

Standardization of pomegranate (*Punica granatum* L.) propagation by cuttings

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(2017-H-157-M)



Division of Fruit Science
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Technology of Kashmir**

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**Standardization of pomegranate (*Punica granatum* L.)
propagation by cuttings**

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Thesis

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2019



*Dedicated
To My Beloved
Parents, Brother
& Teachers*

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Horticulture, Division of Fruit Science

Certificate – I

This is to certify that the thesis entitled “**Standardization of pomegranate (*Punica granatum* L.) propagation by cuttings**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Fruit Science)** to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir**, is a record of bona fide research work carried out by **G Sivakoteswara Rao (Regd. No. 2017-H-157-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

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ABSTRACT

The experiment entitled “**Standardization of pomegranate (*Punica granatum* L.) propagation by cuttings**” was undertaken to ascertain the cultivars with respect to rooting and shooting parameters in pomegranate cuttings when treated with IBA at 0, 2000, 3000, 4000 and 5000 ppm concentrations. Among all the cultivars, maximum values in terms of percentage of rooted cuttings (47.66 and 47.19), survival percentage (80.21 and 80.03) and number of roots per cutting (18.98 and 18.90) were recorded in the cvs. Chawla and Nabha, respectively. However, the maximum number of shoots (2.88 and 2.63), leaves (30.30 and 26.47), leaf area (25.56 and 24.95 cm²) and chlorophyll per cutting (30.16 and 28.32) were recorded in the cvs. Kandhari Kabuli and Nabha, respectively as compared to control. Of all the concentrations of plant growth regulators used, IBA @ 5000 ppm recorded minimum number of days for sprouting, maximum values of root and shoot parameters at 90 DAP followed by 4000 ppm & the minimum values were reported with control.

The interaction of cultivar and growth regulator significantly affected root and shoot parameters. Among all the cultivars early sprouting of cuttings (7.46 and 7.82 days) was observed in cv. Chawla when treated with IBA @ 5000 and 4000 ppm, respectively. Highest percentage of rooted cuttings (62.24 and 59.86) were observed with IBA @ 5000 ppm in cvs. Chawla and Nabha, respectively. Highest survival percentage of rooted cuttings (87.75 and 86.43) were observed in cv. Chawla treated with IBA @ 5000 and 4000 ppm, respectively. Number of roots per cutting (24.97 and 23.80), were recorded significantly maximum with

5000 ppm of IBA in the cvs. Chawla and Nabha, respectively. Number of shoots (4.13 and 3.7), leaf area (34.05 and 29.24 cm²) and chlorophyll per cutting (34.86 and 32.90) were recorded significantly maximum values in the cvs. Kandhari Kabuli and Nabha, respectively with IBA @ 5000 ppm as compared to control. Length of longest root (19.68 and 15.31 cm) were observed in cv. Nabha treated with 5000 and 4000 ppm IBA, respectively. In almost all the root and shoot parameters IBA@ 5000 ppm performed better followed by 4000 and 3000 ppm and least was reported in control. Among the varieties cvs. Chawla, Nabha and Kandhari Kabuli performed better in almost all root and shoot parameters followed by cvs. Ichakdana, Bhagwa, Arakta, Muskat, Mridula, P- 23 and Jodhpur Red. The results showed that cvs. Chawla, Nabha and Kandhari Kabuli were found to be the best suited for propagation under temperate conditions.

Key words: Pomegranate, Propagation, IBA, Root and Shoot parameters.

Signature of Student

Dated : _____

Signature of Major Advisor

Dated: _____

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LIST OF SYMBOLS AND ABBREVIATIONS

% : per cent

@	:	at the rate of
0 ^c	:	degree Centigrade
C.D	:	Critical difference
Cm	:	centimetre
cm ²	:	square centimetre
cv.	:	cultivar
cvs.	:	cultivars
<i>et al.</i>	:	and others
FYM	:	Farm Yard Manure
G	:	gram
g L ¹	:	gram per litre
h	:	Hour
i.e.	:	that is
IAA	:	1-naphthaleneacetic acid
IBA	:	Indole-3-butyric acid
ml	:	millilitre
NS	:	non significant
NAA	:	indole-3-acetic acid
NH ₄ OH	:	ammonium hydroxide
PGPR	:	Plant Growth Promoting Rhizobacteria
PHB	:	p-hydroxybenzoic acid
ppm	:	parts per million
PSB	:	Phosphate solubilizing bacteria
RCBD	:	Randomised Complete Block Design
RHRS	:	Regional Horticultural Research Station
SKUAST- K	:	Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir
SPAD	:	Soil Plant Analysis Development
Viz;	:	namely

Chapter-1

INTRODUCTION

Pomegranate (*Punica granatum* L.) is the member of family Punicaceae and is native from Iran to the Himalayas in Northern India, cultivated and naturalized over the whole Mediterranean region since ancient times (Facciola, 1990). It grows wild in Western Himalayan regions that include states like Himachal Pradesh, Jammu and Kashmir and Uttarakhand (Pandey *et al.*, 2008). Pomegranate could be propagated either sexually by seeds or vegetatively using stem cuttings (softwood, semi- hardwood and hardwood) and sometimes as layers or suckers or by grafting Hartmann *et al.* (1997); Melgarejo *et al.* (2008); Polat and Caliskan (2009).

Plants produced from seed exhibit different characteristics than the parent plants and desirable traits may be lost or undesirable ones acquired from parent to offspring and seeds germinate easily without going through a rest period, but trees are not grown commercially from seed germination because seedlings do not come true to type (Hartmann *et al.*, 1997). Grafting and layering of pomegranate trees are rarely done because many different types of grafts have not been successful enough for use in commercial production. Tissue culture is another method of production that calls for the growth of the plant in a sterile environment using the tissue, seed or cuttings (Abdelrahman and Al-Wasel, 1999).

Vegetative propagation by cuttings is the most commercial, convenient and cheap method to get true to type plants. In order to reduce the high mortality of rooted cuttings under field conditions, it is highly desirable to build a healthy and well developed root system for enabling better field establishment of pomegranate trees through the use of suitable plant growth regulators treatment.

Propagation from cuttings (cloning) produces a plant with the same characteristics as the parent and thus maintains desirable traits. Cutting is undoubtedly, the main method used for the pomegranate tree propagation

(Melgarejo *et al.*, 2008; Saroj *et al.*, 2008; Polat and Caliskan, 2009). The rooting of cuttings is affected by internal factors like genetic material, stored nutrition, hormones in the stems and external factors like pruning, fertilization, irrigation, stem cutting time, hormone application, whose lack can limit the process. Cuttings are the easiest and most satisfactory method of pomegranate propagation with 15-20 cm in length and pencil size or larger in diameter and use of semi-hardwood or hardwood cuttings with rooting hormone. (Melgarejo *et al.*, 2008; Saroj *et al.*, 2008; Polat and Caliskan, 2009).

Rooting ability depends on the genetic characteristics of a plant (De-Klerk and Brugge, 1992), environmental conditions (Levitt, 1980, Moe and Anderson, 1988) and the exogenous and endogenous supply of biochemical constituents. Biochemical constituents present in cuttings play an important role during their rooting process by acting as a reserve energy source. Many experiments have indicated that carbohydrates, phenolics and proteins were critical for the rooting process in cuttings. Knowledge of the biochemical and morphological events associated with root induction and formation may lead to improvement in rooting procedures, which could limit losses, particularly towards the final stages of production.

Pomegranate cuttings often induced roots without exogenous auxin treatment (Melgarejo *et al.*, 2008; Saroj *et al.*, 2008; Polat and Caliskan, 2009). Few studies have investigated the effect of exogenous auxin on rooting capacity and reported that application of exogenous auxins to the cuttings increased the percentage of cuttings that rooted up to three-fold (Melgarejo *et al.*, 2008; Saroj *et al.*, 2008; Polat and Caliskan, 2009).

Various types of growth regulators such as auxins, cytokinins, inhibitors and ethylene influence the root initiation. Among these auxins have the greatest effect on root formation in cuttings. IBA is a plant hormone in the auxin family and is an ingredient in many commercial horticultural plant rooting products (Kaur and Kaur, 2016). It is to be noticed that the optimum concentration of

growth regulators used and biochemical constituents of mother cuttings would help in rapid multiplication of pomegranate cuttings.

Traditionally, pome and stone fruits are major crops of temperate ecosystem. With the changing scenario of climatic conditions, pomegranate is becoming an alternative fruit crop for temperate region. In spite of various pomegranate cultivars grown in different regions of India, there is no known cultivar for mild to high temperate conditions (Shukla *et al.*, 2016).

Since all the pomegranate cultivars were not performing equally well under temperate ecosystem with respect to yield and quality attributes due to extremes of low temperature (Verma *et al.*, 2013). The pomegranate varieties show differential response in rooting due to the physiological conditions of the parent plant, cutting type, planting time, medium type and rooting hormone (Polat and Caliskan, 2009). Keeping in view the present investigation was carried out to assess the performance of different varieties and to select the suitable varieties for commercial propagation under temperate ecosystem.

Pomegranate crop possess drought hardiness and offers immense potential to grow under marginal lands (Verma *et al.*, 2013). Its cultivation help in diversification of horticulture as the crop is suited to high density plantation (Kumar and Rana, 2014). The fruit is now gaining importance in temperate regions due to its hardy nature and capacity to tolerate drought, frost and alkaline conditions.

The aim of this work is to study the rooting capacity of different pomegranate varieties collected from RHRS- Bajaura (Himachal Pradesh) taking into account certain factors which influence root formation in cuttings of this species. In particular, tests will be carried out with IBA application using pomegranate cuttings as a factor influencing the rooting potential of different pomegranate varieties. Moreover, this study will show propagation possibilities

and output for some interesting varieties that could adapt the environmental conditions of Kashmir valley with the following specific objectives.

Objectives

1. To determine the optimum levels of IBA to induce rooting in cuttings of selected varieties of pomegranate.
2. To determine the best variety suited for rooting of cuttings under temperate conditions of Kashmir.

Chapter-2

REVIEW OF LITERATURE

Propagation is one of the most important aspect of horticulture. Commercially, quite a few fruit crop species are propagated primarily from seeds and are often of poor quality. The importance of vegetative propagation in preserving the identity of a cultivar or a clone is well recognized. Several attempts were made to propagate fruit plants by grafting, air layering, suckers and cuttings. This is also true for pomegranate in which several variations have been found and some of them are worth multiplying.

The art of propagation by cuttings is the most preferable technique popular in the field of horticulture including pomegranate. In cuttings, growth substances applied exogenously are found to enhance early and good root formation. Various classes of growth regulators such as auxins, cytokinins, gibberellins and ethylene influence root initiation in cuttings. Of these, auxins have a greater effect on root formation in cuttings. In horticulture, auxins, especially NAA and IBA, are commonly applied to stimulate root initiation in cuttings of plants.

In nature, some plants root very easily whenever they get ideal conditions for rooting. However, plant species vary widely in their response in this respect. Some species, if cut into pieces, each piece behaves as a separate entity, survives and grows satisfactorily. Others, even with utmost care, regenerate very slowly. Pomegranate is considered as a difficult-to-root plant if propagated by cuttings (Naglot, 1987). However, it has now become possible to improve the percentage of success, reduction in total period required and better rooting in a difficult to root species like pomegranate by exploring the techniques such as use of different types of cuttings, pretreatments such as wounding and non wounding and appropriate growth regulators (Naglot, 1987).

2.1 Effect of IBA on rooting and shooting parameters

2.1.1 Percentage of rooted cuttings (%)

Stem cuttings of pomegranate cv. Ganesh treated with IBA solution of different concentration i.e. 500 ppm, 1000 ppm, 1500 ppm and control by quick dip method, the maximum percentage of rooted cuttings (69.14%) was noticed with 500 ppm concentration of IBA (Kumar *et al.*, 2017).

Seiar (2017) treated the semi-hardwood cuttings of pomegranate (*Punica granatum* L.) cv. Bhagwa with a combination of different concentrations (500, 1000 or 1500 ppm) of indole-3-butyric acid (IBA) and (500, 1000 or 1500 ppm) naphthalene acetic acid (NAA) for 8 hours and reported that the highest rooting percentage (60.40) was recorded in cuttings treated with IBA 1500 ppm + NAA 1500 ppm.

Singh (2014) in an experiment treated the stem cuttings of pomegranate (*Punica granatum* L.) cv. Ganesh with IBA solutions of different concentrations i.e. 1, 2, 3, 4 and 5 g L⁻¹ and control by quick dip method. Among all the treatments, the highest percentage of rooted cuttings i.e. (73.33) was observed in 5 g L⁻¹ concentration of IBA.

Shukla *et al.* (2004) studied the effect of IBA (0, 50, 100, 200 and 400 ppm for 24 h) on rooting of pomegranate (cv. Ganesh, Dholka and Kandhari) hardwood cuttings and found that cv. Dholka treated with 100 ppm IBA gave the highest percentage of the rooted cuttings (83.96%).

Prasad and Singh (2003) studied the effect of different IBA concentrations (0, 100, 200, 300 and 400 ppm) on the rooting of semi-hardwood cuttings in pomegranate cv. Jalore Seedless. The percentage of rooted cuttings was highest at 200 ppm i.e. 78.8%, compared to 30.2% in case of control.

Hore and Sen (1995) treated the cuttings of cultivar Bedana of pomegranate with IBA @ 2500, 5000 and 10000 ppm, P-hydroxybenzoic acid 1000 ppm, ferulic acid 1000 ppm, ethep 1000 ppm either alone or together with

IBA. The cuttings gave maximum rooting of 82.77, 94.26 and 74.36 per cent respectively with 1000 ppm PHB + 10000 ppm IBA treatment in all the 3 months (May, July and August)

Dhillon and Sharma (1992) studied the effect of IBA, using low concentrations @ 50, 100 and 200 ppm (dipped for 24 hours) and high concentration @ 500, 1000 and 2000 ppm (quick dip for one minute) on rooting of hardwood cuttings in Ganesh and Assam local cultivars of pomegranate. Highest rooting of cuttings (92 and 78 per cent) was observed in Ganesh and Assam local cultivars respectively with IBA 100 ppm treatment.

2.1.2 Survival percentage of rooted cuttings (%)

Kaur and Kaur (2016) studied the effect of IBA and PHB (p-hydroxybenzoic acid) on rooting of pomegranate (*Punica granatum* L.) cv. Ganesh cuttings, in which six treatments were used comprising of IBA (500 ppm and 1000 ppm) and PHB (500 ppm and 750 ppm), their combinations IBA 500 ppm + PHB 500 ppm and IBA 1000 ppm + PHB 750 ppm along with control. The results of the investigation indicated that IBA 1000 ppm + PHB 750 ppm proved to be the best in terms of maximum survival percentage (86.73%).

Sharma *et al.* (2009) studied the effect of different concentrations of IBA, NAA alone and their combinations and use of borax to induce rooting of both semi-hardwood and hardwood cuttings of pomegranate cv. Ganesh. Cent per cent survival percentage of the rooted cuttings under field plantation when of pomegranate cv. Ganesh was treated with IBA 500 ppm + Borax 1%, IBA 300 ppm + Borax 2% and IBA 5000 ppm.

Hardwood cuttings of pomegranate were given quick dip treatment in IBA (1000, 2000, 3000 and 4000 ppm), NAA (100, 200, 300 and 400 ppm), their combinations (NAA 100 ppm + IBA 1000 ppm, NAA 100 ppm + IBA 2000 ppm, NAA 200 ppm + IBA 1000 ppm, NAA 200 ppm + IBA 2000 ppm). Cuttings treated with IBA 2000 ppm gave highest survival of percentage cuttings i.e.

81.33% followed by 76.85% in NAA 100 ppm + IBA 2000 ppm (Upadhyay and Badyal, 2007).

Shukla *et al.* (2004) studied the effect of IBA (0, 50, 100, 200 and 400 ppm for 24 h) on rooting of pomegranate (cultivars Ganesh, Dholka and Kandhari) hardwood cuttings. The highest survival percentage of cuttings was observed in Dholka treated with 200 ppm IBA.

Deol and Uppal (1990) investigated hardwood and semi-hardwood cuttings of pomegranate planted in 8 types of rooting media (soil, soil + FYM, soil + sand, soil + sawdust, soil + FYM + sand, soil + FYM + sawdust and soil + FYM + sand + sawdust or river silt). Among different rooting media highest survival percentage i.e. (64.99) was obtained with cuttings planted in river silt.

2.1.3 Number of roots per cutting

Kabir *et al.* (2017) carried out an experiment to explore rooting performance of pomegranate (Dalim) in Bangladesh through clonal propagation by stem cutting under 3 different doses of rooting hormone IBA (Indole Butyric Acid). The treatments were (T0 = control, T1 = 0.2% IBA, T2 = 0.4% IBA, T3 = 0.8% IBA). The rooting ability of cuttings was significantly influenced by the application of IBA and the highest root number (32) was recorded with 0.4% IBA.

Hardwood cuttings of pomegranate cv. Ganesh treated with IBA 1000 ppm + PHB 750 ppm, IBA 500 ppm + PHB 500 ppm and 1000 ppm IBA. Among these treatments, highest number of roots per cutting (18.58) was recorded with IBA 1000 ppm + PHB 750 ppm followed by (16.16) with IBA 500 ppm + PHB 500 ppm. (Kaur and Kaur, 2016).

Sharma *et al.* (2009) studied the effect of different concentrations of IBA, NAA alone and their combinations and use of borax to induce rhizogenesis in semi-hardwood and hardwood cuttings of pomegranate cv. Ganesh. Dipping the cuttings (semi-hardwood and hardwood) in IBA 500 ppm + Borax 1% resulted in maximum root number 16.47 and 27.12 respectively.

Hardwood cuttings of pomegranate were given quick dip treatment of IBA (1000, 2000, 3000 and 4000 ppm), NAA (100, 200, 300 and 400 ppm), their combinations (NAA 100 ppm + IBA 1000 ppm, NAA 100 ppm + IBA 2000 ppm, NAA 200 ppm + IBA 1000 ppm, NAA 200 ppm + IBA 2000 ppm). Cuttings treated with IBA 2000 ppm had a maximum number of primary roots (13.23) followed by NAA 100 ppm + IBA 2000 ppm treatment (12.30) under Palampur condition (Upadhyay and Badyal, 2007).

Shukla *et al.* (2004) studied the effect of IBA (0, 50, 100, 200 and 400 ppm for 24 h) on rooting of hardwood cuttings of pomegranate (cv. Ganesh, Dholka and Kandhari). Among these cultivars, Dholka treated with 100 ppm IBA gave the highest number of roots per cutting (32.00).

Navjot and Kahlon (2002) investigated the effect of cutting type (basal, middle and sub-apical portion of the shoots) and IBA concentrations (0, 50, 100 and 200 ppm) on the rooting and growth of pomegranate cv. Kandhari. Middle cuttings treated with 100 ppm IBA results in highest number of root per cutting (32.72).

2.1.4 Average root length (cm)

Singh (2014) conducted an experiment in which the stem cuttings of pomegranate (*Punica granatum* L.) cv. Ganesh was treated with IBA solutions of different concentrations i.e. 1, 2, 3, 4 and 5 g L⁻¹ and control by quick dip method. It was observed that among all the treatments, the maximum average length of roots (24.88 cm) was with 5 g L⁻¹ concentration of IBA.

Navjot and Kahlon (2002) studied the effect of cutting type (basal, middle and sub-apical portion of the shoots) and IBA concentrations (0, 50, 100 and 200 ppm) on the rooting and growth of pomegranate cv. Kandhari. Among all treatments middle cuttings treated with 100 ppm of IBA resulted in highest average of root length (34.00 cm).

2.1.5 Length of longest root per cutting (cm)

Stem cuttings of pomegranate cv. Ganesh treated with IBA solution of different concentrations i.e. 500 ppm, 1000 ppm, 1500 ppm and control by quick dip method. Among all the treatments longest root per cutting (27.88 cm) was noticed with 500 ppm of IBA (Kumar *et al.*, 2017).

Kabir *et al.* (2017) carried out an experiment to explore rooting performance of *Punica granatum* (Dalim) with different doses of rooting hormone IBA (Indole-3-butyric acid). Longest root length (11.75 cm) was obtained from the cuttings treated with 0.2% IBA followed by (7.95 cm) 0.4% IBA.

Seiar (2017) treated the semi-hardwood cuttings of pomegranate cv. Bhagwa with a different concentrations of IBA (500, 1000 or 1500 ppm) and NAA (500, 1000 or 1500 ppm) and their combinations for 8 hours and concluded that longest root length (18.9 cm) was obtained with IBA 1500 ppm + NAA 1500 ppm.

Kaur and Kaur (2016) studied the effect of IBA and PHB (p-hydroxybenzoic acid) on rooting of pomegranate (*Punica granatum* L.) cv. Ganesh cuttings, in which six treatments were used comprising of IBA (500 ppm and 1000 ppm) and PHB (500 ppm and 750 ppm), their combinations IBA 500 ppm + PHB 500 ppm and IBA 1000 ppm + PHB 750 ppm along with control. The results of the investigation indicated that IBA 1000 ppm + PHB 750 ppm treatment resulted in maximum root length (15.40 cm).

Shukla *et al.* (2004) studied the effect of IBA (0, 50, 100, 200 and 400 ppm for 24 h) on rooting of pomegranate (cultivars Ganesh, Dholka and Kandhari) hardwood cuttings. Among these, cultivar Dholka treated with 100 ppm IBA gave the longest root (25.76 cm) per cutting.

2.1.6 Fresh weight of roots (g)

Kumar *et al.* (2017) treated stem cuttings of pomegranate cv. Ganesh with IBA solution of different concentrations i.e. 500 ppm, 1000 ppm, 1500 ppm and

control by quick dip method. The maximum fresh weight of roots per cutting (1.77 g) was noticed with 500 ppm IBA.

Seiar (2017) treated the semi-hardwood cuttings of pomegranate cv. Bhagwa with a different concentrations of IBA (500, 1000 or 1500 ppm) and NAA (500, 1000 or 1500 ppm) and their combinations for 8 hours and concluded that highest fresh weight of roots (2.70 g) per cutting was noticed when cuttings were treated with IBA 1500 ppm + NAA 1000 ppm.

Navjot and Kahlon (2002) studied the effect of cutting type (basal, middle and sub-apical portion of the shoots) and IBA concentrations (0, 50, 100 and 200 ppm) on the rooting and growth of pomegranate cv. Kandhari. The highest fresh root weight (10.24 g) was recorded when middle cuttings were treated with 100 ppm IBA.

2.1.7 Dry weight of roots (g)

Hakim *et al.* (2018) treated stem cuttings of pomegranate cvs. Bhagwa and Ruby with different concentrations of auxins (IBA & NAA) and biofertilizers (Biomix, PSB and PGPR) and noticed the highest dry weight of roots (1.62 and 1.85 g) respectively with the application of IBA 1500 ppm + NAA 1500 ppm + Biomix.

Stem cuttings of pomegranate cv. Ganesh treated with IBA solution of different concentration i.e. 500 ppm, 1000 ppm, 1500 ppm and control by quick dip method. Among all the treatments, the maximum dry weight of root per cutting (1.02 g) was noticed with 500 ppm concentration IBA (Kumar *et al.*, 2017).

Semi-hardwood cuttings of pomegranate cv. Bhagwa were treated with different concentrations of IBA (500, 1000 or 1500 ppm) and NAA (500, 1000 or 1500 ppm) and their combinations for 8 hours and concluded that the highest dry weight of roots (1.63 g) per cutting was recorded with IBA 1500ppm + NAA 1000 ppm (Seiar, 2017).

Rajkumar *et al.* (2016) conducted a greenhouse experiment to optimize the concentration of growth regulator IBA (1000, 1500, 2000 and 2500 ppm) and to evaluate the efficacy of growing medium (sand, perlite, cocopeat and vermiculite) for root and shoot development in stem cuttings of pomegranate cv. Phule Arakta under arid conditions. Highest fresh weight of roots (1.18 g) was recorded with IBA @ 2500ppm in vermiculite.

2.1.8 Number of Days taken for first sprouting

Hakim *et al.* (2018) studied the influence of bio-fertilizers (Biomix, PSB and PGPR) and auxin (IBA & NAA) on growth and rooting of pomegranate (*Punica granatum* L.) cuttings cvs. Bhagwa and Ruby. Early sprouting of cuttings (8.60 and 7.80 days) were recorded in cvs. Bhagwa and Ruby, respectively with the application of IBA 1500 ppm + NAA 1500 ppm + Biomix.

Rajkumar *et al.* (2016) conducted a greenhouse experiment to optimize the concentration of growth regulator IBA (1000, 1500, 2000 and 2500 ppm) and to evaluate the efficacy of growing medium (sand, perlite, cocopeat and vermiculite) for root and shoot development in stem cuttings of pomegranate cv. Phule Arakta under arid conditions. Highest dry weight of roots (0.30 g) was recorded with IBA @ 2500ppm in vermiculite.

Sumanlata (2015) investigated the effect of different concentrations of IBA & NAA with borax on the number of days taken for the initiation of sprouting. The earliest (13.33 days) sprouting was recorded under the treatment IBA 2000 ppm + 1% Borax which was significantly superior to the rest of treatments. Whereas, sprouting was delayed and maximum days (29.33 days) was recorded in case of untreated cuttings.

Kumawat (2009) in his investigation entitled "rooting and growth of pomegranate (*Punica granatum* L.) cv. Mridula cuttings as influenced by different environmental conditions and growth regulators" found that the earliest (7 days)

sprouting of cutting was observed under poly house condition with IBA (1500 ppm) which was significantly better than a net house and open field condition.

2.1.9 Number of shoots per cutting

Rajkumar *et al.* (2016) conducted a greenhouse experiment to optimize the concentration of growth regulator IBA (1000, 1500, 2000 and 2500 ppm) and to evaluate the efficacy of growing medium (sand, perlite, cocopeat and vermiculite) for root and shoot development in stem cuttings of pomegranate cv. Phule Arakta under arid conditions. Maximum number of shoots (2.5) per cutting was noticed with IBA @ 2500ppm in vermiculite

Shukla *et al.* (2004) studied the effect of IBA (0, 50, 100, 200 and 400 ppm for 24 h) on rooting of pomegranate (cultivars Ganesh, Dholka and Kandhari) hardwood cuttings. The highest number of sprouts per cutting (3.77) were observed when cv. Dholka treated with 100 ppm IBA.

Kumawat (2009) noticed that the maximum number of shoots (3.06) per cutting in pomegranate cv. Mridula under poly house condition with IBA (1500 ppm), was significantly superior to net house and open condition. Whereas, the minimum number of shoots (1.23) per cutting was observed in open field condition.

Navjot and Kahlon (2002) studied the effect of cutting type (basal, middle and sub-apical portion of the shoots) and IBA concentrations (0, 50, 100 and 200 ppm) on the rooting and growth of pomegranate cv. Kandhari. The highest value of shoot number (4.76) recorded when middle cuttings treated with 100 ppm IBA.

2.1.10 Length of longest shoot per cutting (cm)

Hakim *et al.* (2018) studied the influence of bio-fertilizers (Biomix, PSB and PGPR) and auxins (IBA & NAA) on growth and rooting of pomegranate (*Punica granatum* L.) cuttings cvs. Bhagwa and Ruby. The results revealed that length of longest shoot (39.73 and 41.53 cm) were recorded in the cvs. Bhagwa

and Ruby respectively with the application of IBA 1500 ppm + NAA 1500 ppm + Biomix.

Mehta *et al.* (2018) studied the effect of IBA concentration and time of planting on rooting in pomegranate (*Punica granatum* L.) cuttings during the winter season 2016-17. Results of the investigation showed that the length of the longest sprout (12.00 cm) was observed in January 10th planting with application of 500 ppm of IBA.

Navjot and Kahlon (2002) carried out an experiment to know the effect of cutting type (basal, middle and sub-apical portion of the shoots) and IBA concentrations (0, 50, 100 and 200 ppm) on the rooting and growth of pomegranate cv. Kandhari. Highest value of shoot length (13.75 cm) was observed when middle cuttings of pomegranate cv. Kandhari treated with 100 ppm IBA.

Semi-hardwood cuttings of pomegranate cv. Bhagwa with a different concentrations of IBA (500, 1000 or 1500 ppm) and NAA (500, 1000 or 1500 ppm) and their combinations for 8 hours. longest sprout 34.50 cm per cutting was noticed that when semi-hardwood cuttings of pomegranate (*Punica garanatum* L.) cv. Bhagwa treated with IBA 1500ppm + NAA 1000ppm (Seiar, 2017).

2.1.11 Number of leaves per cutting

In the experimental findings of Hakim *et al.* (2018), treatment comprising of IBA 1500 ppm + NAA 1500 ppm + Biomix has shown the maximum number of leaves (41.67 and 44.60) per cutting in cvs. Bhagwa and Ruby respectively.

Singh (2014) conducted an experiment in which the stem cuttings of pomegranate (*Punica granatum* L.) were treated with IBA solutions of different concentrations i.e. 1, 2, 3, 4 and 5 g L⁻¹ and control by quick dip method. He found that among all the treatments, the highest average number of leaves (25.33) were noticed in 5 g L⁻¹ concentration of IBA.

Mehta *et al.* (2018) studied the effect of IBA concentrations and time of

planting on rooting in pomegranate (*Punica granatum* L.) cuttings during the winter season 2016-17. Results of the investigation showed that the highest number of leaves on new shoots (15.33) was observed with the application of 500 ppm of IBA and planting time was January.

Kumawat (2009) reported that maximum number (14.90) of leaves per shoot in pomegranate cv. Mridula under poly house condition with IBA (1500 ppm), which was significantly better than net house and control. Whereas, the minimum number (10.30) of leaves per shoot was recorded under open field condition.

2.1.12 Leaf area per cutting (cm²)

Hakim *et al.* (2018) studied the influence of bio-fertilizers (Biomix, PSB and PGPR) and auxins (IBA & NAA) on leaf area of pomegranate (*Punica granatum* L.) cuttings cvs. Bhagwa and Ruby. The results revealed that significantly highest leaf area (41.31 and 42.49 cm²) per cutting in cvs. Ruby and Bhagwa respectively, recorded with IBA1500 ppm + NAA 1500 ppm + Biomix.

Chater *et al.* (2017) conducted an experiment to evaluate the rooting percentages and vegetative growth attributes of hardwood cuttings of twelve cultivars (Ambrosia, Desertnyi, Eversweet, Golden Globe, Green Globe, Haku Botan, Kizakur, Loffani, Nochi Shibori, Parfianka, Phoenicia and Wonderful) utilizing a basal dip in a gel formulation of 3 g L⁻¹ indole-3-butyric acid (IBA). Plants of Wonderful had significantly greater leaf area (15.9 cm²) compared to other cultivars.

Navjot and Kahlon (2002) reported the effect of cutting type (basal, middle and sub-apical portion of the shoots) and IBA concentrations (0, 50, 100 and 200 ppm) on the rooting and growth of pomegranate cv. Kandhari. The highest total leaf area (293.00 cm²) per cutting recorded when middle cuttings were treated with 100 ppm IBA.

2.1.13 Total chlorophyll per cutting (SPAD units)

Chater *et al.* (2017) conducted an experiment to evaluate the rooting percentages and vegetative growth attributes of hardwood cuttings of twelve cultivars (Ambrosia, Desertnyi, Eversweet, Golden Globe, Green Globe, Haku Botan, Kizakuro, Loffani, Nochi Shibori, Parfianka, Phoenicia and Wonderful) utilizing a basal dip in a gel formulation of 3 g L⁻¹ indole-3-butyric acid (IBA). He reported that there were significant differences among cultivars in terms of chlorophyll content and the highest chlorophyll content was reported in cv. Haku Botan (37.6).

Hakim *et al.* 2018 studied the influence of bio-fertilizers (biomix, PSB and PGPR) and auxins (IBA & NAA) on total chlorophyll content of leaf and leaf area on pomegranate (*Punica granatum* L.) cuttings cvs. Bhagwa and Ruby. The results revealed that significantly highest total chlorophyll content in leaves (5.13 and 5.66 mg/g), in cvs. Ruby and Bhagwa respectively with the application of IBA1500 ppm + NAA 1500 ppm + Biomix and the least total chlorophyll content of leaves (2.36 and 2.62 mg/g), in cvs. Ruby and Bhagwa respectively, recorded in control.

2.1.14 Fresh weight of shoots (g)

Hakim *et al.* (2018) studied the influence of bio-fertilizers (biomix, PSB and PGPR) and auxins (IBA & NAA) on growth and rooting of pomegranate (*Punica granatum* L.) cuttings cvs. Bhagwa and Ruby. The results revealed that the fresh weight of shoots (10.80 and 12.60 g) was recorded significantly maximum in both the cvs. Bhagwa and Ruby, respectively with the application of IBA 1500 ppm + NAA 1500 ppm + Biomix.

Semi-hardwood cuttings of pomegranate cv. Bhagwa treated with different concentrations of IBA (500, 1000 or 1500 ppm) and NAA (500, 1000 or 1500 ppm) and their combinations for 8 hours. Highest fresh weight of sprout (9.03 g)

per rooted cutting was noticed with IBA 1500 ppm + NAA 1000 ppm (Seiar 2017).

2.1.15 Dry weight of shoots (g)

Hakim *et al.* (2018) Cuttings of pomegranate cv. Bhagwa and Ruby were treated with biofertilizers (biomix, PSB and PGPR) and auxins (IBA & NAA) to know their effect on growth and rooting. Highest dry weight of shoots (5.80 & 6.60 g) respectively was observed when cuttings were treated with IBA 1500 ppm + NAA 1500 ppm + Biomix.

Seiar (2017) treated semi-hardwood cuttings of pomegranate cv. Bhagwa with different concentrations of IBA (500, 1000 or 1500 ppm) and NAA (500, 1000 or 1500 ppm) and their combinations for 8 hours. Highest dry weight of shoots (4.66 g) per cutting was observed with IBA 1500ppm + NAA 1000ppm.

2.1.16 Root to shoot Ratio (dry weight basis)

Siddiqua *et al.* (2018) conducted an experiment to know the influence of growth regulators IBA, NAA and their combinations on rooting of stem cuttings in dragon fruit [*Hylocereus undatus* (Haworth) Britton & Rose]. The stem cuttings of dragon fruit treated with different plant growth regulators result reveals that the maximum root to shoot ratio (0.67 g) was recorded in cuttings treated with IBA 7000 ppm.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled “**Standardization of Pomegranate (*Punica granatum* L.) propagation through cuttings**” were carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus Srinagar, in the Division of Fruit Science. The details pertaining to materials used, methods adopted and statistical analysis followed during the course of this investigation are described in this chapter.

3.1 Location of experimental site

Location of the trial was at experimental farm of Division of Fruit Science, SKUAST- K, Shalimar. The experimental site is situated at an elevation of 1630 meters above mean sea level having latitude 34°-08' N and longitude 74°-08' E.

3.2 Weather conditions

The location falls under Agro-climatic zone-1(Western Himalayan Region), with an average annual rainfall of 670 mm. It can be generally described as cool in the spring and autumn, mild in the summer and cold in the winter.

3.3 Experiment details

The experimental details on “**Rooting Response of Pomegranate (*Punica granatum* L.) varieties to Indole Butyric Acid (IBA) concentrations under Kashmir conditions**” are given below.

Location of work : Experimental farm of Division of Fruit Science

Crop : Pomegranate

Number of Varieties (V) : 10

V₁ : Arakta

V₂ : Mridula

V₃ : Muskat
V₄ : Ichakdana
V₅ : Chawla
V₆ : Bhagwa
V₇ : Kandhari Kabuli
V₈ : Nabha
V₉ : Jodhpur Red
V₁₀ : P- 23

IBA concentration in ppm (H) : 05 levels

H₁ : Control (without IBA)
H₂ : 2000 ppm
H₃ : 3000 ppm
H₄ : 4000 ppm
H₅ : 5000 ppm

Total number of treatments : 50

Number of replications : 03

Number of cuttings per treatment : 45

Design of experiment : RCBD

Dipping duration : 30 seconds (Quick dip method).

Treatment combinations

T ₁	V ₁ H ₁	T ₁₁	V ₁ H ₂	T ₂₁	V ₁ H ₃	T ₃₁	V ₁ H ₄	T ₄₁	V ₁ H ₅
T ₂	V ₂ H ₁	T ₁₂	V ₂ H ₂	T ₂₂	V ₂ H ₃	T ₃₂	V ₂ H ₄	T ₄₂	V ₂ H ₅
T ₃	V ₃ H ₁	T ₁₃	V ₃ H ₂	T ₂₃	V ₃ H ₃	T ₃₃	V ₃ H ₄	T ₄₃	V ₃ H ₅
T ₄	V ₄ H ₁	T ₁₄	V ₄ H ₂	T ₂₄	V ₄ H ₃	T ₃₄	V ₄ H ₄	T ₄₄	V ₄ H ₅
T ₅	V ₅ H ₁	T ₁₅	V ₅ H ₂	T ₂₅	V ₅ H ₃	T ₃₅	V ₅ H ₄	T ₄₅	V ₅ H ₅
T ₆	V ₆ H ₁	T ₁₆	V ₆ H ₂	T ₂₆	V ₆ H ₃	T ₃₆	V ₆ H ₄	T ₄₆	V ₆ H ₅
T ₇	V ₇ H ₁	T ₁₇	V ₇ H ₂	T ₂₇	V ₇ H ₃	T ₃₇	V ₇ H ₄	T ₄₇	V ₇ H ₅
T ₈	V ₈ H ₁	T ₁₈	V ₈ H ₂	T ₂₈	V ₈ H ₃	T ₃₈	V ₈ H ₄	T ₄₈	V ₈ H ₅
T ₉	V ₉ H ₁	T ₁₉	V ₉ H ₂	T ₂₉	V ₉ H ₃	T ₃₉	V ₉ H ₄	T ₄₉	V ₉ H ₅
T ₁₀	V ₁₀ H ₁	T ₂₀	V ₁₀ H ₂	T ₃₀	V ₁₀ H ₃	T ₄₀	V ₁₀ H ₄	T ₅₀	V ₁₀ H ₅

3.4 Materials used

The study was conducted with stem cuttings of ten pomegranate cultivars *viz*; Arakta, Mridula, Muskat, Ichakdana, Bhagwa, Chawla, Kandhari Kabuli, Nabha, Jodhpur Red and P- 23. Root promoting chemical, IBA were used at five concentrations of 5000 ppm, 4000 ppm, 3000 ppm, 2000 ppm and 0 ppm (without IBA).

3.4.1 Source of cuttings and their preparation

Cuttings of pomegranate cultivars were procured from Regional Horticultural Research Station, Bajaura, Himachal Pradesh. Cuttings were taken in the month of April from properly matured one year old shoots having diameter 0.8 cm to 1.2 cm and 20 cm in length with 4-5 buds each. The slanting cut was made at the basal end just below the bud and at apical end just above the bud. The basal end of the cuttings was given a slant cut to expose maximum absorbing surface for maximum rooting.

3.4.2 Preparation of growth regulator formulations

The required concentrations of growth regulators IBA (2000,3000, 4000 and 5000 ppm were prepared by dissolving 2g, 3g, 4g and 5g of IBA respectively in separate containers in a small quantity of ethanol and the volume made up to 1000 ml by the adding distilled water. Few drops of NH_4OH were added to avoid precipitation of the hormone.

3.4.3 Treatment of cuttings and planting

The basal 5 cm portion of the cutting was dipped in growth regulator formulation for 30 seconds subsequently they were air dried for 15 minutes and planted in soil under open conditions. Cuttings were planted in an inclined position at an angle approximately 60° to the horizontal to avoid dew or raindrops enter through a cut surface and to a depth of 6-8 cm. The cuttings were planted 10 cm apart with row to row distance of 60 cm.

3.4.4 Aftercare

The cuttings were watered at regular intervals for optimum moisture maintenance and weeds in the plots were removed.

3.5 Observations recorded

The planted cuttings were allowed to root for 90 days. The cuttings were watered well prior to removal of cuttings from the soil to record the observations pertaining to roots and shoots. Cuttings (five number per treatment per replication) were labelled and carefully removed from the soil and dipped in water to remove the soil adhering to roots.

3.5.1 Root parameters

3.5.1.1 Percentage of rooted cuttings (%)

This parameter was calculated at 90 days after planting by using the following formula,

$$\text{Percentage of rooted cuttings (\%)} = \frac{\text{Number of cuttings rooted}}{\text{Total number of cuttings}} \times 100$$

3.5.1.2 Survival percentage of rooted cuttings (%)

The total number of cuttings survived under each treatment in each replication was recorded and the survival percentage of rooted cuttings was calculated.

$$\text{Survival Percentage (\%)} = \frac{\text{Number of cuttings survived}}{\text{Total number of cuttings rooted}} \times 100$$

3.5.1.3 Number of roots per cutting

The number of adventitious roots per cutting was counted under each treatment and the mean was expressed as the number of roots per cutting.

3.5.1.4 Average root length (cm)

Length of all the roots per cuttings was measured under each treatment by measuring scale from base to tip and their mean was expressed as the average root length.

3.5.1.5 Length of longest root per cutting (cm)

The length of longest root per cutting in each treatment was measured by measuring scale from base to tip of the root and their mean was used to express the length of the longest root.

3.5.1.6 Fresh weight of roots (g)

Fresh weight of roots per cutting was taken with the help of electronic balance and the mean values were calculated.

3.5.1.7 Dry weight of roots (g)

The washed root samples were completely oven dried at 65°C for 48 hours and dry weights were recorded with the help of electronic balance.

3.5.2 Shoot parameters

3.5.2.1 Number of days taken for first sprouting

The planted cuttings were observed daily under each treatment and the number of days required for sprouting was recorded and their mean was used to calculate the days taken for the first sprout to appear.

3.5.2.2 Number of shoots per cutting

The number of sprouts per cutting were counted 90 days after planting and their mean was used to record this parameter.

3.5.2.3 Length of longest shoot per cutting (cm)

The length of the longest shoot per cutting was measured 90 days after planting and their mean was calculated.

3.5.2.4 Number of leaves per cutting

The number of leaves per cutting was counted 90 days after planting and their mean was used to record this parameter.

3.5.2.5 Leaf area per cutting (cm²)

Leaf area per sprouted cutting under each treatment and replication was measured with the help of leaf area meter and the mean leaf area was calculated.

3.5.2.6 Total chlorophyll per cutting (SPAD units)

It was measured with the help of handheld chlorophyll meter. It was observed at 90 days after planting of randomly selected cuttings in each treatment. One top leaf of every plant was inserted in the equipment, which gives the chlorophyll percentage present in the leaf. Each leaf was clamped in the chlorophyll meter for a fraction of second then chlorophyll meter gave the value in SPAD on the digital display of the screen. The value of chlorophyll index (SPAD) shows the relative distribution of chlorophyll in leaves.

3.5.2.7 Fresh weight of shoots (g)

Fresh weight of the shoots per cutting was taken with the help of electronic balance and the mean values were calculated

3.5.2.8 Dry weight of shoots (g)

The shoots were completely oven dried at 65°C for 48 hours and dry weights were recorded with the help of electronic balance.

3.5.2.9 Root to shoot Ratio (dry weight basis)

After 90 days of planting the labelled cuttings per replication in each treatment were uprooted and roots, shoots separated from the plants. They were oven dried at 65°C for 48 hours, then weight was recorded with electronic balance and their relative proportions the Root to shoot ratio were calculated.

3.6 Statistical analysis

The statistical method described was followed to analyze and interpret the data. The experimental design was a randomized complete block design (RCBD). Each treatment comprised of 45 cuttings of pomegranate and was replicated three times. The test of significance was made with 0.05 level of significance. The data was analyzed by OP stat software.

Chapter-4

EXPERIMENTAL FINDINGS

The results of the present investigation entitled “**Standardization of pomegranate (*Punica granatum* L.) propagation through cuttings**” are being presented in this chapter. The data pertaining to various shoot & root characteristics were subjected to statistical analysis. In support of tabular representation of data, graphs have also been inserted for better understanding. The analysis of data is given in the appendices.

4.1 Rooting parameters

4.1.1 Percentage of rooted cuttings (%)

The data pertaining to percentage of rooted cuttings at the end of 90 days after planting as influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 1 and Figure 1.

The percentage of rooted cuttings was significantly different among cultivars. The cuttings of cv. Chawla (47.66) recorded significantly higher percentage of rooted cuttings than the cuttings of cvs. Arakta (27.40), Mridula (22.87), Muskat (26.85), Ichakdana (34.31), Bhagwa (33.96), Kandhari Kabuli (46.45), Nabha (47.19), Jodhpur Red (17.88) and P- 23 (21.61). It was observed that all the growth regulator treatments significantly promoted rooting in cuttings. The highest rooting (42.80) was noted in cuttings which were treated with IBA 5000 ppm as against the lowest (19.16) recorded in case of control.

The interaction of cultivar and growth regulator significantly affected rooting percentage. Significantly highest percentage of rooting was observed in cv. Chawla treated with IBA 5000 ppm (62.24) followed by cv. Nabha with IBA 5000 ppm (59.86), while the lowest was recorded in cv. Jodhpur Red (10.06) i.e. control.

Table 1: Effect of variety and plant growth regulator concentrations on percentage of rooted cuttings (%) in pomegranate.

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	20.16 (4.59)	23.12 (4.90)	25.84 (5.18)	31.19 (5.67)	36.72 (6.14)	27.40 (5.30)
Mridula	14.34 (3.91)	19.85 (4.56)	23.49 (4.94)	23.93 (4.99)	32.76 (5.80)	22.87 (4.84)
Muskat	19.23 (4.49)	23.29 (4.92)	27.84 (5.37)	29.27 (5.50)	34.62 (5.96)	26.85 (5.25)
Ichakdana	16.99 (4.24)	25.91 (5.18)	36.63 (6.13)	43.73 (6.68)	48.29 (7.01)	34.31 (5.85)
Chawla	27.84 (5.37)	43.98 (6.70)	48.30 (7.01)	55.96 (7.54)	62.24 (7.95)	47.66 (6.91)
Bhagwa	19.80 (4.55)	28.76 (5.45)	37.02 (6.16)	40.54 (6.44)	43.71 (6.68)	33.96 (5.86)
Kandhari Kabuli	25.99 (5.19)	48.06 (7.00)	50.54 (7.17)	52.42 (7.30)	55.27 (7.50)	46.45 (6.83)
Nabha	25.48 (5.14)	46.20 (6.87)	51.58 (7.25)	52.84 (7.33)	59.86 (7.80)	47.19 (6.88)
Jodhpur Red	10.06 (3.32)	15.04 (4.00)	20.04 (4.58)	20.40 (4.62)	23.87 (4.98)	17.88 (4.30)
P- 23	11.72 (3.56)	18.77 (4.44)	20.96 (4.68)	25.90 (5.18)	30.74 (5.63)	21.61 (4.70)
Mean	19.16 (4.44)	29.29 (5.40)	34.22 (5.85)	37.61 (6.13)	42.80 (6.55)	

C.D ($p \leq 0.05$) *Figures in parenthesis indicate square root values

Variety (V)	1.13
IBA concentration (C)	0.80
V × C	2.53

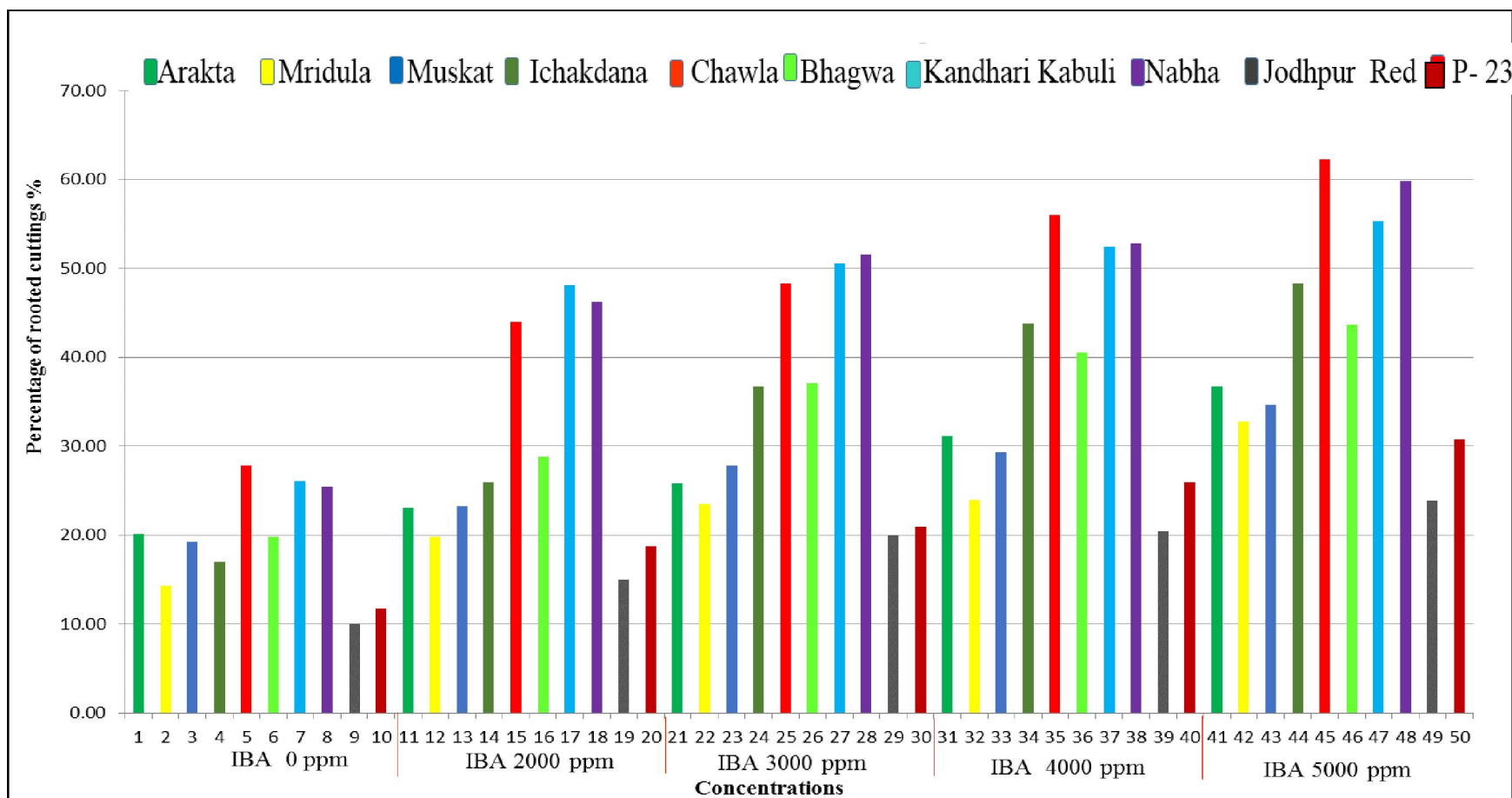


Figure 1: Effect of variety and plant growth regulator concentrations on percentage of rooted cuttings (%) in pomegranate

4.1.2 Survival percentage of rooted cuttings (%)

The data pertaining to survival percentage of rooted cuttings as influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 2 and Figure 2.

The survival percentage of rooted cuttings differed significantly among the cultivars. The survival percentage of rooted cuttings of cv. Chawla (80.21) was observed to be significantly greater than the cuttings of cvs. Arakta (78.88), Mridula (71.25), Muskat (76.81), Ichakdana (79.32), Bhagwa (79.02), Kandhari Kabuli (79.92), Nabha (80.03), Jodhpur Red (62.25), P- 23 (70.40). Survival percentage of rooted cuttings was significantly influenced by IBA concentrations. IBA at 5000 ppm recorded significantly maximum survival percentage (82.34) followed by IBA 4000 ppm (79.56), while least percentage in case of control (68.16).

The growth regulator treatments imposed in the present investigation exhibited a significant interaction with cultivars. The Chawla cuttings treated with IBA 5000 ppm recorded significantly maximum per cent survival (87.75), followed by the cuttings of same cultivar treated with IBA 4000 ppm (86.43) as against the lowest (50.58) in cv. Jodhpur Red (control). The remaining treatments had per cent survival in the range of 53.55-86.22 in rooted cuttings.

Table 2: Effect of variety and plant growth regulator concentrations on survival percentage of rooted cuttings (%) in pomegranate

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	74.47 (8.68)	76.00 (8.77)	79.00 (8.94)	80.41 (9.02)	82.74 (9.15)	78.88 (8.91)
Mridula	63.27 (8.01)	66.01 (8.18)	70.26 (8.43)	76.37 (8.79)	80.37 (9.02)	71.25 (8.49)
Muskat	70.87 (8.47)	73.57 (8.63)	77.43 (8.85)	80.36 (9.02)	81.83 (9.10)	76.81 (8.81)
Ichakdana	71.57 (8.51)	78.45 (8.91)	80.13 (9.00)	82.47 (9.13)	84.02 (9.22)	79.32 (8.95)
Chawla	70.09 (8.43)	74.77 (8.70)	82.02 (9.11)	86.43 (9.35)	87.75 (9.42)	80.21 (9.00)
Bhagwa	74.45 (8.68)	77.55 (8.86)	78.69 (8.92)	81.50 (9.08)	82.95 (9.16)	79.02 (8.94)
Kandhari Kabuli	74.10 (8.66)	77.51 (8.85)	79.84 (8.99)	83.03 (9.16)	85.16 (9.28)	79.92 (8.99)
Nabha	72.26 (8.55)	76.41 (8.79)	80.71 (9.03)	84.56 (9.25)	86.22 (9.33)	80.03 (8.99)
Jodhpur Red	50.58 (7.18)	53.55 (7.38)	63.92 (8.05)	68.43 (8.33)	74.79 (8.70)	62.25 (7.93)
P- 23	60.01 (7.81)	70.60 (8.46)	71.75 (8.53)	72.06 (8.54)	77.59 (8.86)	70.40 (8.44)
Mean	68.16 (8.30)	72.44 (8.55)	76.55 (8.78)	79.56 (8.97)	82.34 (9.12)	

C.D ($p \leq 0.05$) *Figures in parenthesis indicate square root values

Variety (V) 1.32

IBA concentration (C) 0.93

V × C 2.95

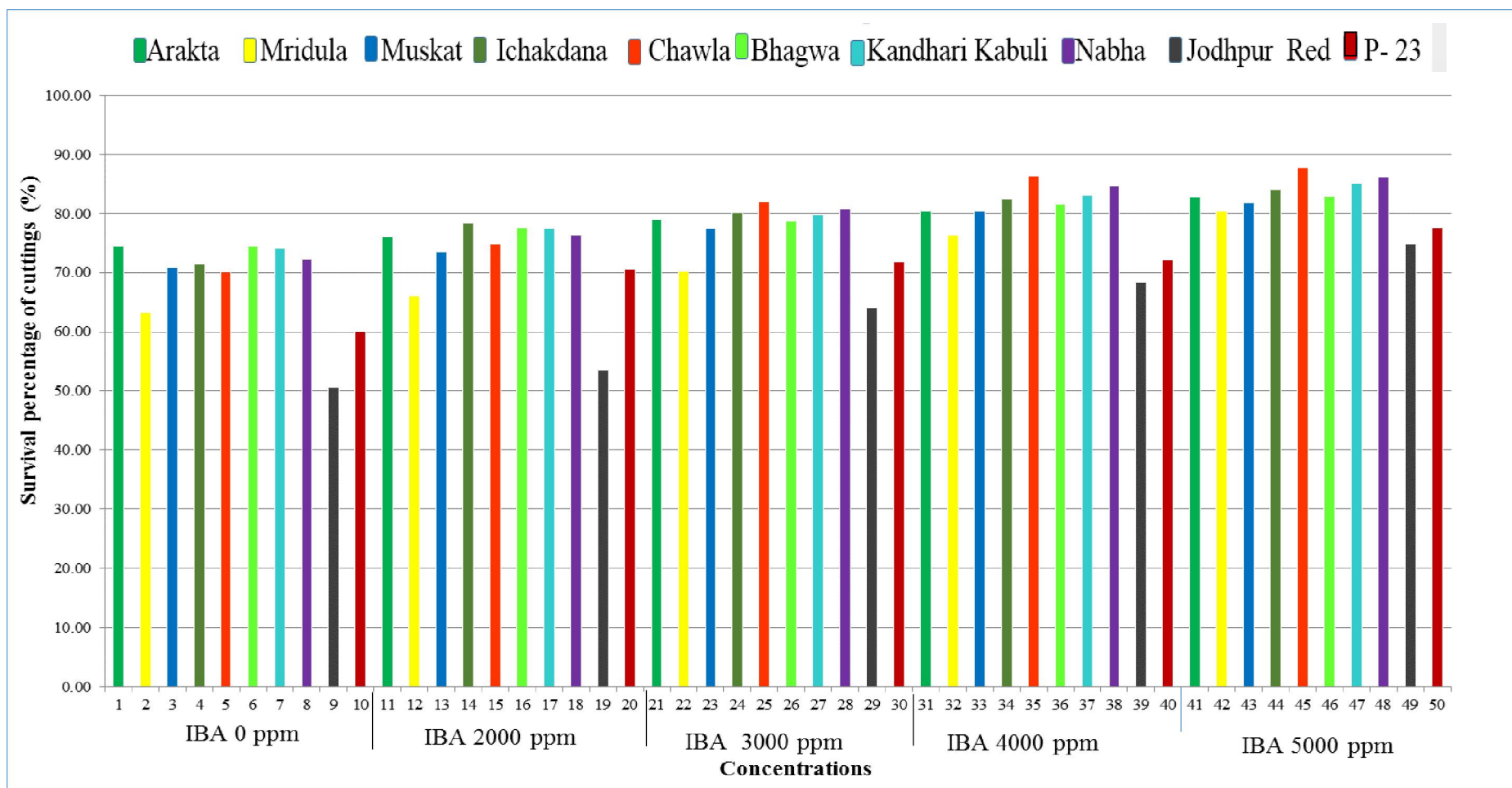


Figure 2: Effect of variety and plant growth regulator concentrations on survival percentage of rooted cuttings (%) in pomegranate

4.1.3 Number of roots per cutting

The data pertaining to average number of roots per cutting as influenced by cultivars, growth regulators and their interaction are presented in Table 3 and illustrated in Figure 3.

The data clearly showed that cuttings of cv. Chawla produced significantly more number of roots (18.98) than cvs. Arakta (17.75), Mridula (14.94), Muskat (16.76), Ichakdana (18.56), Bhagwa (18.05), Kandhari Kabuli (18.67), Nabha (18.90), Jodhpur Red (12.57), P- 23 (14.41). Irrespective of the cultivar tested, IBA at 5000 ppm (20.50) significantly increased the average number of roots compared to IBA at 2000 ppm (15.50), IBA 3000 ppm (16.99), IBA 4000 ppm (18.73).

There existed a significant interaction between cultivars and IBA concentrations in the study. Significantly more number of roots were formed in cuttings of Chawla treated with 5000 ppm IBA (24.97). The next best treatment combinations were Nabha cuttings treated with IBA 5000 ppm (23.80), while least number of roots (10.42) were noticed in Jodhpur Red (control).

Table 3: Effect of variety and plant growth regulator concentrations on mean number of roots per cutting in pomegranate

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	13.10	17.00	18.14	20.06	20.44	17.75
Mridula	12.86	14.44	13.66	13.90	19.87	14.94
Muskat	13.91	14.50	16.90	18.10	20.42	16.76
Ichakdana	13.20	18.80	19.18	20.55	21.08	18.56
Chawla	12.10	14.83	19.50	23.51	24.97	18.98
Bhagwa	14.72	16.86	17.66	20.32	20.68	18.05
Kandhari Kabuli	15.25	16.70	18.66	21.39	21.38	18.67
Nabha	12.80	17.12	19.19	21.58	23.80	18.90
Jodhpur Red	10.42	11.01	13.15	13.47	14.80	12.57
P- 23	12.42	13.80	13.87	14.42	17.55	14.41
Mean	13.08	15.50	16.99	18.73	20.50	

C.D ($p \leq 0.05$)

Variety (V)	0.65
IBA concentration (C)	0.46
V $\times$ C	1.47

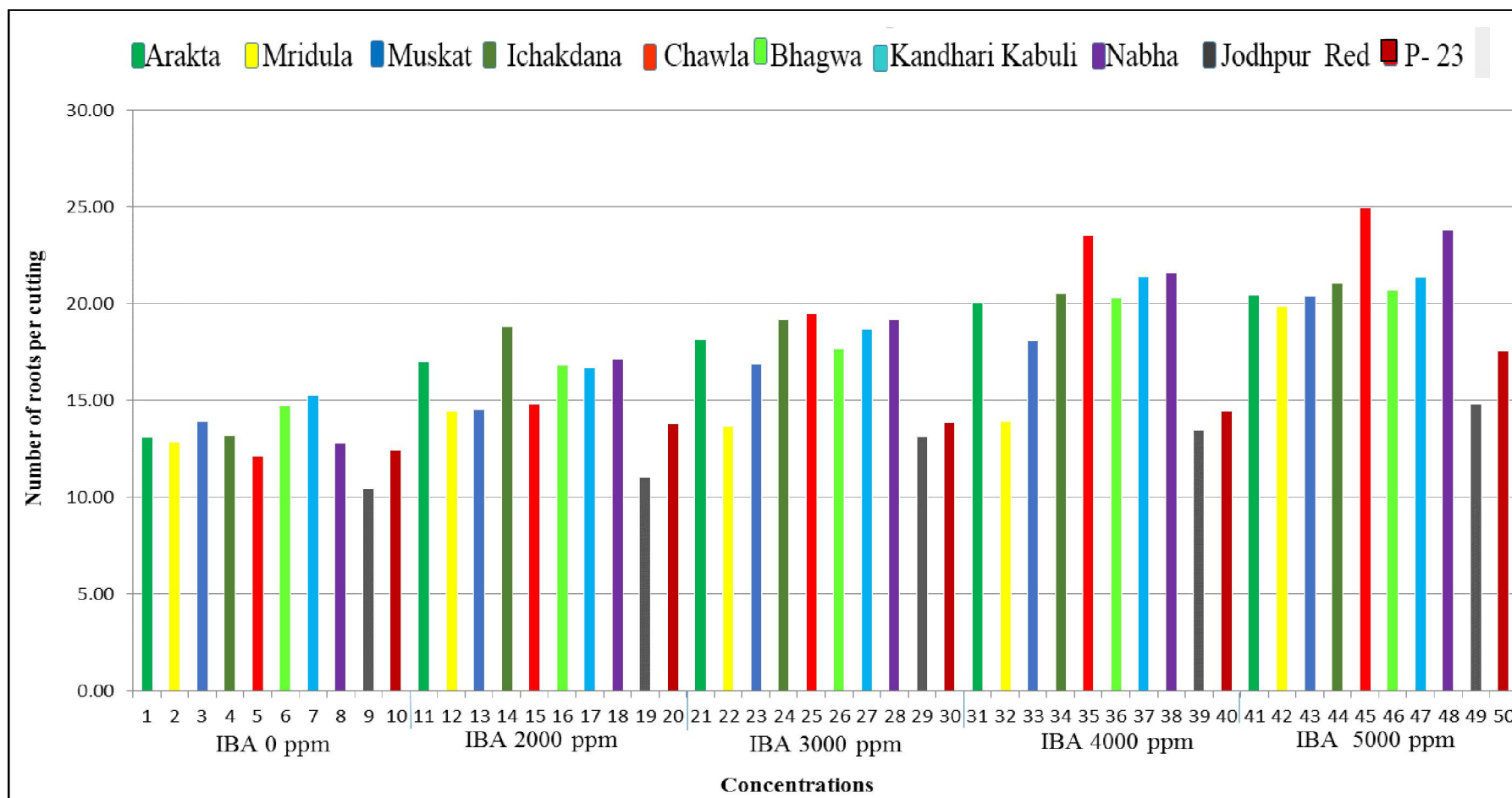


Figure 3: Effect of variety and plant growth regulator concentrations on mean number of roots per cutting in pomegranate



Plate 1: Root growth in cuttings of different varieties of pomegranate (control)



Plate 2: Root growth in cuttings of different varieties of pomegranate treated with 2000 ppm concentrations of IBA

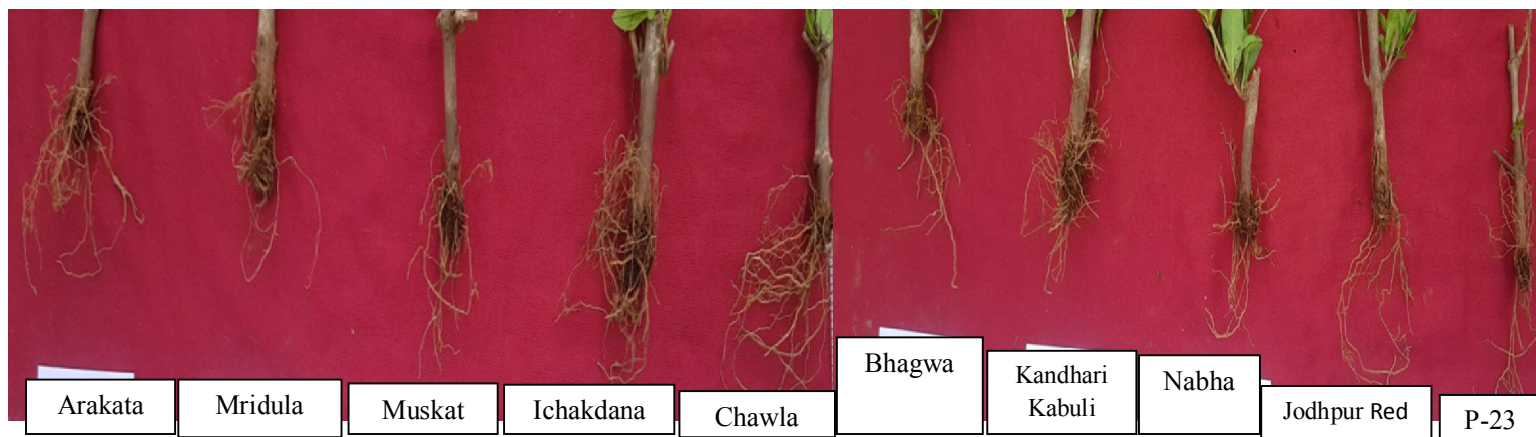


Plate 3: Root growth in cuttings of different varieties of pomegranate treated with 3000 ppm concentrations of IBA

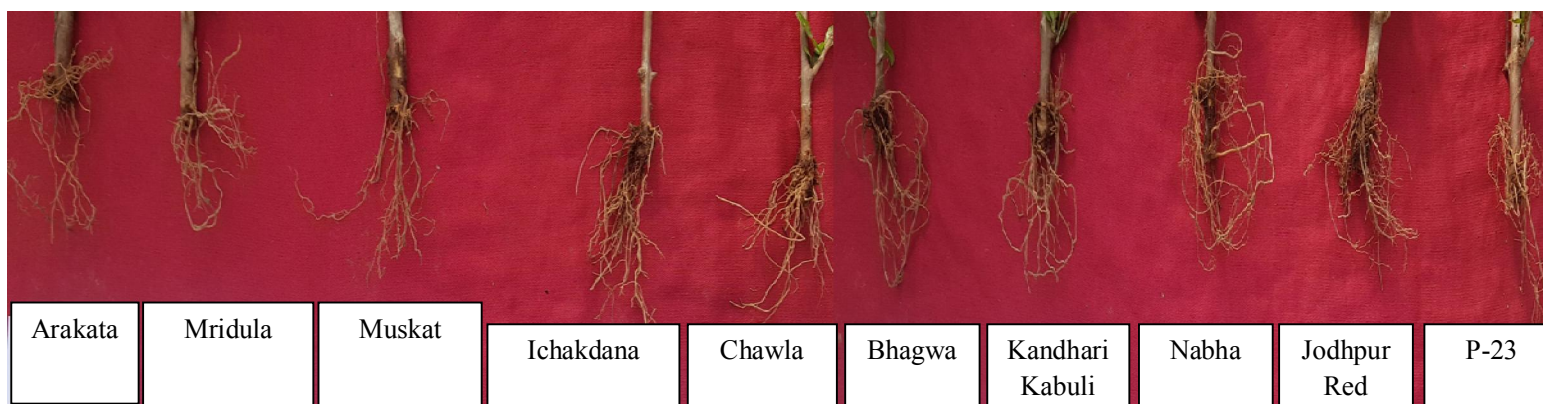


Plate 4: Root growth in cuttings of different varieties of pomegranate treated with 4000 ppm concentrations of IBA

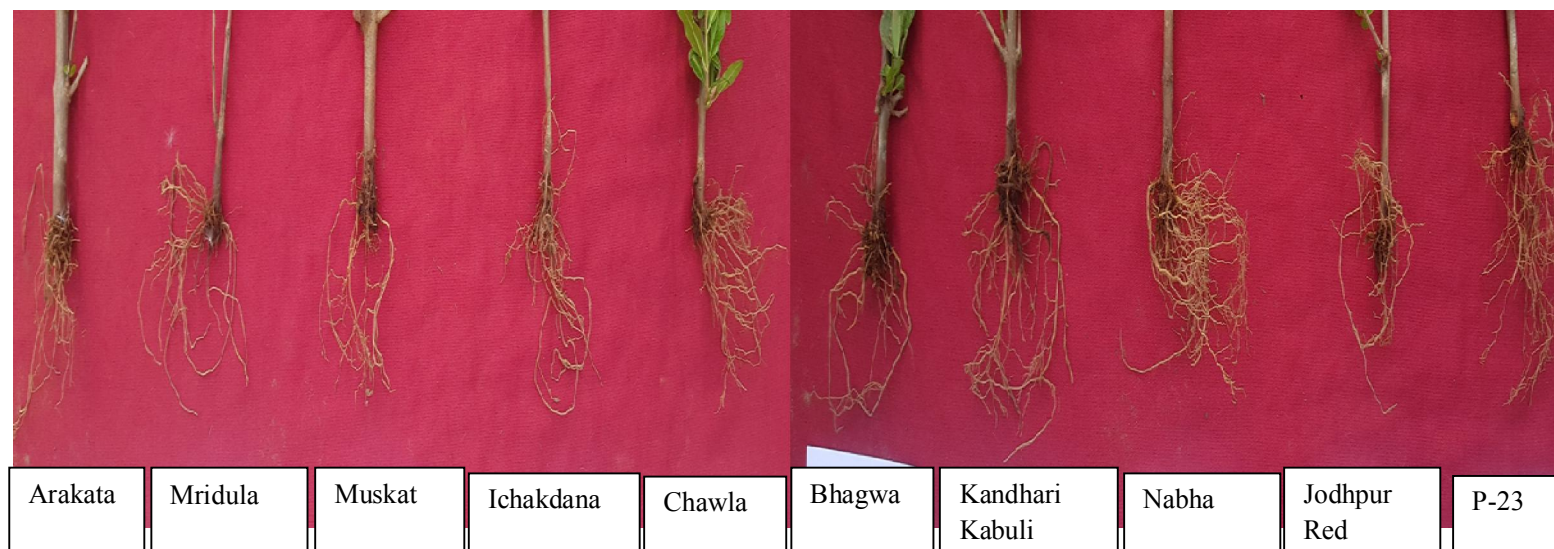


Plate 5: Root growth in cuttings of different varieties of pomegranate treated with 5000 ppm concentrations of IBA

4.1.4 Average root length (cm)

The data pertaining to average root length influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 4 and illustrated in Figure 4.

Root length was significantly differed in cultivars of pomegranate under this study. The root length was maximum in rooted cuttings of Chawla (19.28) than remaining cultivars. Minimum root length was reported in cv. Jodhpur Red (14.37). Among plant growth regulator treatments, IBA 5000 ppm recorded significantly highest root length (20.11) followed by IBA 4000 ppm (18.30) as against lowest root length was observed in control (13.80).

Among the interactions, maximum roots length (24.76) was observed in cuttings of Chawla treated with IBA 5000 ppm followed by 5000 ppm (22.99) in cv. Nabha ,where as minimum root length was reported in cv. P-23 (11.00) i.e. control.

Table 4: Effect of variety and plant growth regulator concentrations on average root length (cm) per cutting in pomegranate

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	13.74	14.90	16.71	18.02	18.97	16.47
Mridula	12.66	13.89	14.95	16.29	17.95	15.15
Muskat	13.73	15.40	16.58	17.13	18.42	16.25
Ichakdana	14.34	15.72	17.05	18.90	21.69	17.54
Chawla	15.99	17.25	17.97	20.43	24.76	19.28
Bhagwa	14.83	15.94	17.90	18.85	19.76	17.45
Kandhari Kabuli	14.53	15.52	18.16	19.72	21.74	17.93
Nabha	16.00	17.44	18.22	20.70	22.99	19.07
Jodhpur Red	11.17	13.14	14.43	15.89	17.22	14.37
P- 23	11.00	12.83	16.22	17.07	17.66	14.95
Mean	13.80	15.20	16.82	18.30	20.11	

C.D ($p \leq 0.05$)

Variety (V)	0.72
IBA concentration (C)	0.50
V $\times$ C	1.61

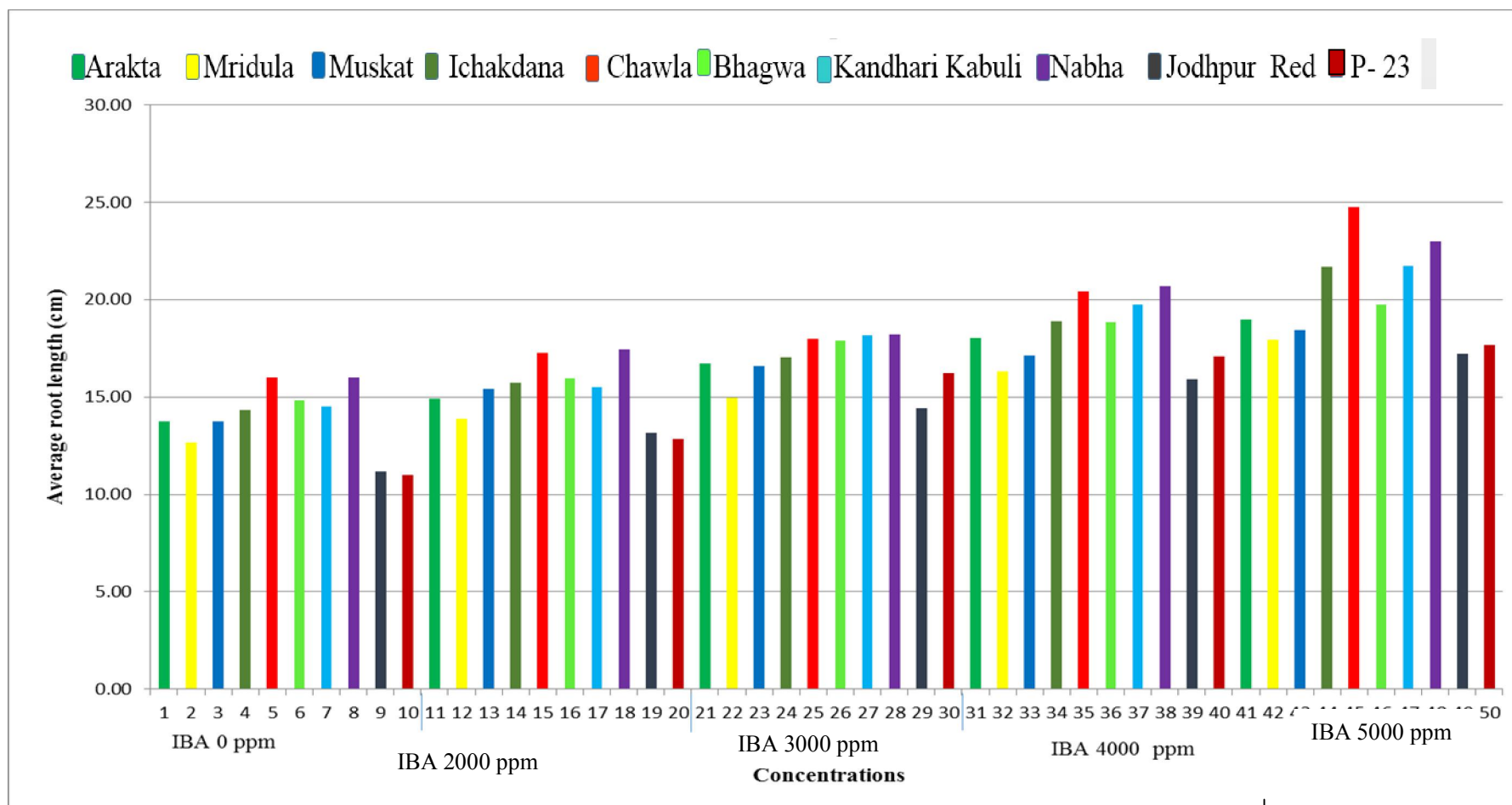


Figure 4: Effect of variety and plant growth regulator concentrations on average root length (cm) per cutting in pomegranate

4.1.5 Length of longest root per cutting (cm)

The data pertaining to length of the longest root as influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 5 and illustrated in Figure 5.

Regardless of growth regulator concentrations, the difference in the average root length due to cultivars was found to be significant during the course of study. The roots of cv. Nabha cuttings (14.13) were longer than remaining cvs. Arakta (12.34), Mridula (11.05), Muskat (11.93), Ichakdana (12.86), Chawla (12.92), Bhagwa (12.51), Kandhari Kabuli (12.52), Jodhpur Red (9.78), P-23 (10.69). There was a progressive and significant improvement in root length of both cultivars with highest concentrations of growth regulators. Maximum length of root (13.89) was observed when the cuttings were treated with IBA 5000 ppm. However, minimum response of this parameter observed in control (10.34).

The interaction values showed varietal variation in different IBA concentrations to average root length. Significantly more root length (19.68) was recorded in cv. Nabha with 5000 ppm of IBA followed by IBA 4000 ppm treatment on same cultivar (15.31). The minimum root length was observed in cv. Jodhpur Red (8.72) i.e. control.

Table 5: Effect of variety and plant growth regulator concentrations on length of longest root (cm) in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	10.02	12.74	12.80	13.07	13.10	12.34
Mridula	10.23	10.36	10.44	11.40	12.80	11.05
Muskat	10.51	10.60	12.65	12.82	13.07	11.93
Ichakdana	11.56	12.31	12.86	13.14	14.46	12.86
Chawla	10.59	12.65	12.85	13.26	15.29	12.92
Bhagwa	11.20	12.39	12.75	12.99	13.24	12.51
Kandhari Kabuli	10.80	11.89	12.95	13.09	13.89	12.52
Nabha	10.42	12.54	12.72	15.31	19.68	14.13
Jodhpur Red	8.72	8.92	10.22	10.43	10.63	9.78
P- 23	9.40	10.29	10.48	10.51	12.78	10.69
Mean	10.34	11.47	12.07	12.60	13.89	

C.D ($p \leq 0.05$)

Variety (V)	0.47
IBA concentration (C)	0.33
V $\times$ C	1.06

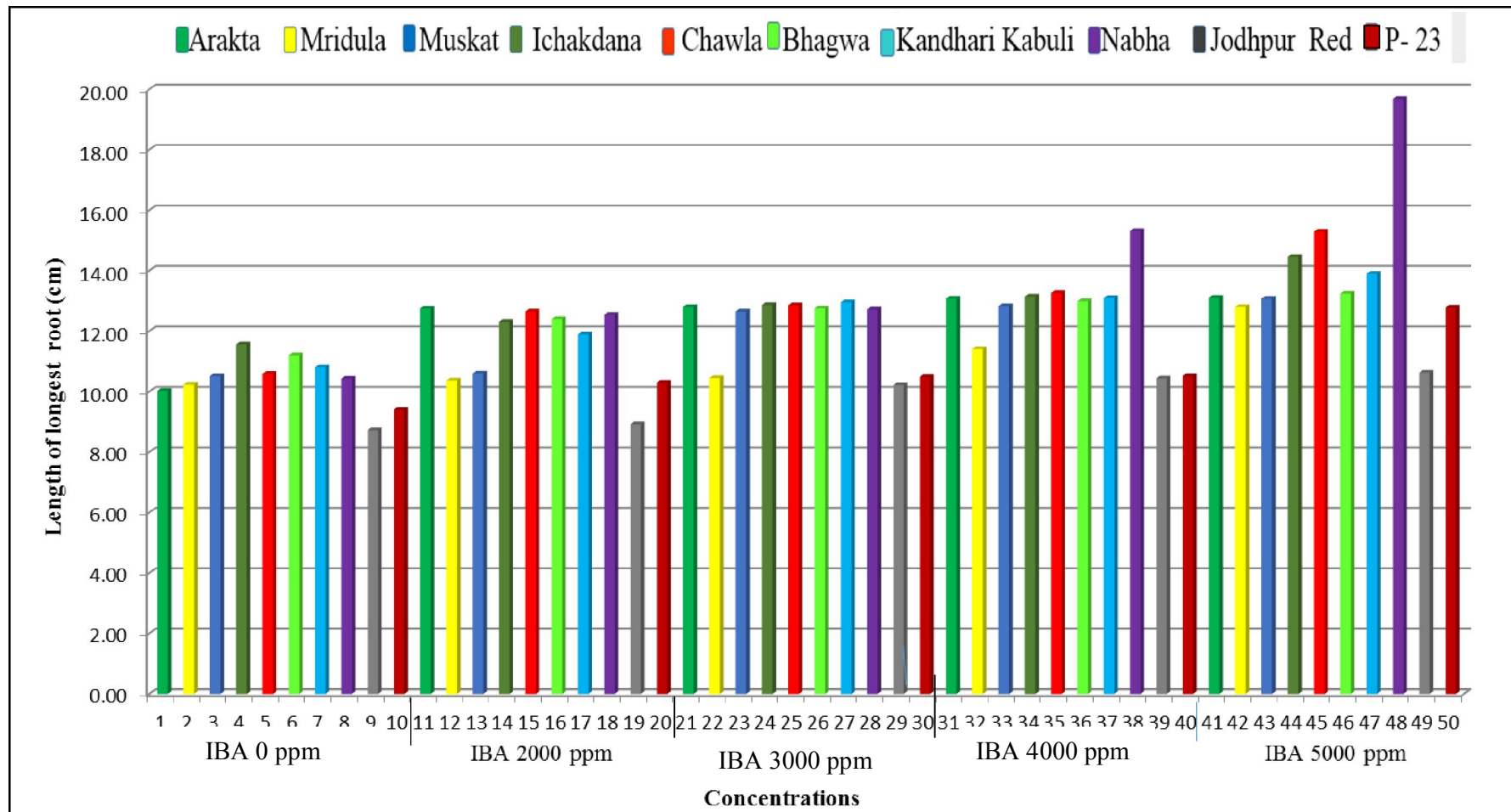


Figure 5: Effect of variety and plant growth regulator concentrations on length of longest root (cm) in pomegranate cuttings

4.1.6 Fresh weight of roots (g)

The data related to fresh weight of roots as influenced by cultivars, different concentrations of growth regulator and their interaction at the end of 90 days after planting are presented in Table 6 and illustrated in Figure 6.

The fresh weight of roots was significantly influenced by cultivars. The cuttings of Nabha gave maximum fresh weight of roots (1.95 g) than cuttings of remaining cultivars. Minimum fresh weight of roots (1.24 g) were reported in cv. Jodhpur Red. With increase in concentration of PGRs, fresh weight of roots also increased. IBA 5000 ppm recorded highest fresh weight of roots (1.91 g) followed by IBA 4000 ppm (1.77 g) and least (1.28 g) was noticed in control.

The effect due to interaction between cultivars and plant growth regulator concentrations was significantly different. Highest fresh weight of roots was observed in cv. Nabha with IBA 5000 ppm (2.95 g) and least was recorded in cuttings of Jodhpur Red (1.14 g) i.e. control.

Table 6: Effect of variety and plant growth regulator concentrations on fresh weight of roots (g) in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	1.20	1.35	1.53	1.59	1.67	1.47
Mridula	1.22	1.32	1.28	1.31	1.60	1.34
Muskat	1.32	1.35	1.45	1.56	1.62	1.46
Ichakdana	1.40	1.42	1.49	2.20	1.99	1.70
Chawla	1.46	1.58	1.25	2.40	2.87	1.91
Bhagwa	1.36	1.43	1.47	1.64	1.78	1.53
Kandhari Kabuli	1.28	1.44	1.51	1.74	1.82	1.55
Nabha	1.19	1.38	1.54	2.69	2.95	1.95
Jodhpur Red	1.14	1.16	1.26	1.29	1.38	1.24
P- 23	1.22	1.30	1.29	1.30	1.49	1.32
Mean	1.28	1.37	1.40	1.77	1.91	

C.D ($p \leq 0.05$)

Variety (V)	0.22
IBA concentration (C)	0.16
V $\times$ C	0.51

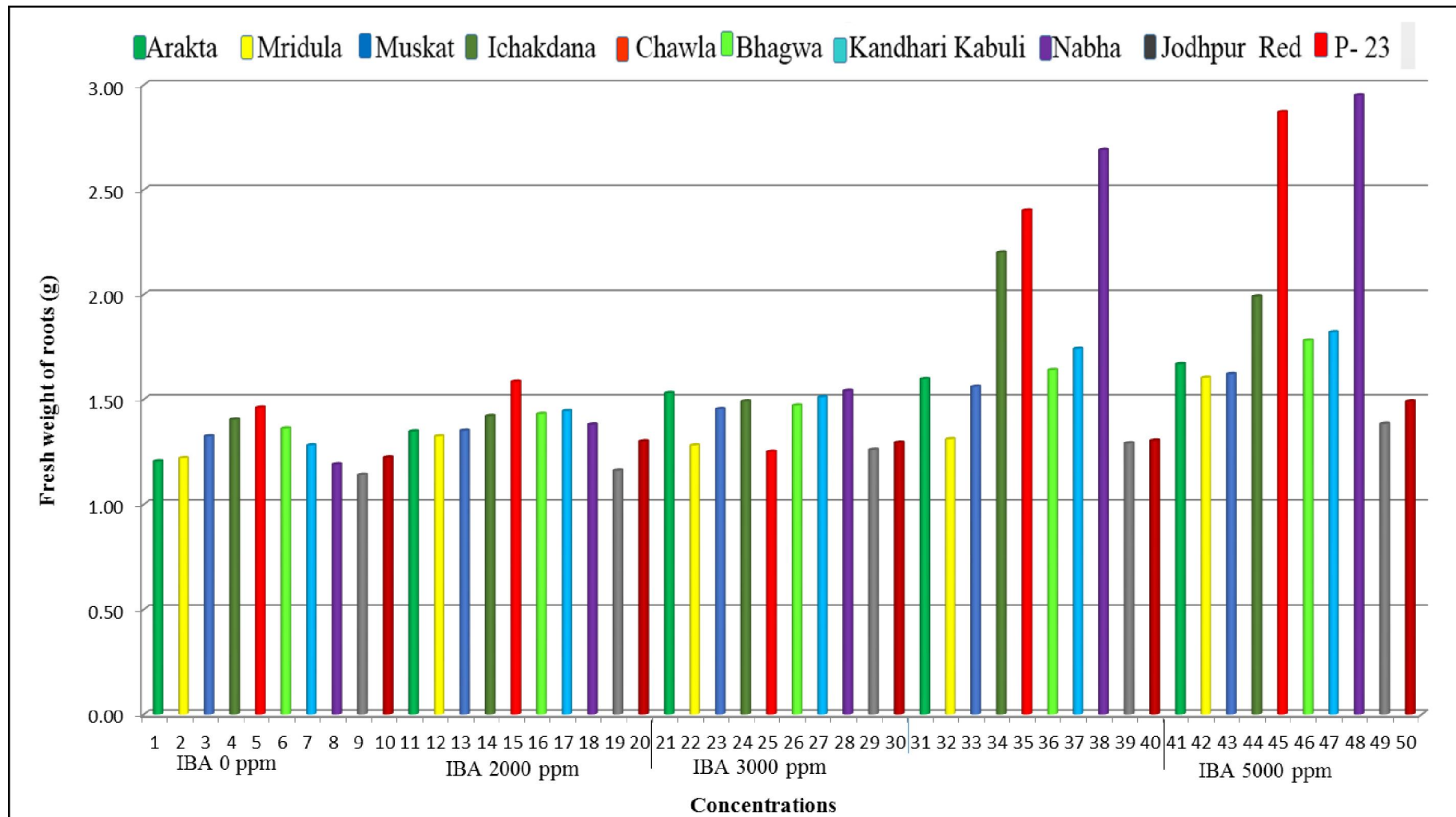


Figure 6: Effect of variety and plant growth regulator concentrations on fresh weight of roots (g) in pomegranate cuttings

4.1.7 Dry weight of roots (g)

The data pertaining to dry weight of roots as influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 7 and Figure 7.

Dry matter accumulation in roots was significantly differed in cultivars of pomegranate under this study. The dry matter was maximum in roots harvested from the cuttings of Nabha (0.94 g) than remaining cultivars. Minimum dry weights of roots were reported in cv. Jodhpur Red (0.29 g). Among plant growth regulator treatments, IBA 5000 ppm recorded significantly highest dry weight of roots (0.91 g) followed by IBA 4000 ppm (0.64 g) as against lowest dry weight recorded in control (0.37 g).

Among the interactions, maximum dry weight of roots (1.70 g) was observed in cuttings of Nabha treated with IBA 5000 ppm followed by cv. Chawla (1.61 g) with same concentration, whereas least dry weight of roots reported in cv. Jodhpur Red (0.25 g) i.e. control.

Table 7: Effect of variety and plant growth regulator concentrations on dry weight of roots (g) in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	0.33	0.39	0.41	0.42	0.50	0.41
Mridula	0.26	0.31	0.43	0.38	0.47	0.37
Muskat	0.32	0.35	0.38	0.40	0.49	0.39
Ichakdana	0.43	0.45	0.47	0.85	1.54	0.75
Chawla	0.45	0.50	0.71	0.90	1.61	0.83
Bhagwa	0.41	0.44	0.46	0.47	0.53	0.46
Kandhari Kabuli	0.34	0.38	0.65	0.70	1.52	0.72
Nabha	0.46	0.51	0.57	1.48	1.70	0.94
Jodhpur Red	0.25	0.26	0.30	0.31	0.36	0.29
P- 23	0.32	0.34	0.37	0.35	0.40	0.35
Mean	0.37	0.40	0.44	0.64	0.91	

C.D ($p \leq 0.05$)

Variety (V)	0.06
IBA concentration (C)	0.04
V × C	0.13

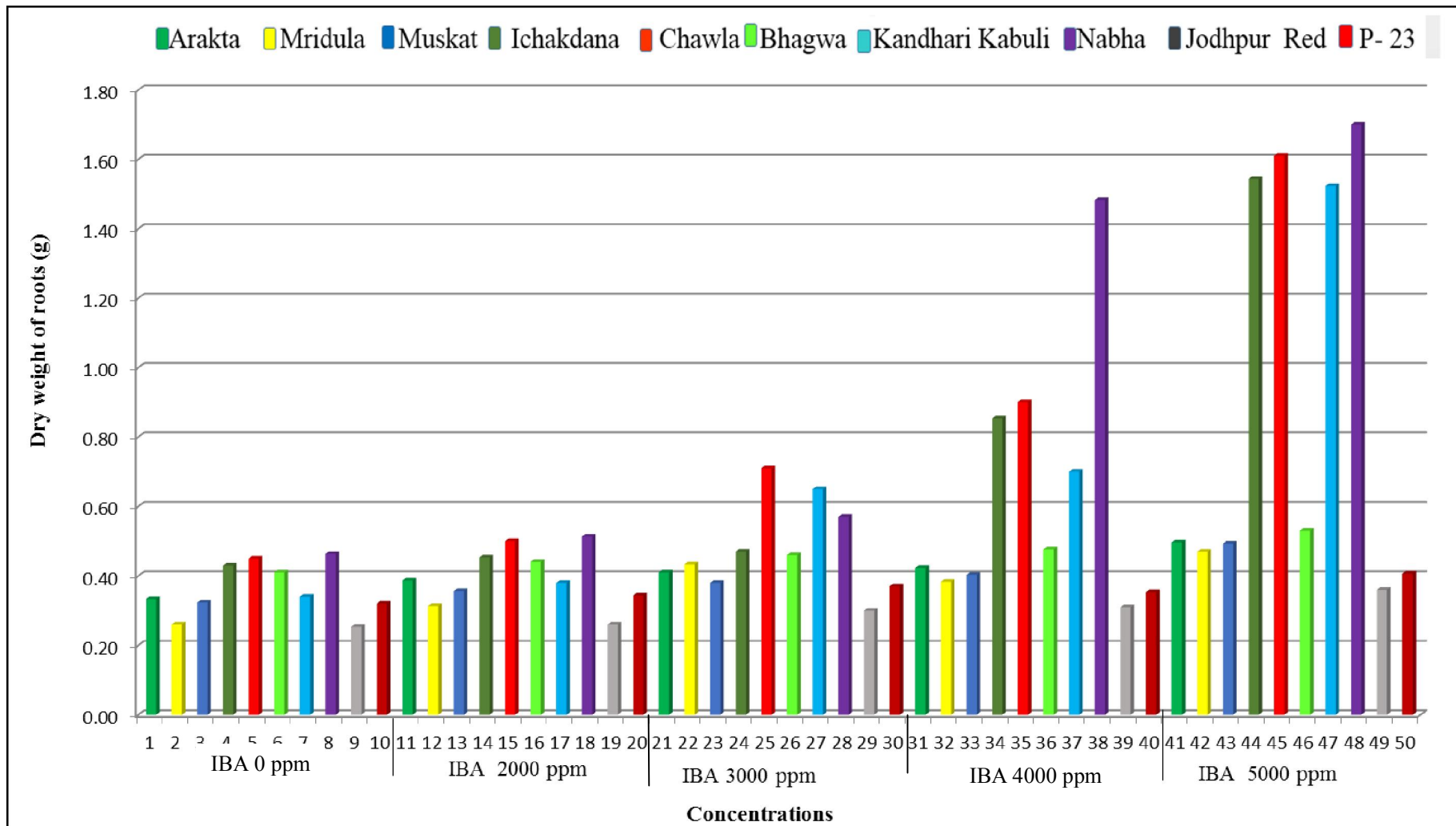


Figure 7: Effect of variety and plant growth regulator concentrations on dry weight of roots (g) in pomegranate cuttings

4.2 Shooting parameters

4.2.1 Number of days taken for first sprouting

The data related to number of days taken for first sprout to appear as influenced by cultivars and different growth regulator concentrations are presented in Table 8 Figure 8.

The data indicated that there were significant differences among cultivars for days taken for first sprout to appear. The cv. Chawla (9.65) took lesser time for sprouting than cvs. Arakta (12.72), Mridula (14.44), Muskat (13.16), Ichakdana (12.28), Bhagwa (12.55), Kandhari Kabuli (11.07), Nabha (10.76), Jodhpur Red (18.99), P- 23 (17.43). Among various growth regulators, IBA 5000 ppm produced significantly early sprouting (11.19). It was followed by IBA 4000 ppm (12.13) and more number of days taken sprouting in control (15.59).

The interaction between cultivars and different concentrations of growth regulator on days to first sprouting differed significantly. It was observed that cuttings of cv. Chawla treated with IBA 5000 ppm (7.46) sprouted significantly earlier followed by same cultivar treated with IBA 4000 ppm (7.82), while maximum number of days (20.67) taken for first sprout to appear was observed in cuttings of cv. Jodhpur Red i.e. control. The remaining treatments were in the range of 8.14-19.65 days.

Table 8: Effect of variety and plant growth regulator concentrations on days to first sprouting in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	15.80	13.19	12.28	12.03	10.30	12.72
Mridula	16.28	15.41	14.46	13.31	12.75	14.44
Muskat	15.08	14.06	13.16	12.46	11.02	13.16
Ichakdana	15.10	13.82	12.75	10.16	9.60	12.28
Chawla	12.52	12.30	8.14	7.82	7.46	9.65
Bhagwa	15.08	13.70	12.57	11.14	10.28	12.55
Kandhari Kabuli	13.17	13.07	10.13	9.91	9.04	11.07
Nabha	12.57	12.51	9.90	9.80	9.02	10.76
Jodhpur Red	20.67	19.65	19.19	18.02	17.42	18.99
P- 23	19.61	18.40	17.51	16.63	15.01	17.43
Mean	15.59	14.61	13.01	12.13	11.19	

C.D ($p \leq 0.05$)

Variety (V)	0.52
IBA concentration (C)	0.36
V $\times$ C	1.16

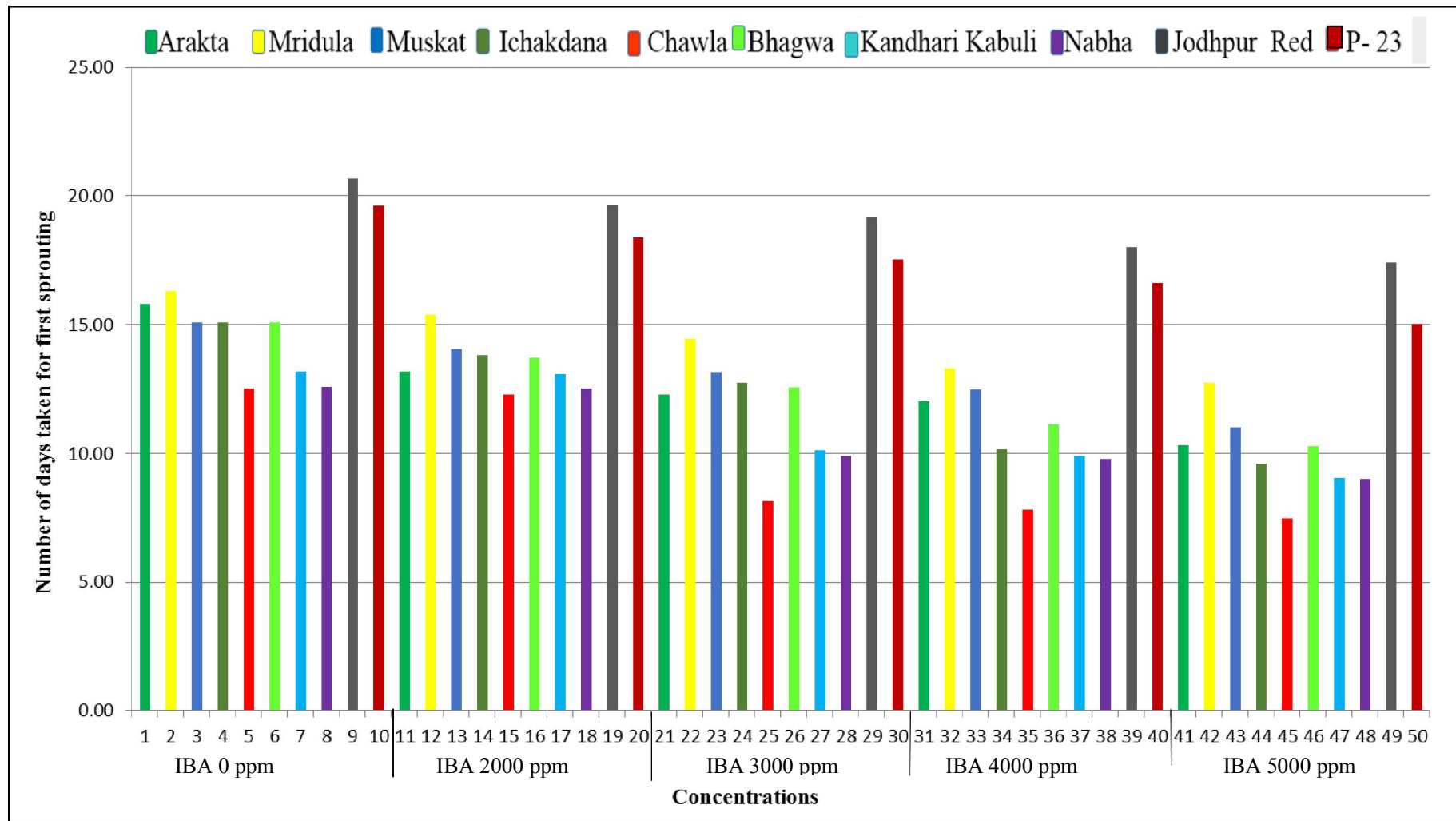


Figure 8: Effect of variety and plant growth regulator concentrations on days to first sprouting in pomegranate cuttings

4.2.2 Number of shoots per cutting

The mean number of shoots per cutting as influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 9 and Figure 9.

The data indicated that there were significant differences among cultivars in number of shoots per cutting. The cuttings of Kandhari Kabuli showed superior result (2.88) with respect to mean number of shoots per cutting than remaining cultivars. Minimum number of shoots per cutting were reported in cv. Jodhpur Red (1.56). Regardless of cultivars, IBA 5000 ppm (2.84) exhibited enhanced performance in relation to number of sprouts per cutting followed by IBA 4000 ppm (2.33), IBA 3000 ppm (2.18) and minimum was observed in (1.45) control.

The interaction between cultivars and different concentrations of growth regulator on number of shoots differed significantly. It was observed that cuttings of cv. Kandhari Kabuli treated with IBA 5000 ppm (4.13) number of shoots followed by cultivar Nabha treated with IBA 5000 ppm (3.73), while least number of shoots (1.08) were reported in cv. Jodhpur Red i.e. control.

Table 9: Effect of variety and plant growth regulator concentrations on number of shoots per cutting in pomegranate

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	1.36	1.83	2.16	2.19	2.58	2.02
Mridula	1.14	1.47	1.89	1.97	2.21	1.73
Muskat	1.26	1.44	1.77	1.95	2.36	1.75
Ichakdana	1.73	2.40	2.61	2.81	3.05	2.52
Chawla	1.52	2.32	2.58	2.78	3.52	2.54
Bhagwa	1.70	1.97	2.27	2.43	2.75	2.22
Kandhari Kabuli	1.92	2.48	2.84	3.03	4.13	2.88
Nabha	1.56	2.42	2.63	2.80	3.73	2.63
Jodhpur Red	1.08	1.47	1.63	1.63	1.98	1.56
P- 23	1.30	1.37	1.50	1.71	2.10	1.59
Mean	1.45	1.91	2.18	2.33	2.84	

C.D ($p \leq 0.05$)

Variety (V)	0.12
IBA concentration (C)	0.08
V × C	0.27

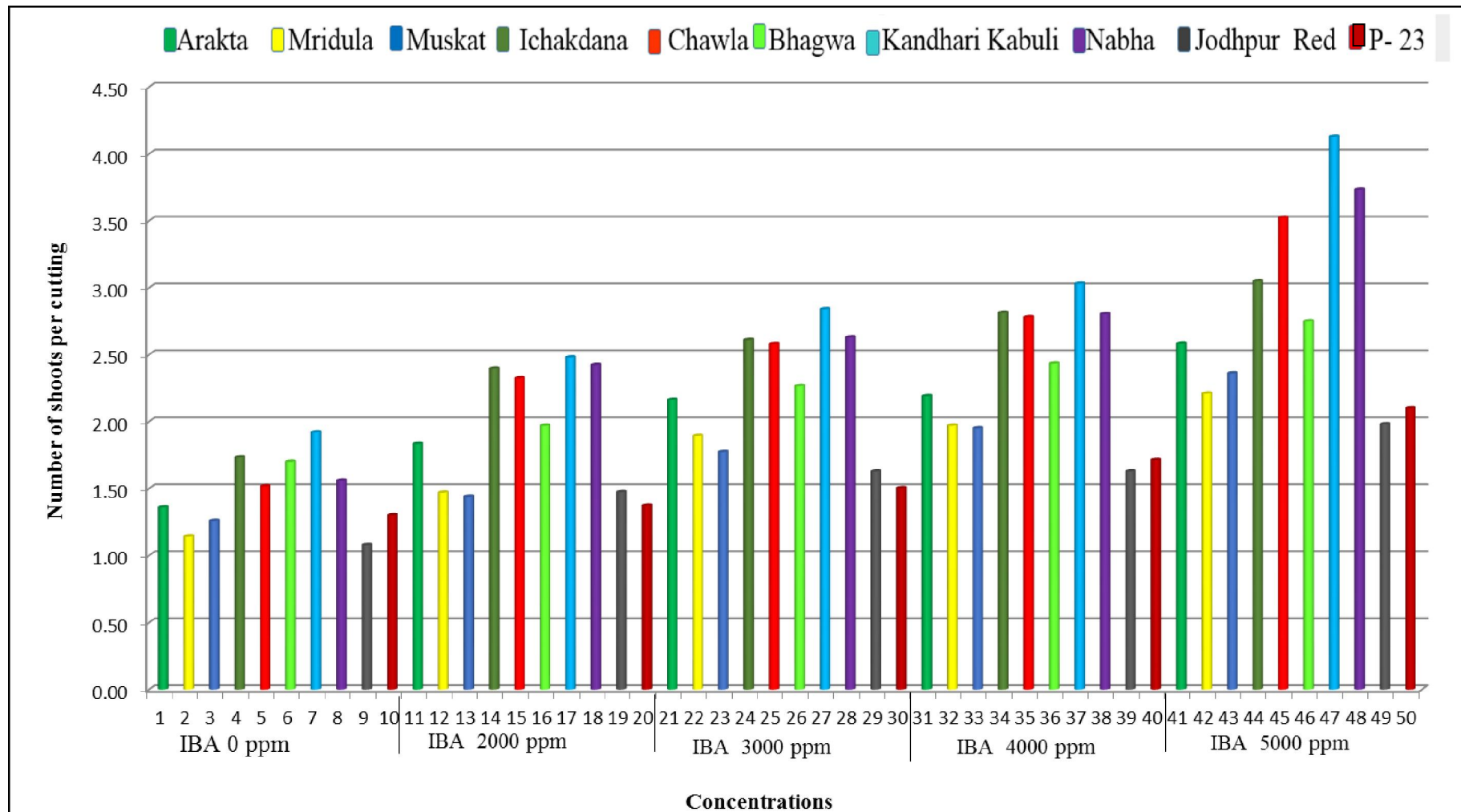


Figure 9: Effect of variety and plant growth regulator concentrations on number of shoots per cutting in pomegranate

4.2.3 Length of longest shoot per cutting (cm)

The data pertaining to length of longest shoot per cutting influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 10 and illustrated in Figure 10.

The length of the longest shoot that emerged on the cuttings was significantly higher in cv. Nabha (26.70) than cuttings of remaining cvs. Arakta (22.04), Mridula (20.25), Muskat (20.30), Ichakdana (22.99), Bhagwa (22.69), Kandhari Kabuli (26.65), Chawla (26.43), Jodhpur Red (18.52), P-23 (19.12). The plant growth regulator significantly increased the shoot length of pomegranate cultivars. IBA 5000 ppm recorded significantly highest shoot length (26.24), while the least (18.57) was observed with control.

The interaction between cultivars and concentrations of growth regulators on length of the longest shoot was significantly different. The cuttings of Nabha treated with IBA 5000 ppm gave longest shoot (33.85) followed by cv. Kandhari Kabuli (32.18) cuttings treated with IBA 5000 ppm, while the least was recorded in Jodhpur Red (16.39) i.e. control.

Table 10: Effect of variety and plant growth regulator concentrations on length of the longest shoot (cm) in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	19.77	20.88	21.99	22.99	24.59	22.04
Mridula	17.55	19.52	20.33	21.35	22.50	20.25
Muskat	17.40	18.29	19.65	22.95	23.23	20.30
Ichakdana	19.39	21.14	22.98	23.43	28.01	22.99
Chawla	21.67	25.42	28.15	27.15	29.78	26.43
Bhagwa	19.05	20.56	24.92	22.84	26.12	22.69
Kandhari Kabuli	21.04	24.40	27.17	28.50	32.18	26.65
Nabha	17.00	23.43	28.75	30.47	33.85	26.70
Jodhpur Red	16.39	17.38	18.53	19.64	20.67	18.52
P- 23	16.47	17.67	19.13	20.83	21.52	19.12
Mean	18.57	20.87	23.16	24.01	26.24	

C.D ($p \leq 0.05$)

Variety (V)	0.99
IBA concentration (C)	0.70
V $\times$ C	2.21

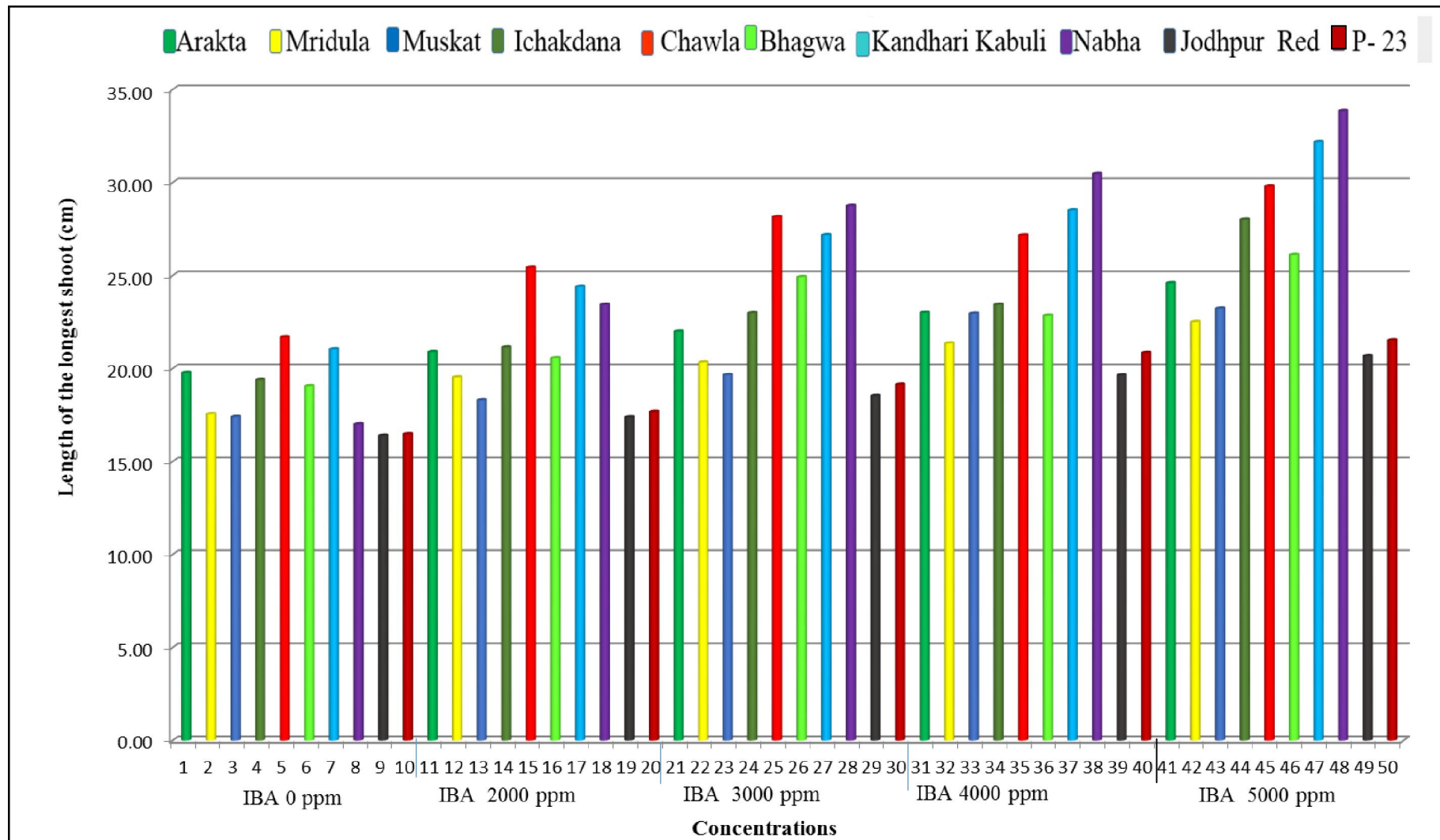


Figure 10: Effect of variety and plant growth regulator concentrations on length of the longest shoot (cm) in pomegranate cuttings



Plate 7: Shoot growth in cuttings of different varieties of pomegranate treated with 2000 ppm concentrations of IBA



Plate 9: Shoot growth in cuttings of different varieties of pomegranate treated with 4000 ppm concentrations of IBA



Plate 10: Shoot growth in cuttings of different varieties of pomegranate treated with 5000 ppm concentrations of IBA

4.2.4 Number of leaves per cutting

The data related to average number of leaves per cutting as influenced by cultivars, different concentrations of growth regulator and their interaction are presented in Table 11 and Figure 11.

There was a significant difference between individual factors and interaction on average number of leaves per cutting. The number of leaves formed on the shoots of Kandhari Kabuli (30.30) cuttings were significantly higher than remaining cultivars. Least number of leaves were reported in cv. Jodhpur Red (20.66). IBA concentrations significantly increased the number of leaves throughout the study. The maximum number of leaves were found in cuttings treated with IBA 5000 ppm (28.05) and minimum number of leaves (20.31) were observed in control.

The cultivars interacted significantly with IBA concentrations throughout the investigation. Cuttings of Kandhari Kabuli produced significantly maximum number of leaves (36.57) followed by same cultivar treated with IBA 4000 ppm (33.63) and least was recorded in Jodhpur Red (18.52) i.e. control.

Table 11: Effect of variety and plant growth regulator concentrations on mean number of leaves per cutting in pomegranate

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	19.77	21.74	23.46	24.77	26.90	23.33
Mridula	19.09	21.60	23.32	24.80	25.62	22.89
Muskat	20.23	21.69	22.91	23.84	25.93	22.92
Ichakdana	19.49	22.78	26.00	27.05	28.57	24.78
Chawla	20.63	21.82	24.53	27.54	30.11	24.92
Bhagwa	20.03	23.01	24.95	25.97	27.69	24.33
Kandhari Kabuli	22.54	27.45	31.32	33.63	36.57	30.30
Nabha	23.29	25.02	25.86	26.91	31.31	26.47
Jodhpur Red	18.52	19.48	20.77	21.43	23.10	20.66
P- 23	19.50	22.04	21.96	23.68	24.76	22.39
Mean	20.31	22.66	24.51	25.96	28.05	

C.D ($p \leq 0.05$)

Variety (V)	0.69
IBA concentration (C)	0.49
V × C	1.56

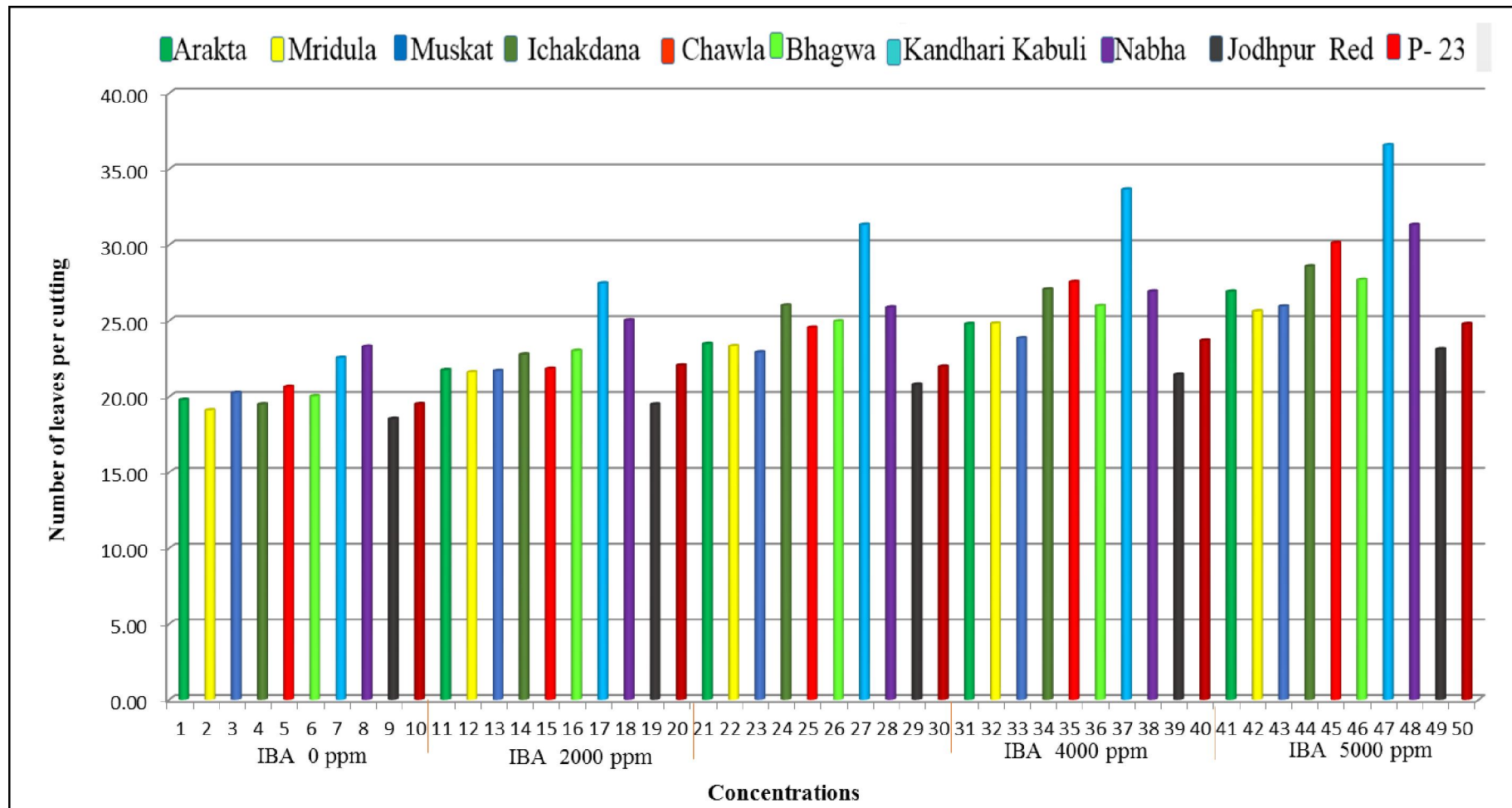


Figure 11: Effect of variety and plant growth regulator concentrations on mean number of leaves per cutting in pomegranate

4.2.5 Leaf area per cutting (cm²)

The data pertaining to leaf area influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 12 and represented in Figure 12.

In respect of leaf area cv. Kandhari Kabuli (25.56) showed significantly superior compared to remaining cultivars. Irrespective of cultivars, different concentrations of growth regulators significantly influenced leaf area per cutting. Maximum leaf area was noticed in cuttings treated with IBA 5000 ppm (25.76) followed by IBA 4000 ppm (23.72), IBA 3000 ppm (22.52), IBA 2000 ppm (21.17) and the least (19.24) was recorded in control.

The interaction effect of cultivars and IBA concentrations was significantly different on leaf area per cutting. In cv. Kandhari Kabuli, maximum leaf area was recorded with IBA 5000 ppm (34.05). The minimum leaf area per cutting was recorded in cuttings of Jodhpur Red (16.10).

Table 12: Effect of variety and plant growth regulator concentrations on leaf area per cutting (cm²) in pomegranate

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	19.97	21.55	22.68	23.72	24.48	22.48
Mridula	18.46	20.24	21.00	21.99	22.87	20.91
Muskat	18.86	19.98	20.94	22.48	23.44	21.14
Ichakdana	20.24	22.05	24.32	25.40	26.73	23.75
Chawla	20.39	22.27	25.59	26.68	28.26	24.64
Bhagwa	19.24	20.67	23.47	24.43	25.83	22.73
Kandhari Kabuli	20.60	22.76	24.02	26.38	34.05	25.56
Nabha	21.04	24.27	24.72	25.51	29.24	24.95
Jodhpur Red	16.10	18.77	18.53	19.53	20.83	18.75
P- 23	17.48	19.12	19.91	21.11	21.93	19.91
Mean	19.24	21.17	22.52	23.72	25.76	

C.D ($p \leq 0.05$)

Variety (V)	0.76
IBA concentration (C)	0.53
V × C	1.69

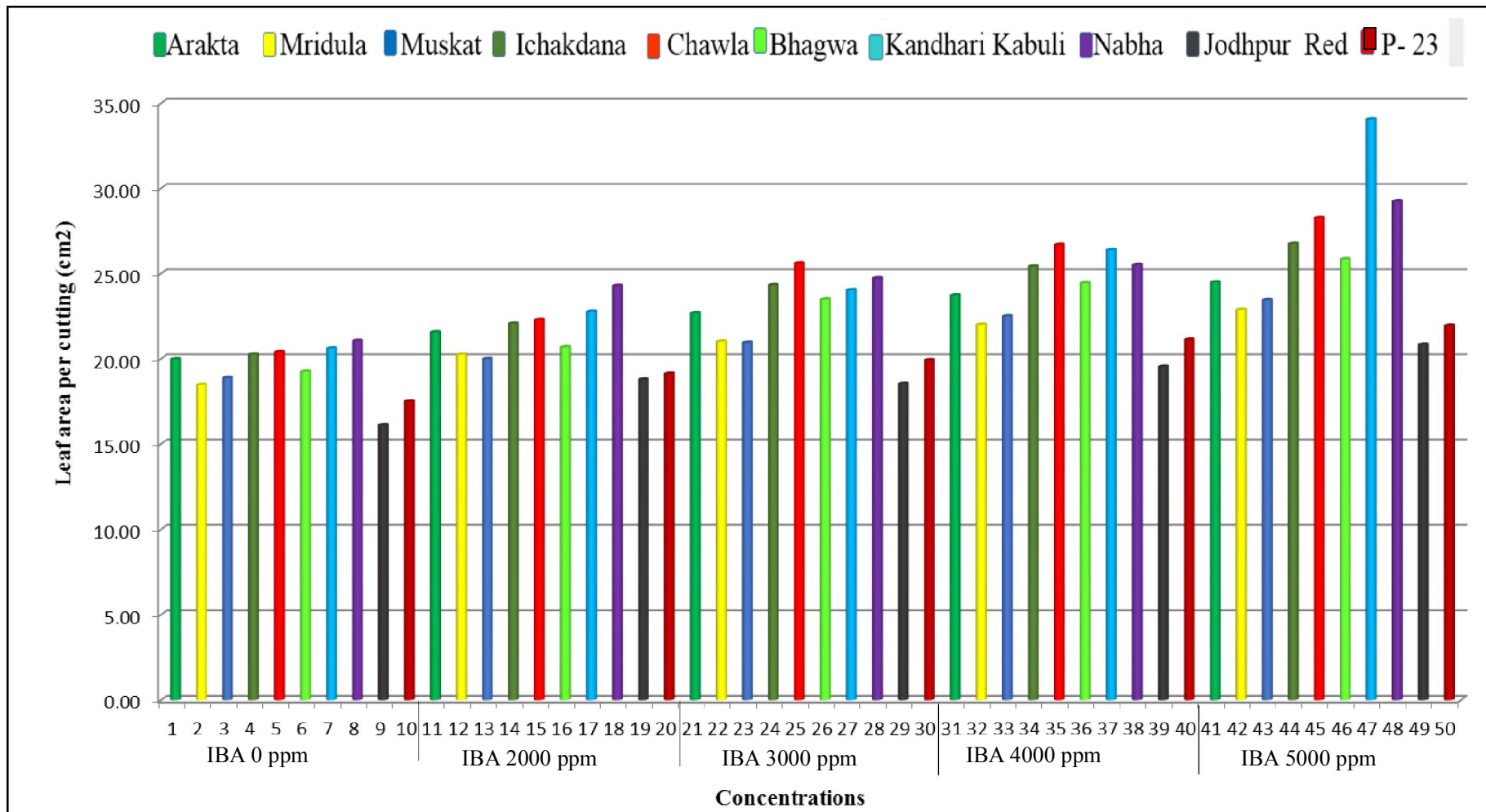


Figure 12: Effect of variety and plant growth regulator concentrations on leaf area per cutting (cm^2) in pomegranate

4.2.6 Total chlorophyll per cutting (SPAD units)

The data related total leaf chlorophyll content per cutting as affected cultivars, IBA concentrations and their interaction are presented in Table 13 and depicted in Figure 13.

The data indicated that there were significant differences among cultivars in total chlorophyll content per cutting. The cuttings of Kandhari Kabuli showed superior result (30.16) with respect to chlorophyll content per cutting than remaining cultivars. Minimum chlorophyll content per cutting were reported in cv. Jodhpur Red (19.20). Regardless of cultivars, IBA 5000 ppm (28.84) exhibited enhanced performance in relation to chlorophyll content per cutting followed by IBA 4000 ppm (26.51), IBA 3000 ppm (24.77) and minimum was observed in (19.88) control.

There was no significant interaction between cultivars and IBA concentrations on total leaf chlorophyll content per cutting.

Table 13: Effect of variety and plant growth regulator concentrations on total chlorophyll per cutting (SPAD units) in pomegranate

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	19.06	22.26	23.07	25.29	28.20	23.57
Mridula	17.35	19.44	21.84	23.20	25.79	21.52
Muskat	18.56	20.87	22.78	25.11	27.52	22.91
Ichakdana	21.02	25.00	26.56	28.43	30.13	26.23
Chawla	22.06	25.44	28.04	29.70	32.27	27.50
Bhagwa	20.15	23.86	24.69	26.83	29.30	24.96
Kandhari Kabuli	25.72	28.38	30.29	31.57	34.86	30.16
Nabha	23.44	26.42	28.20	30.63	32.90	28.32
Jodhpur Red	15.00	17.34	19.34	21.48	22.85	19.20
P- 23	16.44	18.21	22.95	22.90	24.56	21.01
Mean	19.88	22.72	24.77	26.51	28.84	

C.D ($p \leq 0.05$)

Variety (V)	1.37
IBA concentration (C)	0.96
V × C	NS

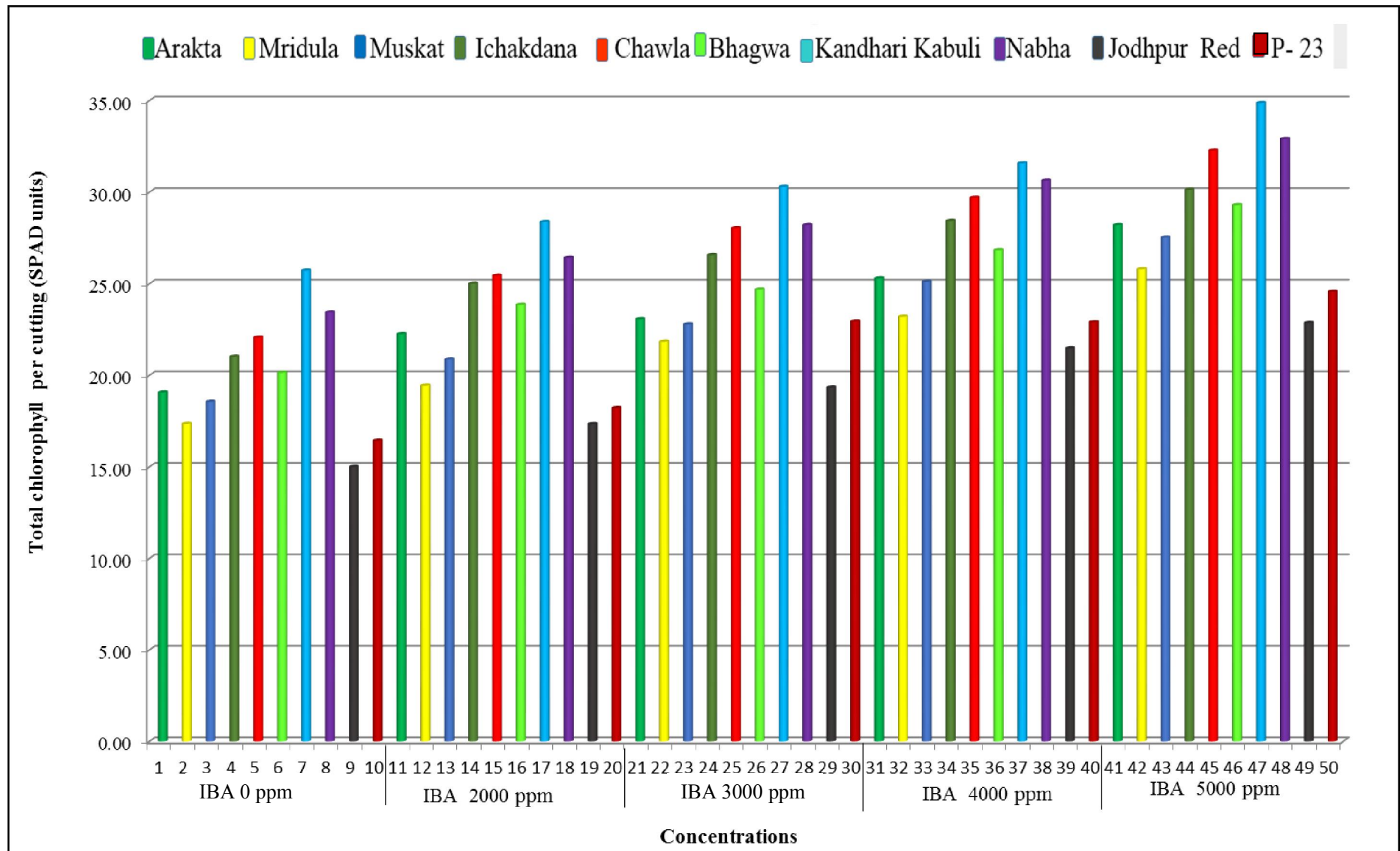


Figure 13: Effect of variety and plant growth regulator concentrations on total chlorophyll per cutting (SPAD units) in pomegranate

4.2.7 Fresh weight of shoots (g)

The data pertaining to fresh weight of shoots as influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 14 and Figure 14.

The fresh weight of shoots was differed significantly among the cultivars. Among all the cultivars, cuttings of cv. Nabha (7.65 g) showed significantly more pronounced effect in regard to fresh weight of shoots than the cuttings of cv. Arakta (6.03 g), Mridula (5.26 g), Muskat (5.29 g), Ichakdana (7.11 g), Bhagwa (6.48 g) , Kandhari Kabuli (7.32 g), Chawla (7.22 g), Jodhpur Red (4.98 g), P-23 (4.82 g). IBA concentrations significantly increased the fresh weight of shoots. Highest fresh weight of shoots was noticed in cuttings treated with IBA 5000 ppm (7.66 g), while the least was recorded in control (4.59 g).

The interaction between cultivars and different IBA concentrations on fresh weight of shoots was significantly different. Maximum fresh weight of shoots was obtained in cuttings of Nabha treated with IBA 5000 ppm (9.35 g) followed by cv. Kandhari Kabuli (8.90 g) with IBA 5000 ppm and least was recorded in cuttings of Jodhpur Red (3.50 g) i.e. control.

Table 14: Effect of variety and plant growth regulator concentrations on fresh weight of shoots (g) in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	4.60	5.40	6.40	6.56	7.20	6.03
Mridula	3.70	4.80	5.20	5.80	6.81	5.26
Muskat	3.90	4.29	5.50	5.69	7.10	5.29
Ichakdana	5.30	7.40	7.20	7.00	8.66	7.11
Chawla	5.19	6.60	7.29	8.29	8.73	7.22
Bhagwa	5.10	5.90	6.69	6.90	7.85	6.48
Kandhari Kabuli	5.00	6.72	7.50	8.50	8.90	7.32
Nabha	5.60	6.84	8.10	8.40	9.35	7.65
Jodhpur Red	3.50	4.59	5.38	5.58	5.86	4.98
P- 23	4.00	4.11	4.41	5.38	6.20	4.82
Mean	4.59	5.66	6.36	6.81	7.66	

C.D ($p \leq 0.05$)

Variety (V) 0.33

IBA concentration (C) 0.23

V × C 0.74

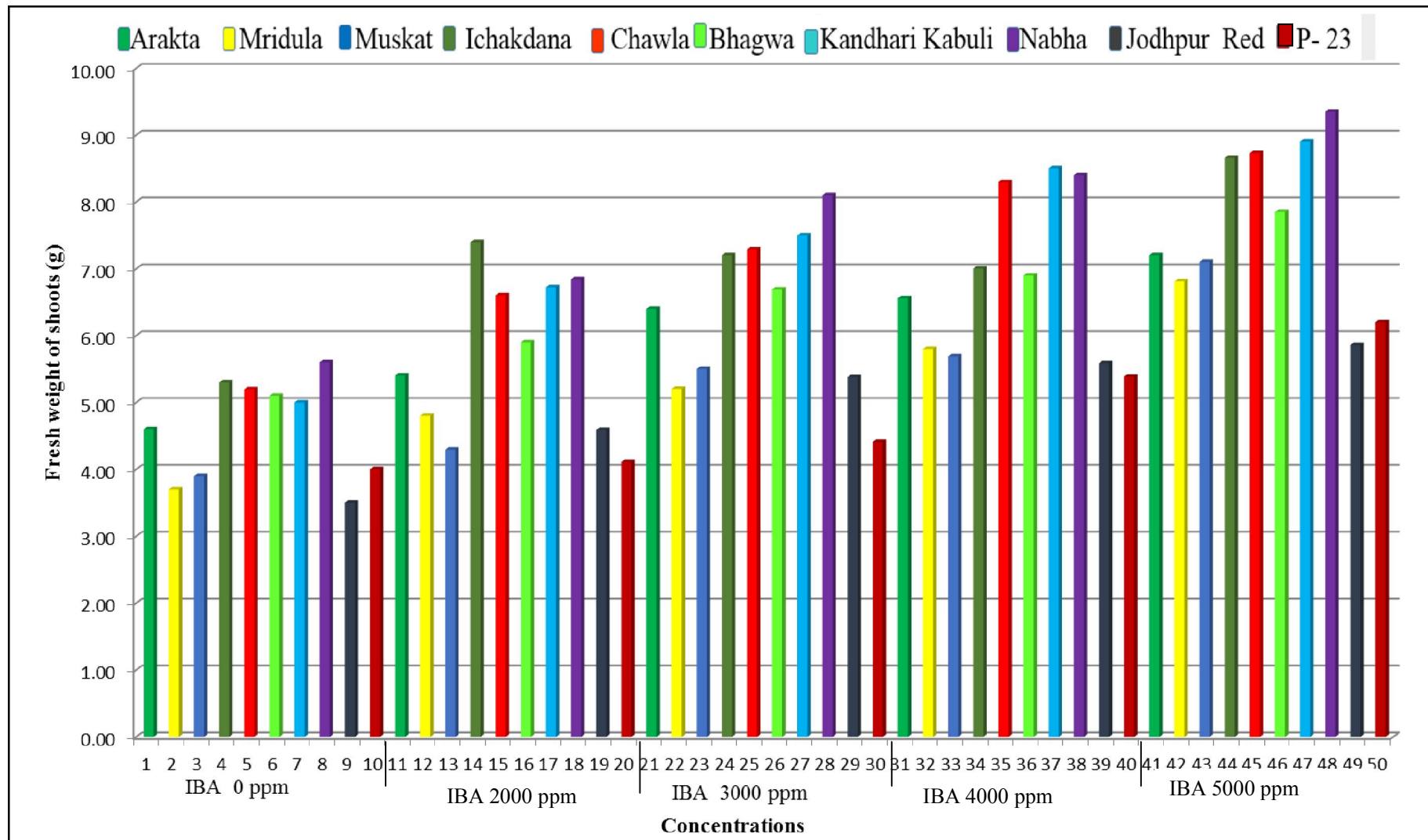


Figure 14: Effect of variety and plant growth regulator concentrations on fresh weight of shoots (g) in pomegranate cuttings

4.2.8 Dry weight of shoots (g)

The data pertaining to dry weight of shoots as influenced by cultivars, growth regulator concentrations and their interaction are presented in Table 15 and Figure 15.

The data clearly showed significant difference among cultivars with respect to dry weight of shoots. The shoots of Nabha (5.03 g) cuttings accumulated greater dry matter than remaining cultivars. Minimum dry weight of shoots (2.76 g) were reported in cv. Jodhpur Red. The IBA concentrations significantly increased the dry matter accumulation of shoots, highest dry matter was obtained in cuttings treated with IBA 5000 ppm (5.13 g) and the least was recorded in control (2.78 g)

The treatments of IBA concentrations interacted significantly with cultivars. The dry matter accumulation in shoots of Nabha was significantly greater in IBA 5000 ppm (6.80 g). Among treatment combinations, least accumulation of dry matter was recorded in cuttings of Jodhpur Red (2.18 g) i.e. control. The remaining treatments were in the range of 2.20 g - 6.40 g.

Table 15: Effect of variety and plant growth regulator concentrations on dry weight of shoots (g) in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	3.10	3.60	4.19	4.50	4.98	4.07
Mridula	2.20	3.09	3.45	4.38	4.65	3.55
Muskat	2.67	3.62	4.15	4.43	4.79	3.93
Ichakdana	2.93	3.90	4.51	4.70	5.21	4.25
Chawla	2.57	3.80	4.21	5.50	6.03	4.42
Bhagwa	2.80	3.75	4.19	4.61	5.11	4.09
Kandhari Kabuli	3.75	4.20	4.54	5.98	6.40	4.97
Nabha	3.18	4.34	4.67	6.20	6.80	5.03
Jodhpur Red	2.18	2.64	2.75	2.97	3.26	2.76
P- 23	2.43	2.87	3.19	3.41	4.11	3.20
Mean	2.78	3.58	3.98	4.66	5.13	

C.D ($p \leq 0.05$)

Variety (V)	0.37
IBA concentration (C)	0.26
V × C	0.82

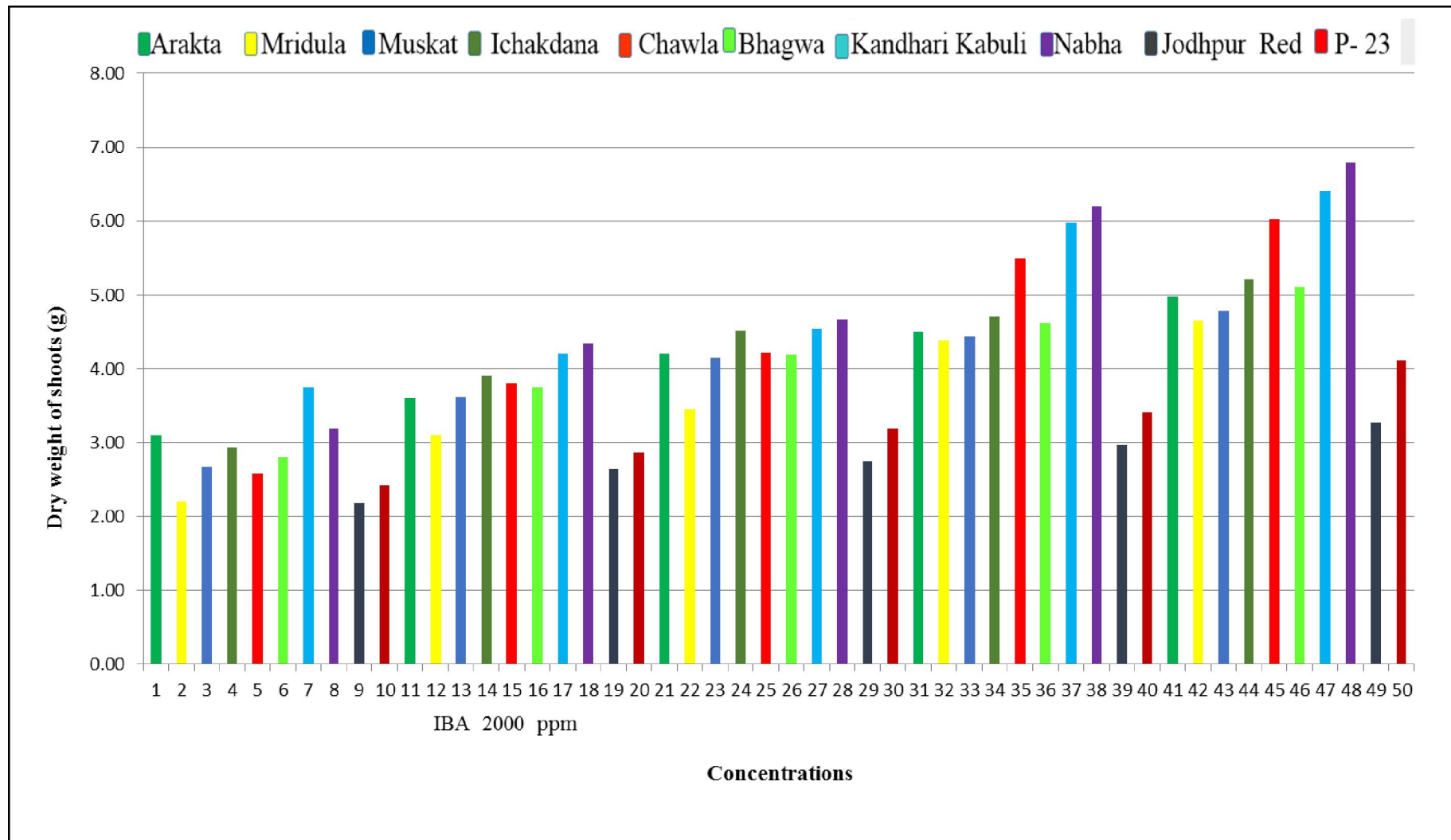


Figure 15: Effect of variety and plant growth regulator concentrations on dry weight of shoots (g) in pomegranate cuttings

4.2.9 Root to shoot Ratio (dry weight basis)

The data pertaining to root to shoot ratio as affected by cultivars , IBA concentrations and their interaction are presented in Table 16 and illustrated in Figure 16.

The data clearly showed significant difference among cultivars with respect to root to shoot ratio. The root to shoot ratio of cv.Chawla (0.181 g) cuttings greater than remaing cultivars. Minimum root to shoot ratio (0.094 g) were reported in cv. Muskat. The IBA concentrations significantly affected the root to shoot ratio, highest root to shoot ratio was obtained in cuttings treated with IBA 5000 ppm (0.168 g) and the least was recorded in cuttings treated with IBA 2000 ppm (0.112 g).

The treatments of IBA concentrations interacted significantly with cultivars. The root to shoot ratio of cv. Ichakdana was significantly greater in IBA 5000 ppm (0.299 g). Among treatment combinations, least root to shoot ratio was recorded in cuttings of Mridula (0.085 g) treated with IBA 4000 ppm.

Table 16: Effect of variety and plant growth regulator concentrations on root to shoot ratio (dry weight basis) in pomegranate cuttings

Variety (V)	IBA Concentration (C)					
	0 ppm	2000 ppm	3000 ppm	4000 ppm	5000 ppm	Mean
Arakta	0.107	0.109	0.101	0.094	0.107	0.104
Mridula	0.117	0.103	0.125	0.085	0.102	0.106
Muskat	0.087	0.099	0.091	0.090	0.103	0.094
Ichakdana	0.146	0.116	0.104	0.182	0.299	0.169
Chawla	0.177	0.131	0.168	0.163	0.266	0.181
Bhagwa	0.146	0.118	0.110	0.103	0.103	0.116
Kandhari Kabuli	0.090	0.090	0.142	0.118	0.237	0.135
Nabha	0.145	0.118	0.123	0.239	0.251	0.175
Jodhpur Red	0.120	0.119	0.120	0.112	0.110	0.115
P- 23	0.131	0.119	0.116	0.109	0.103	0.116
Mean	0.125	0.112	0.116	0.128	0.168	

C.D ($p \leq 0.05$)

Variety (V)	0.019
IBA concentration (C)	0.013
V × C	0.042

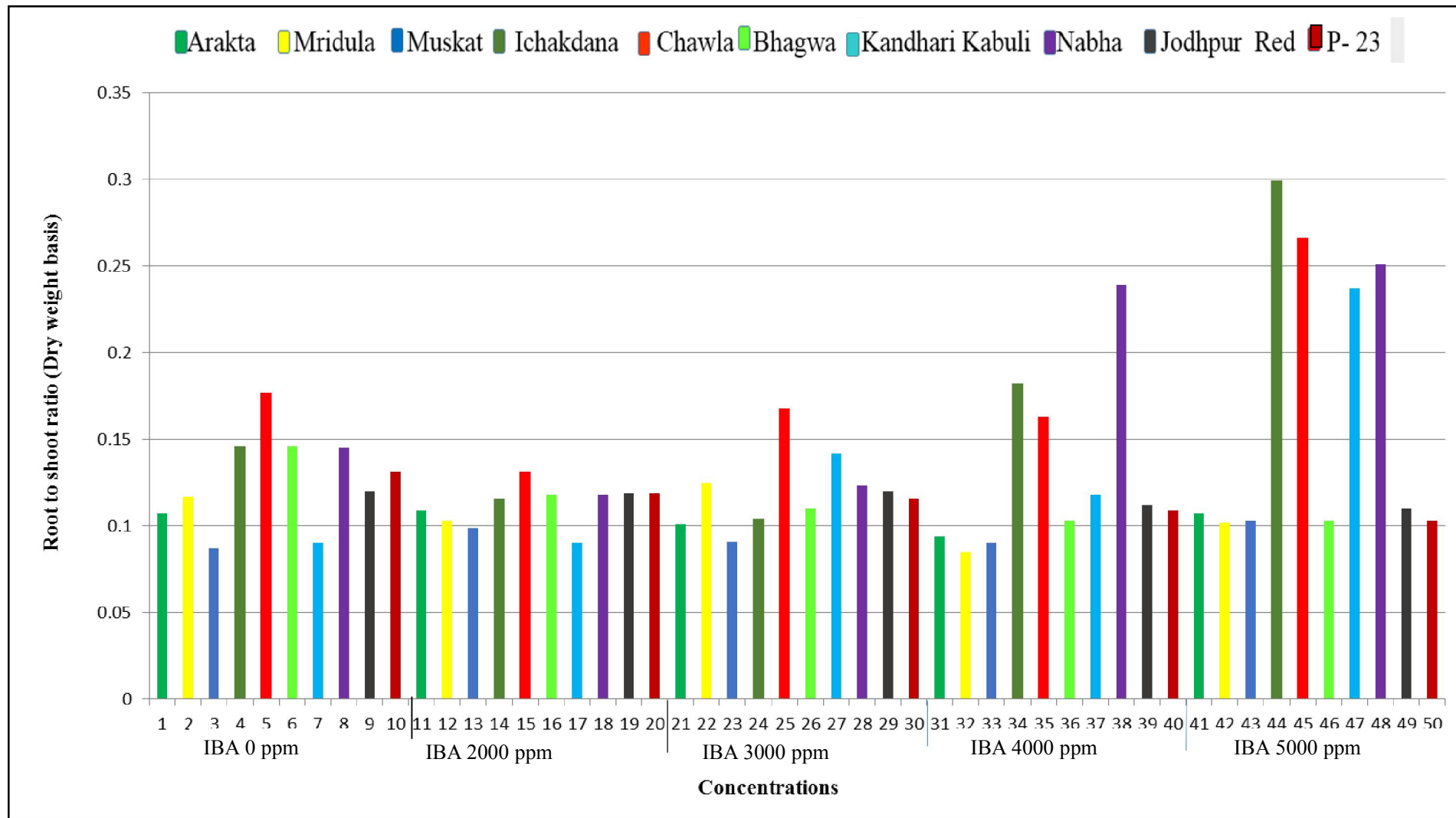


Figure 16: Effect of variety and plant growth regulator concentrations on root to shoot ratio (dry weight basis) in pomegranate cutting

Chapter - 5

DISCUSSION

The present investigation entitled “**Standardization of pomegranate (*Punica granatum* L.) propagation through cuttings**” was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus Srinagar, in the Division of Fruit Science (IBA) to find out the optimum levels of IBA to induce rooting in cuttings of selected varieties of pomegranate. In this present chapter an attempt has been made to evaluate and compare the results obtained with the findings of other workers.

5.1 Rooting parameters

5.1.1 Percentage of rooted cuttings

It is evident from the results given in Table 1 that IBA concentration at 5000 ppm was much more effective to stimulate rooting in the cuttings in pomegranate as compared to remaining IBA concentrations at 2000 ppm, 3000 ppm, 4000 ppm. It could be attributed to the increased doses of IBA encouraging the rooting ability of cutting by changing the structure of root (Weaver, 1972). Hambrick *et al.* (1991); Hartmann *et al.* (1997) considered the differences in carbohydrate in the cuttings as important factor that determine variability in rooting capacity among the genotypes; relatively high carbohydrates are associated with easy rooting. Krieken *et al.* (1993) reported that IBA might have enhanced the rooting by increase in internal free IBA, or synergistically modified the action of IAA or due to synthesis of endogenous IAA.

Melgarejo *et al.* (2000) stated that treatment of cuttings with increasing concentrations of IBA could combine with endogenous auxins already present in the cuttings leading to optimization of auxin levels and consequently improving the percentage of rooting in cuttings but very high concentration of auxin can induce the synthesis of ethylene leading inhibit root elongation and instead enhance adventitious root formation. The results are in agreement with the

findings of Purohit and Shekharappa (1985), who reported that IBA treatment (quick dip) was more effective in inducing roots on hardwood cuttings of pomegranate.

There is a high genetic variation in rootability among cultivars with high interactive effect along with auxins. The present findings agreed with work of Raut *et al.* (2015), Seiar (2017), Sharma *et al.* (2009) on pomegranate (*Punica garanatum* L.) propagation through cuttings.

5.1.2 Survival percentage

The survival percentage of rooted cuttings of cv. Chawla was observed to be significantly greater than the cuttings of remaining cultivars. According to Hartmann and Kester (1989) the survival percentage may vary possibly due to the presence of differential levels of endogenous rooting cofactors and carbohydrates and their differential behavior in different growth parameters.

The highest survival percentage was recorded in cuttings treated with IBA 5000 ppm, it might due to development of effective root system and increase in number and length of roots per cutting as influenced by the uptake of nutrients and water (Rajeswara *et al.*, 2008). The survival of the sprouted cuttings might be directly linked to the formation of adventitious roots on cuttings.

The growth regulator treatments imposed in the present investigation exhibited a significant interaction with cultivars and the cuttings. Chawla treated with IBA 5000 ppm recorded significantly maximum survival per cent. High success of cuttings may be due to high carbohydrate reserves per cutting and optimum concentration of IBA. The same factors brought about maximum number of shoots and roots per cutting and root length which inturn contributed to high survival percentage (Purohit and Shekharappa, 1985). The results are in harmony with the findings of Sharma *et al.* (2009) who obtained highest survival percentage of the rooted cuttings in pomegranate cv. Ganesh treated with IBA 500 ppm + Borax 1% and Rajkumar *et al.* (2016) obtained maximum survival

percentage in pomegranate cv. Phule Arakta treated with IBA @ 2500 ppm and rooting medium was vermiculite.

5.1.3 Number of roots per cutting

The maximum number of roots was observed with IBA 5000 ppm in cv. Chawla which might be due to hormonal effect leading to accumulation of internal substances and their downward movement. This pertains to the fact that the auxin promote cell division, elongation and differentiation of cambial initials into root primordia and in the mobilization of reserve food material to sites of root initiation there by giving higher number of roots per cutting (Sharma, 1999). It also might have been due to increased cell division and their differentiation under the influence of rooting chemicals, enhanced hydrolysis of nutritional reserves resulting into increased root formation zone.

These observations are in agreement with the findings of Polat and Caliskan (2009) who obtained greater number of roots in pomegranate cuttings of cultivar 31-N-01 treated with IBA @1000 ppm than the control. The results are in agreement with the earlier findings of Sharma *et al.* (2009) who obtained highest number of roots in cv.Ganesh treated with IBA 500 ppm + Borax 1% and Panda and Das (1990) who recorded the highest root number with the treatment of 5000 ppm IBA in hardwood cuttings of pomegranate cv. Dholka.

5.1.4 Average root length (cm)

Maximum average root length was observed in cuttings treated with IBA 5000 ppm in cv. Chawla than cuttings treated with IBA 2000 ppm, IBA 3000 ppm, IBA 4000 ppm. This might be due to an early initiation of roots at higher concentrations of IBA and therefore more utilization of the nutrients due to early formation of the roots (Ajaykumar, 2007). The action of auxin activity, which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings and resulted in accelerating cell elongation and cell division (Singh *et al.*, 2003). Singh (2014) also reported the similar result i.e.

maximum average root length per cutting in cv. Ganesh treated with 5g L⁻¹ of IBA.

5.1.5 Length of longest root per cutting (cm)

The genetic variation was reflected in the differences among the cultivars in their response to different concentrations of growth regulators. The differences among auxins could also be related to other factors such as higher stability and a slow rate of conjugation of IBA, so that the free IBA required to induce rooting will be available over a longer period of time than IAA or NAA (Krisantini *et al.*, 2006).

The reason for recording longest root in cv. Nabha may be attributed to the action of auxin activity which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances towards the base of cuttings and resulted in accelerated cell division and cell elongation in suitable environment (Singh *et al.*, 2003). Another possible reason may be due to early formation of roots and more utilization of reserved food materials of the treated cuttings (Ghatnatti, 1997). The early findings reported by Panda and Das (1990), Dhillon and Sharma (1992), Polat and Caliskan (2009), Seiar (2017) on pomegranate propagation are in accordance with the results obtained in the present study.

5.1.6 Fresh weight of roots (g)

Increase in fresh weight of roots in cv. Nabha with IBA 5000 ppm probably due to increased root number, average length of roots which is evident from Tables 3 and 4. The varietal and climatic differences during the study in relation to chemical regimes were reflected in producing heavier roots which inturn increased fresh weight of roots. Low auxin activity and its slow degradation by auxin destroying enzyme lead to the growth and vigour of roots. This might also be due to the reserved food in the cuttings (Singh *et al.*, 2013). The increase in number of roots and length of roots have directly influenced the fresh weight of roots. The results are in agreement with the earlier findings of Seiar (2017), who

obtained maximum fresh weight of roots with IBA 1500ppm + NAA 1000ppm. The results are similar to findings of Kamboj *et al.* (2017), Hakim *et al.* (2018) on propagation of pomegranate.

5.1.7 Dry weight of roots (g)

The cuttings of cv. Nabha treated with IBA 5000 ppm resulted in highest dry weight of roots compared to remaining treatments. This may be due to cultivar contained higher amounts of stored carbohydrates, when coupled with IBA increased the number of roots resulting in higher root dry matter accumulation. Cuttings of pomegranate treated with optimum concentration of IBA recorded more number of roots, resulting increases dry weight of roots. The Seiar (2017) also reported similar results i.e. maximum dry weight roots with IBA 1500 ppm + NAA 1000 ppm. The present findings are agreement with the findings of Hakim *et al.* (2018) on propagation of pomegranate.

5.2 Shooting parameters

5.2.1 Number of days taken for first sprouting

The minimum number of days to first sprouting was recorded in cuttings of cv. chawla treated with higher concentration of IBA (5000 ppm). The early sprouting of cuttings may be due to increased level of auxins which resulted in earlier completion of physiological processes in rooting and sprouting of cuttings. Chandramouli (2001) found that the increase in the concentration of IBA significantly decreased the number of days to first sprouting of cuttings and earliness in sprouting might be due to better utilization of stored carbohydrates, nitrogen and other factors with the help of growth regulators. These results are in conformity with findings of Damar *et al.* (2014) on propagation of pomegranate. These results are in accordance with the findings of Hakim *et al.* (2018), Kumawat (2009) on propagation of pomegranate through cuttings.

5.2.2 Number of shoots per cutting

It was observed that cuttings of cv. Kandhari Kabuli treated with IBA 5000 ppm sprouted significantly earlier compared to remaining treatments. The increased number of sprouts per cutting may be attributed to increased cell division and elongation at higher concentrations of IBA as reported by Alikhani *et al.* (2011) found maximum number of shoots per cutting of pomegranate treated with NAA 4000 ppm. These results are in agreement with the findings of Navjot and Kahlon (2002), who obtained maximum number of shoots in cv. Kandhari with IBA100 ppm. Shukla *et al.* (2004) also obtained maximum number of shoots when cv. Dholka treated with 100 ppm IBA.

5.2.3 Length of the longest shoot per cutting (cm)

The cultivar Nabha treated with IBA 5000 ppm recorded the longest shoot per cutting this may due to maximum number of roots per cutting enhanced the nutrient uptake and resulted in more photosynthate production. Food in the form of photosynthetates provide required energy for cell division and cell elongation and it results in maximum shoot length (Shahab *et al.*, 2013). Longest shoot on cuttings may be attributed to the better utilization of stored carbohydrates, nitrogen and other factors with the help of growth regulators (Chandramouli, 2001). The early findings reported by Singh (2014), Polat and Caliskan (2009), Seiar (2017) on pomegranate propagation are in accordance with the results obtained in the present study.

5.2.4 Number of leaves per cutting

Maximum number of leaves were produced in cuttings of cv. Kandhari Kabuli treated with IBA 5000 ppm. This might be due to activation of shoot growth which probably increased the number of nodes that leads to development of more number of leaves. IBA at 5000 ppm produced healthier, lengthy roots which helps in absorbtion of water and nutrients that have great influence on production of more number of leaves by the cuttings. The increase in number of

leaves may be attributed to increased cell division and elongation at higher IBA concentrations and its possible reason for increase and activation of shoot growth which probably increased the number of nodes that lead to development of more number of leaves. These results are in accordance with findings of Singh (2014), who obtained maximum number of leaves in cv. Ganesh with IBA 5000 ppm. The results are similar to the findings of Seiar (2017), who obtained maximum number of leaves with IBA 1000 ppm + NAA 1500 ppm in cv. Bhagwa.

5.2.5 Leaf area per cutting (cm²)

The cuttings of cv. Kandhari Kabuli treated with IBA 5000 ppm recorded the highest leaf area. Ismail and Asghar (2007) reported that when the cuttings treated with increasing concentrations of IBA results in more number of roots which increased nutrient uptake and aerial growth of the plants resulted in highest leaf area. There is a need to improve the photosynthetic rate and to produce more photosynthates by expanding their leaves and hence more leaf area was observed (Sahab *et al.*, 2013). The present findings are similar to findings of Navjot and Kahlon (2002), they obtained highest total leaf area (293.00 cm²) per cutting in cv. Kandhari when middle cuttings were treated with 100 ppm IBA.

5.2.6 Total chlorophyll per cutting (SPAD units)

The cuttings of cv. Kandhari Kabuli treated with IBA 5000 ppm recorded maximum total leaf chlorophyll content per cutting. The increased leaf area with increased concentrations of auxins might activated more photosynthates resulting in more chlorophyll content of leaves per cutting. Growth hormones have been shown to play an important role in regulating the amount and distribution of assimilates in plants (Galston and Davies, 1969). Sahab *et al.* (2013) observed that cuttings with more number of leaves enhanced nutrients uptake thereby increased the photosynthates production and provided sufficient food contents for the metabolic activities of the plants. The present results are in accordance with findings of Kumari (2014) in pomegranate propagation in cv. Ganesh.

5.2.7 Fresh weight of shoots (g)

Cuttings of Nabha treated with IBA 5000 ppm resulted in maximum fresh weight of shoots. This may be due to absorption of more number of nutrients and water (Sandhu and Singh, 1986). Maximum fresh weight of shoots per cutting probably due to increase in number of leaves and number of shoots per cutting which is evident from the data presented in Table 9. Hakim *et al.* (2018) fresh weight of shoots (10.80 and 12.60 g) was recorded significantly maximum in both the cvs. Bhagwa and Ruby, respectively with the application of IBA 1500 ppm + NAA 1500 ppm + Biomix, Seiar (2017) highest fresh weight of sprout (9.03 g) per rooted cutting was noticed with IBA 1500 ppm + NAA 1000 ppm, these findings are in accordance with the results obtained in the present study respectively.

5.2.8 Dry weight of shoots (g)

The cuttings of cv. Nabha treated with IBA 5000 ppm recorded the maximum dry weight of shoots. This might be due to reason that, auxins activate shoot growth resulted in elongation of stems and leaves through cell division accounting for higher dry weight of shoot. The present finding are in accordance with findings of Seiar (2017), he observed highest dry weight of shoots (4.66 g) per cutting when treated with IBA 1500ppm + NAA 1000ppm.

5.2.9 Root to shoot Ratio (dry weight basis)

The highest root to shoot ratio was recorded in cuttings of cv. Ichakdana when treated with 5000 ppm of IBA this might be due to more number of roots, shoots, root thickness and loss of moisture from roots and shoots is less compared to other treatments during drying, results in maximum root to shoot ratio.

Chapter- 6

SUMMARY AND CONCLUSION

The present investigation entitled “**Standardization of pomegranate (*Punica granatum* L.) propagation through cuttings**” was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus Srinagar, in the Division of Fruit Science.

The broad objective of the investigation was to study the effect of IBA at different concentrations on cuttings of pomegranate cultivars *viz*; Arakta, Mridula, Muskat, Ichakdana, Chawla, Bhagwa, Kandhari Kabuli, Nabha, Jodhpur Red and P- 23 to elicit their rooting and shooting parameters during rhizogenesis under Kashmir conditions. The experiment was carried out in Factorial Randomised Block Design with 3 replications comprising 50 treatment combinations which include two factors *viz*; cultivars at ten levels and plant growth regulators at five levels. The results obtained from the experiment were summarized here under:

1. In general, the cultivars Chawla, Nabha, Kandhari Kabuli of pomegranate performed well compared to remaining varieties depending on their genetic nature.
2. The cuttings of all the cultivars which were under investigation with the influence of different concentrations of IBA showed that IBA at 5000 ppm gave better results in all the cultivars whereas, the least performance was observed in untreated cuttings (control).
3. Rooting parameters like percentage of rooted cuttings, average number of roots per cutting, average root length per cutting were recorded maximum in cuttings of Chawla followed by Nabha, Kandhari Kabuli, Ichakadana, Bhagwa, Arkata, Muskat, Mridula, P-23, Jodhpur red. All these rooting parameters were observed to be best in cuttings treated with IBA 5000 ppm followed by lower levels of IBA i.e. 4000 ppm, 3000 ppm, 2000 ppm while the least was noticed in untreated cuttings (control).

4. Rooting parameters like length of longest root per cutting, fresh weight of roots and dry weight of roots per cutting were recorded maximum in cuttings of Nabha followed by Chawla, Ichakadana, Kandhari Kabuli, Bhagwa, Arkata, Muskat, Mridula, P-23, Jodhpur red. All these rooting parameters were observed to be best in cuttings treated with IBA 5000 ppm followed by lower level of IBA 4000 ppm, 3000 ppm, 2000 ppm while the least was noticed in untreated cuttings (control).
5. The number of days taken to first sprouting differed significantly among treatment combinations. The cuttings of Chawla treated with IBA 5000 ppm recorded minimum days to sprout (7.46), while it was maximum in cuttings of Jodhpur Red (20.67) i.e. control.
6. The shooting parameters namely number of shoots, number of leaves, leaf area, chlorophyll per cutting were observed to be maximum in cuttings of Kandhari Kabuli, followed by Nabha, Chawla, Ichakadana, Bhagwa, Arkata, Muskat, Mridula, P-23, Jodhpur red. All these rooting parameters were observed to be best in cuttings treated with IBA 5000 ppm followed by lower level of IBA 4000 ppm, 3000 ppm, 2000 ppm while the least was noticed in untreated cuttings (control).
7. The shooting parameters namely length of longest shoot, Fresh weight of shoots and dry weight of shoots per cutting and root to shoot ratio were observed to be maximum in cuttings of Nabha followed by Kandhari Kabuli, Chawla, Ichakadana, Bhagwa, Arkata, Muskat, Mridula, P-23, Jodhpur red. All these rooting parameters were observed to be best in cuttings treated with IBA 5000 ppm followed by lower level of IBA 4000 ppm, 3000 ppm, 2000 ppm while the least was noticed in untreated cuttings (control).
8. Survival percentage of cuttings was observed to be maximum in cuttings of Chawla, followed by Nabha, Kandhari Kabuli, Ichakadana, Bhagwa,

Arkata, Muskat, Mridula, P-23, Jodhpur red.

9. In almost all the root and shoot parameters IBA @ 5000 ppm performed better followed by 4000 ppm and 3000 ppm as compared to control.
10. Among the ten cultivars studied, cvs. Chawla, Nabha and Kandhari kabuli performed superior in almost all root and shoot parameters followed by cvs. Ichakdana, Bhagwa, Arakta, Muskat, Mridula, P- 23 and Jodhpur red. The results showed that cvs.Chawla, Nabha and Kandhari Kabuli were found to be best suited for propagation under Kashmir conditions.

FUTURE LINE OF WORK

1. Pre-treatments such as girdling and etiolation in combination with root promoters and their effect on rooting could be tried.
2. Use of different types of biofertilizers with different rooting hormones could be tried.
3. Development of protocol for multiplication of commercial varieties of pomegranate through tissue culture.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. O. C. Sharma, Senior Scientist, CITH, Srinagar during Viva-Voce examination held on 29-07-2019 have been incorporated in the manuscript entitled “**Standardization of pomegranate (*Punica granatum* L.) propagation by cuttings**” submitted by **Mr. G Sivakoteswara Rao (Regd. No. 2017-H-157-M)**.

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