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Rose rootstocks position and auxins affect grafting take of 'Inca'

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Abstract

Inadequate grafting take of some of the rose cultivars may cause economic losses. The study was conducted to determine the effects of cutting position (top, middle and bottom) of *Rosa hybrida* rootstocks ('Natal Briar' and 'Rosa Progress') and auxins (0 %, 0.4 % IBA and 0.2 % NAA) on rooting and grafting take of rose cultivar 'Inca'. Changes in endogenous carbohydrate content during rooting were measured on days 0, 3 and 7 after sticking. The experiment was factorial in a completely randomized design. Interaction between cutting position and rootstock was significant ($P \leq 0.05$) for most of the parameters measured. The shoot height, root number, percent rooting and grafting take increased towards the basal position in 'Rosa Progress'. In 'Natal Briar', the shoot and root growth parameters increased towards the top though non significant except grafting take that significantly increased towards the basal position. The auxin treated cuttings recorded significantly ($P \leq 0.05$) higher grafting take and rooting percentage than the control. 0.4 % IBA exhibited higher shoot height, leaf number and root number than 0.2 % NAA. The rootstock 'Natal Briar' recorded significantly ($P \leq 0.05$) higher rooting percentage and grafting take than 'Rosa Progress'. Middle and top position cuttings of 'Rosa Progress' and 'Natal Briar' recorded higher carbohydrate content, respectively than bottom position cuttings. Bottom position recorded higher sucrose content on day 3 than days 0 and 7 after planting in 'Rosa Progress'. 'Natal Briar' exhibited significantly ($P \leq 0.05$) higher carbohydrate content than 'Rosa Progress'. The increase in growth with top position cuttings of 'Natal Briar' could be attributed to high carbohydrate content. The high growth responses in bottom position cuttings of 'Rosa Progress' could be attributed to high sucrose content on day 3 after planting. The stem cuttings of rootstocks for top grafting rose cultivar 'Inca' should be taken from bottom position cuttings of both rootstocks, and auxins should be applied to increase rooting and grafting take.

Key words: Cutting position, rose rootstocks, NAA concentration, IBA concentration, endogenous carbohydrate, grafting take.

Introduction

Rose (*Rosa* spp) is one of the most important flower crops in the world and has an economic value in ornamental, pharmaceutical and cosmetic trade. Roses are conventionally propagated by cuttings, budding, grafting/stenting and layering. Stenting, where cutting and grafting are performed simultaneously and the formation of the graft union and adventitious root development occurs concurrently, by far is the most commonly used propagation method for roses around the world (Nazari *et al*., 2009) and is also an efficient technique in propagating species of conifers, rhododendron, apple, pears and plums. Rose rootstocks commonly used in stenting include 'Natal Briar', 'Indica major', 'Multiflora', 'Canina Inermis' and 'Rosa Progress' (Robert *et al*., 2001). Choice of the rootstock type essentially depends on compatibility with the scion material with respect to the desired traits which may include vigour, capacity to increase the leaf area, yield and quality of the grafted variety, phytosanitary status. (Robert *et al*., 2001). The excellent grafting take helps auxin and carbohydrate transport to the base of cuttings and influences their rooting (Izadi *et al*., 2004). Higher percentage survival has been reported in rose cultivars 'Milva' and 'Shocking vasilla' grafted on 'Natal Briar' (Otiende *et al*., 2011) than own rooted cuttings (Otiende *et al.,* 2010). The cuttings for stenting can be obtained from the vertical or horizontal shoots on the rootstock mother plant and, rooting ability and axillary bud growth may vary between cuttings originating from the different positions on the same shoot. This could be due to changes in degree of maturation, carbohydrates, auxins and rooting co-factors. High rooting from basal cuttings has been attributed to high carbohydrate content as a nutritional source and stem maturity (Saifuddin, *et al*., 2013; Ezekiel, 2010). On the other hand, Kassahun *et al*. (2013) reported higher rooting in top position cuttings of *Stevia rebaudiana* Bertoni, attributed to the presence of actively differentiating juvenile tissues (Tchoundjeu and Leakey, 2001) and high concentration of endogenous root promoting substances from the terminal buds.

Auxins have been shown to play an important role in the development of adventitious roots, improving quality of roots and increasing root mass (Opuni-Frimpong *et al*., 2008). The promotive effect of auxin on rooting has been attributed to its role in stimulating cell division in the vascular cambium which leads to the formation of root primordia (Rahman *et al*., 2002). Both Naphthalene-acetic acid (NAA) and Indole-butyric acid (IBA) are typically the principal auxins used for rooting of cuttings and majority of plant species are responsive to them. The difference among auxins could be related to their stability and conjugation rate as well as their toxic nature (Hartman *et al*., 2002).

The relationship between carbohydrates and adventitious root formation remains controversial. Some literature reports no effect of carbohydrates (Veierskov and Andersen, 1982) or even a negative effect on rooting (Treeby and Considine, 1982). However, there is a big body of evidence demonstrating that carbohydrates may influence rooting of cuttings positively (Druege *et al*., 2000). In such cases carbohydrates have been explained to contribute to the formation of adventitious roots by supplying energy and carbon necessary for cell divisions, establishment of the new root meristems and root formation itself (da Costa *et al*., 2013). Other studies have shown that the initial carbohydrate content of the cutting should be enough to supply the energy reserves throughout the rooting period (Druege *et al*., 2004) even though there are also reports that carbohydrate allocation and distribution within the cutting could be more important than the content itself (Druege, 2009; Ruedell *et al*., 2013).

In commercial propagation, rootstock mother plants are often limited necessitating acquisition of as much rootstocks material as possible from each mother plant. In this effort a branch may be cut into a number of segments leading to production of rootstock materials of varying physiological ages from the base to the tip of every branch. Even though this is a common practice there is limited information on the effect of cutting position of the rootstock on rooting of grafted scion cultivar in roses. Most studies have dwelt on nodal positions of own rooted cuttings. This study was therefore conducted to investigate the effects of cutting position of rose rootstocks and auxin treatment on rooting and grafting take of rose cultivar 'Inca'. The rootstocks, being of different physiological and ontological stages, were analysed for endogenous carbohydrate content to establish any relationship between cutting position and carbohydrate content and propagation performance.

Materials and methods

Plant materials: The cuttings were collected from 3-months old rootstocks of 'Natal Briar' and 'Rosa Progress' grown in a greenhouse at Finlays Flower company, Kericho, Kenya. The stem cuttings were chosen on the basis of height, presence of bud and 5-leaflet leaves. Medium sized vertical shoots, each measuring 120-150 cm long, were selected and divided into three equal segments of top, middle and bottom. Each stem cutting was 5-6 cm long. The scions were obtained from the shoots of 'Inca' at full bloom stage at portions where five-leaflet leaves occurred. The scion and rootstock were joined together and the union held in place with a silicon material.

Treatments and experimental design: The treatments consisted of three cutting positions of top, middle and bottom, two rootstocks of 'Rosa Progress' and 'Natal Briar' and two different auxins of 0.2 % NAA and 0.4 % IBA and the control (0%). The auxin levels were selected based on previous studies with self-rooted stem cuttings. The 18 treatments namely two rootstock varieties, three cutting positions and three auxin treatments were factorially combined and laid out in a completely randomized design. Each experimental unit had 20 plants replicated three times. The basal ends of each of the grafts were dipped in the respective auxin treatments for 5 seconds before sticking in the media. The auxins were applied in their powdered formulation (auxin x talcum powder) which also contained 0.05% fungicide, Bavistin. 30 extra non-auxin treated cuttings from the same rootstocks and cutting positions were planted alongside the main experiment to provide samples for carbohydrate analysis. They were also replicated 3 times.

Planting: The cuttings were planted immediately after the auxin treatments in jiffy bags filled with sterilized coccus with a pH of 6.5-7.5 and electrical conductivity (EC) of 0.18-0.24 mS/cm, inside a greenhouse equipped with the misting and heating systems. Relative humidity was maintained at 85-90%, with minimum day and night temperature of 30-35 ^{o}C and 22-24 ^{o}C, respectively. Misting cycles of 10-30 minutes (day) and 1-2 h (night) were maintained in the first 2 weeks and then gradually reduced to harden the plants. Misting was stopped completely at 4 weeks after planting. Light intensity was maintained at 300 watts/M^2 during the day throughout the growing period. Fertigation started 14 days after planting and every 4 days thereafter depending on measured electrical conductivity. Crop protection was provided against diseases and pests by foliar spray using appropriate insecticides and fungicides, as and when required.

Recordings and measurements

Growth parameters: During the rooting process, 10 plants were sampled for shoot height and leaf number, 5 plants were sampled for destructive growth measurements such as root number and root length at 4 weeks after planting. Grafting take as determined by presence of shoot and roots and rooting percentage were determined on 20 plants at 4 weeks after planting.

Carbohydrate analysis: Stem cutting samples (1 cm at the basal end) from the different cutting positions of the rootstocks ('Natal Briar' and Rosa 'progress') were collected on the day of planting (0 day) and 3 and 7 days after planting. Five grams of each of the fresh stem cutting samples were ground to fine particles in a Wiley mill to homogenize the samples. Soluble carbohydrate content (fructose, glucose and sucrose) was determined using high performance liquid chromatography (HPLC) method (Rybak-Chmielewska, 2007) based on chromatographic separation of sugars and their retention time.

Statistical analysis: A three-way Analysis of Variance (ANOVA) was done using GENSTAT statistical package to determine the effect of treatments on carbohydrate content, growth parameters and rooting of *Rosa hybrida* rootstocks. Mean separation was done using least significant difference (LSD) at P=0.05 significant level.

Results

Effects of cutting position of *Rosa hybrida* rootstocks on root and shoot growth characteristics of top grafted 'Inca': The cutting position significantly ($P \leq 0.05$) influenced the shoot and root traits measured in both rootstocks. The effect was more pronounced for 'Rosa Progress' than 'Natal briar. Shoot height, root number, grafting take and rooting percentage increased towards the basal portion in 'Rosa Progress' with top position having lower root and shoot growth traits than bottom position cuttings (Table 1). In 'Natal Briar', only the grafting take was affected by cutting position (Table 1) and it increased towards the basal portion. The other parameters were non significant ($P \leq 0.05$) and increased towards the top position. Irrespective of auxins and rootstocks, cutting position also influenced total root length and leaf number. Middle position cuttings exhibited higher

Table 1. Effect of cutting position and rootstocks on shoot and root growth parameters of grafted *Rosa hybrida* cultivar 'Inca'

Rootstock	Cutting position	Shoot height (cm)	Leaf number	Root number	Total root length (cm)	Grafting take percentage	Percent rooting
'Rosa Progress'	Top	3.65	3.83	7.81	90.5	34.8	51.1
	Middle	5.25	4.83	7.52	115.1	63.7	72.2
	Bottom	5.69	5.64	13.89	111.6	81.5	87.8
'Natal Briar'	Top	4.97	4.44	9.11	77.4	69.6	84.4
	Middle	4.16	4.06	9.78	104.9	71.1	82.2
	Bottom	4.12	4.42	9.97	83.1	85.2	72.2
LSD		1.42*	NS	3.80*	NS	12.9**	15.7**

NB: LSD= Least significant difference, NS=Not significant, * and ** probability level at P=0.05 and P=0.001, respectively.

total root length than bottom and top position cuttings (Table 1) while the leaf number increased towards the basal portion. 'Natal Briar' and 'Rosa Progress' had 85.2% and 81.5% grafting take respectively in bottom position cuttings. Top position cuttings of 'Natal Briar' exhibited significantly ($P \leq 0.05$) higher grafting take and rooting percentage than 'Rosa Progress' (Table 1). '

Effects of auxin application and rootstocks on root and shoot growth characteristics of top grafted 'Inca': The interaction between auxin and rootstock was not significant ($P \leq 0.05$) for the parameters measured except the rooting percentage. However, the main factor of auxin was significant ($P \leq 0.05$) for all the parameters measured except for grafting take. Average shoot height and leaf number differed significantly between the auxins. Taller shoots per cutting were recorded with 0.4% IBA than 0.2 % NAA treated cuttings. However, the control and 0.4% IBA treated cuttings exhibited non significantly different shoot height and leaf number (Table 2). Higher root number was recorded with 0.4% IBA than 0.2% NAA and the control (Table 2), however, the difference between the latter two were not significant. Lowest total root length was recorded in control than the auxin treated cuttings (Table 2). Higher grafting take was recorded in auxin treated cuttings than the control though, non significant (Table 2). The auxin treated cuttings recorded significantly higher rooting percentage than the control in 'Natal Briar' (data not presented). Rooting percentage of 'Rosa Progress' was influenced by auxin treatment and auxin treated cuttings had higher rooting percentage. The rose cultivar 'Inca' grafted on the rootstock 'Rosa Progress' exhibited significantly ($P \leq 0.05$) higher shoot height and total root length than on the rootstock 'Natal Briar' (Table 3). Higher percent rooting and grafting take of 'Inca' were obtained from the rootstock 'Natal Briar'.

Changes in carbohydrate content during rooting as influenced by days after planting and cutting position of Rosa hybrida rootstocks

Glucose and fructose content: In 'Rosa Progress', cutting position recorded no significant ($P \leq 0.05$) effect on glucose and fructose content on days 0 and 3 after planting, however on day 7, bottom position recorded lower amounts than the top and middle positions (Figs. 1 and 2). The number of days after planting had a significant ($P \leq 0.05$) effect and middle position cuttings had higher glucose and fructose content on day 7 than days 0 and 3 after planting. However, the latter two days were not significant. Top position cuttings exhibited higher glucose and fructose content on day 7 than days 0 and 3 after planting (Figs. 1 and 2).

In Natal briar, cutting position had no significant ($P \leq 0.05$) effect on glucose and fructose content at days 3 and 7 after planting even though top position had higher glucose and fructose content than bottom and middle position cuttings on day 0 (Figs. 1 and 2). Generally glucose and fructose contents exhibited no significant ($P \leq 0.05$) change between day 0 and day 3 but were significantly higher on day 7 for all cuttings. The number of days after planting had significant effect on fructose and glucose content.

Sucrose content: In 'Rosa Progress', cutting position significantly ($P \leq 0.05$) affected sucrose content on days 3 and 7 after planting (Fig. 3). Bottom position recorded significantly higher sucrose content than top and middle position cuttings on day 3 after planting while on day 7, middle position recorded higher sucrose content than top and bottom position cuttings. The number of days after planting had significant effect on sucrose content. Bottom position recorded a significant increase to day 3 after planting

Table 2. Effect of auxins on shoot and root growth parameters of grafted *Rosa hybrida* cultivar 'Inca'

Auxins	Shoot height (cm)	Leaf number	Root number	Total root length (cm)	Grafting take percentage	Percent rooting
Control	4.81	4.42	7.93	64.1	64.4	62.8
0.2 % NAA	4.18	4.07	8.46	110.0	67.0	80.6
0.4 % IBA LSD	5.42	5.12	12.65	117.1	71.5	81.7
LSD P=0.05	0.82	0.65	2.69	18.7	NS	11.1

NB: LSD= Least significant difference, NS=Not significant

Table 3. Effect of rootstocks on shoot and root growth parameters of grafted *Rosa hybrida* cultivar 'Inca'

Rootstock	Shoot height (cm)	Leaf number	Root number	Total root length (cm)	Grafting take percentage	Percent rooting
'Rosa Progress'	5.19	4.77	9.74	105.7	60.0	70.4
'Natal Briar'	4.42	4.31	9.62	88.5	75.3	79.6
LSD P=0.05	0.67	NS	NS	15.3	7.4	9.1

NB: LSD= Least significant difference, NS=Not significant

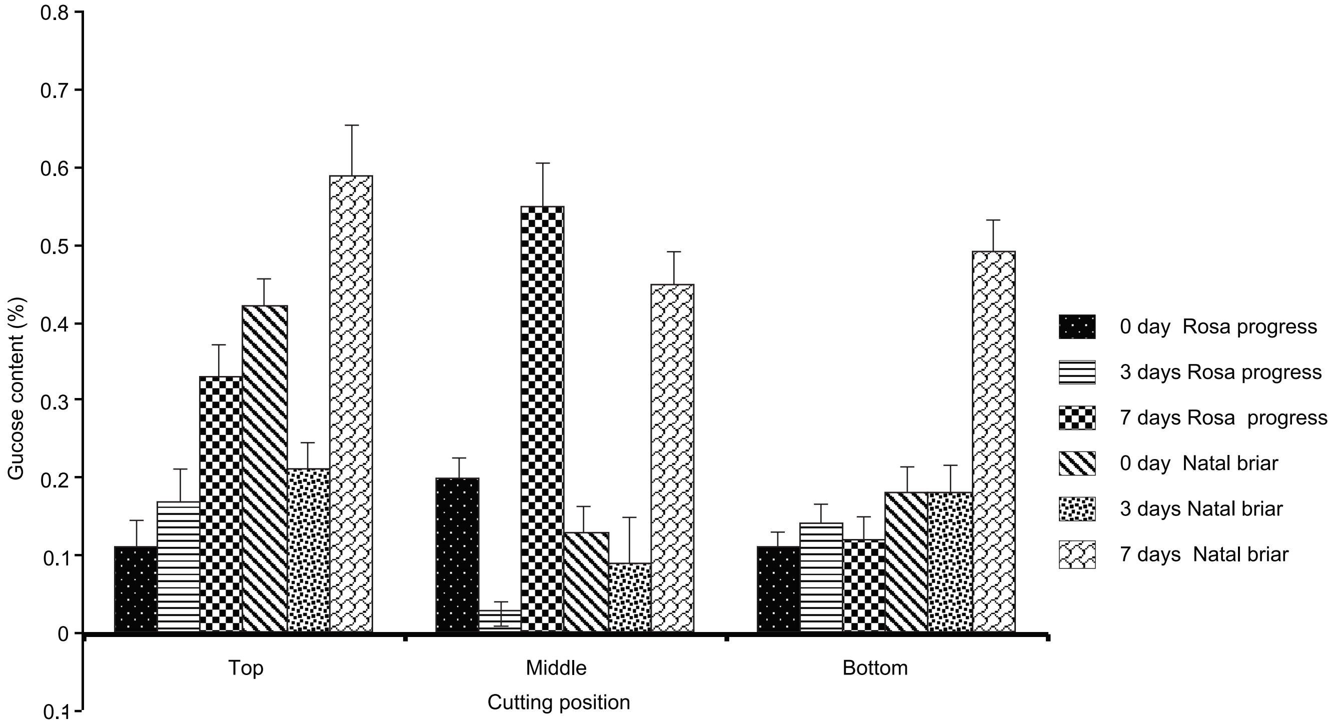

Fig. 1. Effect of cutting position and days after planting on glucose content of 'Rosa Progress' and 'Natal Briar'.

followed by a significant decrease to day 7 after planting (Fig. 3). Middle position recorded a non significant decrease to day 3 after planting followed by a significant increase to day 7 after planting. Top position had relatively constant sucrose content from day 0 to day 7 after planting.

In 'Natal Briar', cutting position had no significant effect on sucrose content on days 0 and 3 after planting, however on day 7 after planting, top position recorded higher sucrose content than middle and bottom position cuttings (Fig. 3). The number of days after planting was significant ($P \leq 0.05$) and the top position recorded a consistent increase from day 0 to day 7 after planting.

Middle and bottom positions recorded a non significant increase to day 3 followed by a non significant decrease to day 7 after planting (Fig. 3). The rootstock 'Natal Briar' had significantly higher glucose, fructose and sucrose content than the rootstock 'Rosa Progress' (Table 4).

Table 4. Carbohydrate content of the Rosa *hybrida* rootstocks

Rootstock	Glucose (%)	Fructose (%)	Sucrose (%)
'Rosa Progress'	0.21	0.23	0.46
'Natal Briar'	0.34	0.35	0.73
LSD	0.04**	0.06*	0.14*

NB: LSD= Least significant difference, NS=Not significant, * and ** probability level at P=0.05 and P=0.001, respectively..

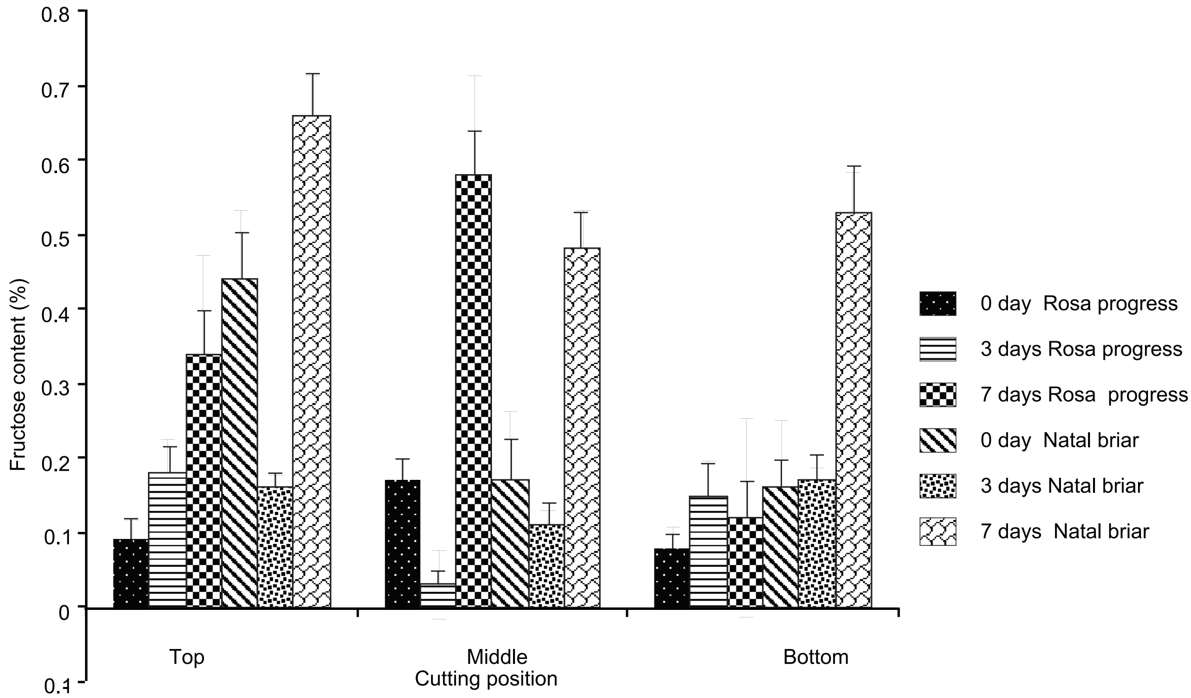

Fig. 2. Effect of cutting position and days after planting on fructose content of 'Rosa Progress' and 'Natal Briar'.

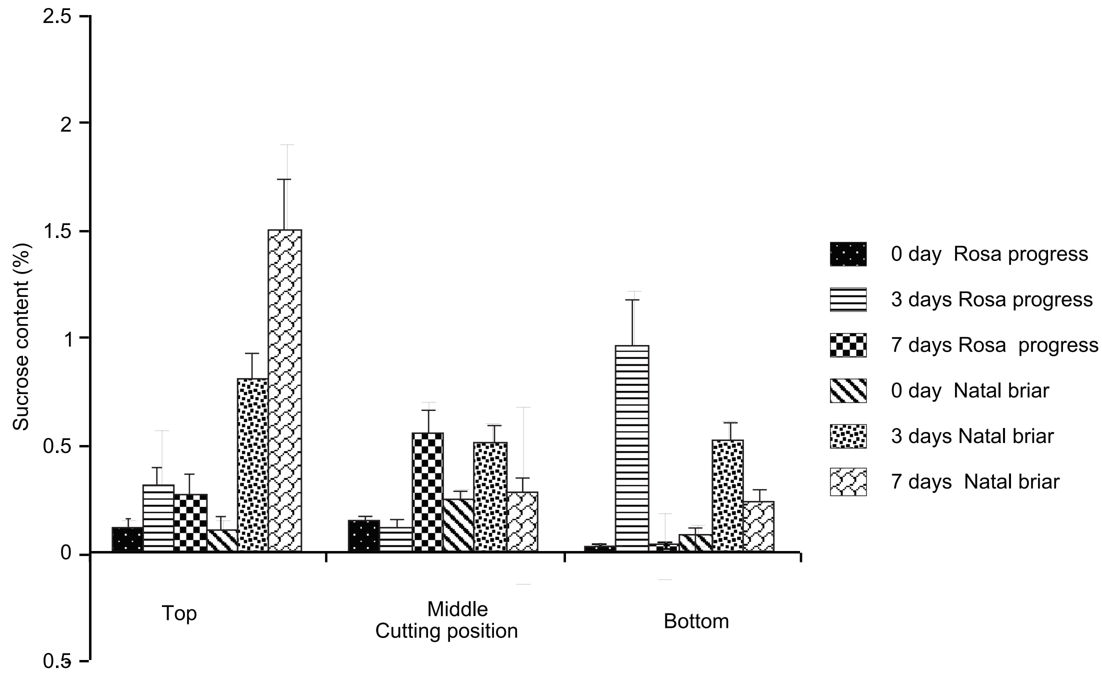

Fig. 3. Effect of cutting position and days after planting on sucrose content of 'Rosa Progress' and 'Natal Briar'.

Discussion

Effects of cutting position of *Rosa hybrida* rootstocks on rooting of top grafted 'Inca' and its relation to changes in endogenous carbohydrates during rooting: The root and shoot growth parameters of the cultivar 'Inca' grafted on the rootstock 'Rosa Progress' increased towards the basal portion. In 'Natal Briar' on the other hand, the same parameters were promoted towards the top position except for grafting take which exhibited an increase in growth towards the basal portion. Rooting success of any species is directly related to the growth stage of the parent plant and position of stem cutting. The stem position may influence root formation because of changes in the degree of juvenility along the stem. This includes distribution of available carbohydrates and other metabolites within the cuttings before and after severance. In 'Rosa Progress', an increase in shoot height towards the basal position was recorded and has also reported in other *Rosa hybrida* cultivars (Bredmose *et al*., 2004). The higher number of leaves observed in bottom position cuttings was also recorded in *P. pterocarpum* cuttings (Saifuddin *et al.,* 2013). The middle position cuttings produced significantly higher root length than top position cuttings but non significant from bottom position cuttings. Similar findings were reported in cuttings of *Rosa centifolia* (Al-Saqri and Alderson, 1996). Bottom position cuttings exhibited higher root number than the top position cuttings as was also observed in *Gonystylus bancanus* (Aini *et al*., 2010). The bottom position cuttings also exhibited higher percent rooting and grafting take of top grafted 'Inca' than the top position cuttings in 'Rosa Progress'. The increased basal growth could have been attributed to high sucrose content recorded on bottom position on day 3 after planting. Ezekiel (2010) and Saifuddin *et al*. (2013) also attributed high rooting to high availability of carbohydrate as a nutritional source and stem maturity of basal position cuttings. The decreased amount of sucrose on day 7 after planting would probably indicate that sucrose had been hydrolysed to fructose and glucose that readily releases energy for the rooting process or the available sucrose were exhausted on day 3 after planting and since sucrose is the most commonly found sugar in the phloem of angiosperms and immediate carbon substrate in plant tissues further supply to the stem cutting depends on photosynthetic capacity of the leaf. In grafting, leafless stem cuttings of rootstocks are used and the amount of carbohydrate content at the time of severance may influence adventitious root formation of grafts. In most cases, the formation of graft union and adventitious roots occur simultaneously (Nazari *et al*., 2009) and further supply of photosynthates from the leaves to the stem only occurs once the graft union has formed successfully. This was possibly true in 'Rosa Progress' because the top position cuttings recorded relatively constant sucrose content from day 0 to day 7 after planting. The high amount of glucose and fructose in top and middle position cuttings and high sucrose content in middle position cuttings recorded on day 7 after planting was inversely related to growth performance observed. This probably implied that some other endogenous factors such as IAA as well as external factors regulate rooting of apical cuttings rather than carbohydrate content. The variation in rooting ability could also be due to the difference in degree of maturity of the stem and activities of the scion.

It is possible that there was a movement of more photoassimilates and/or phytohormones from the scion 'Inca' to the stock base following successful graft union healing that facilitated rooting in bottom position. The vascular connection transports assimilates and storage products, as well as endogenous growth regulators and other substances both upwards and downwards through the plant (Hartman *et al*., 2002).

In 'Natal Briar', top position recorded increased accumulation of sucrose from day 0 to day 7 than bottom position cuttings. The fructose and glucose content was also higher for top position cuttings than other positions on days 0 and 3 after planting, though on day 7 all the positions exhibited no significant difference in content. The high carbohydrate content in top position cuttings was in line with apical increase in root and shoot growth parameters in 'Natal Briar' except grafting take that was high in bottom position cuttings. The rooting percentage was not influenced by the cutting position, however, high rooting percentage was recorded in top position cuttings. Low carbohydrate levels in cuttings at the beginning of rooting limit the intensity of subsequent adventitious root formation (Druege *et al*., 2004), whereas application of sugars to the rooting medium increases subsequent root formation (Takahashi *et al*., 2003). The carbohydrate pools of sugars (soluble and insoluble/storage) are essential during the initial days of propagation to sustain respiration and guarantee survival and further support the energy cost with the initial growth related to the first anatomical events preceding root regeneration (wound healing and callus formation). The higher growth responses with top position than bottom position cuttings in 'Natal Briar' was probably due to the observed high accumulation of fructose, glucose and sucrose in basal ends of top position cuttings as was recorded on day 7 after planting than bottom position cuttings. The basipetally transported sucrose delivers energy for cell differentiation and a considerable portion is converted to starch, which probably acts as the carbon source when the adventitious roots grow (Ahkami *et al*., 2009). Moreover, increased basipetal transport of sugars in cuttings would also allow for accelerated co-transport of amino acids such as tryptophan within the phloem along with sucrose. Sucrose therefore enhances the sensitivity to auxin (Calamar and de Klerk, 2002) and the involvement of auxins in the formation of adventitious root formation has been reported in many species. Auxins stimulate cell division in the vascular cambium which leads to the formation of root primordial. The low growth parameters of bottom position cuttings except grafting take was concomitant with low sucrose, glucose and fructose content in the stem base of 'Natal Briar'. This could be due to negative regulatory effect of low carbohydrates and hormones on mitotic activity of the cambium (Osterc *et al*., 2009).

The bottom position cuttings exhibited higher percent rooting and grafting take of top grafted 'Inca' than the top position cuttings in 'Rosa Progress'. Similar findings were recorded in tree species and was attributed to more sugars which were necessary for nutrient supply in initiating new root and shoot tips (Saifuddin *et al*., 2013).

The rootstocks may affect either directly or indirectly scion characteristics such as vigor, nutrient status, flower yield and quality. The cultivar 'Inca' grafted on the rootstock 'Natal Briar' exhibited higher grafting take than 'Rosa Progress'. Rootstock differences have been reported in pomegranate (Karimi, 2011) and apple (Sadowski and Gorski, 2003). The effect of the rootstock on grafting take may be related to the formation of the callus bridge at the graft union which seemingly occurred faster in 'Natal Briar' and facilitated translocation of root and shoot promoting materials such as auxins and rooting co-factors between the scion and the rootstock.

Effects of auxin treatment on rooting of *Rosa hybrida* rootstocks: Application of IBA caused significant increase in shoot height, leaf number and root number than NAA. The lower efficiency of NAA in stimulating shoot growth and root number could be explained by the connection between the levels of endogenous IAA and adventitious root formation. It might be due to the exogenously applied synthetic NAA that has not been efficiently oxidized to IAA for plant utilization and therefore, more energy may be needed by the cutting to convert it to IAA to be used by the cutting. The additional energy used up might eventually lead to insufficient energy needed for cell growth and development. Energy is needed in converting NAA to IAA, hence displaying reduced responses of NAA in root elongation (Zolman *et al*., 2008).

The 0.4% IBA treated cuttings also exhibited higher root number, root length and rooting percentage than the control. Higher root number with IBA treatment has been reported in *Cestrum nocturnum* (Rahbin *et al*., 2012). The application of exogenous auxin is needed to achieve satisfactory rooting responses. Endogenous auxin produced in the shoot apex and transported basipetally to the cut surface may be complemented by exogenously applied phytohormone aiming at improving the rooting response (Pop *et al*., 2011). The effectiveness of auxin to raise rooting percentage of the cuttings could be through increased cambial activity and differentiation of root primordia or by stimulating redistribution and mobilization of some auxin cofactors towards the base of the cuttings (Kuroha *et al*., 2009; da Costa *et al*., 2013).

The 0.4% IBA treated cuttings exhibited higher leaf number than the control. However, the shoot height of the control and 0.4% IBA treated cuttings were non significant. The promotive effect of IBA on the vegetative growth may be caused by the enhancement of rooting percentage and root growth on the treated cuttings leading to more uptake of water and nutrients from the growing medium resulting in an increment in vegetative growth. Auxins may indirectly influence the shoot growth through some other factors such as cytokinins being produced in the roots tips of IBA treated cuttings. Cytokinins are involved in cell division, chloroplast biogenesis, bud and root differentiation and shoot meristem initiation and growth (Kuroha *et al*., 2009). Consequently the presence of endogenous cytokinin in the stem tissues with the addition of auxin into the medium might have eventually promoted the formation of shoots from the cuttings. Studies on Schefflera and Stephanotis have suggested that accelerated root formation, accelerated the onset of axillary bud growth in cuttings (Hansen and Kristensen, 2006). The high grafting take with IBA treatment could have been associated with increased cell division stimulated by the auxin at the graft union (Karimi, 2011).

Cutting position on the shoot is an important factor as it may determine whether rooting occurs readily or with difficulty in certain rootstocks used for grafting. Results proved that maximum rooting and growth of top grafted 'Inca' can be obtained from bottom position cuttings in 'Rosa Progress' and top and middle position cuttings in 'Natal Briar'. This was also consistent with high sucrose content in bottom position in 'Rosa Progress' and high fructose, glucose and sucrose content in top position cuttings in 'Natal Briar' partly indicating positive role of endogenous carbohydrate on adventitious root formation. Regarding the auxins, IBA was found to be more effective in promoting adventitious root formation in both rootstocks.

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