AJH
eISSN- 0976-724X

THE ASIAN JOURNAL OF HORTICULTURE
Volume **11** | Issue 2 | December, 2016 | 261-268
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RESEARCH PAPER

DOI : 10.15740/HAS/TAJH/11.2/261-268

Article history **:**
Received : 26.08.2016
Revised : 01.10.2016
Accepted : 15.10.2016

Influence of plant growth regulators and *Azospirillum* on rooting of air layers in guava (*Psidium guajava* L.)

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ABSTRACT : Investigation was carried out on air layering in guava as influenced by growth regulators and *Azospirillum* was carried out in the Orchard, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalainagar during 2013-14 aimed to find out suitable root inducing treatment in mature shoot air-layers of guava cv. L-49. There were 14 treatment combinations with three replications laid out in Randomised Block Design. In general, both growth regulators *viz*., IBA, NAA alone and in combination with *Azospirillum* favoured rooting in air-layers. Among the different combinations, the layers which had received *Azospirillum* 37.5g + IBA (Indole butyric acid) 3000 ppm + NAA (Naphthalene acetic acid) 3000 ppm (T_{12}) recorded significantly higher percentage (91.68%) of rooting with desirable root characters such as higher number of primary and secondary roots, longer length of primary roots and higher girth of primary roots. Next to this treatment, the other favorable treatments were IBA, 3000 ppm + NAA, 3000 ppm (T_6), IBA, 2000 ppm (T_1), *Azospirillum* 37.5g + IBA, 4000 ppm (T_8), *Azospirillum* 37.5 g + IBA, 6000 ppm (T_9), *Azospirillum* 37.5 g + IBA 2000 ppm + NAA 2000 ppm (T_{11}). The use of medium concentration (3000 ppm) of both the growth regulators (IBA and NAA) with *Azospirillum* 37.5g was more effective as compared to either lower (2000 ppm) or higher (6000 pm) concentrations of IBA and NAA.

KEY WORDS : Plant growth regulator, *Azospirillum*, Guava, Rooting

HOW TO CITE THIS ARTICLE : Anandhanambi, D., Arivazhagan, E. and Kandasamy, R. (2016). Influence of plant growth regulators and *Azospirillum* on rooting of air layers in guava (*Psidium guajava* L.). *Asian J. Hort.*, **11**(2) : 261-268, **DOI : 10.15740/HAS/TAJH/11.2/261-268.**

Guava (*Psidium guajava* L.) is one of the hardy fruit crops being cultivated throughout India. It is native of tropical America and is widely distributed throughout the tropical and sub tropical regions of the world. Guava is fourth most important fruit in area and production after mango, banana and citrus in India. Guava shares 3.3 per cent of area and 3.3 per cent of production of total fruit crop grown all over India. Guava is 5th in productivity among different fruit crops grown in India. It is being cultivated in India on 2.04 lakh hectares area with an annual production of 22.70 lakh tonnes (Salaria and Salaria, 2013). Uttar Pradesh leads in area and production while Karnataka leads in productivity (21.6 t/ha) of guava.

Uttar Pradesh is the highest guava producing state, accounting for about half of the total area of guava in the country. Allahabad has the reputation of growing the best guava of the world. The other important guava growing states are Karnataka, Bihar, Madhya Pradesh, Maharashtra and Tamil nadu. Allahabad Safeda, Sardar (Lucknow-49) and red fleshed are the important grown varieties of guava. Guava is considered as "common man's apple" and 'the apple of tropics' because of its availability for a longer time during the year at very moderate price. The major components of guava fruits are vitamin 'C' (250 mg/100 g fresh fruits), carbohydrates (13%) and minerals (calcium 29 mg, phosphorus 10 mg and iron 0.5 mg/100 mg fresh fruits). It is a very rich and cheap source of vitamin 'C' as it contains 4-6 times more vitamin 'C' than citrus fruit. Guava fruits are rich in pectin content, hence are extensively used in preparation of jelly. Besides, its diabetic value, the fruit is also used in preparing jelly, cheese, butter, paste, juice, juice concentrate, powder, canned slice/shell, nectar, puree and ice cream. Guava being a hardy crop is grown in variety of soils and climatic conditions. However, the suited are red loams, medium black and other well drained soils.

The guava plants can be propagated by several ways such as seed, cuttings, air layers, grafting etc. The seed propagation was wide spread earlier is now restricted to raising of rootstock material. The vegetative propagations by air layering are becoming more and more popular on account of their better success, cheaper cost and easy method. However, greater deal of variation in per cent success is observed in air layering. One of the causes for variation has been observed to be the age of shoots/ trees used in air layering. Although germplasm trees are known to give higher success, use of such trees in commercial nursery is rather limited. Most of the nurserymen use mature trees which are also used for commercial fruit production obviously the percentage of success is lower in air layers in such trees on account of exhaustion by crop load. It is possible that if the trees, especially the mature germplasm trees are exclusively used for air-layering or making cuttings, the percentage of success would not only be higher but also quicker which goes a long way in making available genuine planting material (air-layering) in abundance to meet the ever increasing demand.

The rooting ability of air layered shoots is decided by several factors that vary with the crops, cultivar and biochemical constituents of the clone (*viz*., carbohydrates, nitrogen, sugars, starch, phenols, auxins levels etc.) and the climatic conditions prevailing in the season (*viz*., temperature, relative humidity, rain fall etc.) of layering. All these factors should be at optimum level to attain better rooting of a guava layers.

Kumar and Syamal (2005) observed that the highest number of primary roots was produced using IBA 3,000 ppm treatment followed by NAA 2,000 ppm. High number of roots was recorded with IBA + NAA (1:1) at 2,000 ppm each. Etiolation along with exogenous application of auxin had stimulating effect on producing longer roots. The longer primary roots of 11.30 cm were obtained with 3,000 ppm of IBA followed by NAA at 2,000 ppm, each produced 9.17 cm long primary roots. Etiolation along with auxins treatment had marked influence on rooting of air layers. Use of IBA 3,000 ppm had maximum success of 93.34 per cent followed by NAA 1,000 ppm with a success of 86.68 per cent. *Azospirillum* is nitrogen fixing bacterium that lives in symbiotic (associative) relationship in the rhizosphere of several tropical crops. It stimulates plant growth through nitrogen fixation and production of growth promoting substances like auxins, gibberellins and cytokinin. It is estimated that almost 10 to 15 per cent of the required nitrogen can be met by *Azospirillum* (Tanuja and Purohit, 2008). Govind and Pandey (1985) have found that pepper cuttings inoculated with *Azospirillum* spp. had higher rooted cuttings, length of sprout, more number of fully opened leaves. According to them the bacteria apart from producing root hormone (IAA) also synthesized gibberellic acid which had enhanced vegetative growth. Keeping these points in view, the present study was undertaken with the specific objectives to study the effect of growth regulators and *Azospirillum* at different concentrations on rooting of guava air layers.

RESEARCH METHODS

The present investigation was carried out in the Vegetable Unit, Department of Horticulture, Faculty of Agriculture, Annamalai University during 2013-2014. The mature shoots used for air layering in present study were in the plants in Orchard, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalainagar. The air layers were prepared from single known clone of Lucknow– 49. The plants were planted at close spacing of 1.6 x 1.6 m. The severance itself serves as pruning which help in development of forced shoots from the dormant buds of the plant. Such shoots are known to behave as mature shoots physiologically. Air layering in the present study was conducted on such forced shoots. About twenty five shoots in each plant were used for air layering. The experiment was laid out in Randomized Block Design. There were 14 treatments consisting of growth regulators and microbial inoculants singly or in combination at different concentrations. The treatment details are as follows.

T_1 – IBA @ 2000 ppm
T_2 – IBA @ 4000 ppm
T_3 – IBA @ 6000 ppm
T_4 – IBA @ 1000 ppm + NAA @ 1000 ppm
T_5 – IBA @ 2000 ppm + NAA @ 2000 ppm
T_6- IBA @ 3000 ppm + NAA @ 3000 ppm
T_7 – *Azospirillum* 37.5 g + IBA @ 2000 ppm
T_8 – *Azospirillum* 37.5 g + IBA @ 4000 ppm
T_9 – *Azospirillum* 37.5 g + IBA @ 6000 ppm
T_{10} – *Azospirillum* 37.5 g + IBA @ 1000 ppm + NAA @ 1000 ppm
T_{11} – *Azospirillum* 37.5 g + IBA @ 2000 ppm + NAA @ 2000 ppm
T_{12} - *Azospirillum* 37.5 g + IBA @ 3000 ppm + NAA @ 3000 ppm
T_{13} – *Azospirillum* 37.5 g
T_{14} - Control

Twenty five air layers were used in each treatment which was replicated three times. Required quantity of growth regulators (IBA/NAA) and *Azospirillum* as per the treatment to prepare 100 g of powder formulation were weighed in an analytical balance and dissolved in 50 ml of 80 per cent alcohol. Required quantity of talc powder was weighed separately. The dissolved growth regulator/s were mixed with the weighed talc powder and made into paste by stirring. The mixture was kept for air drying over night for evaporation of alcohol. Then they were powdered and mixed with *Azospirillum* and made into paste again with water before application. Lignite based microbial culture *Azospirillum* (787.5 g) was obtained from the Department of Agricultural Microbiology, Faculty of Agriculture, Annamalai University, and 0.5 g of lignite based *Azospirillum* culture with more than 10^8 cells/g was used for inoculation. Selected mature shoots were girdled by removing 2.5 cm ring of bark in the internodal region, 25 cm below the tip of shoot. Fifteen days after girdling, the layering operation was done on 16th June, 2013. A ring of bark of 2 mm was removed from just above the upper cut, to expose the fleshy tissues for absorption of applied growth regulator and microbial inoculants from formulations. Girdled portion was moistened with distilled water and formulations of growth regulator and microbial inoculants were applied with a soft camel-hair brush to the upper cut surface and also 2 cm portion stem above the cut. The exposed region was immediately covered with a ball of moist, chopped sphagnum moss without disturbing the applied growth regulator and microbial inoculants. The moss was covered with polythene tubing of 250 gauge thickness and both the ends were secured firmly using gunny thread. The layers were kept under constant observation to prevent from any mechanical damage and loss of moisture. During July – August period the occurrence of showers made the weather favourable for the retention of moisture in sphagnum moss. All the air-layers were detached from mother plants two and half months after air layering. The detached air layers were dipped in water and the sphagnum moss adhering to the roots was removed carefully using forceps to avoid damage to the roots. Observations like days taken for root emergence, rooting percentage, number of primary roots per air layer, number of secondary roots per air layer, length of primary roots per air layer, length of secondary roots per air layer, girth of primary roots and biochemical analysis like starch content, total sugars, total carbohydrates, total nitrogen, carbohydrates/nitrogen (C/N) ratio and total phenols were recorded in the experiment.

RESEARCH FINDINGS AND DISCUSSION

Both the growth regulators *viz*., IBA and NAA and *Azospirillum* favoured rooting. However, the favourable effect was more marked when both the growth regulators used in combination and in equal proportion with *Azospirillum.* From the Table 1, the percentage of rooting with IBA 2000 ppm alone was 66.38 which was raised significantly to 79.07 per cent when it was mixed with equal proportion of NAA. Similarly, the treatment combination IBA, 3000 ppm + NAA, 3000 ppm recorded the higher rooting percentage of 88.49. For the same treatment when the *Azospirillum* 37.5 g per treatment was mixed resulted in significantly highest 91.68 rooting percentage (Table 1). The growth regulators are known to exert synergistic influence when used in combination. Probably, in the present study also the higher percentage of rooting may be due to synergistic effect of two growth regulators used in combination in addition with *Azospirillum.* Bhandary and Kololgi (1960); Karunakara (1997); Kumar and Syamal (2005); Maurya *et al.* (2012) and Das *et al.* (2014) in guava also had made similar observation in guava air-layering and attributed the higher success in air-layers to the synergistic effect of two growth regulators IBA and NAA. Sateesh Kumar (1999) reported that dipping of pomegranate cuttings in *Azospirillum brasilense* gave maximum rooting percentage. It is interesting to note that use of medium concentration of (IBA 4000 ppm) when applied singly was also effective as compared to their lower (2000 ppm) or higher (6000 ppm) concentration. Besides giving higher percentage of rooting, the layers which received combination treatments of equal proportion (3000 ppm each) of IBA and NAA along with *Azospirillum* 37.5 g excelled in all root characters. The treatments involving combination of IBA, 3000 ppm +NAA, 3000 ppm, IBA singly at 4000 ppm, *Azospirillum* 37.5 g + IBA, 4000 ppm, *Azospirillum* 37.5 g + IBA 6000 ppm and *Azospirillum* 37.5 g + IBA 2000 ppm + NAA 2000 ppm were the next in the order with respect to root characters (Table 2). The *Azospirillum* 37.5 g + IBA 3000 ppm + NAA 3000 ppm showed root emergence in shorter period

Table 1 : Influence of growth regulators and *Azospirillum* on rooting characters of guava air layer

Treatments	Days taken for root emergence	Rooting percentage	Number of primary roots
T_1 – IBA @ 2000 ppm	44.75	66.38	7.96
T_2 – IBA @ 4000 ppm	39.40	81.76	10.72
T_3 – IBA @ 6000 ppm	44.50	79.84	9.85
T_4 – IBA @ 1000 ppm + NAA @ 1000 ppm	39.38	73.15	8.76
T_5 – IBA @ 2000 ppm + NAA @ 2000 ppm	37.40	79.07	9.42
T_6 – IBA @ 3000 ppm + NAA @ 3000 ppm	31.25	88.49	11.34
T_7 – *Azospirillum* @ 37.5g + IBA @ 2000 ppm	42.75	67.68	8.19
T_8 – *Azospirillum* @ 37.5g + IBA @ 4000 ppm	38.40	82.45	11.04
T_9 – *Azospirillum* @ 37.5g + IBA @ 6000 ppm	46.76	80.84	10.25
T_{10} – *Azospirillum* @ 37.5g + IBA @ 1000 ppm + NAA @ 1000 ppm	37.25	74.38	9.72
T_{11} – *Azospirillum* @ 37.5g + IBA @ 2000 ppm + NAA @ 2000 ppm	35.75	80.46	10.42
T_{12} – *Azospirillum* @ 37.5g + IBA @ 3000 ppm + NAA @ 3000 ppm	30.75	91.68	12.85
T_{13} – *Azospirillum* @ 37.5g	48.25	43.42	6.96
T_{14} – Control	51.75	38.51	3.82
Mean	40.60	73.43	9.37
S.E.±	1.63	1.78	0.33
C.D. (P=0.05)	3.36	3.67	0.68

Table 2 : Influence of growth regulators and *Azospirillum* on rooting characters of guava air layer

Treatments	Number of secondary roots	Length of primary roots (cm)	length of secondary roots (cm)	Girth of primary roots (mm)
T_1 – IBA @ 2000 ppm	16.29	6.80	10.92	5.23
T_2 – IBA @ 4000 ppm	22.83	7.95	14.67	6.03
T_3 – IBA @ 6000 ppm	20.35	7.63	13.79	5.37
T_4 – IBA @ 1000 ppm + NAA @ 1000 ppm	17.39	6.98	13.37	5.42
T_5 – IBA @ 2000 ppm + NAA @ 2000 ppm	19.37	7.27	14.45	5.54
T_6 – IBA @ 3000 ppm + NAA @ 3000 ppm	23.18	8.24	16.36	6.28
T_7 – *Azospirillum* @ 37.5g + IBA @ 2000 ppm	16.76	7.11	11.12	5.41
T_8 – *Azospirillum* @ 37.5g + IBA @ 4000 ppm	23.11	8.06	15.54	6.13
T_9 – *Azospirillum* @ 37.5g + IBA @ 6000 ppm	20.89	7.83	14.15	5.62
T_{10} – *Azospirillum* @ 37.5g + IBA @ 1000 ppm + NAA @ 1000 ppm	17.96	7.26	13.66	5.68
T_{11} – *Azospirillum* @ 37.5g + IBA @ 2000 ppm + NAA @ 2000 ppm	20.14	7.79	15.16	5.76
T_{12} – *Azospirillum* @ 37.5g + IBA @ 3000 ppm + NAA @ 3000 ppm	25.22	9.16	18.33	7.54
T_{13} – *Azospirillum* @ 37.5g	9.47	4.57	5.38	4.88
T_{14} – Control	8.98	3.29	4.90	4.15
Mean	18.71	7.13	12.98	5.64
S.E.±	0.34	0.32	0.32	0.32
C.D. (P=0.05)	0.71	0.67	0.67	0.67

(30.75 days). This was followed by IBA, 3000 ppm + NAA, 3000 ppm (31.25 days). Probably the synergistic influence could have been there for induction of early rooting, since NAA is known for promoting emergence of roots when used at optimum concentration in combination with IBA (Sulladmath and Kololgi, 1969 in sapota, Karunakara, 1997, in guava; Athani *et al*., 2001 in guava air-layering, Maurya *et al.*, 2012 and Das *et al.*, 2014) in guavas. Regarding the primary and secondary roots, the layers treated with combination of *Azospirillum* 37.5 g + IBA 3000 ppm + NAA 3000 ppm produced significantly higher number of roots. This is followed by the treatments IBA 3000 ppm + NAA 3000 ppm, IBA 4000 ppm, *Azospirillum* 37.5 g + IBA 4000

Table 3 : Influence of growth regulators and *Azospirillum* on biochemical characters of guava air layer

Treatments	Starch content (% dry wt.)	Total sugars (% dry wt.)	Carbohydrates (% dry wt.)
T_1 – IBA @ 2000 ppm	7.28	8.68	15.96
T_2 – IBA @ 4000 ppm	7.24	8.78	16.02
T_3 – IBA @ 6000 ppm	7.27	8.71	15.98
T_4 – IBA @ 1000 ppm + NAA @ 1000 ppm	7.24	8.73	15.98
T_5 – IBA @ 2000 ppm + NAA @ 2000 ppm	7.22	8.78	16.00
T_6 – IBA @ 3000 ppm + NAA @ 3000 ppm	7.19	8.80	15.99
T_7 – *Azospirillum* @ 37.5g + IBA @ 2000 ppm	7.23	8.72	15.94
T_8 – *Azospirillum* @ 37.5g + IBA @ 4000 ppm	7.19	8.83	16.02
T_9 – *Azospirillum* @ 37.5g + IBA @ 6000 ppm	7.21	8.75	15.96
T_{10} – *Azospirillum* @ 37.5g + IBA @ 1000 ppm + NAA @ 1000 ppm	7.18	8.78	15.96
T_{11} – *Azospirillum* @ 37.5g + IBA @ 2000 ppm + NAA @ 2000 ppm	7.17	8.82	15.99
T_{12} – *Azospirillum* @ 37.5g + IBA @ 3000 ppm + NAA @ 3000 ppm	7.15	8.85	16.00
T_{13} – *Azospirillum* @ 37.5g	7.31	8.37	15.98
T_{14} – Control	7.36	8.65	16.01
Mean	7.23	8.73	15.98
S.E.±	NS	NS	NS
C.D. (P=0.05)			

NS=Non-significant

Table 4 : Influence of growth regulators and *Azospirillum* on biochemical characters of guava air layer

Treatments	Nitrogen (% dry wt.)	Carbohydrate / nitrogen ratio	Total phenols (mg/g dry wt.)
T_1 – IBA @ 2000 ppm	1.22	13.08	1.29
T_2 – IBA @ 4000 ppm	1.20	13.35	1.36
T_3 – IBA @ 6000 ppm	1.21	13.20	1.33
T_4 – IBA @ 1000 ppm + NAA @ 1000 ppm	1.22	13.09	1.32
T_5 – IBA @ 2000 ppm + NAA @ 2000 ppm	1.20	13.33	1.34
T_6 – IBA @ 3000 ppm + NAA @ 3000 ppm	1.19	13.43	1.36
T_7 – *Azospirillum* @ 37.5g + IBA @ 2000 ppm	1.20	13.29	1.32
T_8 – *Azospirillum* @ 37.5g + IBA @ 4000 ppm	1.18	13.57	1.37
T_9 – *Azospirillum* @ 37.5g + IBA @ 6000 ppm	1.18	13.52	1.39
T_{10} – *Azospirillum* @ 37.5g + IBA @ 1000 ppm + NAA @ 1000 ppm	1.19	13.41	1.34
T_{11} – *Azospirillum* @ 37.5g + IBA @ 2000 ppm + NAA @ 2000 ppm	1.17	13.66	1.36
T_{12} – *Azospirillum* @ 37.5g + IBA @ 3000 ppm + NAA @ 3000 ppm	1.14	14.03	1.37
T_{13} – *Azospirillum* @ 37.5g	1.25	12.78	1.24
T_{14} – Control	1.27	12.60	1.21
Mean	1.20	13.31	1.32
S.E.±	NS	NS	NS
C.D. (P=0.05)			

NS=Non-significant

ppm, *Azospirillum* 37.5 g + IBA 6000 ppm, *Azospirillum* 37.5 g + IBA 2000 ppm + NAA 2000 ppm (Table 2). These results got the support from finding in other crops *viz*., Bid and Mukherjee (1969) in mango and Uthaiah *et al*. (1976) in sapota. Similar trend was observed by Karunakara (1997) in guava, Patil *et al*. (2004) in pomegranate air-layers and Gowda *et al*. (2006) in sapota, Maurya *et al.* (2012) and Das *et al.* (2014) in guava. With respect to mean length of primary and secondary roots, the treatments *Azospirillum* 37.5 g + IBA 3000 ppm + NAA 3000 ppm and IBA 3000 ppm + NAA 3000 ppm were found to be better than all other treatments. This may be due to the fact that early root initiation might have provided enough time for higher rate of cell division and cell elongation which ultimately might have promoted higher length of roots. Similar trend was observed by Sulladmath and Kololgi (1969) in sapota and Rajan and Sant Ram (1985) in mango and Karunakara (1997) and Rymbai and Reddy (2010) in guava air layers and Patil *et al*. (2004), Owais (2010) in pomegranate air layers. The foregoing indicate that combination treatment of *Azospirillum* 37.5 g + IBA 3000 ppm + NAA 3000 ppm has been found to induce better root system in guava mature shoot air- layers. The increase in number of roots per layer may be due to accumulation of rooting cofactors. Cofactors react with auxins and a large number of root regenerates, as reported by Brahmchari *et al.* (1997) in litchi. Better rooting with the application of IBA 5000 ppm was also expressed by Dimri and Nautiyal (2000) and Mandal *et al.* (1988) in litchi. All the treatments were significantly superior over control in respect of average length of roots. It may be due to increase in the level of auxins which in higher concentration acts as antagonistic effect. Auxin elongate the length of primary roots. Same view was expressed by Kumar (1998) in jackfruit. *Azospirillum* is nitrogen fixing bacterium that lives in symbiotic (associative) relationship in the rhizosphere of several tropical crops. It stimulates plant growth through nitrogen fixation and production of growth substances like auxins, gibberellins and cytokinin. It is estimated that almost 10 to 15 per cent of the required nitrogen can be met by *Azospirillum* (Tanuja and Purohit, 2008). The response of IBA with increasing concentration might be due to the activity of auxin at cambial may be adequate for initiating root primordial (Bhagat *et al.*, 1999). The maximum number of primary and secondary roots might be due to the hormonal effect leading to accumulation of internal substances and their downward movement as well as more cell division. The maximum mean length of shoots, suggesting that higher concentration of IBA stimulated faster growth of roots resulting in maximum length as reported by Tyagi and Patel (2004). The early root initiation might be due to the production of growth promoting substances like IAA and IBA by inoculants. Barea *et al.* (1976); Satta and Gaur (1987); Nagaraj (2002) and Owais (2010) in pomegranate and Rymbai and Reddy (2010) in guava have reported the production of growth promoting substances like auxins and gibberellins by *Azospirillum*. It is a well known fact that the different biochemical constituents have an important role during rooting. This may be mainly related to sugars, total carbohydrates, total nitrogen, C/N ratio and total phenols. Rooting co-factors which act synergistically with auxins have also been reported to promote rooting. These biochemical factors as related to the different treatments in the present work are discussed below. In all the estimation of biochemical factors done in the present study, there was only a marginal change during the process of rooting both in the treated and untreated layers. The steady decline in the level of sugars and starch during the initiation and growth of the roots indicates breakdown of carbohydrates during root development. Arslonov (1979) observed breakdown of carbohydrates during the initial stages of root growth in lemon cuttings, and also noted a rise in catalase and peroxidase activities which accompanied the breakdown of carbohydrates. There was a reduction in starch content both in treated and untreated layers. But the reduction was more in case of treated layers. The difference in the magnitude of decline of starch content between the treated and untreated layers showed that the exogenous application of auxins might have enhanced the hydrolysis of starch. According to Arslonov (1979) the exogenous application of auxins produced changes in the redox regime and this resulted in the utilization of the stored food substances for quicker root formation in lemon cuttings. Further, among different growth regulators used at different concentrations, there has been difference in the rate of decline in the starch content. This indicates that there exists differential capacity of growth regulators in enhancing the hydrolysis of starch. In the present study *Azospirillum* 37.5 g + IBA 3000 ppm + NAA 3000 ppm showed higher magnitude of hydrolysis of starch whereas, the layers which had received *Azospirillum* 37.5 g + IBA 3000 ppm + NAA 3000 ppm recorded lowest percentage of nitrogen and carbohydrates as compared to the untreated layers (Table 3). This indicates higher utilization of nitrogen in treated layers. A similar trend was noted by Rao *et al*. (1990) in cashew and Karunakara (1997) and Owais (2010) in pomegranate and Rymbai and Reddy (2010) in guava air-layers, respectively and opined that low nitrogen brings about an increase in the activity of rooting co-factors, thus causing better rooting.The carbohydrate/nitrogen ratio was found to be slightly higher in treated layers as compared to untreated layers in the present study (Table 4). It has been opined that higher the C/N ratio, the greater would be the activity of rooting cofactors and thereby better rooting (Uthaiah *et al*., 1976 and Telang, 1981). With regard to total phenol content, it was marginally higher in the treated layers as compared to untreated layers at the end of the rooting period, after a steady decline from the initial level. The layers treated with *Azospirillum* 37.5 g + IBA 3000 ppm + NAA 3000 ppm maintained a higher level of total phenols in which rooting was maximum (Table 4). Similarly, several workers (Karunakara, 1997) were of the opinion that the phenolic compounds act as synergists to the auxin action in root promotion, also attributed the higher percentage of rooting observed in Gulabi cultivar of grape to the higher level of phenolic compounds present as compared to its content in Thompson seedless cultivar of grape.

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