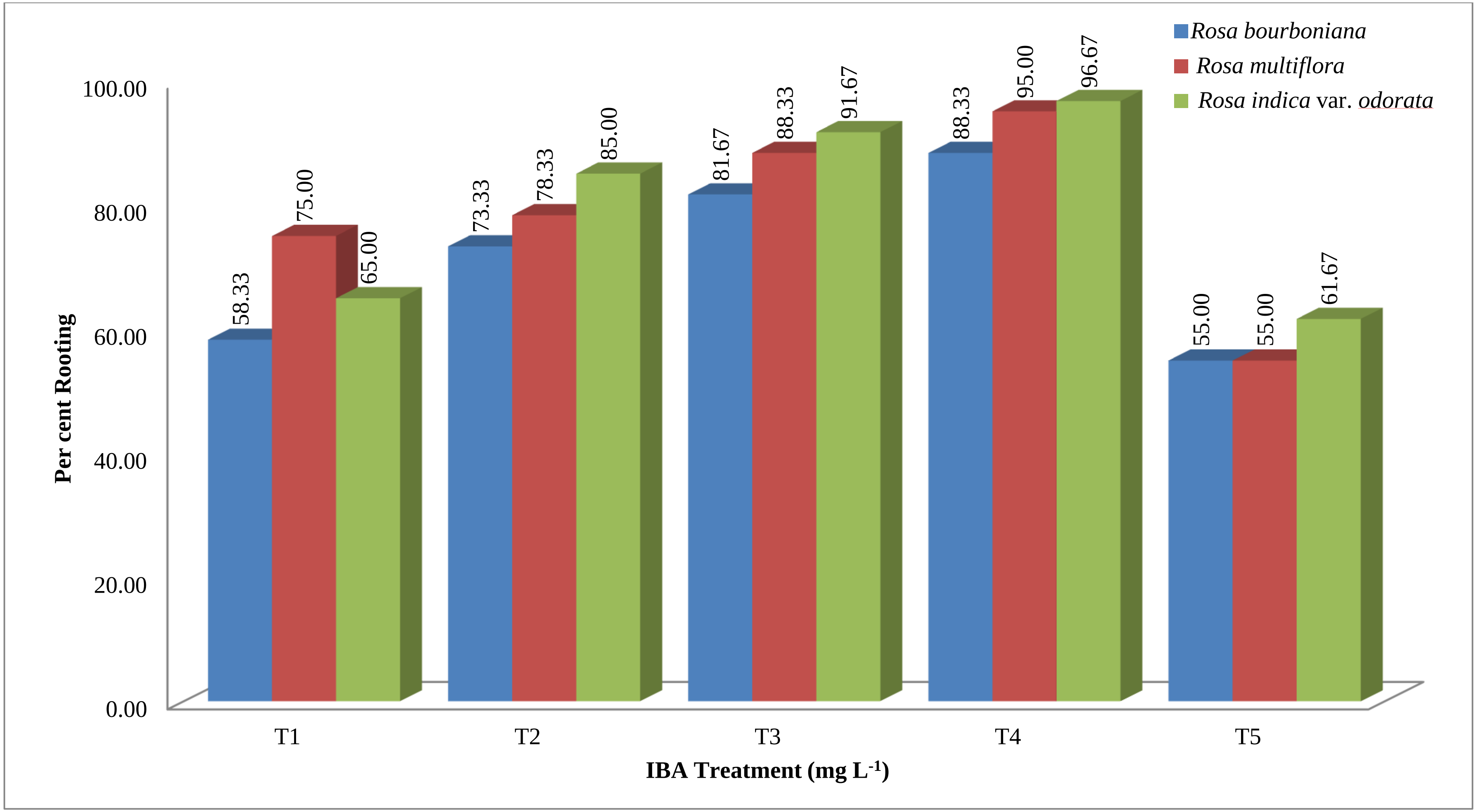

Fig. 3: Effect of growth regulator treatment on per cent rooting in budded cuttings in *Rosa hybrida* L. cv. First Red

Swelling of scion bud of *Rosa hybrid* L on rootstock

Callus formation on rootstock cuttings treated with IBA

Plate 1: Initial stages of the budded cuttings of *Rosa hybrida* L. in the experiment

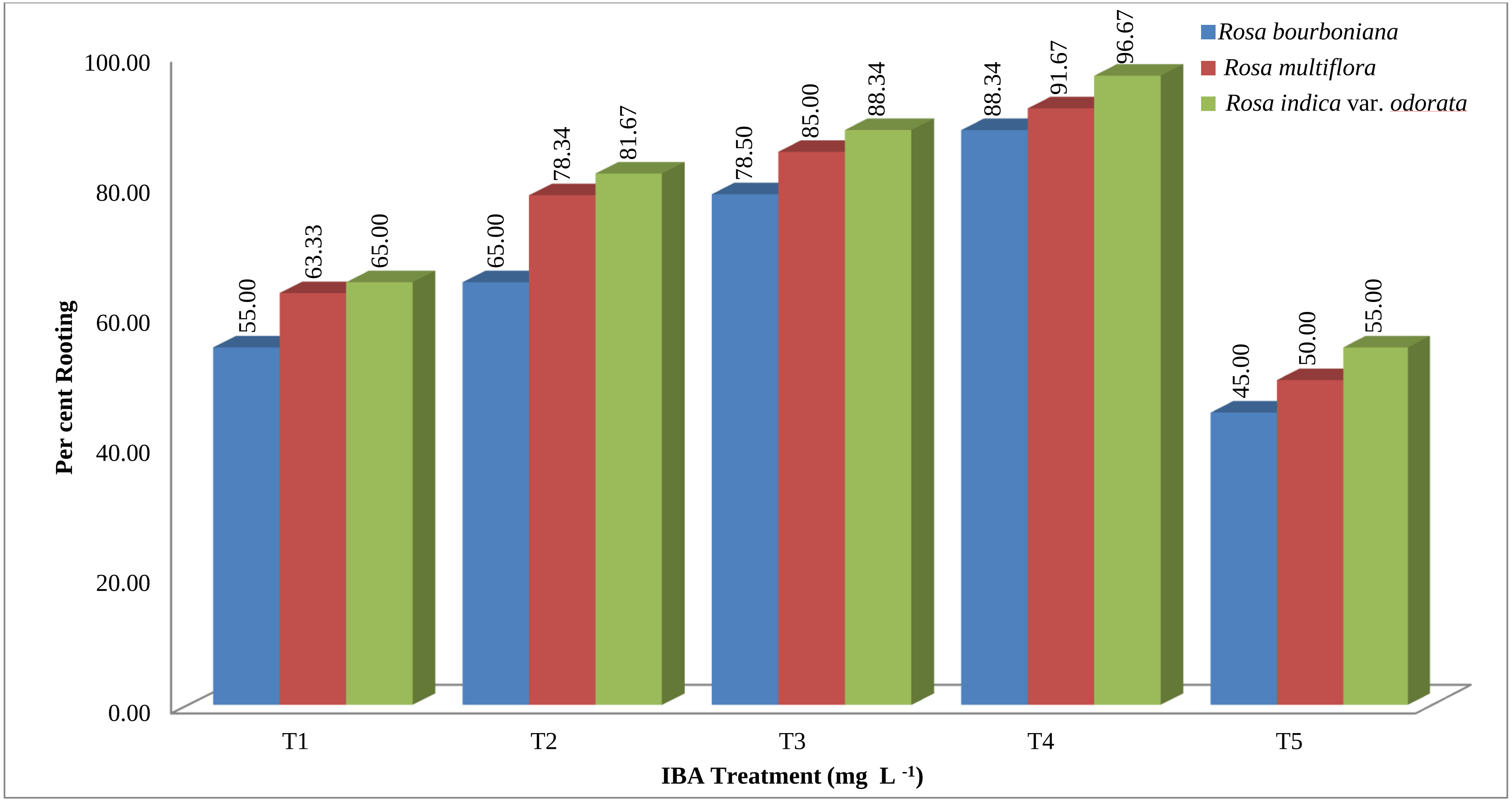

Fig. 4: Effect of growth regulator treatment on per cent rooting in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 3b: Effect of growth regulator treatment and rootstock on rooting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	
T1	70.00	64.17	56.67	63.61d
T2	83.33	78.34	69.17	76.94c
T3	90.00	86.67	80.08	85.58b
T4	96.67	93.33	88.34	92.78a
T5	57.67	52.63	50.52	53.61e
Mean	79.53a	75.03b	68.95c	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

rootstocks (*R. multiflora*, *R. indica* var. *odorata*, *R. witchuriana* and *R. bourboniana*) on different rose cultivars and *R. indica* var. *odorata* was found superior with respect to root parameters (days to root initiation, percentage of rooted cuttings, number of roots per cutting and length of root). The present results are also in conformity with Malik (1980) where *R. indica* var. *odorata* was the best rootstock than *R. bourboniana* and *R. muliflora* for grafted plants. Randhawa and Mukhopadhyay (1986) observed that the quick dip treatment of cuttings with auxins (1000-10,000 ppm) resulted in better rooting. Hartmann and Kester (1989) reported that in roses auxins were used for better initial root growth and enhanced rooting of cuttings might be due to increased hydrolysis of carbohydrates.

4.1.3 Survival of the budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The effect of different rootstocks and IBA concentrations on survival of the cuttings budded with cvs. First Red and Grand Gala are presented in Table 4a, 4b and Fig. 5, 6. The significant influence of rootstocks and IBA concentrations were observed on survival of budded cuttings. The treatment T4 (IBA 2000 mg L^{-1}) was best treatment for survival in both the genotypes. On averaging across the years and genotypes, the maximum survival 57.78 % (i.e. 59.45 % in cv. First Red and 57.78 % in cv. Grand Gala) was observed in treatment T4 (IBA 2000 mg L^{-1}). The lowest survival was observed as 35.56 % (i.e. 36.11 % in cv. First Red and 35.00 % in cv. Grand Gala) in T5 (control). The survival of the budded cuttings was also differing significantly among the genotypes. In cv. First Red the survival of the budded cuttings was 47.22 % which was significantly higher than cv. Grand Gala where the survival was 46.00 % (Table 4a).

Sprouting of scion bud of *Rosa hybrid* L cv. First Red on rootstock

Sprouting of scion bud of *Rosa hybrid* L cv. Grand Gala on rootstock

Plate 2: Showing sprouting of scion bud of *Rosa hybrid* L on rootstock in the experiment

Table 4a: Effect of growth regulator treatment on survival (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock	First Red		Mean	Grand Gala		Mean	Grand Mean
		Year			Year			
		2014-15	**2015-16**		**2014-15**	**2015-16**		
T1	*Rosa indica* var. *odorata*	43.33	46.67	38.33d	40.00	43.33	38.33d	38.33d
	Rosa multiflora	36.67	40.00		36.67	40.00		
	Rosa bourboniana	30.00	33.33		33.33	36.67		
T2	*Rosa indica* var. *odorata*	56.67	60.00	48.34c	53.33	56.67	46.67c	47.51c
	Rosa multiflora	46.67	50.00		46.67	46.67		
	Rosa bourboniana	36.67	40.00		36.67	40.00		
T3	*Rosa indica* var. *odorata*	63.33	63.33	53.89b	60.00	63.33	53.89b	53.89b
	Rosa multiflora	53.33	56.67		53.33	56.67		
	Rosa bourboniana	43.33	43.33		43.33	46.67		
T4	*Rosa indica* var. *odorata*	66.67	70.00	59.45a	63.33	66.67	56.11a	57.78a
	Rosa multiflora	63.33	66.67		56.67	60.00		
	Rosa bourboniana	43.33	46.67		43.33	46.67		
T5	*Rosa indica* var. *odorata*	43.33	40.00	36.11e	36.67	40.00	35.00e	35.56e
	Rosa multiflora	33.33	36.67		33.33	36.67		
	Rosa bourboniana	30.00	33.33		30.00	33.33		
Mean		46.00	48.44	47.22a	44.44	47.56	46.00b	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

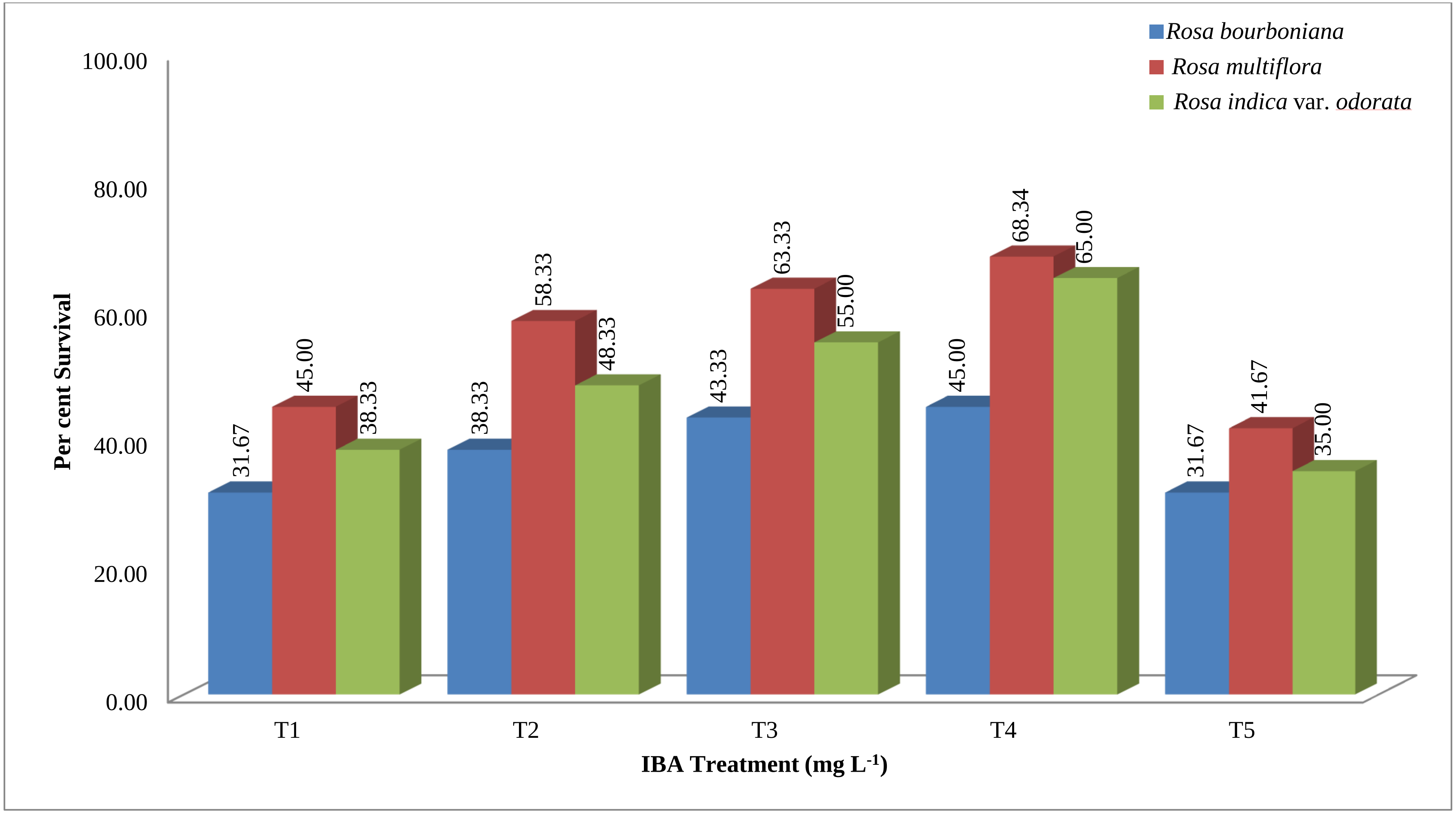

Fig. 5: Effect of growth regulator treatment on per cent survival in budded cuttings in *Rosa hybrida* L. cv. First Red

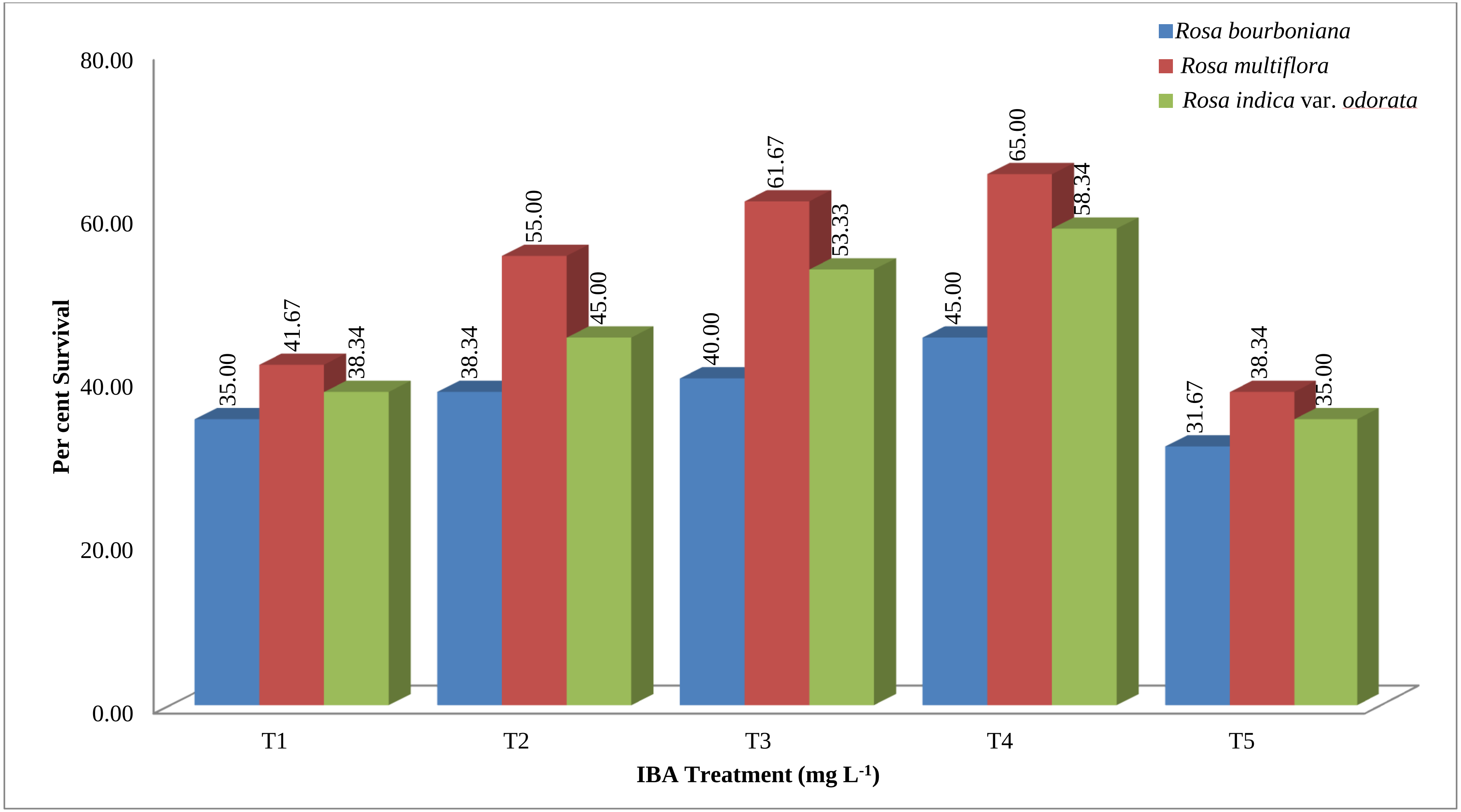

Fig. 6: Effect of growth regulator treatment on per cent survival in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 4b: Effect of growth regulator treatment and rootstock on survival (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	
T1	43.33	38.34	33.33	38.33d
T2	56.67	47.50	38.34	47.50c
T3	62.50	55.00	44.17	53.89b
T4	66.67	61.67	45.00	57.78a
T5	40.00	35.00	31.67	35.56e
Mean	53.83a	47.50b	38.50c	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

In table 4b, on averaging across the years, genotypes and treatments the maximum survival (53.83 %) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum survival percentage averaged across the years, genotypes and treatments was found in *R. bourboniana* (38.50 %). However, among treatments the maximum survival (66.67 %) was in treatment T4 (IBA 2000 mg L^{-1}) in rootstock *R. indica* var. *odorata*. These findings were in agreement with Swarup and Malik (1974) where *R. indica* var. *odorata* found the best rootstock due to resistance to powdery mildew, vigorous growth of scion buds, floriferousness, better rooting of cuttings, bud take and longer plant life. The results are in conformity with Sharma (1979) who concluded that *R. indica* var. *odorata* was better than other rootstocks with respect to rooting of cuttings and bud take under Hisar conditions.

In cv. First Red, on averaging across the years the maximum survival (68.34 %) was observed in T4 (IBA 2000 mg L^{-1}) in *R. indica* var. *odorata*, whereas, the minimum survival (45.00 %) was observed in T5 (control) in *R. bourboniana* (Fig 5). Similarly, in Grand Gala, on averaging across the years the maximum survival (65.00 %) was observed in T4 (IBA 2000 mg L^{-1}) in *R.indica* var. *odorata*. The minimum survival was observed (45.00 %) in T5 (control) in *R. bourboniana* (Fig 4). The present results are also in conformity with Malik (1980) where *R. indica* var. *odorata* was the best rootstock than *R. bourboniana* and *R. muliflora* for grafted plants.

4.1.4 Shoot length of budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The shoot length of plants of the First Red and Grand Gala were recorded after three months of planting the budded cuttings. The shoot length was found significantly influenced by the different rootstocks and Treatments (Table 5a, 5b, 5c and Fig. 7, 8).

Among the different growth treatments the T4 (IBA 2000 mg L^{-1}) resulted best for shoot length in both the genotypes irrespective of the rootstocks. Likewise, in cv. First Red (Fig. 7) the maximum shoot length was (13.64 cm) in T4 (IBA 2000 mg L^{-1}) in *R. indica* var. *odorata* and minimum shoot length (5.15 cm) was in T5 (control) in *R. bourboniana* (i.e. 13.43 cm in 2014-15 and 13.86 cm in 2015-16 , 5.08 cm in 2014-15 and 5.22 cm in 2015-16, respectively, in Table 5a). Similarly, in plants of *cv.* Grand Gala (Fig. 8) the maximum shoot length was (16.29 cm) in T4 (IBA 2000 mg L^{-1}) in *R. indica* var. *odorata* and minimum shoot length (5.34 cm) was in T5 (control) in *R. bourboniana* (i.e. 15.97 cm in 2014-15 and 16.62 cm in 2015-16 , 5.21 cm in 2014-15 and 5.48 cm in 2015-16, respectively, in Table 5a). The present findings regarding plant height after treating the cutting with growth regulator were in confirmation with earlier findings. Akhtar *et al* (2002) reported that the maximum length of shoots, number of branches and number of roots were obtained in the cuttings treated with IBA in roses.

In table 5b, among treatments the maximum shoot length (12.77 cm) was in treatment T4 (IBA 2000 mg L^{-1}). On averaging across the years and treatments the maximum shoot length (10.63 cm) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum shoot length across the years and treatments was found in *R. bourboniana* (7.46 cm). The increase in shoot length in rootstock *R. indica* var. *odorata* is probably due to their better root growth. These findings were in agreement with Swarup and Malik (1974) where *R. indica* var. *odorata* found the best rootstock due to resistance to powdery mildew, vigorous growth of scion buds, floriferousness, better rooting of cuttings, bud take and longer plant life. The results are in conformity with Sharma (1979) who concluded that *R. indica* var. *odorata* was better than other rootstocks with respect to rooting of cuttings and bud take under Hisar conditions. The influence of rootstocks on shoot growth has been studied by various workers like Swarup and Malik (1974), Pandey and Sharma (1976) and Sharma (1979). The performance of rose cultivars may depend much on the rootstock used; however, the performance of cultivars on particular rootstock may be suitable for a particular locality and may not perform well in another (Karadi and Patil 2006).

Table 5a: Effect of growth regulator treatment on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Genotype Mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	8.06	8.45	6.13	6.84	5.24	5.92	6.66	8.70b
	T2	11.18	11.88	8.85	9.43	6.50	6.57	9.02	
	T3	11.93	12.71	10.09	10.73	7.48	8.83	10.29	
	T4	13.43	13.86	10.97	11.54	9.14	9.74	11.37	
	T5	7.50	7.34	5.70	6.12	5.08	5.22	6.16	
Grand gala	T1	7.71	7.61	7.10	7.23	6.20	6.29	7.02	9.46a
	T2	9.19	9.68	8.20	8.68	6.89	7.41	8.34	
	T3	13.18	13.61	11.81	12.36	10.15	10.50	11.93	
	T4	15.97	16.62	14.73	15.31	10.91	11.50	14.17	
	T5	6.33	6.66	5.43	5.78	5.21	5.48	5.82	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

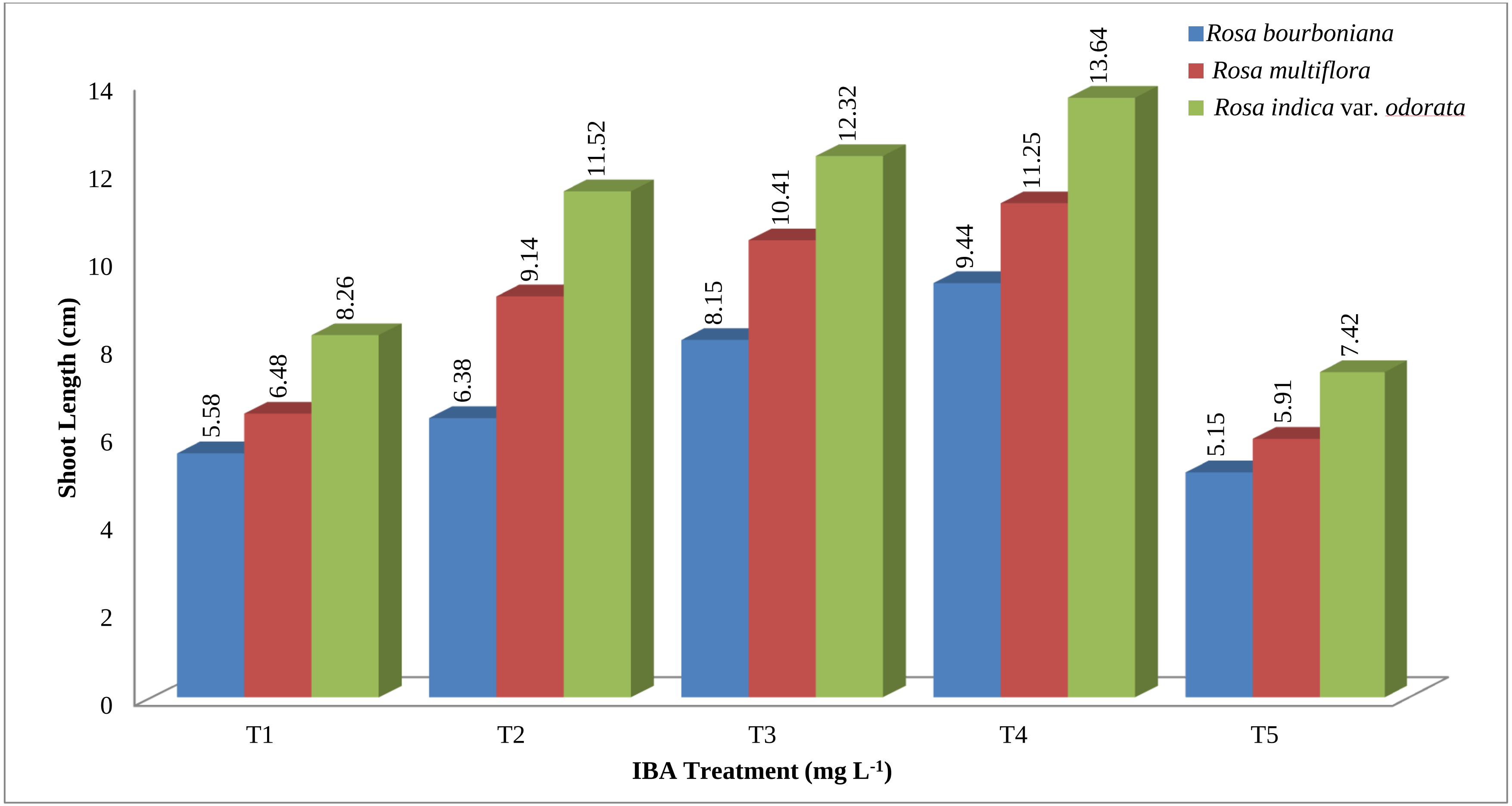

Fig. 7: Effect of growth regulator treatment on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cv. First Red

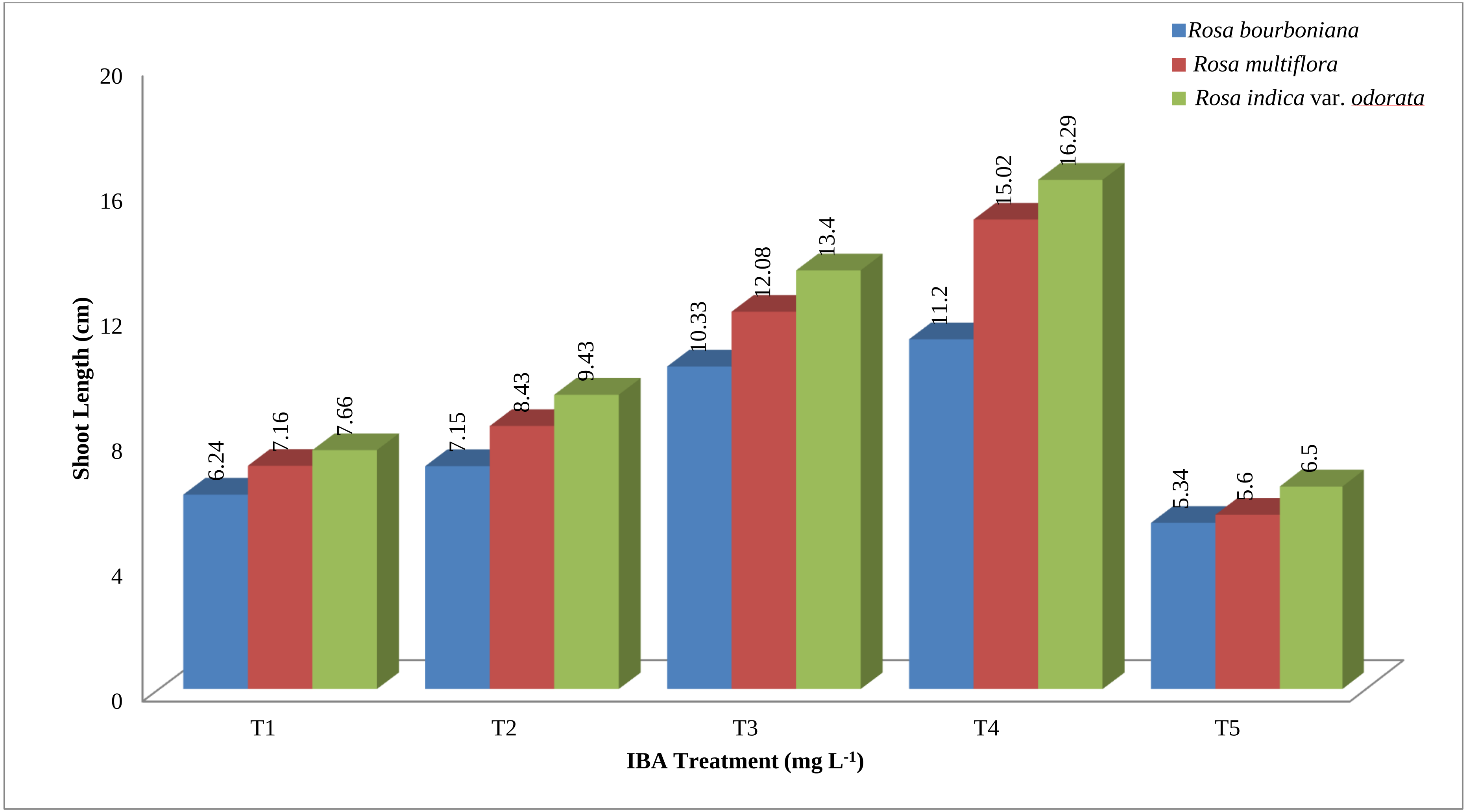

Fig. 8: Effect of growth regulator treatment on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 5b: Effect of growth regulator treatment and rootstock on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	
T1	7.87	6.89	5.75	**6.84d**
T2	10.53	8.78	6.74	**8.68c**
T3	12.86	11.25	9.24	**11.11b**
T4	14.94	13.05	10.32	**12.77d**
T5	6.96	5.76	5.25	**5.99e**
Mean	**10.63a**	**9.15b**	**7.46c**	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 5c: Effect of growth regulator treatment on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	6.66	7.02	**6.84d**
T2	9.02	8.34	**8.68c**
T3	10.29	11.93	**11.11b**
T4	11.37	14.17	**12.77a**
T5	6.16	5.82	**5.99e**
Mean	**8.70b**	**9.46a**	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

In table 5c, on averaging across the years and rootstocks, the maximum shoot length (9.46 cm) was observed in the plants of cv. Grand Gala which was significantly higher than the shoot length of the plants of cv. First Red (8.70 cm). However, on averaging among genotypes, the significantly maximum shoot length was 12.77 cm (i.e. 11.37 cm in cv. First Red and 14.17 cm in cv. Grand Gala) in treatment T4 (IBA 2000 mg L^{-1}).

4.1.5 Plant height of budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The plant height of plants of the First Red and Grand Gala were recorded after three months of planting the budded cuttings. The plant height was found significantly influenced by the different rootstocks and Treatments (Table 6a, 6b, 6c and Fig. 9, 10).

In cv. First Red the maximum plant height among all treatments was 20.60 cm in *R. indica* var. *odorata* (Fig. 9) in T4 (IBA 2000 mg L^{-1}), likewise, the highest plant height in 2014-15 was 19.97 cm and in 2015-16 was 21.23 cm (Table 6a). On averaging across the years the minimum plant height was 7.75 cm in T5 (control) in *R. bourboniana* (Fig. 9), likewise the plant height was 8.10 cm in 2014-15 and 7.39 cm in 2015-16 (Table 6a).

Similarly, in plants of *cv.* Grand Gala, the maximum plant height among all treatments was 20.66 cm in *R. indica* var. *odorata* (Fig. 10) in T4 (IBA 2000 mg L^{-1}), likewise, the maximum plant height was 20.41 cm in 2014-15 and 20.90 cm in 2015-16. On averaging across the years the lowest plant height (8.35 cm) observed in T5 (control) in *R. bourboniana* (Fig. 10), likewise the plant height was 8.60 cm in 2014-15 and 8.10 cm in 2015-16 (Table 6a). The maximum plant height was probably due to the better root growth of the cuttings, which helps in the absorption of the nutrients and assimilate them to the upper part of the cuttings which leads to the more plant growth. The results are in conformity with Akhtar *et al* (2002) reported that the maximum length of shoots, number of branches and number of roots were obtained in the cuttings treated with IBA in roses.

In table 6b, among treatments the maximum plant height (17.54 cm) was in treatment T4 (IBA 2000 mg L^{-1}). On averaging across the years and treatments the maximum plant height (14.35 cm) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum plant height, across the years and treatments was found in *R. bourboniana* (10.99 cm). The maximum plant height was probably due to the better root growth of the cuttings, which helps in the absorption of the nutrients and assimilate them to the upper part of the cuttings which leads to the more plant growth.

In *table 6*c, on averaging across the years and rootstocks, the maximum plant height (13.18 cm) was observed in the plants of cv. Grand Gala which was significantly higher than the plant height of the plants of cv. First Red (12.14 cm). However, on averaging among genotypes, the significantly maximum plant height was 17.60 cm (i.e. 17.03 cm in cv. First Red and 18.18 cm in cv. Grand Gala) in treatment T4 (IBA 2000 mg L^{-1}).

Table 6a: Effect of growth regulator treatment on plant height (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Genotype Mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	11.65	11.39	9.00	8.88	9.35	8.62	9.82	12.14b
	T2	13.14	13.55	10.73	10.41	10.54	10.40	11.46	
	T3	15.28	16.68	14.96	15.33	10.86	11.76	14.15	
	T4	19.97	21.23	17.98	17.02	12.57	13.38	17.03	
	T5	8.06	9.28	7.58	8.89	8.10	7.39	8.22	
Grand gala	T1	13.10	12.78	11.53	10.95	10.74	10.38	11.58	13.18a
	T2	14.00	13.86	11.70	11.79	11.15	11.49	12.33	
	T3	16.25	16.19	14.24	13.80	12.99	12.70	14.36	
	T4	20.41	20.90	18.69	18.49	15.59	14.98	18.18	
	T5	10.27	10.26	9.80	9.62	8.60	8.10	9.44	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

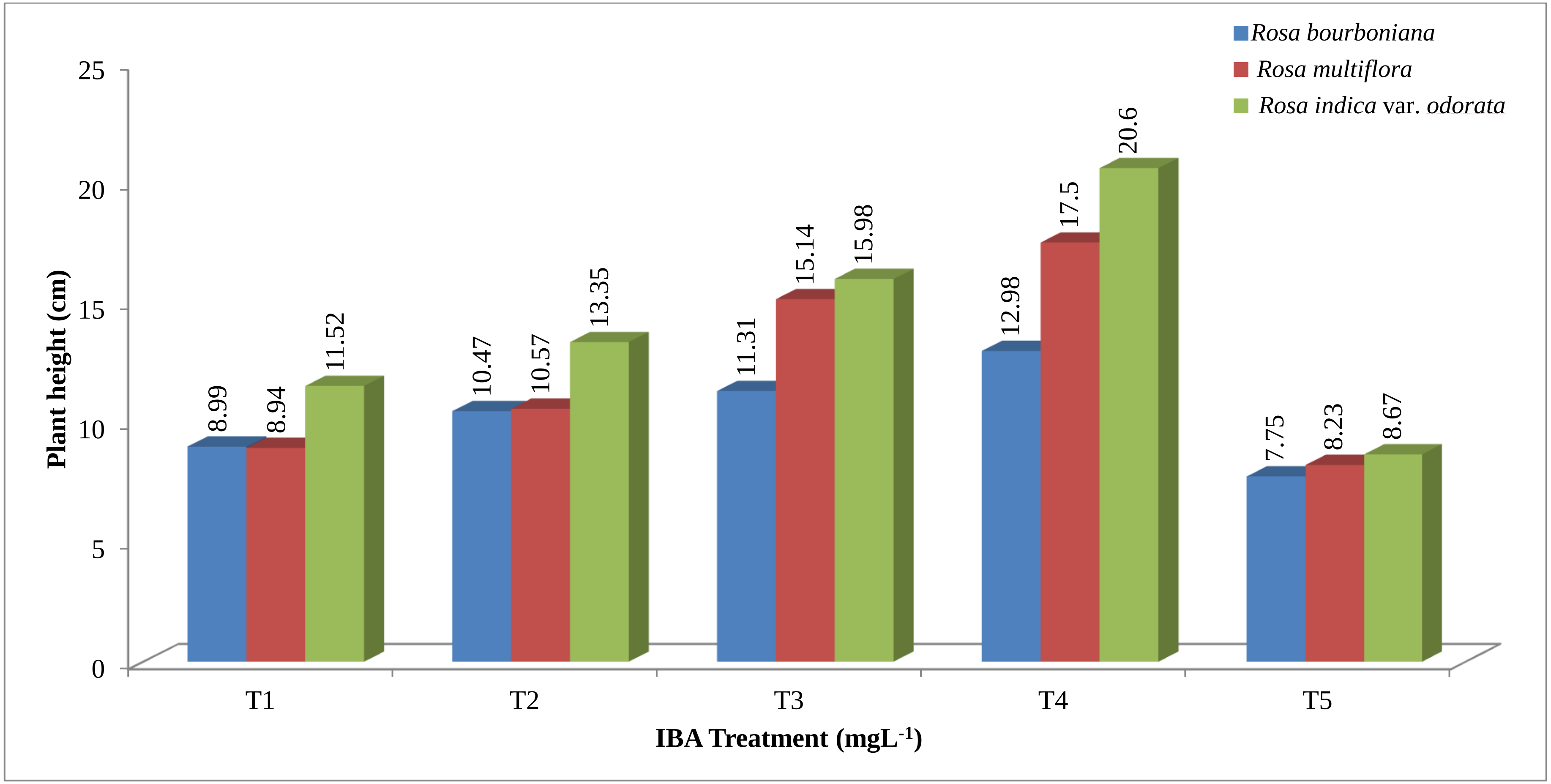

Fig. 9: Effect of growth regulator treatment on Plant height (cm) in budded cuttings in *Rosa hybrida* L. cv. First Red

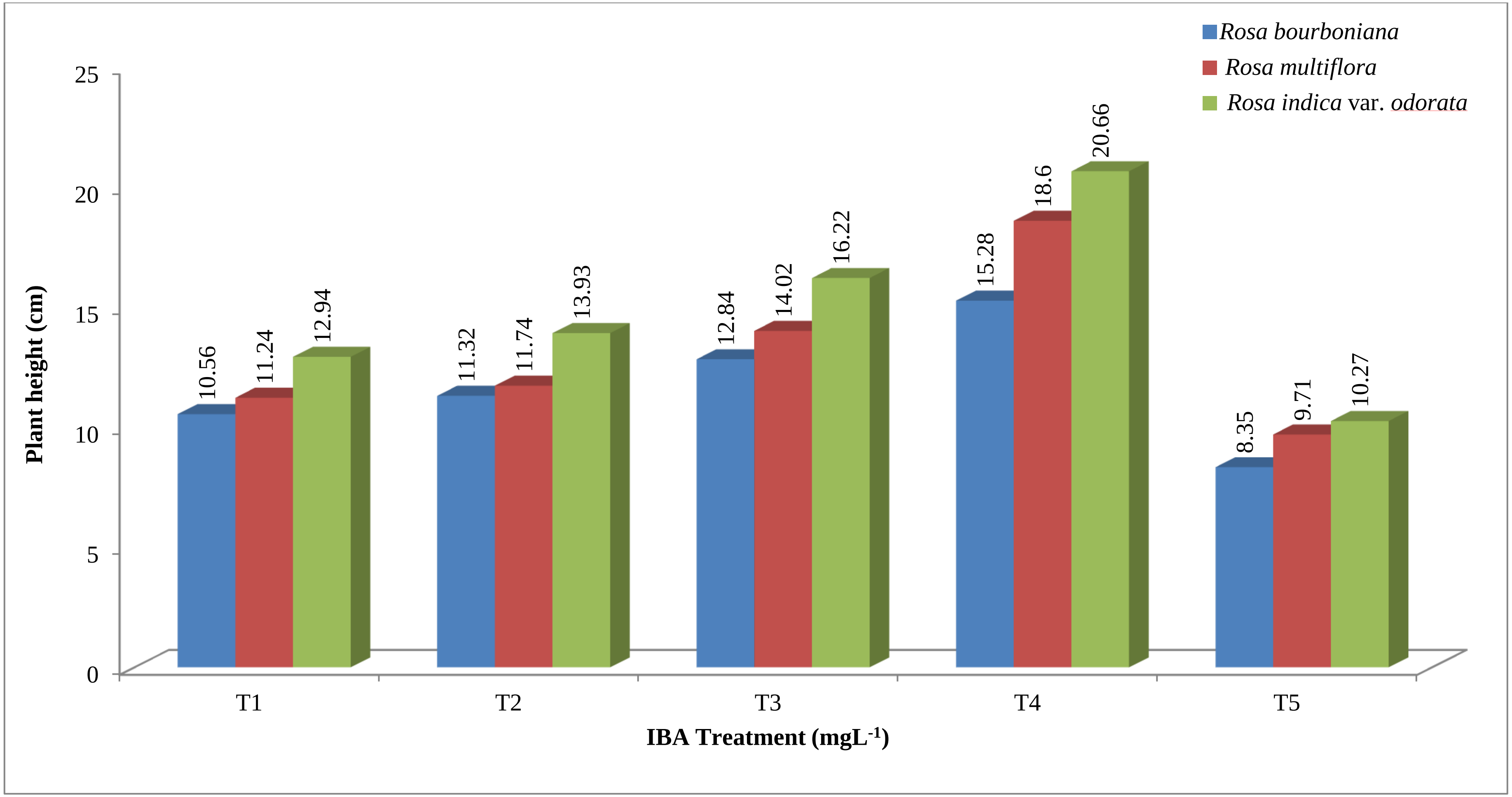

Fig. 10: Effect of growth regulator treatment on Plant height (cm) in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 6b: Effect of growth regulator treatment and rootstock on plant height (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	
T1	12.23	10.91	9.86	**10.99d**
T2	13.62	10.68	10.80	**11.70c**
T3	15.90	14.57	11.94	**14.14b**
T4	20.46	17.95	14.21	**17.54a**
T5	9.55	9.28	8.15	**8.99e**
Mean	**14.35a**	**12.68b**	**10.99c**	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 6c: Effect of growth regulator treatment on plant height (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		Mean
	First Red	**Grand Gala**	
T1	9.82	11.58	**10.70d**
T2	11.46	12.33	**11.89c**
T3	14.15	14.36	**14.26b**
T4	17.03	18.18	**17.60a**
T5	8.22	9.44	**8.83e**
Mean	**12.14b**	**13.18a**	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

4.1.6 Number of branches per plant of *Rosa hybrida* L. cvs. First Red and Grand Gala

In the present studies, it was observed that number of branches per plant significantly varied among the rootstocks and treatments after three months of planting the budded cuttings of cvs. First Red and Grand Gala (*Table 7*a, 7b, 7c and Fig. 11, 12).

Table 7a: Effect of growth regulator treatment on number of branches in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Genotype mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	1.40	1.43	1.25	1.17	1.17	1.20	1.27	1.69a
	T2	1.58	1.43	1.33	1.30	1.25	1.33	1.37	
	T3	2.43	2.27	1.73	1.67	1.42	1.35	1.81	
	T4	3.23	3.17	3.00	2.73	2.63	2.67	2.91	
	T5	1.12	1.18	1.06	1.03	1.00	1.00	1.07	
Grand gala	T1	1.40	1.48	1.33	1.38	1.19	1.21	1.33	1.64a
	T2	1.53	1.65	1.45	1.51	1.24	1.26	1.44	
	T3	2.05	2.11	1.93	2.00	1.56	1.70	1.89	
	T4	2.82	2.85	2.58	2.62	2.00	2.12	2.50	
	T5	1.10	1.17	1.02	1.05	1.00	1.00	1.06	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

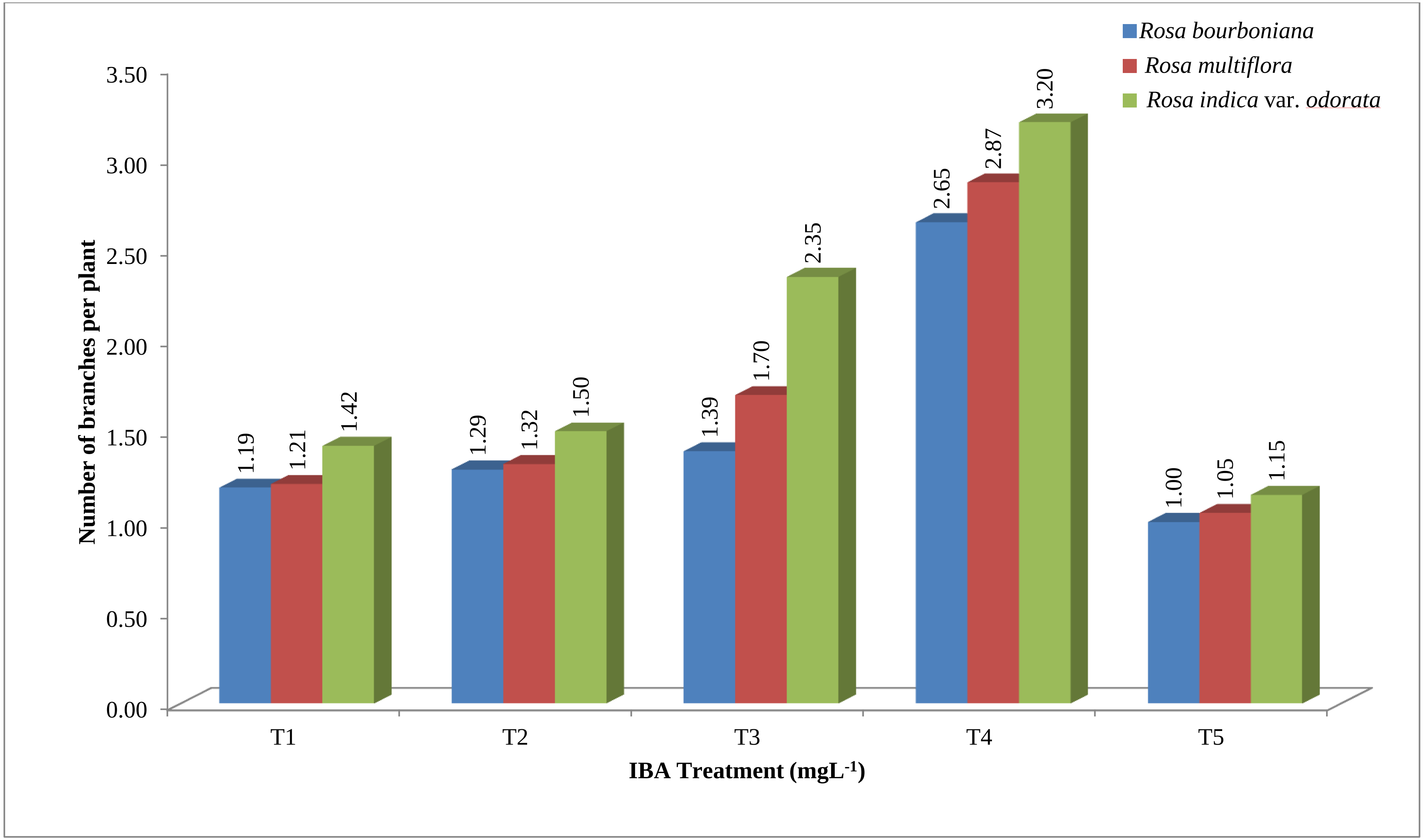

Fig. 11: Effect of growth regulator treatment on number of branches per plant in budded cuttings in *Rosa hybrida* L. cv. First Red

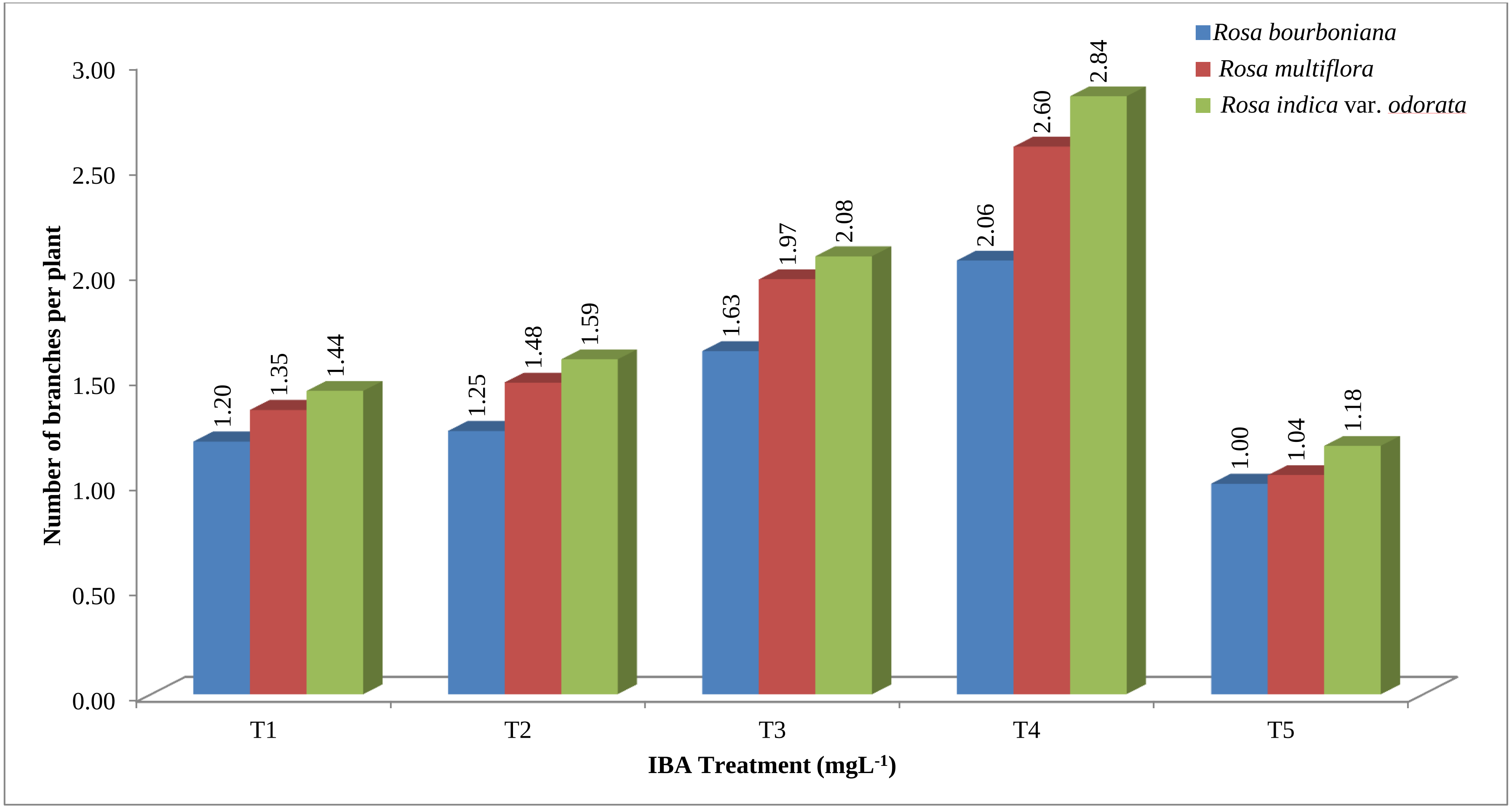

Fig. 12: Effect of growth regulator treatment on number of branches per plant in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 7b: Effect of growth regulator treatment and rootstock on number of branches in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	
T1	1.43	1.28	1.19	1.30d
T2	1.55	1.40	1.27	1.41c
T3	2.22	1.83	1.51	1.85b
T4	3.02	2.73	2.36	2.70a
T5	1.14	1.04	1.00	1.06e
Mean	1.87a	1.66b	1.47c	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 7c: Effect of growth regulator treatment on number of branches in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		Mean
	First Red	**Grand Gala**	
T1	1.27	1.33	1.30d
T2	1.37	1.44	1.41c
T3	1.81	1.89	1.85b
T4	2.91	2.5	2.71a
T5	1.07	1.06	1.07e
Mean	1.69a	1.64a	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to

DMRT. ns = non significant *Significant at $p < 0.05$

Among the different growth treatments T4 (IBA 2000 mg L^{-1}) resulted in the maximum number of branches per plant irrespective of the rootstocks. In cv. First Red the maximum number of branches per plant was 3.20 in T4 (IBA 2000 mg L^{-1}) in *R.indica* var. *odorata* (Fig. 11), likewise, the maximum number of branches was 3.23 in 2014-16 and 3.17 in 2015-16 (Table 7a). However, the lowest number of branches per plant (1.00) found in control (T5) in *R. bourboniana* (Fig. 11), similarly, the number of branches per plant was 1.00 in 2014-15 and 2015-16 (Table 7a). Similarly, in cv. Grand Gala, the maximum number of branches per plant was 2.84 in T4 (IBA 2000 mg L^{-1}) in *R.indica* var. *odorata* (Fig. 12). Likewise, the maximum number of branches was 2.82 in 2014-15 and 2.85 in 2015-16. Whereas, the minimum number of branches per plant (1.00) found in control (T5) in *R. bourboniana*, likewise, the number of branches per plant was 1.00 in 2014-15 and 2015-16 (Table 7a).

The effect of treatments and rootstocks on number of branches per plant is presented in table 7b. Among treatments the maximum number of branches per plant (2.70) was in treatment T4 (IBA 2000 mg L^{-1}). On averaging across the years and treatments the maximum number of branches per plant (1.87) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum number of branches per plant, across the years and treatments was found in *R. bourboniana* (1.47).

In table 7c, on averaging across the years and rootstocks, the number of branches per plant (1.69) of cv. First Red was at par with the number of branches per plant of cv. Grand Gala (1.64). However, on averaging among genotypes the number of branches per plants was significantly different among treatments. The maximum number of branches per plant was 2.71 (i.e. 2.91 in cv. First Red and 2.50 in cv. Grand Gala) in treatment T4 (IBA 2000 mg L^{-1}).

4.1.7 Number of leaves per plant of cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

In plants leaves are important organ for the photosynthesis, more number of leaves leads to more photosynthates which results to the biomass and flower production in plants. The effect of rootstock and auxin on number of leaves per plant was recorded after three months of planting of budded cuttings of cvs. First Red and Grand Gala (Table 8a, 8b, 8c and Fig. 13, 14).

The IBA treatments showed conspicuous effect on number of leaves per plant than control (Table 8a). In cv. First Red the maximum number of leaves (9.61) recorded in *R. indica* in T4 (IBA 2000 mg L^{-1}) which was higher than others (Fig 13). Similarly, the maximum number of leaves was 9.39 in 2014-15 and 9.83 in 2015-16 in treatment T4 (IBA 2000 mg L^{-1}). The more number of leaves are due to the more number of branches and height

Table 8a: Effect of growth regulator treatment on number of leaves in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Genotype mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	6.18	6.54	5.67	5.61	4.53	4.62	5.53	6.21b
	T2	6.27	6.33	5.61	5.55	4.62	5.18	5.59	
	T3	8.42	8.42	7.29	7.09	6.30	6.24	7.29	
	T4	9.39	9.83	7.82	7.79	6.62	6.30	7.96	
	T5	5.23	5.17	4.51	4.49	4.43	4.23	4.68	
Grand gala	T1	7.16	7.16	6.87	6.67	5.47	5.56	6.48	7.39a
	T2	7.88	7.75	7.78	7.77	6.12	6.60	7.32	
	T3	9.19	9.50	8.13	9.50	6.77	6.61	8.28	
	T4	10.83	11.50	10.21	10.29	8.23	8.50	9.93	
	T5	5.05	5.10	5.20	5.24	4.43	4.62	4.94	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

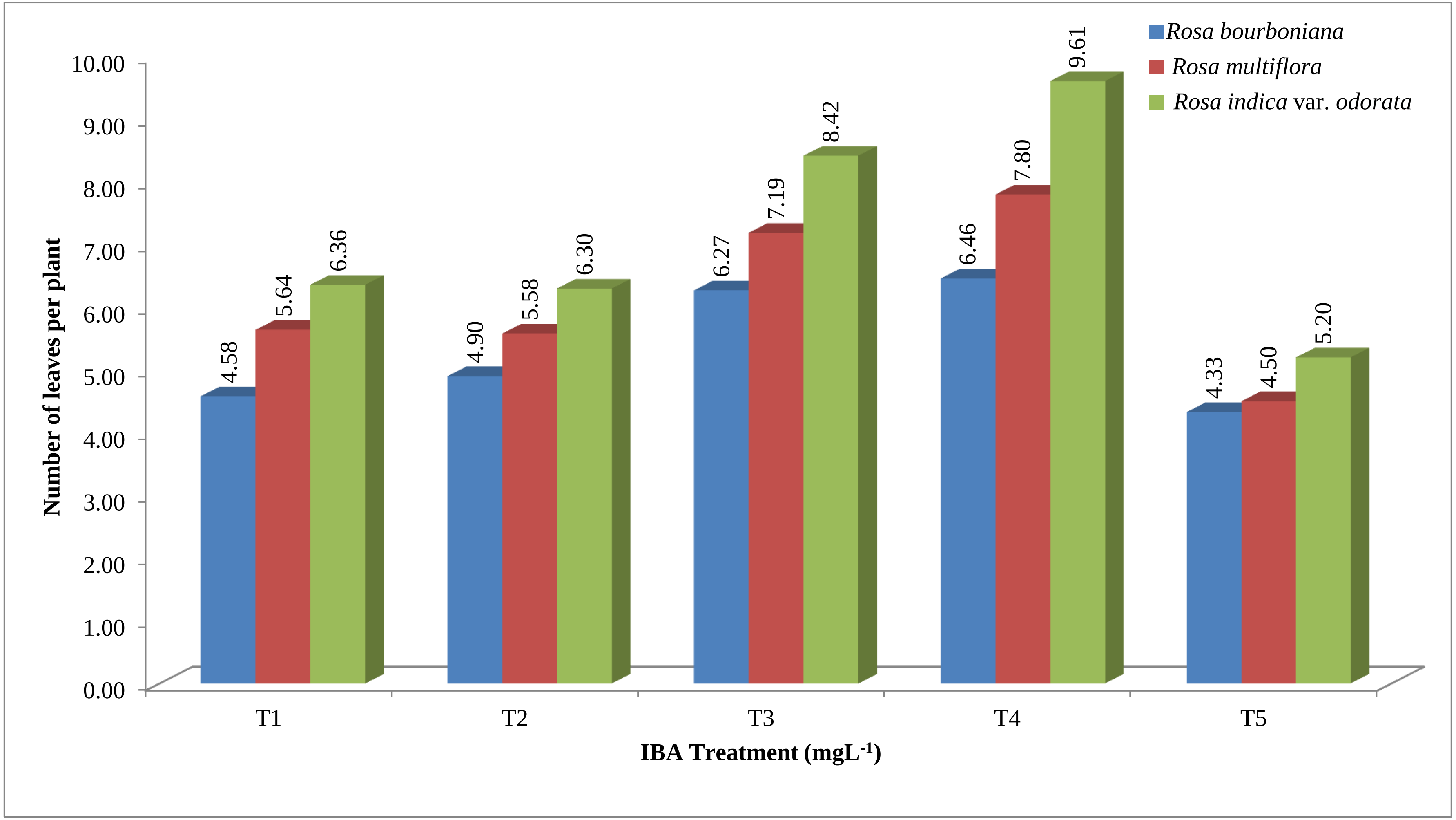

Fig. 13: Effect of growth regulator treatment on number of leaves per plant in budded cuttings in *Rosa hybrida* L. cv. First Red

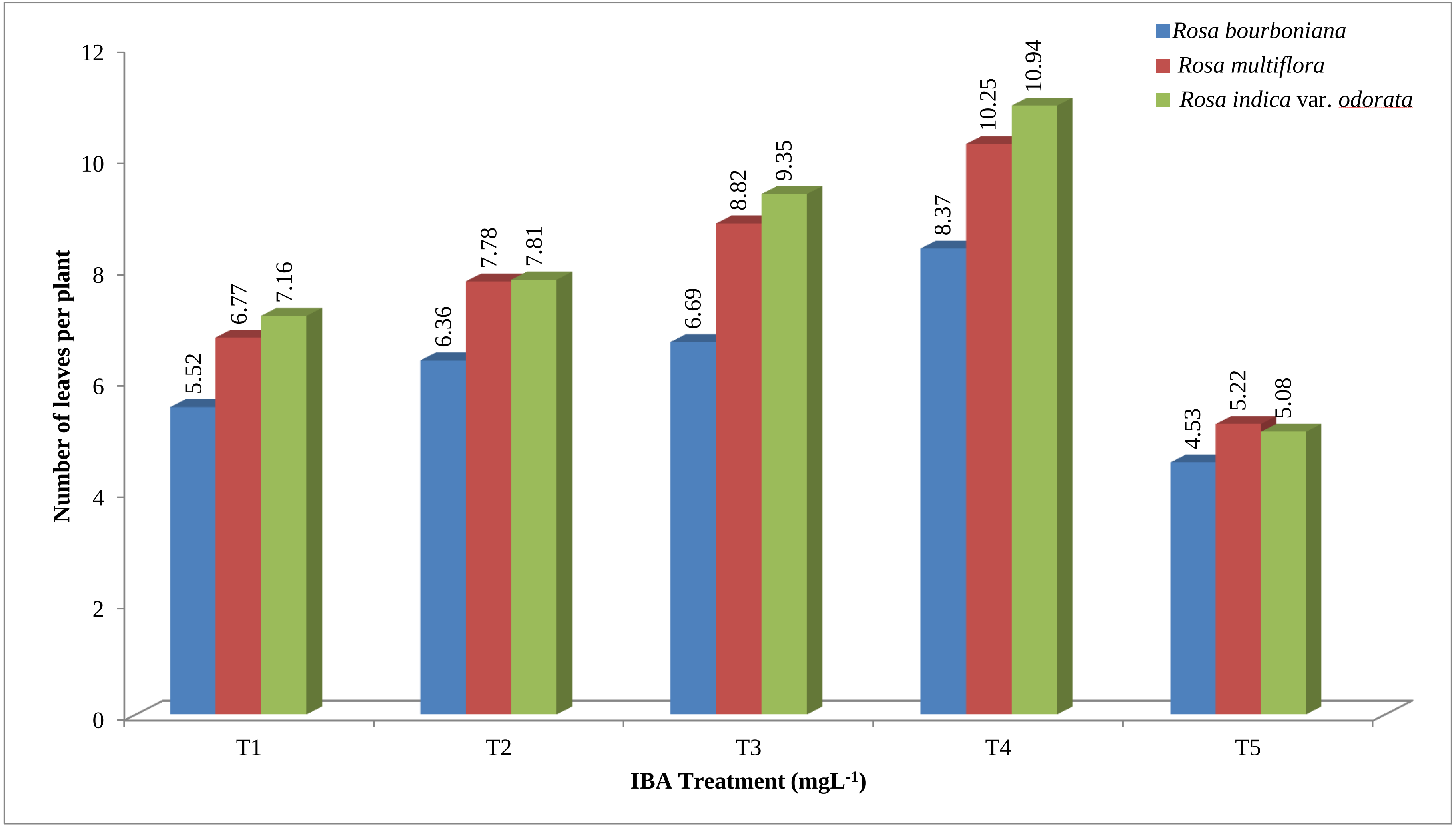

Fig. 14: Effect of growth regulator treatment on number of leaves per plant in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 8b: Effect of growth regulator treatment and rootstock on number of leaves in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica var. *odorata*	*Rosa multiflora*	*Rosa bourboniana*	
T1	6.76	6.21	5.05	6.00d
T2	7.06	6.68	5.63	6.46c
T3	8.88	8.00	6.48	7.79b
T4	10.39	9.03	7.41	8.94a
T5	5.14	4.86	4.43	4.81e
Mean	7.65a	6.95b	5.80c	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 8c: Effect of growth regulator treatment on number of leaves in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		Mean
	First Red	Grand Gala	
T1	5.53	6.48	6.00d
T2	5.59	7.32	6.46c
T3	7.29	8.28	7.79b
T4	7.96	9.93	8.94a
T5	4.68	4.94	4.81e
Mean	6.21b	7.39a	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

of the plant. The lowest number of leaves per plant was 4.33 in T5 (control) in *R. bourboniana* (Fig 13), similarly, number of leaves per plant was 4.43 in 2014-15 and 4.23 in 2015-16. Similarly, in cv. Grand Gala the maximum number of leaves (10.94) was recorded in *R.indica* var. *odorata* in T4 (IBA 2000 mg L^{-1}) which was higher than others (Fig 14). Likewise, the maximum number of leaves was 10.83 in 2014-15 and 11.50 in 2015-16 in treatment T4 (IBA 2000 mg L^{-1}). The minimum number of leaves observed in T5 (control) in all rootstocks. The lowest number of leaves per plant was 4.53 in T5 (control) in *R. bourboniana* (Fig 14), similarly number of leaves per plant was 4.43 in 2014-15 and 4.62 in 2015-16.

The use of auxins has been reported for the rooting of in cuttings of roses by many research workers. The numerous and vigorous root system leads to the better foliage of the plant. The present results are in line with De Souza and Inforzato (1958). Similarly, Yeshiwas *et al* (2015) observed the effects of different concentrations of IBA on growth and development of grafted rose cuttings in environmental conditions of Bahir Dar. Rose cuttings treated with IBA had shown positive effects on most of the root and shoot parameters including root length, number of root per cutting, root fresh weight, root dry weight, shoot fresh and dry weight, leaf number and shoot length.

The treatments and rootstocks have significant effect on number of leaves (Table 8b). Among treatments the maximum number of leaves (8.94) was in treatment T4 (IBA 2000 mg L^{-1}). On averaging across the years and treatments the maximum number of leaves (7.65) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum number of leaves per plant, across the years and treatments was found in *R. bourboniana* (5.80).

In table 8c, on averaging across the years and rootstocks, the number of leaves per plant (7.39) of cv. Grand Gala was significantly higher than the cv. First Red (6.21). However, on averaging among genotypes the number of leaves per plants was significantly different among treatments. The maximum number of leaves per plant was 8.94 (i.e. 7.96 in cv. First Red and 9.93 in cv. Grand Gala) in treatment T4 (IBA 2000 mg L^{-1}).

4.1.8 Number of days to bud emergence of *Rosa hybrida* L. cv. First Red and Grand Gala

The data showed that there was non significant difference between the rootstocks and the treatments for the number of days to bud emergence in cvs. First Red and Grand Gala (Table 9a, 9b and 9c). However, minimum number of days to bud emergence (54.03) was found in cv. First Red. Among the treatments the minimum days to bud emergence were 49.00 in 2014-15 and 49.67 in 2015-16 in T4 (IBA 2000 mg L^{-1}) in *R.indica* var. *odorata*.

Development of leaves of scion bud on *R. indica*

Development of leaves of scion bud on *R. multiflora*

Plate 3: Showing development of leaves of scion bud on different rootstock

Table 9a: Effect of growth regulator treatment on Days to flower bud emergence in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Genotype mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	51.00	50.00	55.67	54.00	55.00	57.67	53.89	54.03a
	T2	53.67	53.00	54.00	56.00	56.33	51.00	54.00	
	T3	51.33	53.33	54.33	52.67	54.67	54.67	53.50	
	T4	49.00	49.67	54.00	54.30	49.67	50.67	51.22	
	T5	59.00	57.67	58.67	57.67	58.00	54.33	57.56	
Grand gala	T1	52.16	51.23	55.00	54.67	56.67	56.00	54.29	54.35a
	T2	53.67	53.00	53.67	55.33	55.67	55.33	54.45	
	T3	51.33	53.33	53.33	53.67	54.00	54.33	53.33	
	T4	50.00	52.76	52.67	53.00	53.67	53.00	52.52	
	T5	59.00	57.67	57.00	56.33	57.33	55.67	57.17	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 9b: Effect of growth regulator treatment and rootstock on Days to flower bud emergence in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica var. *odorata*	*Rosa multiflora*	*Rosa bourboniana*	
T1	51.10	54.84	56.34	54.09a
T2	53.34	54.75	54.58	54.22a
T3	52.33	53.50	54.42	53.42a
T4	50.36	53.49	51.75	51.87a
T5	58.34	57.42	56.33	57.36b
Mean	53.09a	54.80ab	54.68b	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 9c: Effect of growth regulator treatment on Days to flower bud emergence in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		Mean
	First Red	Grand Gala	
T1	53.89	54.29	54.09a
T2	54.00	54.45	54.22a
T3	53.50	53.33	53.42a
T4	51.22	52.52	51.87a
T5	57.56	57.17	57.36b
Mean	54.03a	54.35a	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to

DMRT. ns = non significant *Significant at $p< 0.05$

In table 9b, the minimum days to bud emergence (53.09) was in *R.indica* var. *odorata* which was at par with *R. multiflora,* whereas, significantly lower than *R. bourboniana*. Among treatments the days to bud emergence was significantly lower than T5 (control). On averaging across years, treatments and rootstocks, there was non significant difference among genotypes (Table 9c).

4.1.9 Days taken to full bloom of *Rosa hybrida* L. cvs. First Red and Grand Gala

The days taken to full bloom (Table 10a) have the non significant effect between different IBA treatments in cvs. First Red and Grand Gala. However, minimum number of days to full bloom was 64.24 in cv. First Red and 66.17 in cv. Grand Gala. In table 10b, the minimum days to full bloom (64.28) was in *R. indica* var. *odorata* which was significantly lower than *R. multiflora* and *R. bourboniana*. Among treatments the days to full bloom was significantly lower than T5 (control). On averaging across years, treatments and rootstocks, there was non significant difference among genotypes (Table 10c).

4.1.10 Number of flowers per plant of *Rosa hybrida* L. cv. First Red and Grand Gala

In the present studies, it was observed that number of flowers per plant significantly varied among the rootstocks and treatments after three months of planting the budded cuttings of cvs. First Red and Grand Gala (Table 11a, 11b, 11c and Fig. 15, 16).

Among the different growth treatments T4 (IBA 2000 mg L^{-1}) resulted in the maximum number of flowers per plant irrespective of the rootstocks. In cv. First Red the maximum number of flowers per plant was (3.09) was recorded in *R. indica* var. *odorata* (Fig. 15) in T4 (IBA 2000 mg L^{-1}), likewise, the maximum number of flowers per plant was 3.05 in 2014-15 and 3.12 in 2015-16 (Table 11a). However, the lowest number of flowers per plant (1.00) found in control (T5) in *R. bourboniana* (Fig. 15), similarly, the number of flowers per plant was 1.00 in 2014-15 and 2015-16 (Table 11a). Similarly, in cv. Grand Gala, the maximum number of flowers per plant was 2.07 in T4 (IBA 2000 mg L^{-1}) in *R. indica* var. *odorata* (Fig. 16). Likewise, the maximum number of flowers was 2.08 in 2014-15 and 2.05 in 2015-16. Whereas, the minimum number of flowers per plant (0.95) found in control (T5) in *R. bourboniana* (Fig. 16), likewise, the number of flowers per plant was 0.94 in 2014-15 and 0.96 in 2015-16 (Table 11a).

The effect of treatments and rootstocks on number of flowers per plant is presented in table 11b. Among treatments the maximum number of flowers per plant (2.23) was in treatment T4 (IBA 2000 mg L^{-1}). On averaging across the years and treatments the maximum number of flowers per plant (1.58) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum number of branches per plant, across the years and treatments was found in *R. bourboniana* (1.30).

Table 10a: Effect of growth regulator treatment on days taken to full bloom in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Genotype mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	62.00	62.67	65.33	63.67	65.33	64.67	63.95	64.24a
	T2	64.33	63.67	63.33	65.33	65.67	63.33	64.28	
	T3	61.33	60.33	65.33	63.67	65.67	63.67	63.33	
	T4	60.00	62.00	62.00	62.33	61.33	62.33	61.67	
	T5	67.67	66.33	69.67	68.67	66.67	68.00	67.84	
Grand gala	T1	65.93	67.22	67.26	68.48	65.81	67.18	66.98	66.17a
	T2	65.76	67.17	64.22	66.50	66.14	68.33	66.35	
	T3	61.22	63.29	61.2	63.13	67.69	69.91	64.41	
	T4	63.85	65.08	64.44	65.59	65.61	67.04	65.27	
	T5	67.19	68.54	67.40	69.22	66.76	67.82	67.82	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

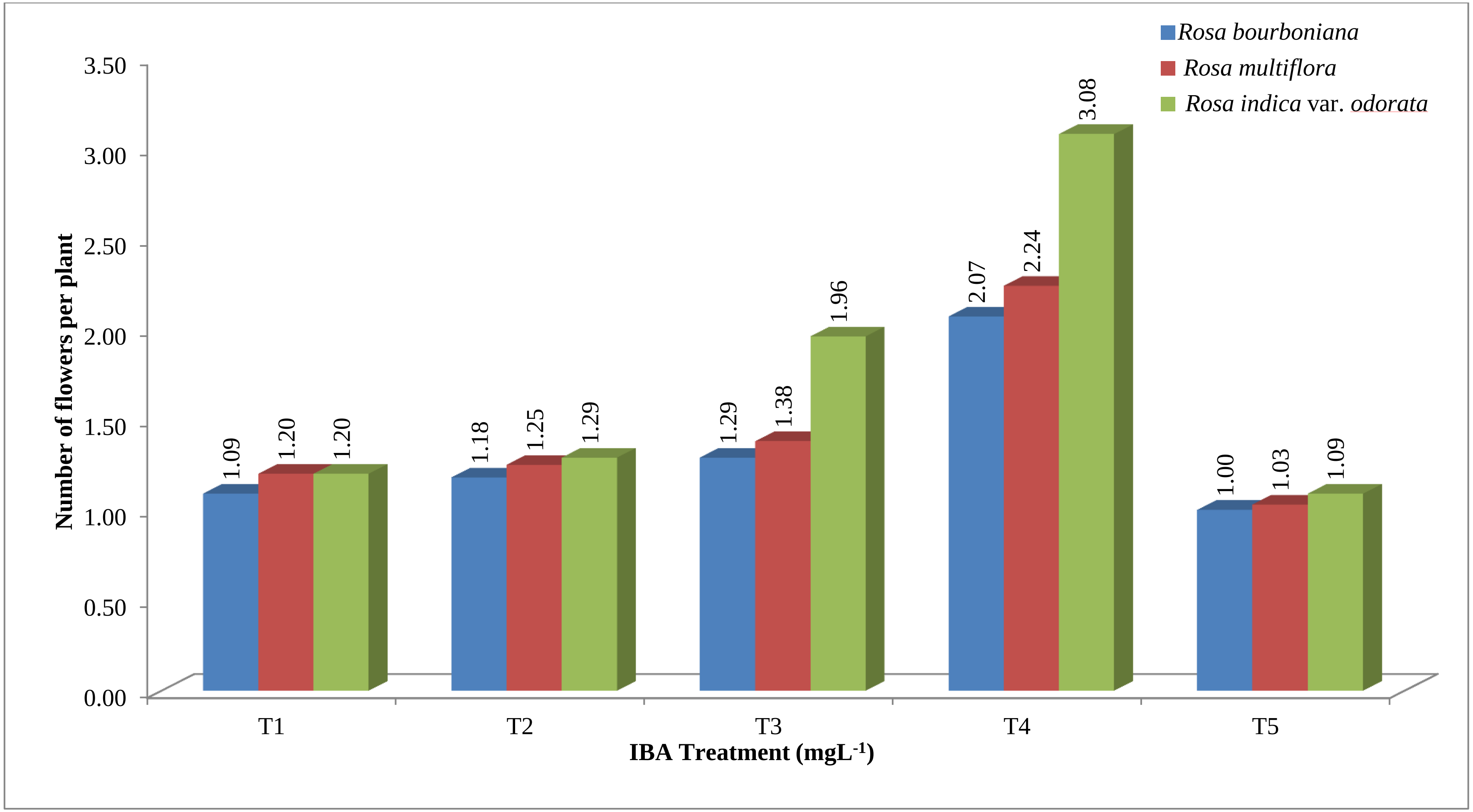

Fig. 15: Effect of growth regulator treatment on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cv. First Red

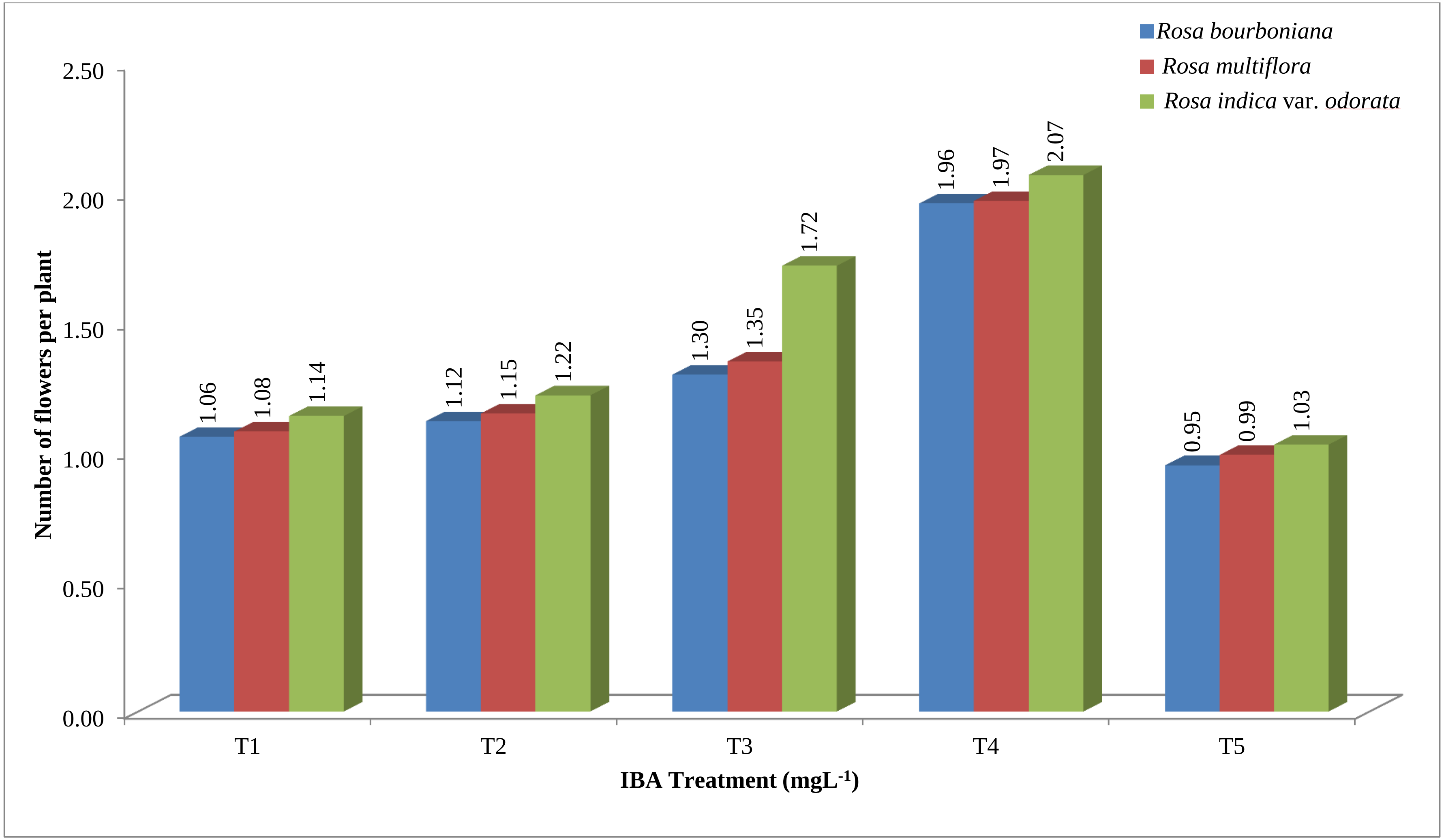

Fig. 16: Effect of growth regulator treatment on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 10b: Effect of growth regulator treatment and rootstock on days taken to full bloom in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			Mean
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	
T1	64.46	66.19	65.75	65.46a
T2	65.23	64.85	65.87	65.32a
T3	61.54	63.33	66.74	63.87a
T4	62.73	63.59	64.08	63.47a
T5	67.43	68.74	67.31	67.83b
Mean	64.28a	65.34ab	65.95b	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 10c: Effect of growth regulator treatment on days taken to full bloom in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		Mean
	First Red	**Grand Gala**	
T1	63.95	66.98	65.46a
T2	64.28	66.35	65.32a
T3	63.33	64.41	63.87a
T4	61.67	65.27	63.47a
T5	67.84	67.82	67.83b
Mean	64.21a	66.17a	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 11a: Effect of growth regulator treatment on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Genotype mean
		2014-15	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**		
First Red	T1	1.18	1.21	1.15	1.25	1.08	1.10	1.16	1.50a
	T2	1.27	1.31	1.23	1.27	1.17	1.20	1.24	
	T3	1.95	1.98	1.35	1.42	1.28b	1.31	1.60	
	T4	3.05	3.12	2.23	2.25	2.04	2.09	2.46	
	T5	1.09	1.10	1.02	1.05	1.00	1.00	1.04	
Grand gala	T1	1.13	1.15	1.07	1.10	1.05	1.07	1.10	1.34b
	T2	1.20	1.23	1.13	1.16	1.10	1.13	1.16	
	T3	1.67	1.76	1.32	1.37	1.27	1.34	1.46	
	T4	2.08	2.05	1.92	2.02	2.03	1.88	2.00	
	T5	1.02	1.03	0.98	1.00	0.94	0.96	0.99	

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 11b: Effect of growth regulator treatment and rootstock on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	1.17	1.14	1.08	1.13d
T2	1.25	1.20	1.15	1.20c
T3	1.84	1.37	1.31	1.50b
T4	2.58	2.11	2.01	2.23a
T5	1.06	1.01	0.98	1.02e
Mean	1.58a	1.36b	1.30b	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 11c: Effect of growth regulator treatment on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	1.16	1.10	1.13d
T2	1.24	1.16	1.20c
T3	1.60	1.46	1.53b
T4	2.46	2.00	2.23a
T5	1.04	0.99	1.02e
Mean	1.50a	1.34b	*

T1- IBA 500 mg L^{-1}, T_2 - IBA 1000 mg L^{-1}, T_3 - IBA 1500 mg L^{-1}, T_4 - IBA 2000 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

In table 11c, on averaging across the years and rootstocks, the number of flowers per plant (1.50) of cv. First Red was significantly higher than the number of flowers per plant of cv. Grand Gala (1.34). However, on averaging among genotypes the number of flowers per plants was significantly different among treatments. The maximum number of flowers per plant was 2.23 (i.e. 2.46 in cv. First Red and 2.00 in cv. Grand Gala) in treatment T4 (IBA 2000 mg L^{-1}).

The present results are with conformity of the observation of Goujan (1974). He found that cvs. Carina, Lara, Super Star and Zorina produced more flowers per plant on *R.indica* var. *major*. Similarly, Malik (1980) reported that rose cv. Sonia produced more number of marketable blooms when budded on *R.indica* var. *odorata rootstock* than own rooted plants. Mukhopadhyay and Bankar (1986) reported that thornless rootstock produced maximum number of flowers followed by *R. multiflora* and *R.indica* var. *odorata.* Dubois *et al* (1990) found that the *R. indica* var. *manetti, R. indica* var. *major* and the seedling rootstock *R. multiflora* produced maximum flowers.

4.2 Effect of rootstocks and cytoknin treatments on growth and flowering of different genotypes of rose

The plant growth regulators (cytokinin) play an important role in improving the rooting of cuttings. The effect of cytokinin treatments on rootstocks cuttings on sprouting of budded cuttings, rooting of cuttings, survival of budded cuttings, plant height, shoot length, number of primary branches, leaves per plant, days taken to emergence, days to taken to full bloom and number of flowers per plant were recorded. The stem cuttings of the rose rootstocks *R. indica, R. multiflora* and *R. bourboniana* treated with 1500 mg L^{-1} IBA. These IBA treated cuttings then budded with scion bud of cvs. First Red and Grand Gala after treating with cytokinin (BAP) as per experiment and planted in the pots.

4.2.1 Sprouting of the budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The sprouting of the cuttings was significantly influenced by the different rootstocks and BAP treatments ((Table 12a, 12b and Fig. 17, 18).

The treatment T4 (BAP 20 mg L^{-1}) was best treatment for sprouting in both the genotypes. On averaging across the years and genotypes, the maximum sprouting 80.84 % (i.e. 80.00 % in cv. First Red and 81.67 % in cv. Grand Gala) was observed in treatment T4 (BAP 20 mg L^{-1}). The lowest sprouting observed as 43.34 % (i.e. 47.22 % in cv. First Red and 39.45 % in cv. Grand Gala) in T5 (control). The sprouting of the budded cuttings was also differing significantly among the genotypes. In cv. First Red the sprouting of the budded cuttings was 63.78 % which was significantly higher than cv. Grand Gala where the sprouting was 60.14 % (Table 12a).

Budded cuttings of *Rosa hybrid* L. cv. First Red (IBA 2000 mg L^{-1})

Budded cuttings of *Rosa hybrid* L. cv. Grand Gala (IBA 2000 mg L^{-1})

Plate 4: Showing effect of IBA treatment on *Rosa hybrid* L. in the experiment

Table 12a: Effect of growth regulator treatment on sprouting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock	First Red		Mean	Grand Gala		Mean	Grand Mean
		Year			Year			
		2014-15	2015-16		2014-15	2015-16		
T1	*Rosa indica* var. *odorata*	63.33	66.67	58.33d	56.67	60.00	52.78d	55.56d
	Rosa multiflora	60.00	60.00		53.33	56.67		
	Rosa bourboniana	46.67	53.33		43.33	46.67		
T2	*Rosa indica* var. *odorata*	66.67	66.67	60.56c	63.33	66.67	56.67c	58.62c
	Rosa multiflora	63.33	66.67		56.67	60.00		
	Rosa bourboniana	50.00	50.00		46.67	46.67		
T3	*Rosa indica* var. *odorata*	83.33	86.67	72.78b	76.67	80.00	70.00b	71.39b
	Rosa multiflora	70.00	73.33		70.00	70.00		
	Rosa bourboniana	60.00	63.33		60.00	63.33		
T4	*Rosa indica* var. *odorata*	90.00	93.33	80.00a	86.67	90.00	81.67a	80.84a
	Rosa multiflora	80.00	80.00		83.33	86.67		
	Rosa bourboniana	66.67	70.00		70.00	73.33		
T5	*Rosa indica* var. *odorata*	50.00	53.33	47.22e	43.33	46.67	39.45e	43.34e
	Rosa multiflora	46.67	50.00		36.67	40.00		
	Rosa bourboniana	36.67	46.67		33.33	36.67		
Mean		65.22	65.33	63.78a	58.67	61.56	60.14b	

T1- BAP 5 mg L^{-1}, T_2 - BAP 10 mg L^{-1}, T_3 - BAP 15 mg L^{-1}, T_4 - BAP 20 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

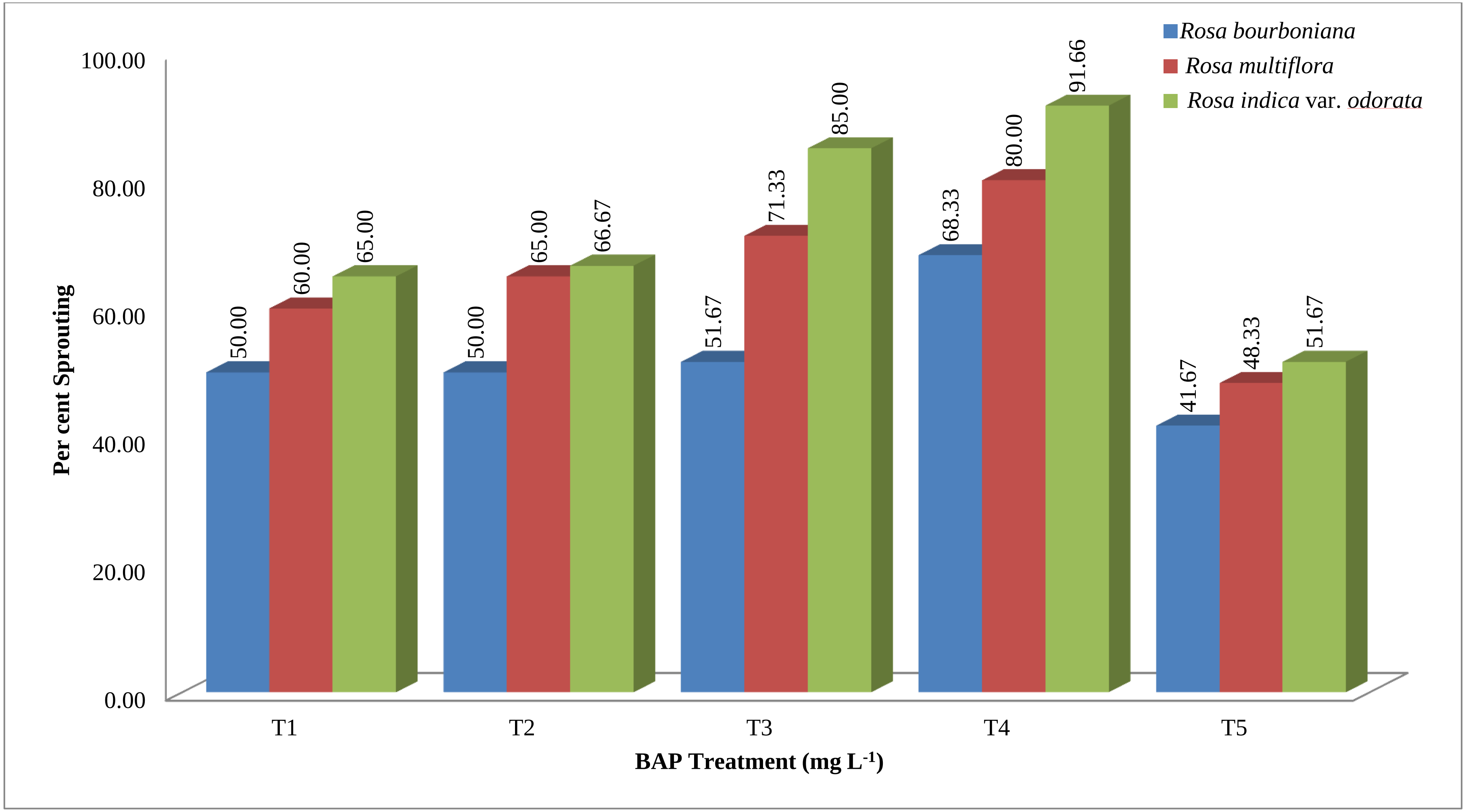

Fig. 17: Effect of growth regulator treatment on per cent sprouting in budded cuttings in *Rosa hybrida* L. cv. First Red

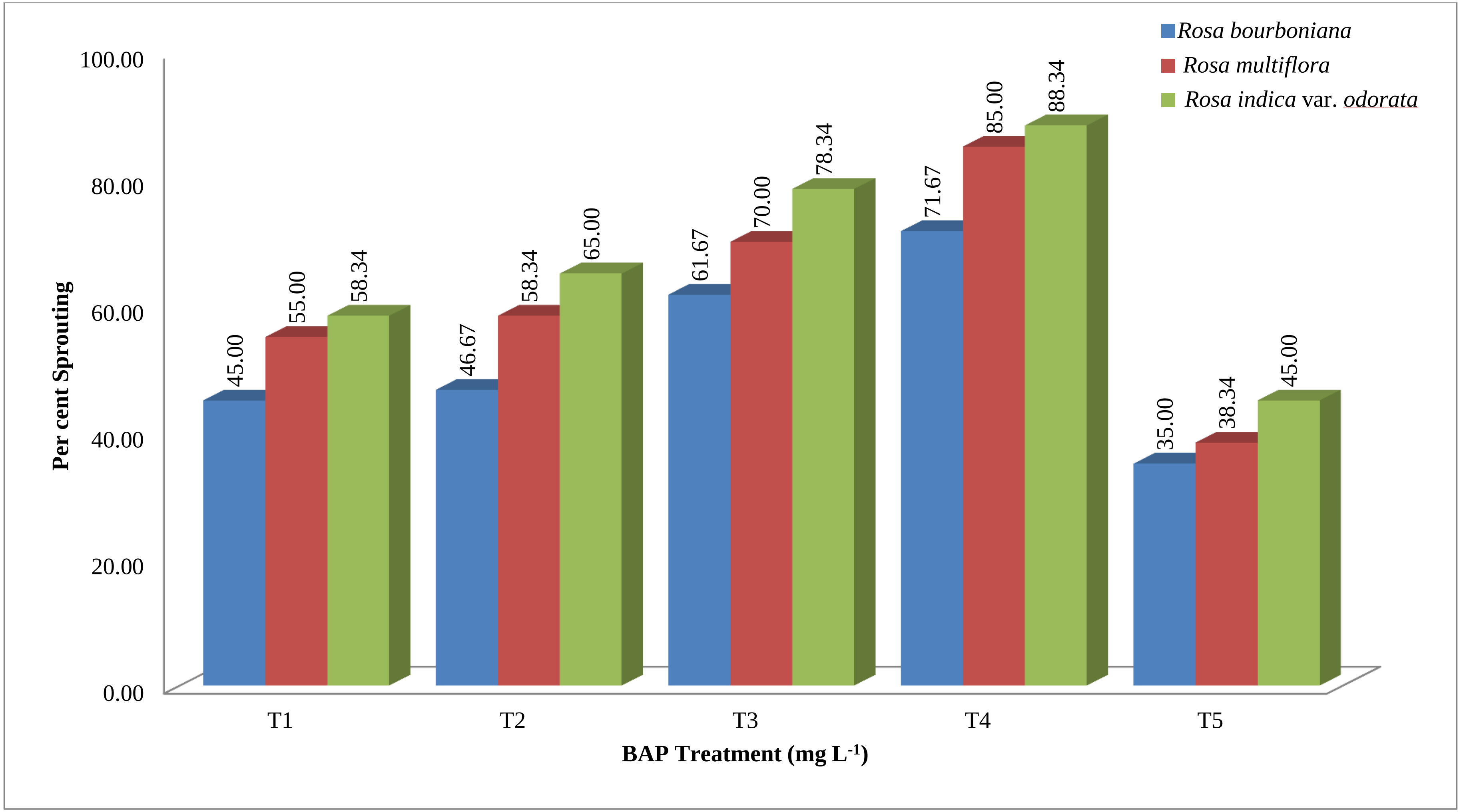

Fig. 18: Effect of growth regulator treatment per cent sprouting in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 12b: Effect of growth regulator treatment and rootstock on sprouting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	61.67	57.50	47.50	55.56c
T2	65.84	61.67	48.34	58.61c
T3	81.67	70.83	61.67	71.39b
T4	90.00	82.50	70.00	80.84a
T5	48.33	43.34	38.34	43.33d
Mean	69.50a	63.17b	53.17c	*

T1- BAP 5 mg L^{-1}, T_2 - BAP 10 mg L^{-1}, T_3 - BAP 15 mg L^{-1}, T_4 - BAP 20 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

On averaging across the years, genotypes and treatments the maximum sprouting (69.50 %) observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum sprouting across the years, genotypes and treatments found in *R. bourboniana* (53.17 %). However, among treatments the maximum sprouting (90.00%) was in treatment T4 (BAP 20 mg L^{-1}) in rootstock *R. indica* var. *odorata* (Table 12b). These findings were in agreement with Swarup and Malik (1974) where *R. indica* var. *odorata* found the best rootstock due to resistance to powdery mildew, vigorous growth of scion buds, floriferousness, better rooting of cuttings, bud take and longer plant life.

The best treatment for sprouting was treatment T4 (BAP 20 mg L^{-1}) in all the rootstocks. In cv. First Red, on averaging across the years the highest sprouting (91.66 %) was observed in T4 (BAP 20 mg L^{-1}) in *R. indica*, whereas, the minimum sprouting (41.67 %) was observed in T5 (control) in *R. bourboniana* (Fig 17). Similarly, in Grand Gala, on averaging across the years the maximum sprouting (88.34 %) was observed in T4 (BAP 20 mg L^{-1}) in *R.indica* var. *odorata*. The minimum sprouting was observed as 35.00 % in T5 (control) in *R. bourboniana* (Fig 18).

Similarly, Swarup and Malik (1974) observed that the bud take varied with the type of rootstock used. The percentage of bud take on *R. indica* var. *odorata* was the highest in Super Star (100), Dr Homi Bhaba (88) and Pusa Sonia (80) while bud take of Queen Elizabeth was the highest (96) on *R. multiflora.* Some cultivars gave equally good results on two different rootstocks, McGredys Sunset on Edouard and *R. multiflora*, McGredys Yellow on Edouard and *R. indica* var. *odorata* and Happiness on *R. indica* var. *odorata* and *R. multiflora.*

4.2.2 Rooting of the budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The impact of different rootstocks and BAP concentrations on rooting of the cuttings is presented in Table 13a, 13b and Fig. 19, 20. The treatment T4 (BAP 20 mg L^{-1}) was best treatment for rooting in both the genotypes. On averaging across the years and genotypes, the maximum rooting 82.62 % (i.e. 87.78 % in cv. First Red and 89.45 % in cv. Grand Gala) was observed in treatment T4 (BAP 20 mg L^{-1}) which was at par with T3 (BAP 15 mg L^{-1}). The lowest rooting was observed as 48.06 % (i.e. 47.22 % in cv. First Red and 48.89 % in cv. Grand Gala) in T5 (control). The rooting of the budded cuttings has non significant difference among the genotypes. In cv. First Red the rooting of the budded cuttings was 77.55 % which was significantly higher than cv. Grand Gala where the rooting was 75.91 % (Table 13a).

In table 13b, on averaging across the years, genotypes and treatments the maximum rooting (80.67 %) was observed in rootstock *R. indica* var. *odorata* which was at par with *R. multiflora* (77.83 %). The minimum rooting percentage across the years, genotypes and treatments was found in *R. bourboniana* (71.67 %).

In cv. First Red, on averaging across the years the maximum rooting (91.67 %) was observed in T4 (BAP 20 mg L^{-1}) in *R. indica* var. *odorata*, whereas, the minimum rooting (41.67 %) was observed in T5 (control) in *R. bourboniana* (Fig 19). Similarly, in Grand Gala, on averaging across the years the maximum rooting (88.34 %) was observed in T4 (BAP 20 mg L^{-1}) in *R.indica* var. *odorata*. The minimum rooting was observed as 35.00 % in T5 (control) in *R. bourboniana* (Fig 20).

Likewise, Singh *et al* (2011) observed stionic effect of rootstocks (*R. multiflora*, *R. indica* var. *odorata*, *R. witchuriana* and *R. bourboniana*) on different rose cultivars and *R. indica* var. *odorata* was found superior with respect to root parameters (days to root initiation, percentage of rooted cuttings, number of roots per cutting and length of root). The results are in line with Malik (1980) where *R. indica* var. *odorata* was the best rootstock than *R. bourboniana* and *R. muliflora* for grafted plants. Similarly, Randhawa and Mukhopadhyay (1986) also reported that *R. indica* var. *odorata* was better rootstock due to resistance to powdery mildew and better suitability to North Indian conditions.

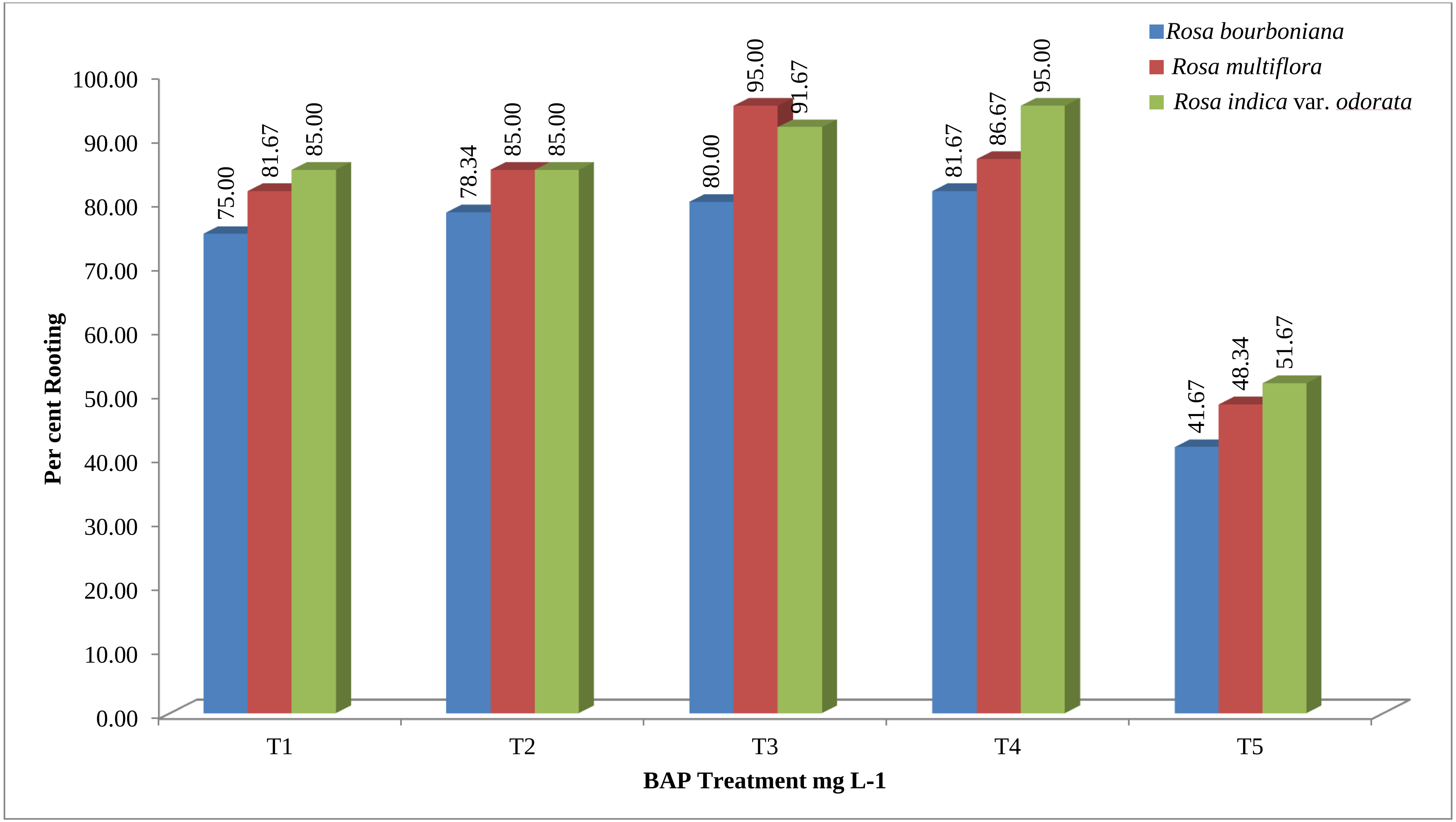

Fig. 19: Effect of growth regulator treatment per cent rooting in budded cuttings in *Rosa hybrida* L. cv. First Red

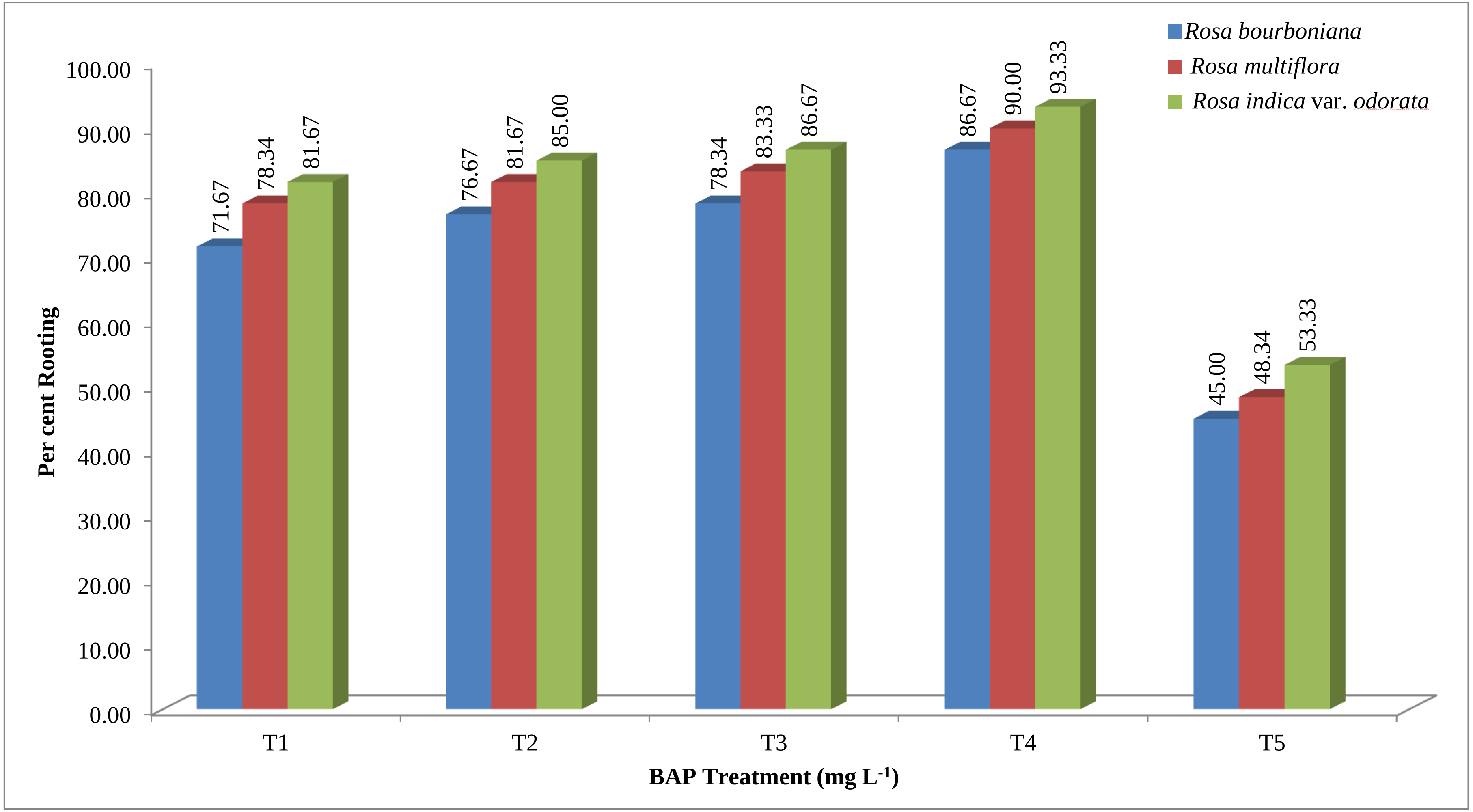

Fig. 20: Effect of growth regulator treatment per cent rooting in budded cuttings in *Rosa hybrida* L. cv. First Red

Table 13a: Effect of growth regulator treatment on rooting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock	First Red		Mean	Grand Gala		Mean	Grand Mean
		Year			Year			
		2014-15	2015-16		2014-15	2015-16		
T1	*Rosa indica* var *odorata*	86.67	83.33	81.11	80.00	83.33	77.22	79.17b
	Rosa multiflora	83.33	80.00		76.67	80.00		
	Rosa bourboniana	76.67	76.67		70.00	73.33		
T2	*Rosa indica* var. *odorata*	86.67	83.33	82.77	83.33	86.67	81.22	81.94b
	Rosa multiflora	86.67	83.33		80.00	83.33		
	Rosa bourboniana	76.67	80.00		76.67	76.67		
T3	*Rosa indica* var. *odorata*	90.00	93.33	88.89	86.67	86.67	82.78	85.84a
	Rosa multiflora	93.33	96.67		83.33	83.33		
	Rosa bourboniana	80.00	80.00		76.67	80.00		
T4	*Rosa indica* var. *odorata*	93.33	96.67	87.78	90.00	93.33	89.45	88.62a
	Rosa multiflora	86.67	86.67		90.00	90.00		
	Rosa bourboniana	83.33	80.00		86.67	86.67		
T5	*Rosa indica* var. *odorata*	50.00	53.33	47.22	53.33	53.33	48.89	48.06c
	Rosa multiflora	46.67	50.00		46.67	50.00		
	Rosa bourboniana	40.00	43.33		46.67	43.33		
Mean		77.33	77.78	77.55a	75.11	76.67	75.91a	

T1- BAP 5 mg L^{-1}, T_2 - BAP 10 mg L^{-1}, T_3 - BAP 15 mg L^{-1}, T_4 - BAP 20 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 13b: Effect of growth regulator treatment and rootstock on rooting (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	83.33	80.00	74.17	79.17b
T2	85.00	83.33	77.50	81.95b
T3	89.17	89.17	79.17	85.83a
T4	93.33	88.34	84.17	88.61a
T5	52.50	48.34	43.33	48.06c
Mean	80.67a	77.83a	71.67b	*

T1- BAP 5 mg L^{-1}, T_2 - BAP 10 mg L^{-1}, T_3 - BAP 15 mg L^{-1}, T_4 - BAP 20 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

4.2.3 Survival of the budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The effect of different rootstocks and BAP concentrations on survival of the cuttings budded with cvs. First Red and Grand Gala are presented in Table 14a, 14b and Fig. 21, 22. The significant influence of rootstocks and BAP concentrations were observed on survival of budded cuttings. The treatment T4 (BAP 20 mg L^{-1}) was best treatment for survival in both the genotypes. On averaging across the years and genotypes, the maximum survival 74.45 % (i.e. 75.00 % in cv. First Red and 73.89 % in cv. Grand Gala) was observed in treatment T4 (BAP 20 mg L^{-1}). The lowest survival was observed as 40.56 % (i.e. 41.67 % in cv. First Red and 39.44 % in cv. Grand Gala) in T5 (control). The survival of the budded cuttings was not significantly differing among the genotypes. In cv. First Red the survival of the budded cuttings was 57.78 % which was significantly higher than cv. Grand Gala where the survival was 56.42 % (Table 14a).

In table 14b, on averaging across the years, genotypes and treatments the maximum survival (65.71 %) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum survival percentage averaged across the years, genotypes and treatments was found in *R. bourboniana* (47.33 %). However, among treatments the maximum survival (74.45 %) was in treatment T4 (BAP 20 mg L^{-1}) in rootstock *R. indica* var. *odorata*.

In cv. First Red, on averaging across the years the maximum survival (86.67 %) was observed in T4 (BAP 20 mg L^{-1}) in *R. indica* var. *odorata*, whereas, the minimum survival (38.33 %) was observed in T5 (control) in *R. bourboniana* (Fig 21). Similarly, in Grand Gala,

Table 14a: Effect of growth regulator treatment on survival (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock	First Red		Mean	Grand Gala		Mean	Grand Mean
		Year			Year			
		2014-15	2015-16		2014-15	2015-16		
T1	*Rosa indica* var. *odorata*	60.00	60.00	52.22	56.67	56.67	50.00	51.11c
	Rosa multiflora	53.33	56.67		50.00	53.33		
	Rosa bourboniana	40.00	43.33		40.00	43.33		
T2	*Rosa indica* var. *odorata*	63.33	66.67	55.00	63.33	63.33	54.44	54.72c
	Rosa multiflora	56.67	56.67		53.33	56.67		
	Rosa bourboniana	43.33	43.33		43.33	46.67		
T3	*Rosa indica* var. *odorata*	76.67	73.33	65.00	70.00	73.33	62.94	63.97b
	Rosa multiflora	66.67	70.00		63.33	67.67		
	Rosa bourboniana	50.00	53.33		50.00	53.33		
T4	*Rosa indica* var. *odorata*	86.67	86.67	75.00	86.67	86.67	73.89	74.45a
	Rosa multiflora	73.33	76.67		76.67	70.00		
	Rosa bourboniana	63.33	63.33		60.00	63.33		
T5	*Rosa indica* var. *odorata*	46.67	43.33	41.67	40.00	43.33	39.44	40.56d
	Rosa multiflora	40.00	43.33		40.00	43.33		
	Rosa bourboniana	36.67	40.00		33.33	36.67		
Mean		57.11	58.44	57.78a	55.11	57.17	56.42a	

T1- BAP 5 mg L^{-1}, T_2 - BAP 10 mg L^{-1}, T_3 - BAP 15 mg L^{-1}, T_4 - BAP 20 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

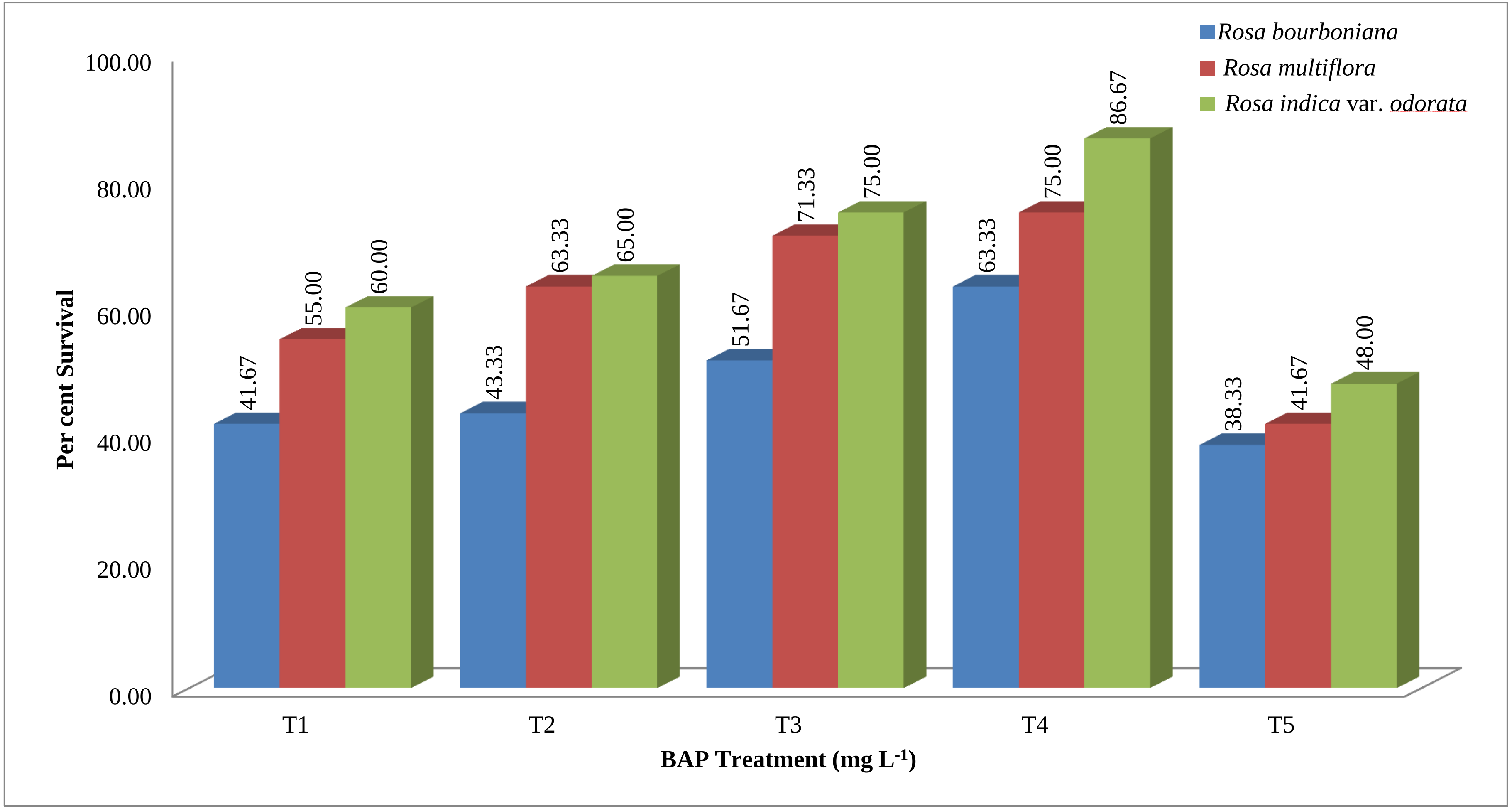

Fig. 21: Effect of growth regulator treatment on per cent survival in budded in *Rosa hybrida* L. cv. First Red

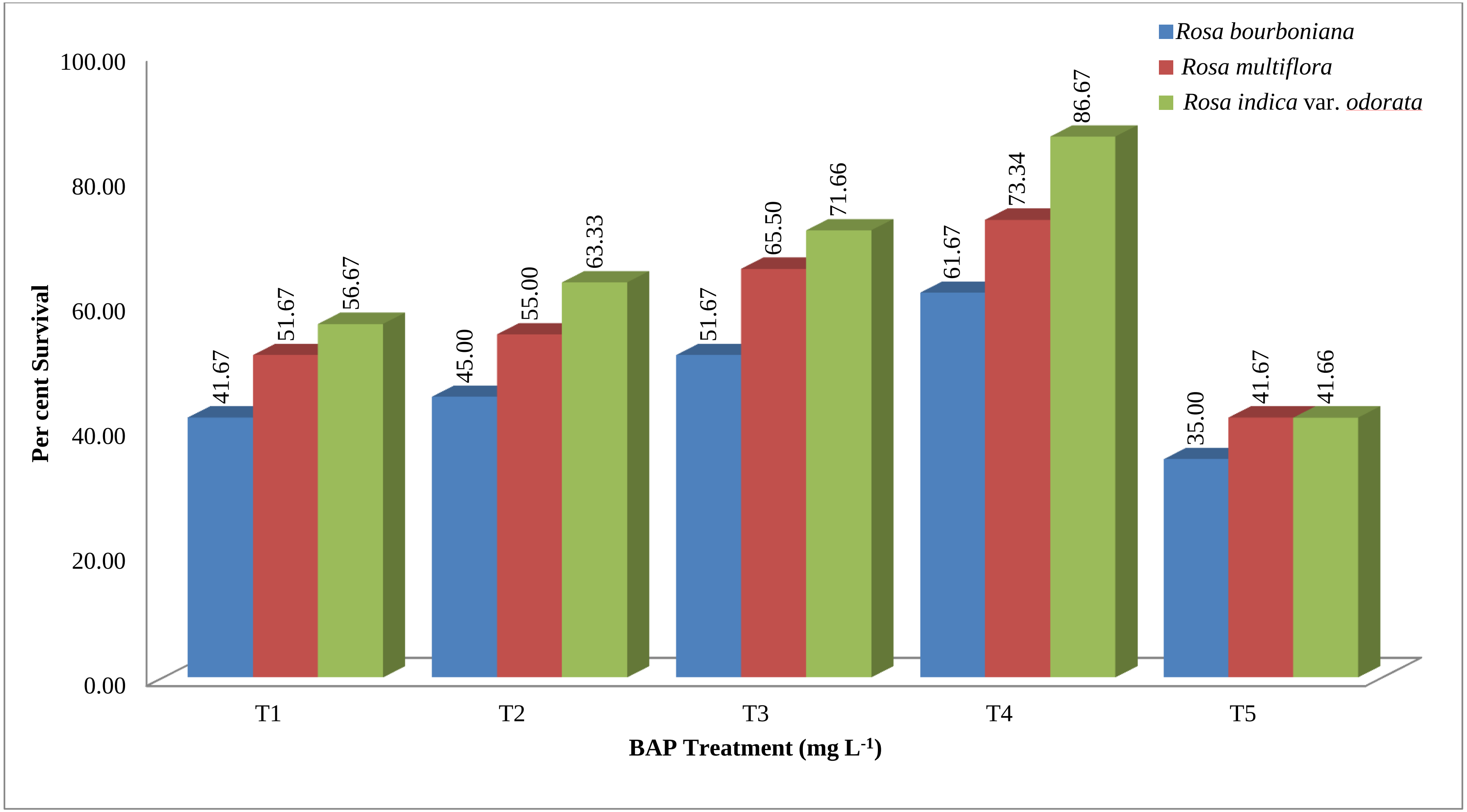

Fig. 22: Effect of growth regulator treatment on per cent survival in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 14b: Effect of growth regulator treatment and rootstock on survival (%) of budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	58.34	53.33	41.67	51.11c
T2	64.17	55.84	44.17	54.72c
T3	73.33	66.92	51.67	63.97b
T4	86.67	74.17	62.50	74.45a
T5	43.33	41.67	36.67	40.56d
Mean	65.17a	58.38b	47.33c	*

T1- BAP 5 mg L^{-1}, T_2 - BAP 10 mg L^{-1}, T_3 - BAP 15 mg L^{-1}, T_4 - BAP 20 mg L^{-1}, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

on averaging across the years the maximum survival (86.67 %) was observed in T4 (BAP 20 mg L^{-1}) in *R.indica* var. *odorata*. The minimum survival was observed (35.00 %) in T5 (control) in *R. bourboniana* (Fig 22). The present results are also in conformity with Malik (1980) where *R. indica* var. *odorata* was the best rootstock than *R. bourboniana* and *R. muliflora* for grafted plants.

The cytokinin plays an important role to improve the bud take and bud break, which proceeds to the plant survival (Wickson and Thimman, 1958). Richards and wilknsons (1984) have been reported about the bud break by cytokinin. The role of BAP treatments in bud union and bud break might be due to the promotion of cell division and growth. The bud union is directly related to the plant survival. Bud break effect of cytokinins has been reported by Carpenter and Rodrigues (1971), Okhawa (1979).

4.2.4 Shoot length of budded plants of *Rosa hybrida* L. cvs. First Red and Grand Gala

The shoot length of plants of the First Red and Grand Gala were recorded after three months of planting the budded cuttings. The shoot length was found significantly influenced by the different rootstocks and Treatments (Table 15a, 15b, 15c and Fig. 23, 24).

Among the different growth treatments the T4 (BAP 20 mg L^{-1}) resulted best for shoot length in both the genotypes irrespective of the rootstocks. Likewise, in cv. First Red (Fig. 23) the maximum shoot length was (15.01 cm) in T4 (BAP 20 mg L^{-1}) in *R. indica* var. *odorata* and minimum shoot length (4.53 cm) was in T5 (control) in *R. bourboniana* (i.e. 14.79 cm in 2014-15 and 15.22 cm in 2015-16 , 4.29 cm in 2014-15 and 4.76 cm in 2015-16,

Table 15a: Effect of growth regulator treatment on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Grand mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	8.25	8.68	7.79	8.02	6.81	7.18	7.79	9.57b
	T2	11.24	11.98	10.19	10.83	8.15	8.49	10.15	
	T3	13.95	13.09	11.86	11.37	9.83	9.16	11.54	
	T4	14.79	15.22	12.14	12.64	10.08	10.25	12.52	
	T5	7.20	7.79	5.18	5.89	4.29	4.76	5.85	
Grand gala	T1	8.21	8.31	7.60	7.93	6.79	6.94	7.63	10.55a
	T2	10.14	10.78	9.15	9.78	8.36	8.25	9.41	
	T3	14.78	14.91	13.41	13.66	12.10	11.63	13.42	
	T4	17.47	18.42	16.23	17.11	13.00	13.00	15.87	
	T5	6.95	7.17	6.05	6.29	6.10	5.85	6.40	

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

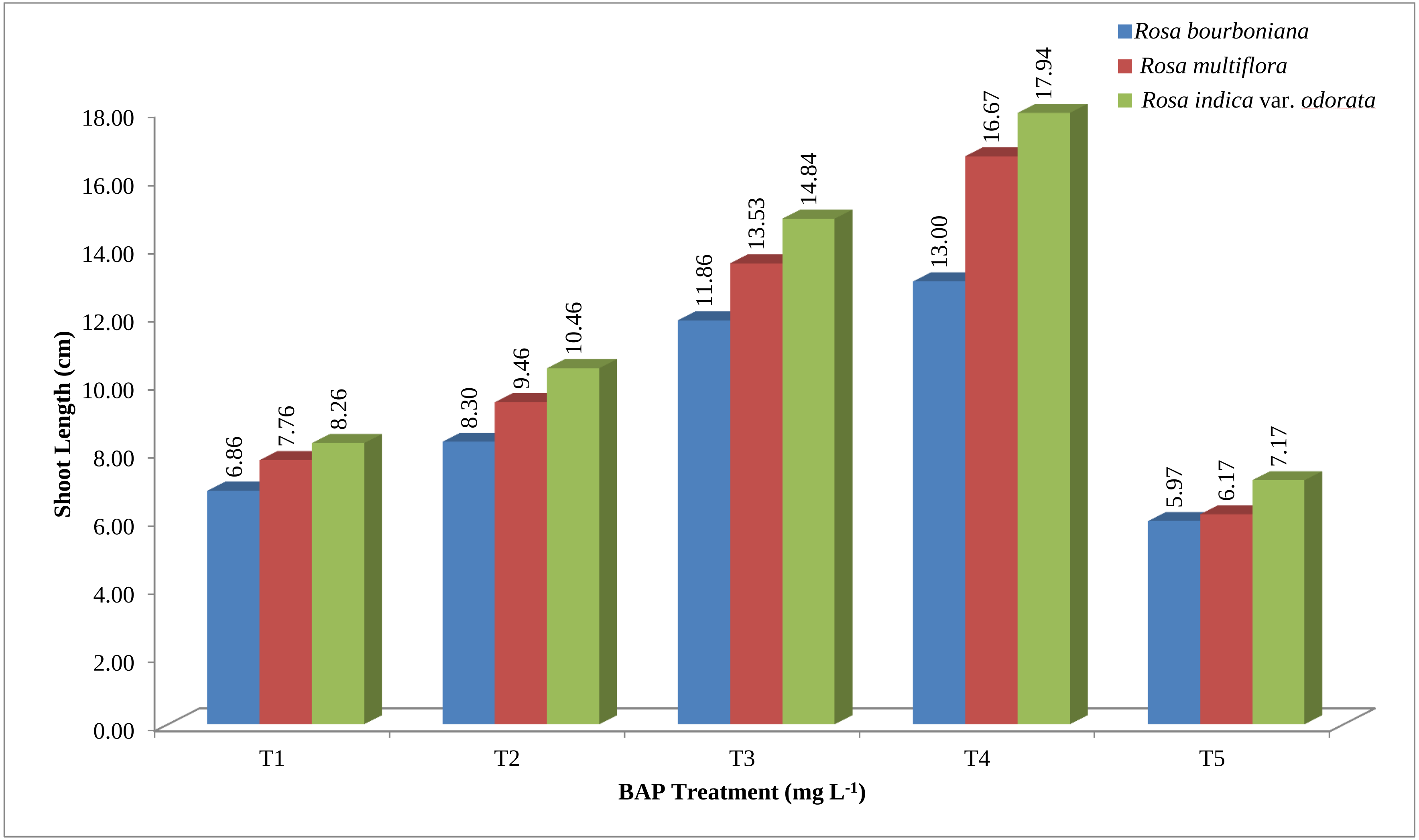

Fig. 23: Effect of growth regulator treatment shoot length (cm) in budded cuttings in *Rosa hybrida* L. cv. First Red

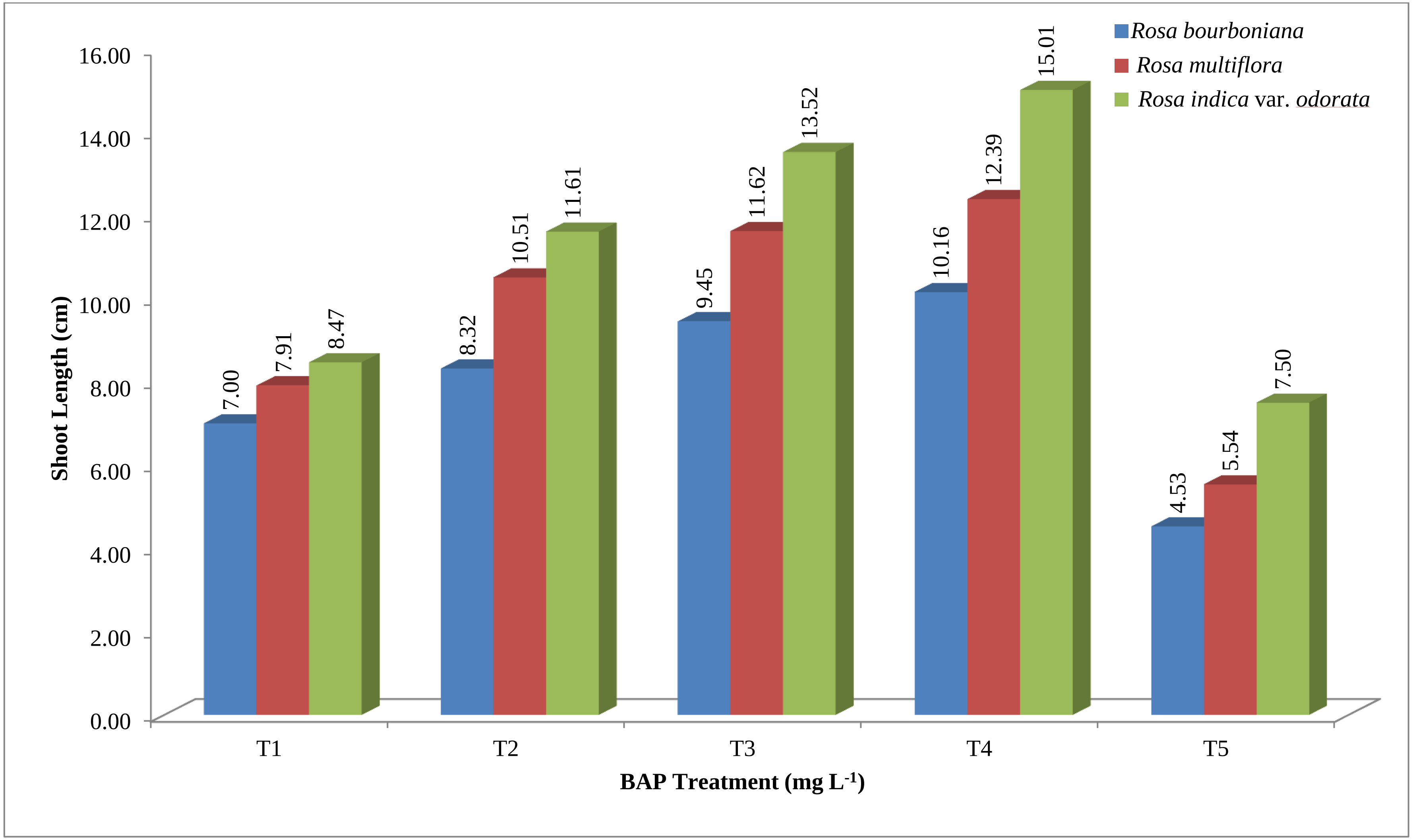

Fig. 24: Effect of growth regulator treatment shoot length (cm) in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 15b: Effect of growth regulator treatment and rootstock on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica var. *odorata*	*Rosa multiflora*	*Rosa bourboniana*	Mean
T1	8.36	7.84	6.93	7.71d
T2	11.04	9.99	8.31	9.78c
T3	14.18	12.58	10.68	12.48b
T4	16.48	14.53	11.58	14.20a
T5	7.28	5.85	5.25	6.13e
Mean	11.47a	10.16b	8.55c	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at p < 0.05 according to DMRT. ns = non significant *Significant at p< 0.05

Table 15c: Effect of growth regulator treatment on shoot length (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	Grand Gala	Mean
T1	7.79	7.63	7.71d
T2	10.15	9.41	9.78c
T3	11.54	13.42	12.48b
T4	12.52	15.87	14.20a
T5	5.85	6.40	6.13e
Mean	9.57b	10.55a	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at p < 0.05 according to DMRT. ns = non significant *Significant at p< 0.05

respectively, in Table 15a). Similarly, in plants of *cv.* Grand Gala (Fig. 24) the maximum shoot length was (17.94 cm) in T4 (BAP 20 mg L^{-1}) in *R. indica* var. *odorata* and minimum shoot length (5.97 cm) was in T5 (control) in *R. bourboniana* (i.e. 17.47 cm in 2014-15 and 18.42 cm in 2015-16, 6.10 cm in 2014-15 and 5.85 cm in 2015-16, respectively, in Table 15a).

In table 15b, among treatments the maximum shoot length (14.20 cm) was in treatment T4 (BAP 20 mg L^{-1}). On averaging across the years and treatments the maximum shoot length (11.47 cm) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum shoot length across the years and treatments was found in *R. bourboniana* (8.55 cm). The role of BAP in increasing the shoot length can be attributed to the involvement of cytokinins in cell growth and cell differentiation. The increase in shoot length in rootstock *R. indica* var. *odorata* is probably due to their better root growth.

The influence of rootstocks on shoot growth has been studied by various workers like Swarup and Malik (1974), Pandey and Sharma (1976) and Sharma (1979). The performance of rose cultivars may depend much on the rootstock used; however, the performance of cultivars on particular rootstock may be suitable for a particular locality and may not perform well in another (Karadi and Patil 2006). The maximum shoot length was observed in *R. indica* which is probably due to their better root growth.

In table 15c, on averaging across the years and rootstocks, the maximum shoot length (10.55 cm) was observed in the plants of cv. Grand Gala which was significantly higher than the shoot length of the plants of cv. First Red (9.57 cm). However, on averaging among genotypes, the significantly maximum shoot length was 14.20 cm (i.e. 12.52 cm in cv. First Red and 15.87 cm in cv. Grand Gala) in treatment T4 (BAP 20 mg L^{-1}).

4.2.5 Plant height of budded cuttings of *Rosa hybrida* L. cvs. First Red and Grand Gala

The plant height of plants of the First Red and Grand Gala were recorded after three months of planting the budded cuttings. The plant height was found significantly influenced by the different rootstocks and Treatments (Table 16a, 16b, 16c and Fig. 25, 26).

In cv. First Red the maximum plant height among all treatments was 23.01 cm in *R. indica* var. *odorata* (Fig. 25) in T4 (BAP 20 mg L^{-1}), likewise, the highest plant height in 2014-15 was 22.79 cm and in 2015-16 was 23.22 cm (Table 16a). On averaging across the years the minimum plant height was 8.13 cm in T5 (control) in *R. bourboniana* (Fig. 25), likewise the plant height was 7.89 cm in 2014-15 and 8.36 cm in 2015-16 (Table 16a). Similarly, in plants of *cv.* Grand Gala, the maximum plant height among all treatments was 24.15 cm in *R. indica* var. *odorata* (Fig. 26) in T4 (BAP 20 mg L^{-1}), likewise, the maximum plant height was 24.61 cm in 2014-15 and 23.70 cm in 2015-16. On averaging across the years the lowest plant height (8.90 cm) observed in T5 (control) in *R. bourboniana* (Fig. 26), likewise the plant height was 9.00 cm in 2014-15 and 8.80 cm in 2015-16 (Table 16a).

Budded cuttings of *Rosa hybrid* L. cv. First Red (BAP 20 mg L^{-1})

Budded cuttings of *Rosa hybrid* L. cv. Grand Gala (BAP 20 mg L^{-1})

Plate 5: Showing effect of BAP treatment on *Rosa hybrid* L. in the experiment

Table 16a: Effect of growth regulator treatment on plant height (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Grand mean
		2014-15	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**		
First Red	T1	14.15	14.58	13.69	13.92	12.71	13.08	13.69	15.71a
	T2	17.54	18.28	16.49	17.13	14.45	14.79	16.45	
	T3	20.75	19.89	18.66	18.17	16.63	16.96	18.51	
	T4	22.79	23.22	20.14	20.64	17.80	18.25	20.47	
	T5	10.80	11.39	8.78	9.49	7.89	8.36	9.45	
Grand Gala	T1	15.20	14.68	13.63	12.85	12.84	12.28	13.58	15.60a
	T2	16.50	16.56	14.20	14.49	13.65	14.19	14.93	
	T3	19.25	19.39	17.24	17.00	15.99	15.90	17.46	
	T4	24.61	23.70	22.89	22.29	19.79	18.78	22.01	
	T5	10.67	10.96	10.20	10.32	9.00	8.80	9.99	

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 16b: Effect of growth regulator treatment and rootstock on plant height (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	14.65	13.52	12.73	13.63d
T2	17.22	15.58	14.27	15.69c
T3	19.82	17.77	16.37	17.99b
T4	23.58	21.49	18.66	21.24a
T5	10.96	9.70	8.51	9.72e
Mean	17.25a	15.61b	14.11b	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 16c: Effect of growth regulator treatment on plant height (cm) in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	13.69	13.58	13.63d
T2	16.45	14.93	15.69c
T3	18.51	17.46	17.99b
T4	20.47	22.01	21.24a
T5	9.45	9.99	9.72e
Mean	15.71a	15.60a	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Cytokinin involvement in cell division and cell growth leads to increase in plant height. The maximum plant height was also probably due to the better root growth of the cuttings, which helps in the absorption of the nutrients and assimilate them to the upper part of the cuttings which leads to the more plant growth.

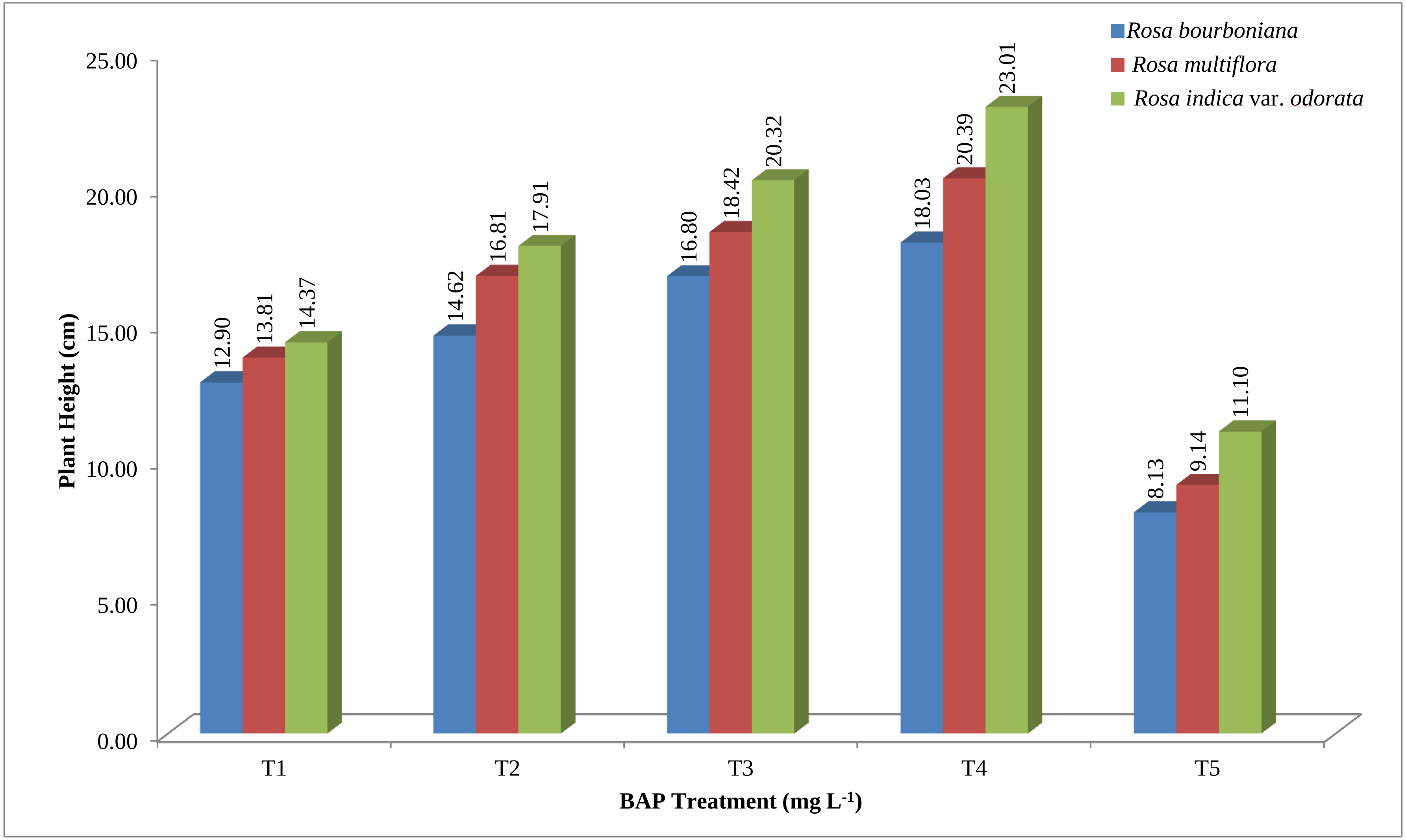

Fig. 25: Effect of growth regulator treatment plant height (cm) in budded cuttings in *Rosa hybrida* L. cv. First Red

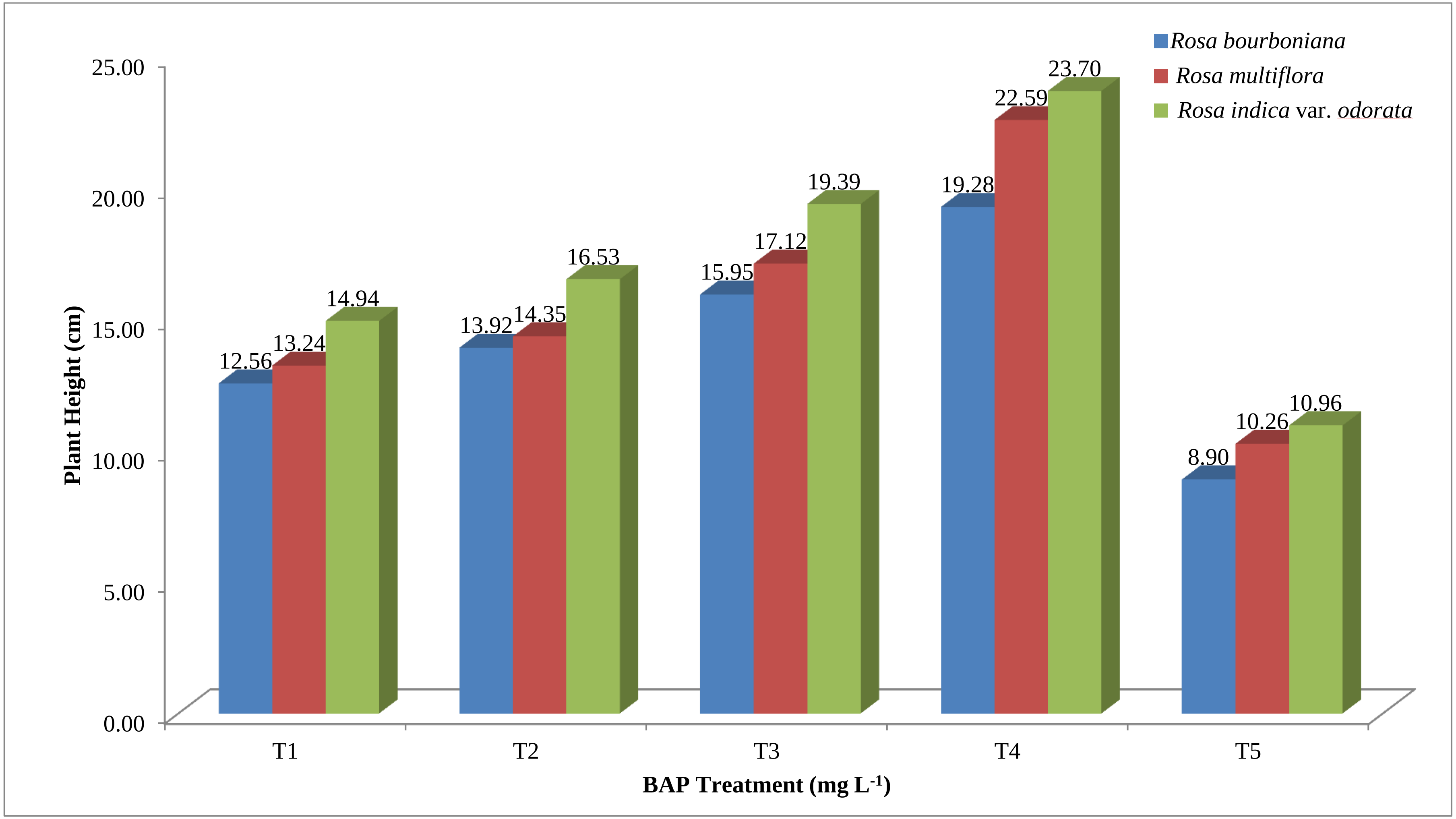

Fig. 26: Effect of growth regulator treatment plant height (cm) in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

In table 16b, among treatments the maximum plant height (21.24 cm) was in treatment T4 (BAP 20mg L^{-1}). On averaging across the years and treatments the maximum plant height (17.25 cm) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum plant height, across the years and treatments was found in *R. bourboniana* (14.11 cm).

In table 16c, on averaging across the years and rootstocks, the maximum plant height (15.71 cm) was observed in the plants of cv. First Red which was at par with plant height of the plants of cv. Grand Gala (15.60 cm). However, on averaging among genotypes, the significantly maximum plant height was 21.24 cm (i.e. 20.47 cm in cv. First Red and 22.01 cm in cv. Grand Gala) in treatment T4 (BAP 20 mg L^{-1}).

4.2.6 Number of branches per plant of *Rosa hybrida* L. cvs. First Red and Grand Gala

In the present studies, it was observed that number of branches per plant significantly varied among the rootstocks and treatments after three months of planting the budded cuttings of cvs. First Red and Grand Gala (Table 17a, 17b, 17c and Fig. 27, 28).

Among the different growth treatments T4 (BAP 20 mg L^{-1}) resulted in the maximum number of branches per plant irrespective of the rootstocks. In cv. First Red the maximum number of branches per plant was 3.53 in T4 (BAP 20 mg L^{-1}) in *R. indica* var. *odorata* (Fig. 27), likewise, the maximum number of branches was 3.45 in 2014-16 and 3.60 in 2015-16 (Table 17a). However, the lowest number of branches per plant (1.00) found in control (T5) in *R. bourboniana* (Fig. 27), similarly, the number of branches per plant was 1.00 in 2014-15 and 2015-16 (Table 17a). Similarly, in cv. Grand Gala, the maximum number of branches per plant was 3.39 in T4 (BAP 20 mg L^{-1}) in *R.indica* var. *odorata* (Fig. 28). Likewise, the maximum number of branches was 3.32 in 2014-15 and 3.47 in 2015-16. Whereas, the minimum number of branches per plant (1.00) found in control (T5) in *R. bourboniana,* likewise, the number of branches per plant was 1.00 in 2014-15 and 2015-16 (Table 17a).

The effect of treatments and rootstocks on number of branches per plant is presented in table 17b. Among treatments the maximum number of branches per plant (3.07) was in treatment T4 (BAP 20 mg L^{-1}). On averaging across the years and treatments the maximum number of branches per plant (2.09) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum number of branches per plant, across the years and treatments was found in *R. bourboniana* (1.61). The number of branches in BAP treated plants may be due to the ability of cytokinin to reducing the apical dominance and producing adventitious shoots in plants.

In table 17c, on averaging across the years and rootstocks, the number of branches per plant (1.88) of cv. First Red was at par with the number of branches per plant of cv. Grand

Table 17a: Effect of growth regulator treatment on number of branches in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica var. odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Grand mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	1.51	1.58	1.39	1.53	1.23	1.30	1.42	1.88a
	T2	1.69	1.76	1.46	1.62	1.32	1.41	1.54	
	T3	2.69	2.72	2.11	2.00	1.87	1.90	2.22	
	T4	3.45	3.60	3.14	3.05	2.76	2.82	3.14	
	T5	1.15	1.18	1.10	1.08	1.00	1.00	1.09	
Grand Gala	T1	1.46	1.53	1.34	1.48	1.18	1.25	1.37	1.79a
	T2	1.59	1.66	1.36	1.52	1.22	1.31	1.44	
	T3	2.53	2.56	1.95	1.84	1.71	1.74	2.06	
	T4	3.32	3.47	3.01	2.92	2.63	2.69	3.01	
	T5	1.12	1.15	1.07	1.05	1.00	1.00	1.07	

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

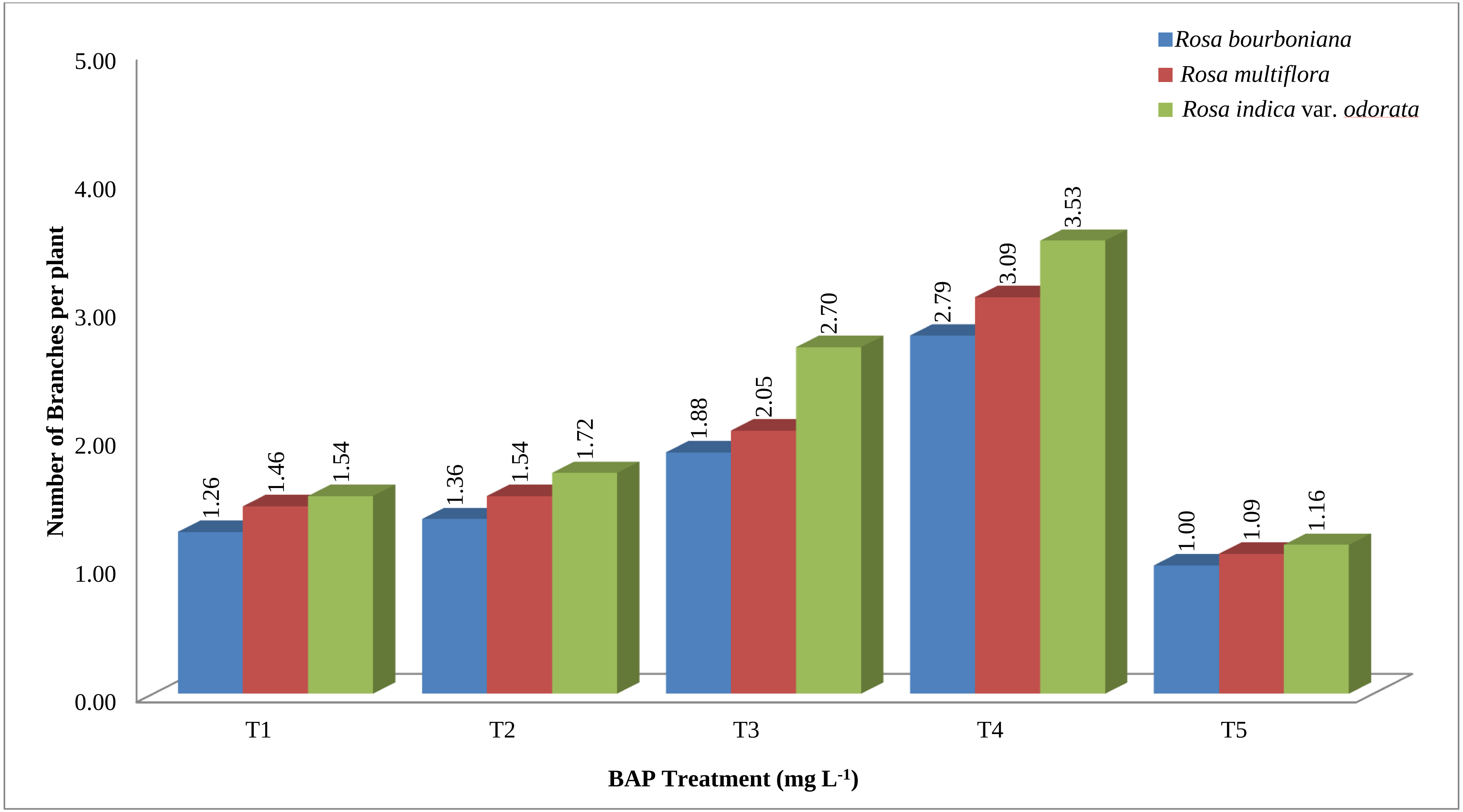

Fig. 27: Effect of growth regulator treatment on number of branches in budded cuttings in *Rosa hybrida* L. cv. First Red

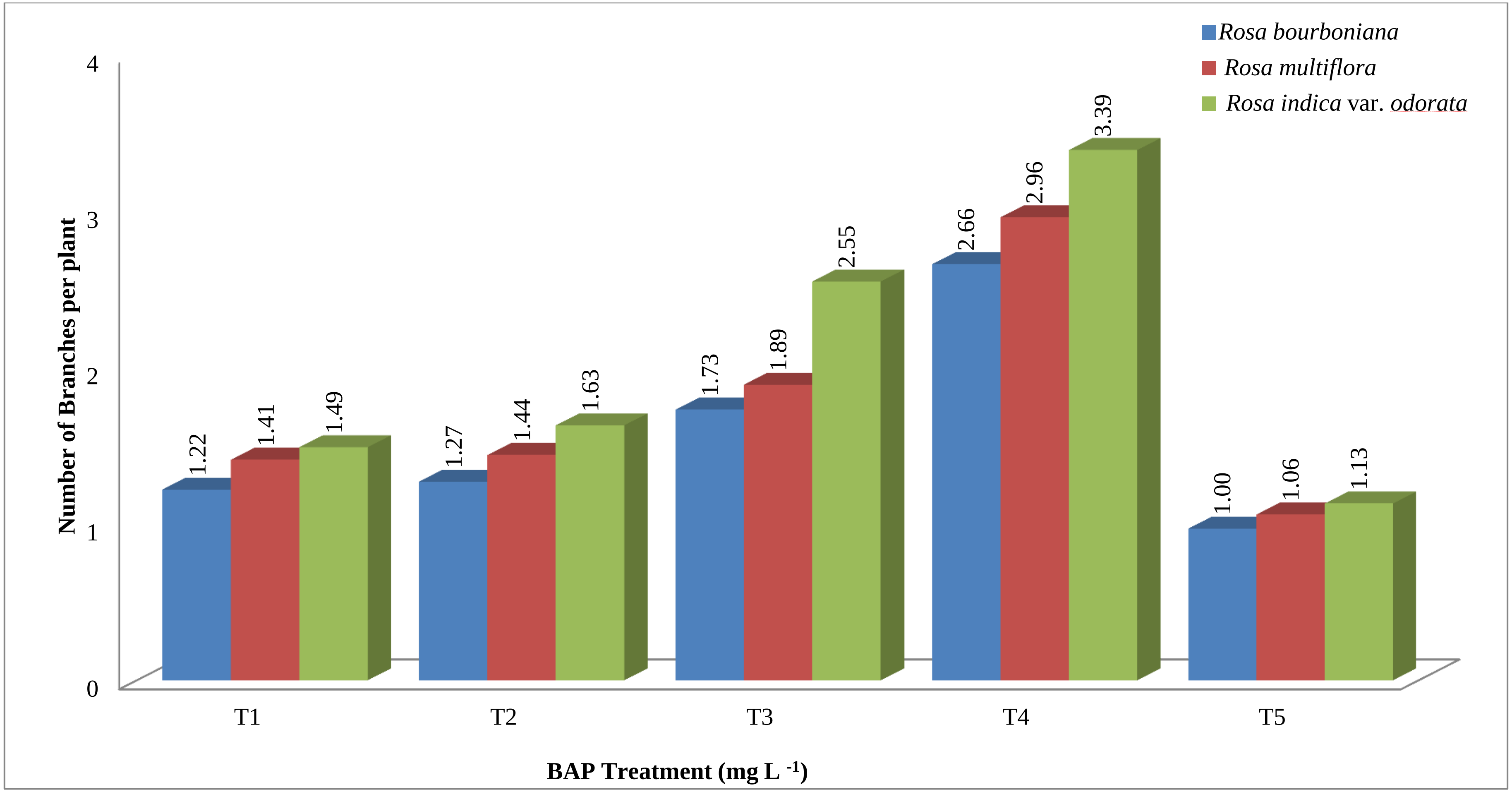

Fig. 28: Effect of growth regulator treatment on number of branches per plat in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 17b: Effect of growth regulator treatment and rootstock on number of branches in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	1.52	1.44	1.24	1.40c
T2	1.68	1.49	1.32	1.49c
T3	2.63	1.98	1.81	2.14b
T4	3.46	3.03	2.73	3.07a
T5	1.15	1.08	0.99	1.07d
Mean	2.09a	1.80b	1.61c	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 17c: Effect of growth regulator treatment on number of branches in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	1.42	1.37	1.40c
T2	1.54	1.44	1.49c
T3	2.22	2.06	2.14b
T4	3.14	3.01	3.07a
T5	1.09	1.06	1.07d
Mean	1.88a	1.79a	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Gala (1.79). However, on averaging among genotypes the number of branches per plants was significantly different among treatments. The maximum number of branches per plant was 3.07 (i.e. 3.14 in cv. First Red and 3.01 in cv. Grand Gala) in treatment T4 (BAP 20 mg L^{-1}).

4.2.7 Number of leaves per plant of plants of *Rosa hybrida* L. cvs. First Red and Grand Gala

In plants leaves are important organ for the photosynthesis, more number of leaves leads to more photosynthates which results to the biomass and flower production in plants. The effect of rootstock and auxin on number of leaves per plant was recorded after three months of planting of budded cuttings of cvs. First Red and Grand Gala (Table 18a, 18b, 18c and Fig. 29, 30).

The BAP treatments showed conspicuous effect on number of leaves per plant than control (Table 18a). In cv. First Red the maximum number of leaves (9.95) recorded in *R. indica* in T4 (BAP 20 mg L^{-1}) which was higher than others (Fig 29). Similarly, the maximum number of leaves was 10.02 in 2014-15 and 9.88 in 2015-16 in treatment T4 (BAP 20 mg L^{-1}). The more number of leaves are due to the more number of branches and height of the plant. The lowest number of leaves per plant was 4.21 in T5 (control) in *R. bourboniana* (Fig 29), similarly, number of leaves per plant was 4.20 in 2014-15 and 4.21 in 2015-16. Similarly, in cv. Grand Gala the maximum number of leaves (11.31) was recorded in *R. indica* var. *odorata* in T4 (BAP 20 mg L^{-1}) which was higher than others (Fig 30). Likewise, the maximum number of leaves was 11.38 in 2014-15 and 11.24 in 2015-16 in treatment T4 (BAP 20 mg L^{-1}). The minimum number of leaves observed in T5 (control) in all rootstocks. The lowest number of leaves per plant was 4.85 in T5 (control) in *R. bourboniana* (Fig 30), similarly number of leaves per plant was 4.85 in 2014-15 and 4.85 in 2015-16 (Table 18a). The more number of leaves are due to the more number of branches and height of the plant. The numerous and vigorous root system leads to the better foliage of the plant. Cytokinin retarded the leaf senescence and this leads to presence of more number of leaves at a particular time.

The treatments and rootstocks have significant effect on number of leaves (Table 18b). Among treatments the maximum number of leaves (9.37) was in treatment T4 (BAP 20 mg L^{-1}). On averaging across the years and treatments the maximum number of leaves (7.91) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum number of leaves per plant, across the years and treatments was found in *R. bourboniana* (6.78).

In *table 18*c, on averaging across the years and rootstocks, the number of leaves per plant of cv. Grand Gala (7.78) was significantly higher than the cv. First Red (6.77). However, on averaging among genotypes the number of leaves per plants was significantly different among treatments. The maximum number of leaves per plant was 9.37 (i.e. 8.69 in cv. First Red and 10.05 in cv. Grand Gala) in treatment T4 (BAP 20 mg L^{-1}).

Table 18a: Effect of growth regulator treatment on number of leaves in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Grand mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	6.26	6.16	5.32	5.33	5.84	5.74	5.78	6.77b
	T2	7.49	7.42	7.47	7.57	6.59	6.42	7.16	
	T3	8.03	7.81	7.58	7.62	7.20	7.13	7.56	
	T4	10.02	9.88	8.34	8.24	7.89	7.78	8.69	
	T5	5.46	5.36	4.30	4.37	4.20	4.21	4.65	
Grand Gala	T1	6.73	6.63	6.31	6.21	5.79	5.80	6.25	7.78a
	T2	8.61	8.54	8.06	8.17	7.71	7.54	8.11	
	T3	9.66	9.44	9.21	9.25	8.83	8.76	9.19	
	T4	11.38	11.24	9.70	9.60	9.25	9.14	10.05	
	T5	6.10	6.00	4.94	5.01	4.85	4.85	5.29	

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

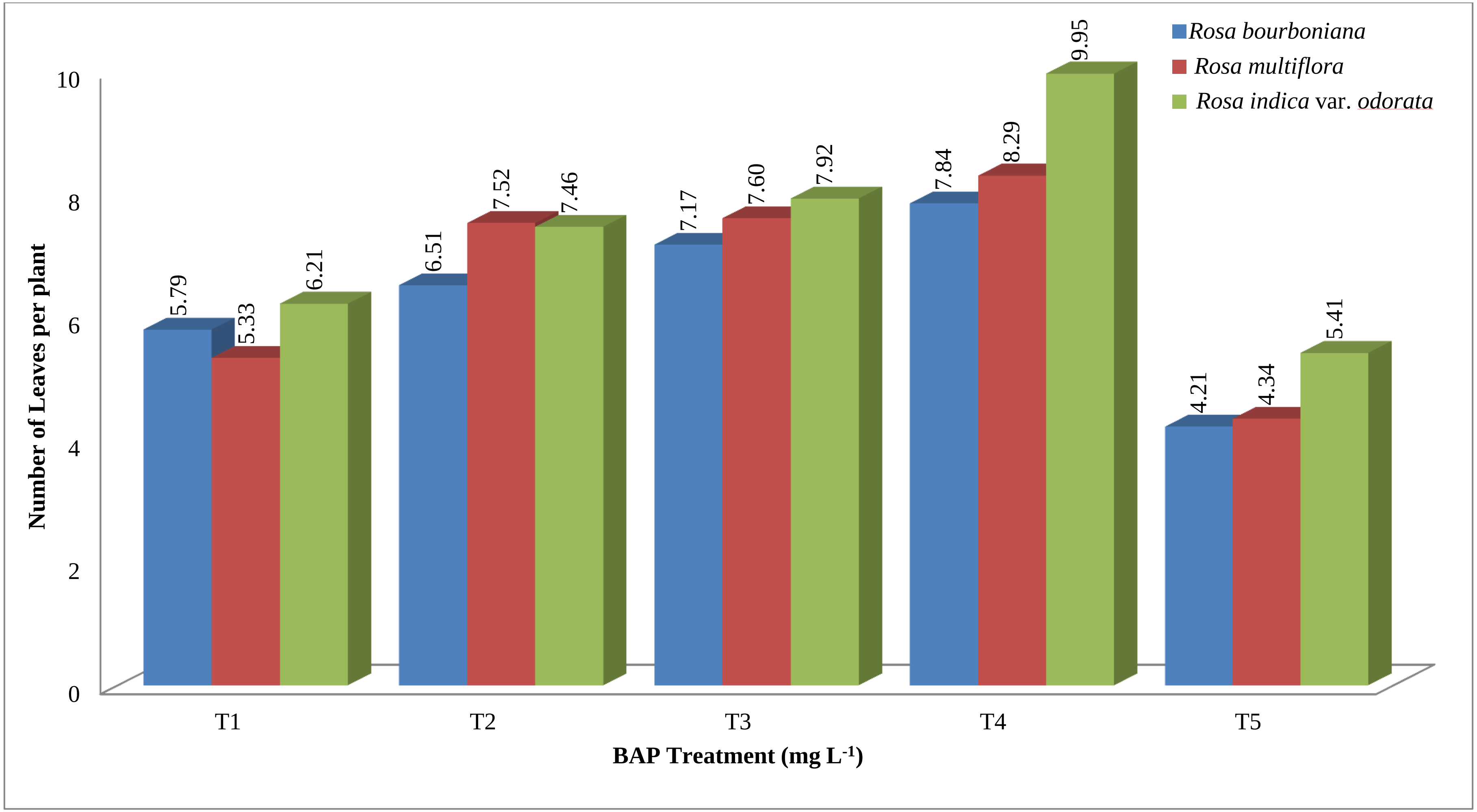

Fig. 29: Effect of growth regulator treatment on number of leaves in budded cuttings in *Rosa hybrida* L. cv. First Red

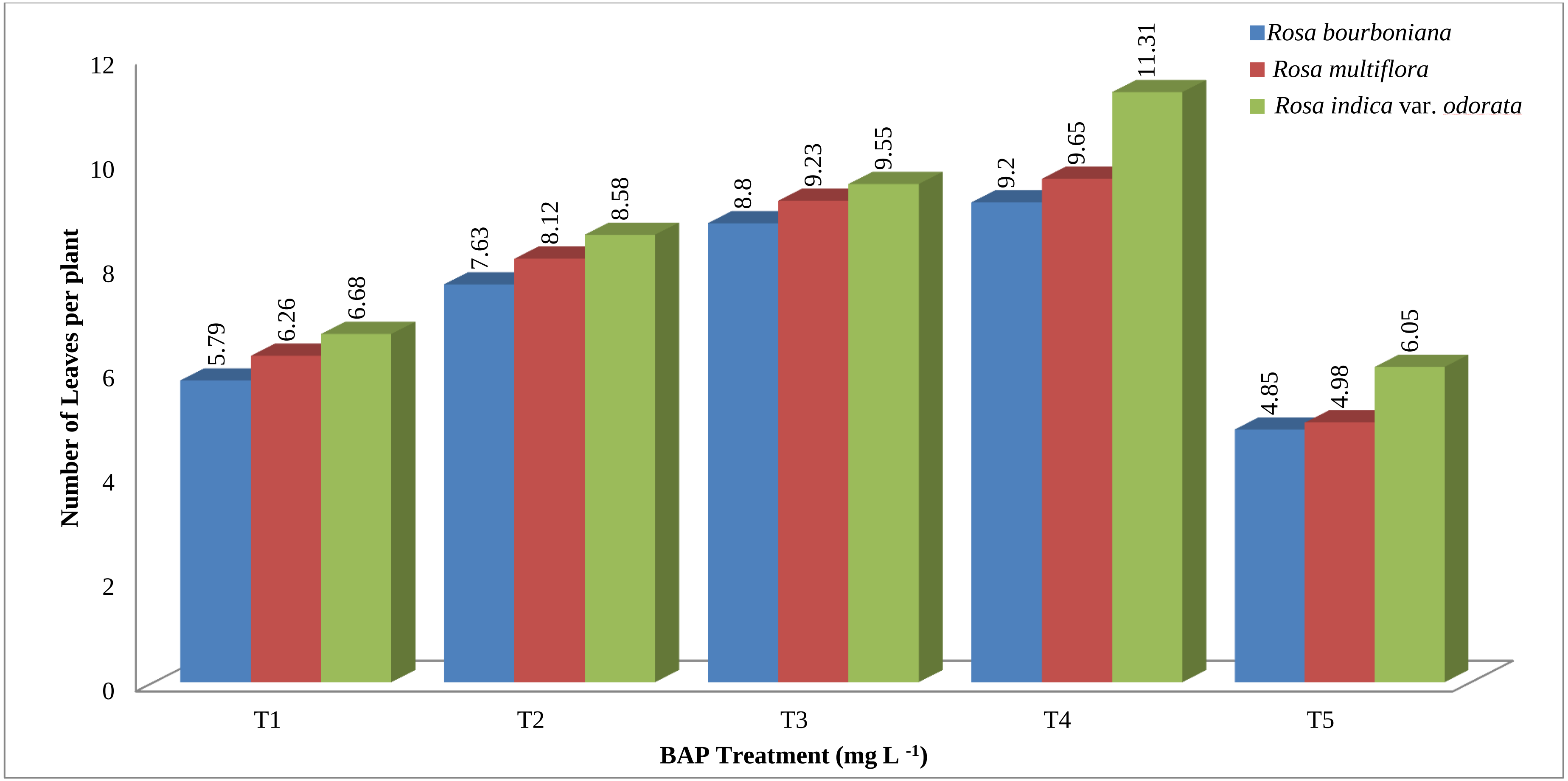

Fig. 30: Effect of growth regulator treatment on number of leaves per plant in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 18b: Effect of growth regulator treatment and rootstock on number of leaves in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	6.45	5.79	5.79	6.01d
T2	8.02	7.82	7.07	7.63c
T3	8.74	8.42	7.98	8.38b
T4	10.63	8.97	8.52	9.37a
T5	5.73	4.66	4.53	4.97e
Mean	7.91a	7.13b	6.78c	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 18c: Effect of growth regulator treatment on number of leaves in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	5.78	6.25	6.01d
T2	7.16	8.11	7.63c
T3	7.56	9.19	8.38b
T4	8.69	10.05	9.37a
T5	4.65	5.29	4.97e
Mean	6.77b	7.78a	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

4.2.8 Number of days to bud emergence of *Rosa hybrida* L. cv. First Red and Grand Gala

The data showed that there was non significant difference between the rootstocks and the treatments for the number of days to bud emergence in cvs. First Red and Grand Gala (Table 19a, 19b and 19c). However, minimum number of days to bud emergence (53.72) was found in cv. First Red. Among the treatments the minimum days to bud emergence were 49.83 in 2014-15 and 51.06 in 2015-16 in T4 (BAP 20 mg L^{-1}) in *R. indica* var. *odorata* (Table 19a).

Table 19a: Effect of growth regulator treatment on Days to flower bud emergence in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Grand mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	55.08	56.43	54.33	55.55	54.33	55.39	55.19	53.72a
	T2	53.00	54.29	50.75	52.61	53.83	55.20	53.28	
	T3	50.58	52.77	51.50	53.78	53.42	55.61	52.94	
	T4	49.83	51.06	49.95	50.98	51.00	52.43	50.88	
	T5	53.08	54.49	55.92	57.74	57.17	59.39	56.30	
Grand gala	T1	56.44	57.79	57.04	58.86	55.96	57.02	57.19	54.78a
	T2	54.20	55.61	52.14	54.42	54.95	56.32	54.61	
	T3	50.47	51.70	51.19	52.34	54.06	56.25	52.67	
	T4	51.05	53.24	51.22	53.08	52.36	53.79	52.46	
	T5	54.63	55.92	55.96	57.18	57.64	59.86	56.87	

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 19b: Effect of growth regulator treatment and rootstock on Days to flower bud emergence in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	56.44	56.45	55.68	56.19a
T2	54.28	52.48	55.08	53.94a
T3	51.38	52.20	54.84	52.81a
T4	51.30	51.31	52.40	51.67a
T5	54.53	56.70	58.52	56.58a
Mean	53.58a	53.83a	55.30a	ns

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 19c: Effect of growth regulator treatment on Days to flower bud emergence in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	55.19	57.19	56.19a
T2	53.28	54.61	53.94a
T3	52.94	52.67	52.81a
T4	50.88	52.46	51.67a
T5	56.30	56.87	56.58a
Mean	53.72a	54.76a	ns

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

In table 19b, the minimum days to bud emergence (53.58) was in *R. indica* var. *odorata* which was at par with *R. multiflora* and *R. bourboniana*. Among treatments the days to bud emergence was significantly lower than T5 (control). On averaging across years, treatments and rootstocks, there was non significant difference among genotypes (Table 19c).

4.2.9 Days taken to full bloom of *Rosa hybrida* L. cvs. First Red and Grand Gala

The days taken to full bloom (Table 20a) have the non significant effect between different IBA treatments in cvs. First Red and Grand Gala. However, minimum number of days to full bloom was 63.91 in cv. First Red and 62.67 in cv. Grand Gala. In table 20b, the days to full bloom were non significant among rootstocks and treatments. On averaging across years, treatments and rootstocks, there was non significant difference among genotypes (Table 20c).

4.2.10 Number of flowers per plant of *Rosa hybrida* L. cv. First Red and Grand Gala

In the present studies, it was observed that number of flowers per plant significantly varied among the rootstocks and treatments after three months of planting the budded cuttings of cvs. First Red and Grand Gala (Table 21a, 21b, 21c and Fig. 31, 32).

Among the different growth treatments T4 (BAP 20 mg L^{-1}) resulted in the maximum number of flowers per plant irrespective of the rootstocks. In cv. First Red the maximum number of flowers per plant was (2.21) was recorded in *R. indica* var. *odorata* (Fig. 31) in T4 (BAP 20 mg L^{-1}), likewise, the maximum number of flowers per plant was 2.22 in 2014-15 and 2.21 in 2015-16 (Table 21a). However, the minimum number of flowers per plant (1.00) found in control (T5) in *R. bourboniana* (Fig. 31), similarly, the number of flowers per plant was 1.00 in 2014-15 and 2015-16 (Table 21a). Similarly, in cv. Grand Gala, the maximum number of flowers per plant was 2.50 in T4 (BAP 20 mg L^{-1}) in *R.indica* var. *odorata* (Fig. 32). Likewise, the maximum number of flowers was 2.36 in 2014-15 and 2.64 in 2015-16. Whereas, the minimum number of flowers per plant (0.94) found in control (T5) in *R. bourboniana* (Fig. 32), likewise, the number of flowers per plant was 0.95 in 2014-15 and 0.92 in 2015-16 (Table 21a).

The effect of treatments and rootstocks on number of flowers per plant is presented in table 21b. Among treatments the maximum number of flowers per plant (2.23) was in treatment T4 (BAP 20 mg L^{-1}). On averaging across the years and treatments the maximum number of flowers per plant (1.58) was observed in rootstock *R. indica* var. *odorata* which was significantly higher than *R. multiflora* and *R. bourboniana*. The minimum number of branches per plant, across the years and treatments was found in *R. bourboniana* (1.30).

In table 21c, on averaging across the years and rootstocks, the number of flowers per plant (1.50) of cv. First Red was significantly higher than the number of flowers per plant of cv. Grand Gala (1.34). However, on averaging among genotypes the number of flowers per

***Table* 20a: Effect of growth regulator treatment on days taken to full bloom in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala**

Genotype	**Treatment/ rootstock**	***Rosa indica* var. *odorata***		***Rosa multiflora***		***Rosa bourboniana***		**Mean**	**Grand mean**
		2014-15	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**		
First Red	T1	62.83	63.96	62.33	63.65	64.00	65.25	63.67	63.91a
	T2	64.08	65.33	62.83	64.72	65.00	66.02	64.66	
	T3	61.33	62.32	60.17	61.20	63.42	65.30	62.29	
	T4	59.58	61.50	60.08	61.75	63.83	64.93	61.95	
	T5	65.08	66.20	65.58	67.18	67.83	69.87	66.96	
Grand gala	T1	62.96	64.84	62.19	59.84	63.37	63.89	62.85	62.67a
	T2	62.19	64.21	59.61	66.06	62.71	63.81	63.10	
	T3	59.70	63.32	60.70	64.08	62.78	64.66	62.54	
	T4	59.11	61.03	58.81	61.28	62.64	63.62	61.08	
	T5	63.72	60.69	64.46	62.02	67.36	64.39	63.77	

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 20b: Effect of growth regulator treatment and rootstock on days taken to full bloom in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	63.65	62.00	64.13	63.26a
T2	63.95	63.31	64.39	63.88a
T3	61.67	61.54	64.04	62.42a
T4	60.31	60.48	63.76	61.51a
T5	63.92	64.81	67.36	65.37a
Mean	62.70a	62.43a	64.73a	ns

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

Table 20c: Effect of growth regulator treatment on days taken to full bloom in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	63.67	62.85	63.26a
T2	64.66	63.10	63.88a
T3	62.29	62.54	62.42a
T4	61.95	61.08	61.51a
T5	66.96	63.77	65.37a
Mean	63.91a	62.67a	ns

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p< 0.05$

***Table* 21a: Effect of growth regulator treatment on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala**

Genotype	Treatment/ rootstock	*Rosa indica* var. *odorata*		*Rosa multiflora*		*Rosa bourboniana*		Mean	Grand mean
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16		
First Red	T1	1.12	1.18	1.05	1.08	1.03	1.05	1.09	1.41a
	T2	1.53	1.46	1.28	1.36	1.13	1.16	1.32	
	T3	1.72	1.80	1.56	1.65	1.27	1.29	1.55	
	T4	2.22	2.21	2.13	2.18	1.92	1.98	2.11	
	T5	1.05	1.00	1.00	1.03	1.00	1.00	1.01	
Grand gala	T1	1.21	1.26	1.13	1.25	1.06	1.14	1.18	1.43a
	T2	1.36	1.44	1.26	1.34	1.11	1.13	1.27	
	T3	1.81	1.93	1.68	1.62	1.48	1.53	1.68	
	T4	2.36	2.64	1.99	1.87	1.61	1.64	2.02	
	T5	1.04	1.06	1.02	1.03	0.92	0.95	1.00	

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

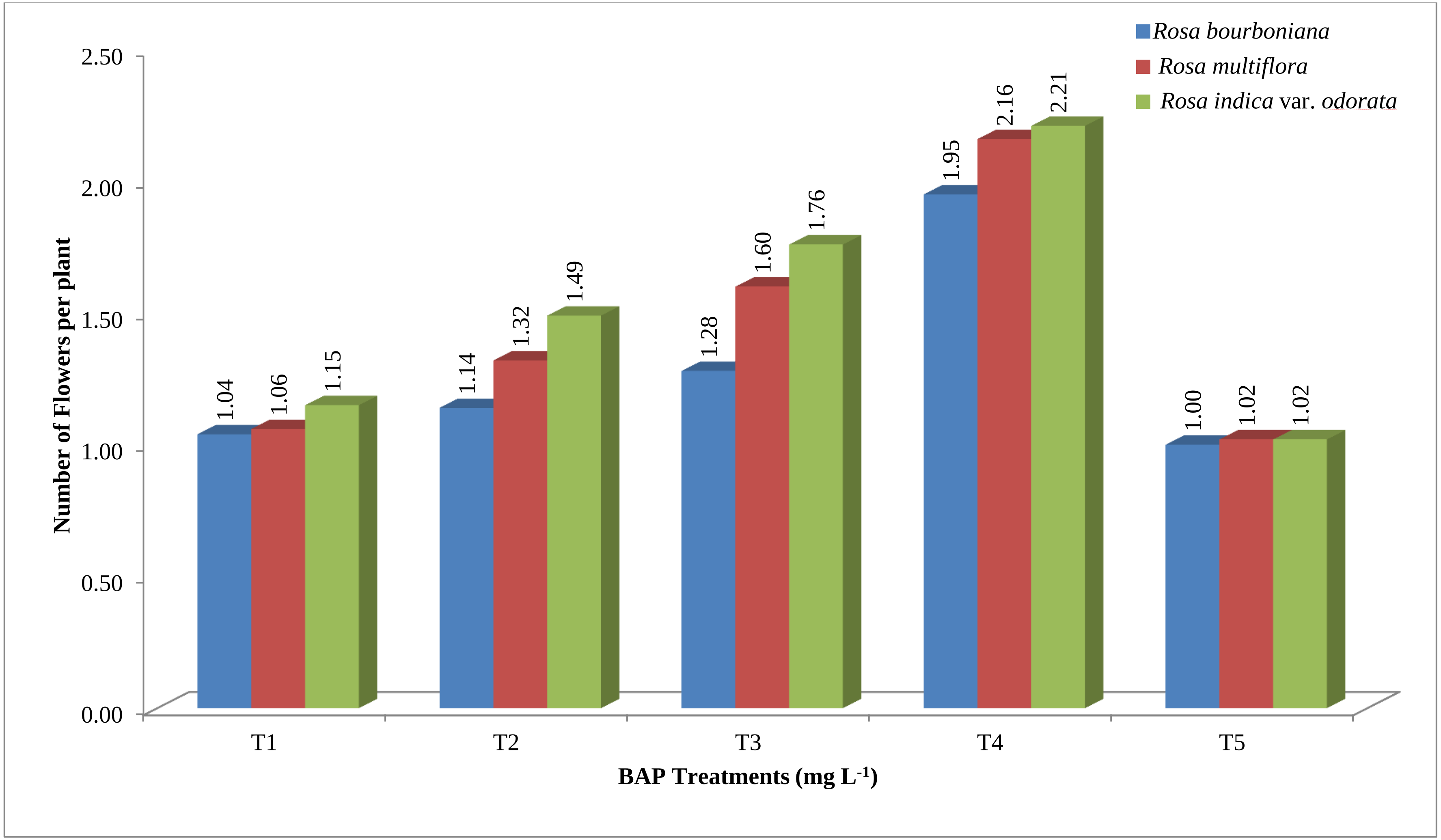

Fig. 31: Effect of growth regulator treatment number of flowers per plant in budded cuttings in *Rosa hybrida* L. cv. First Red

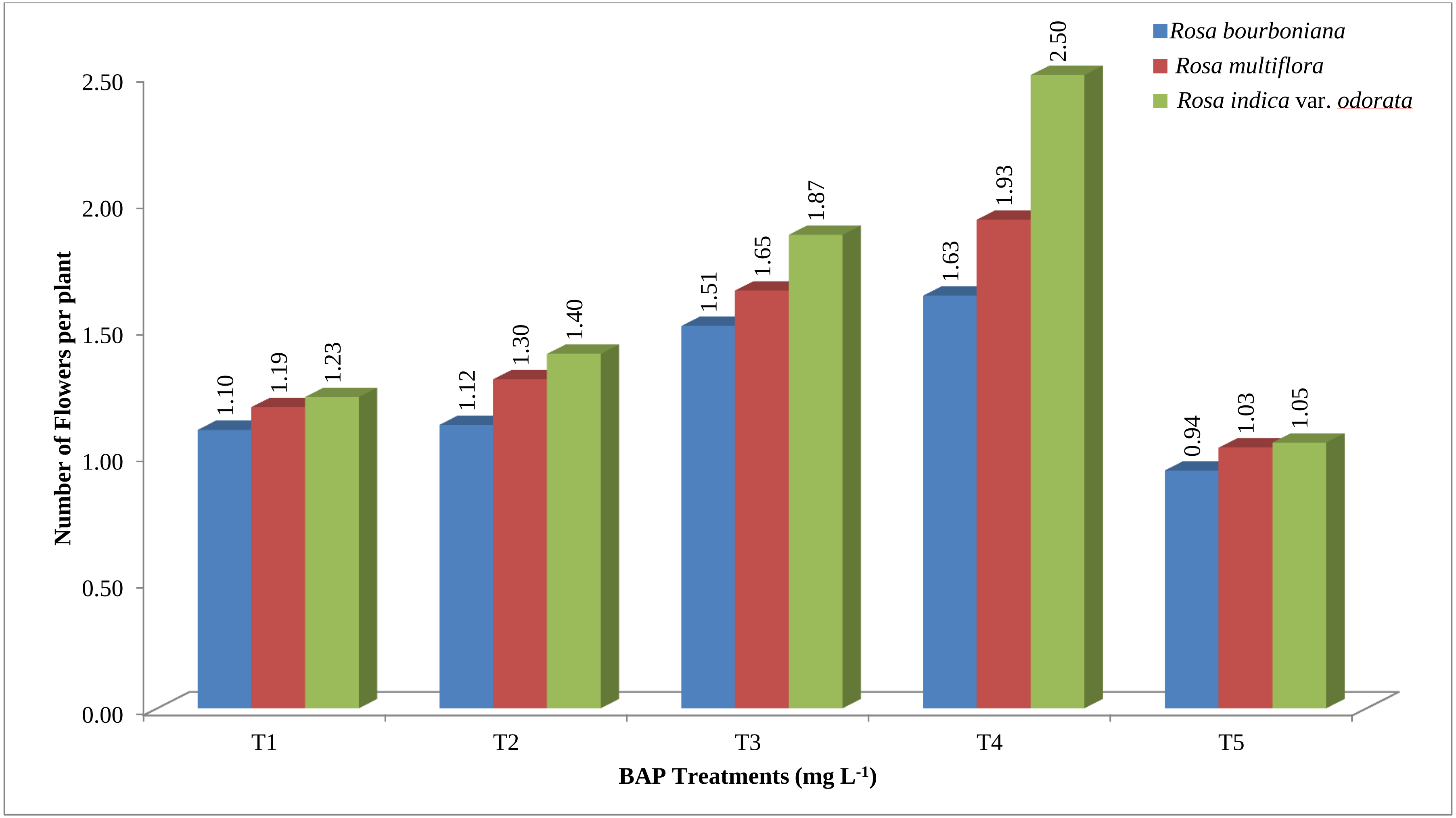

Fig. 32: Effect of growth regulator treatment number of flowers per plant in budded cuttings in *Rosa hybrida* L. cv. Grand Gala

Table 21b: Effect of growth regulator treatment and rootstock on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Rootstock			
	Rosa indica* var. *odorata	***Rosa multiflora***	***Rosa bourboniana***	**Mean**
T1	1.19	1.13	1.07	1.13d
T2	1.45	1.31	1.13	1.30c
T3	1.82	1.63	1.39	1.61b
T4	2.36	2.04	1.79	2.06a
T5	1.04	1.02	0.97	1.01e
Mean	1.57a	1.43b	1.27c	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

Table 21c: Effect of growth regulator treatment on number of flowers per plant in budded cuttings in *Rosa hybrida* L. cvs. First Red and Grand Gala

Treatment	Genotype		
	First Red	**Grand Gala**	**Mean**
T1	1.09	1.18	1.13d
T2	1.32	1.27	1.30c
T3	1.55	1.68	1.61b
T4	2.11	2.02	2.06a
T5	1.01	1.00	1.01e
Mean	1.41a	1.43a	*

T1- BAP 5 mg L-1, T2 - BAP 10 mg L-1, T3 - BAP 15 mg L-1, T4 - BAP 20 mg L-1, Control
Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. ns = non significant *Significant at $p < 0.05$

plants was significantly different among treatments. The maximum number of flowers per plant was 2.23 (i.e. 2.46 in cv. First Red and 2.00 in cv. Grand Gala) in treatment T4 (BAP 20 mg L^{-1}).

The present results are with conformity of the observation of Goujan (1974). He found that cvs. Carina, Lara, Super Star and Zorina produced more flowers per plant on

R.indica var. *major*. Similarly, Malik (1980) reported that rose cv. Sonia produced more number of marketable blooms when budded on *R. indica* var. *odorata* rootstock than own rooted plants. Mukhopadhyay and Bankar (1986) reported that thornless rootstock produced maximum number of flowers followed by *R. multiflora* and *R.indica* var. *odorata*. Dubois *et al* (1990) found that the *R. indica* var. *manetti*, *R. indica* var. *major* and the seedling rootstock *R. multiflora* produced maximum flowers.

CHAPTER V

SUMMARY

The present investigations entitled "Effect of growth regulators on *in vivo* budding in roses (*Rosa hybrida a* L.)" were carried out on the Research Farm, Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana, during 2014-16. The experiments were conducted to study the effect of auxin on the rooting of the budded cuttings and effect of cytokinin on bud take in *Rosa hybrida a* L. in two different cultivars, *viz*. First Red and Grand Gala.

The mature shoots (>1 yr old) of rootstocks, *viz*. *R.indica* var. *odorata* , *R. multiflora* and *R. bourboniana* were used for making the stem cuttings. The rootstock cuttings (8-9 inches long, pencil thickness) were treated with different concentrations of IBA for rooting as per the experiment and budded with the scion of rose cvs. First Red and Grand Gala in December- February. The plants of two commercial cultivars were pruned in end September to mid October and cut ends were pasted with Blitox paste to control the incidence of die back disease on the pruned shoots (canes). The plants were fertilized with decomposed FYM and recommended doses of fertilizers. The scion was taken from healthy shoots of the rose plants for T- budding on different rootstocks cuttings.

In the present studies, the rootstocks significantly varied with respect to plant growth and flowering of the rose plants in both the cultivars (First Red and Grand Gala). The per cent sprouting, survival, shoot length, plant height, number of leaves and flowers per plant were observed the highest in rootstock *R.indica* var. *odorata* , whereas, per cent rooting and number of branches were at par in *R.indica* var. *odorata* and *R. multiflora.* The days taken to flower bud emergence and full bloom has not shown any significant difference among these three rootstocks in both varieties.

The growth regulator treatments significantly affected the plant growth and flowering of the rose plants in both the cultivars (First Red and Grand Gala). The per cent sprouting, rooting, survival, shoot length, plant height, number of branches, leaves and flowers per plant increased significantly with the different growth regulator concentrations, whereas, the days taken to flower bud emergence and full bloom has not shown any significant difference among all the treatments of growth regulators in both varieties.

The plant growth and flowering of cvs. First Red and Grand Gala significantly differ with each others with IBA treatments. The per cent sprouting (58.89), rooting (75.33), survival (47.22) and flowers per plant (1.50) significantly higher in First Red than Grand Gala. shoot length (8.70 cm), plant height (13.18 cm) and number of leaves plant (7.39) significantly higher in Grand Gala than First Red. The number of branches, days to bud emergence and days to full bloom were non significant among genotypes. The per cent sprouting (63.78) was significantly higher in First Red than Grand Gala whereas, shoot length (10.55 cm) was higher in Grand Gala and First Red with BAP treatments. The per cent rooting, survival, plant height, Shoot length, Number of leaves and flowers per plant, number of branches, days to bud emergence and days to full bloom were non significant among genotypes.

The IBA treatment T4 (2000 mg L^{-1}) found best regarding per cent sprouting (85.00, 81.67), rooting of cuttings (91.67, 96.67), survival (68.34, 65.00), shoot length (13.64 cm, 16.29 cm), plant height (20.60, 20.66 cm), number of branches (3.20, 2.84), leaves (9.61, 10.94) and flowers per plant (3.08, 2.07) in cultivars First Red and Grand Gala, respectively.

The treatment with BAP significantly affect the plant growth and flowering of the both the rose cultivars First Red and Grand Gala. The per cent sprouting, survival, shoot length, plant height, number of branches, leaves and flowers per plant increased significantly with the different BAP concentrations. The best BAP treatment for per cent sprouting (91.66, 88.34), survival (86.67, 86.67), shoot length (15.01 cm, 17.94 cm), plant height (23.01 cm, 24.15 cm), number of branches (3.53, 3.39), leaves (9.95, 11.31) and flowers per plant (2.21, 2.50) was in treatment T4 (BAP 20 mg L^{-1}) in cultivars First Red and Grand Gala, respectively.

It was concluded that the rootstock *R.indica* var. *odorata* performed better for First Red and Grand Gala among the different rootstocks tested. The auxin and cytokinin improved the vegetative growth and flowering of the rose plants. The treatment of cuttings with IBA @ 2000 mg L^{-1} and scion bud with BAP @ 20 mg L^{-1} were the best for the plant growth and flowering of cv. First Red and Grand Gala budded on *R.indica* var. *odorata* rootstock.

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