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Quality of Greenhouse Roses (*Rosa hybrida* L.) as Affected by Height and Stage of Shoot Bending and Flower Bud Removal

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ABSTRACT
The study was conducted to investigate the effect of different heights, stages of shoot bending and flower bud removal from the bent stem on the quality of rose cultivar “Lovely Jewel” at Ziway, Ethiopia. From the conducted study, a highly significant interaction effect was noticed from bending height and flower bud removal on stem length. Accordingly, bending at junction and the removal of flower buds from the bent stems resulted in the longest stem. In response to the stem thickness, differences being observed among bending heights and bending stages. Consequently, bending at junction and bending after the flower bud showed color provided highest thick stems, respectively. Two way interactions of bending height and flower bud removal as well as bending stage and flower bud removal was also noticed on bud length. Bending at junction combined with flower removal showed the maximum bud length. The bending position, stage and flower bud removal had highly significant effects on bud width. As a result, bending at junction when the bud shows color with removed flower gave the maximum bud width. The maximum vase life was obtained from bending above 2nd bud. In a similar manner, removal of flowers from bent stem performed best in terms of maintaining the lasting quality. Thus, from the experiment a combination of bending at junction after the flower bud showed color with the removal of flowers being proved to be better than all the other combinations for most of the parameters. However, further researches in line with the yield and economic aspects should be conducted to give concrete recommendations.

Key words: *Rosa hybrida*, shoot bending, flower bud removal, bending height, bending stage, vase life

INTRODUCTION
Roses (*Rosa hybrida* L.) are one of the most important commercial crops grown for a variety of purposes such as pot plant, garden plant and cut flower production (Azadi *et al*., 2007). Among all other cut flowers, roses lead in popularity because of their beauty, fragrance and long lasting blooming qualities (Ghaffoor *et al*., 2000; Tabassum *et al*., 2002).

Ethiopia has an ideal production climate for cut rose production. The floriculture sector had shown a very dramatic growth in Ethiopia, even surpassing most African nations that have an established operation long before Ethiopia starts growing flowers (EHPEA, 2010).

Rose production in Ethiopia has shown remarkable growth over the past decades. 80% of the existing flower farms are producing rose flowers. Consequently, the country export volume rises rapidly and in no more than 7 years Ethiopia became the second largest flower exporter in Africa (next to Kenya) to the EU market (Gebreeyesus and Sonobe, 2009).

Rose cultivation techniques underwent evolution in the late 20th century. Shoot bending growing technique was progressively replacing the traditional upright growing technique in greenhouse production. This new technique posed new challenges to both cultivation and research (Sarkka, 2004).

Shoot bending is one of the cultivation techniques used commonly in greenhouse rose production in Ethiopia and elsewhere in the world. Bending, the curving of non-productive shoots (short and/or potential blinds) down into the canopy or towards the aisle, became a standard method in cut rose production and is generally done repetitively over the entire growing season. Several research reports revealed that bending results in higher shoot quality, in view of the fact that the bent stem supply photosynthates to shoots that develop from the basal buds. This cultivation technique also believed to reduce plant size, allow easy harvest, permit light to pass well to center of the canopy and let longer stem to harvest (Kool and Lenssen, 1997). Similar results were also reported by Kim and Lieth (2004) that bending nonproductive shoots resulted in higher stem length, fewer blind shoots (aborted flower buds) and higher yield in cultivar like 'Mercedes'.

The success of applying bending to cut rose production has been generally attributed to the possibility of bent shoots acting as a source of carbohydrates, assuming that they capture ample light and actively photosynthesize after bending. Stems grown with the bending method have the potential to be much stronger than those grown conventionally. In roses, economic return is directly related to the stem length and number of shoots produced. Bending increased the development rate, stem diameter, weight, Leaf Area Index (LAI) and cross-sectional area of basal shoots (Sarkka, 2004).

Shoot bending technique, in Ethiopia, is practiced in almost all rose production units irrespective of cultivar types and without considering the bending height (personal observation). The bending height is not the same from place to place and the stage of bending varies accordingly. Flower bud removal is practiced by most of the growers though the priority being given to this practice is not as such high. Knowing the effect of such production techniques on production and quality of cut roses is mandatory to boost production through agronomically viable and economically feasible methods.

This study was, therefore, proposed with the objective of determining the appropriate height and stage of shoot bending and to rectify the necessity of flower bud removal from the bent stem for better quality of "Lovely Jewel" cultivar of rose.

MATERIALS AND METHODS

The greenhouse trail was conducted at AQ Roses PLC, located at Ziway, Ethiopia (latitude 7°55' 60" N, longitude 38°43' 0" E, altitude of 1642 m above sea level), in the compound of Shar Ethiopia PLC. The greenhouse temperature and relative humidity were kept in the range of 15 to 30°C and 50 to 65%, respectively.

Rosa hybrida L. Cultivar "Lovely Jewel" was used for the study. This cultivar was selected because it is newly introduced and its growing packages have not yet been standardized to the Ethiopian growing conditions. The cultivar is categorized as an intermediate cultivar which has a clear pink tone on a greenish cream bud. The planting materials (grafted rooted cuttings) of the cultivar were obtained from AQ Roses PLC propagation unit. The plot sizes for one replication and one treatment combination were 8.44 and 0.52 m^2, respectively. The plots were prepared in the form of a trapezoid bed with a dimension of 40 cm wide at the top, 60 cm wide at the bottom and 35 cm high. The grafted rooted cuttings were planted in two rows spaced at 20 cm and the same distance was also maintained between plants. After establishment of the grafted rooted cuttings, the primary shoot of all treatments was initially bent (because these shoots are generally too short and weak to be harvested as cut flowers) at the junction when the flower bud reached the pea size stage. Moreover, the pea sized flower buds were removed during bending from all the shoots in order to ensure uniformity. Right after the newly flushes appeared, the shoots were bent as per the predefined treatments. Bending direction was towards the aisle (walking path). All other cultural and growing practices were uniformly applied to all the treatments as per the farm's operational procedures.

Experimental design and treatments: The experiment was laid down as a 3×2×2 factorial experiment with Randomized Complete Block Design (RCBD). The treatments consisted of three different bending positions (bending at junction (BJ), Bending above 2 Buds (B2B) and above 4 buds (B4B)), two different stages of bending (curving the shoots when the flower bud is less than the size of a pea (BP) and bending it just after it showed color (BC)) and with or without removal of the flower buds from the bent stem. The third factor comprised of two levels vis-α-vis removing the flower bud (when it is at attains the size of a pea) from the bent shoot (FR) and retention of the bud on the bent shoot until the flower opens (FNR). The experiment was replicated 3 times.

Measurements: When the flowering shoots were ready for harvest, the quality parameters were measured from five randomly selected stems in each plot. Accordingly, the stem length of the flowering shoots was measured from the junction of the base stem to the top of the flower bud. Stem thickness (diameter) was evaluated from above the first five leaflets of the stems. The length and width of the flower buds was quantified by using manual caliper. Conversely, the vase life of flowers was evaluated as the number of days the stems remained in a vase before losing aesthetic value owing to bent neck and petal drop. For this purpose the flowers were first pre-cooled in a cold room at a temperature of 2°C for two hours immediately after harvesting to remove the field heat. After removing the flowers from the cold room, they were dry stored for one day in order to simulate the actual practice. Following this, each flower stem was kept in a glass vase filled 1/3 of its volume with de-mineralized water at room temperature (20°C).

Data analysis: The data collected for all the parameters were subjected to analysis of variance using Factorial Randomized Complete Block Design (RCBD). Data were checked for meeting the various ANOVA assumptions and SAS Version 9.2 statistical software package was used for the analysis of variance and estimation of correlation among traits (Montgomery, 2005). LSD procedures at 0.05 probability level of significance were used to determine differences between treatment means whenever the treatment effects were found to be significant.

RESULTS

Effect on stem length: Combined effect between bending height and flower bud removal was observed on stem length of cut rose. Accordingly, the highest stem length (66.13 cm) was obtained from bending at the junction (BJ) together with flower bud removal (FR) from the bent shoot. Whilst, the shortest stem length (49.56 cm) was acquired when shoots were bent above four buds without the practice of flower bud removal from the bent shoots (Fig. 1).

Apart from the above mentioned results, better growth was also observed when bending was done after the flower bud showed color (56.64 cm) (Table 1).

Effect on stem thickness: A highly significant difference (p<0.01) was ascertained among the different bending heights and bending stages on the stem thickness. Subsequently, bending at junction revealed the maximum stem thickness (10.01 mm). Regarding the bending stage, shoots curved after the flower bud showed color exhibited the maximum stem thickness (8.52 mm) as opposed to bending the shoots at pea size (7.42 mm). When shoot bending is practiced at a later stage, substantial increment in the rate of growth and shoot diameter may result (Table 2).

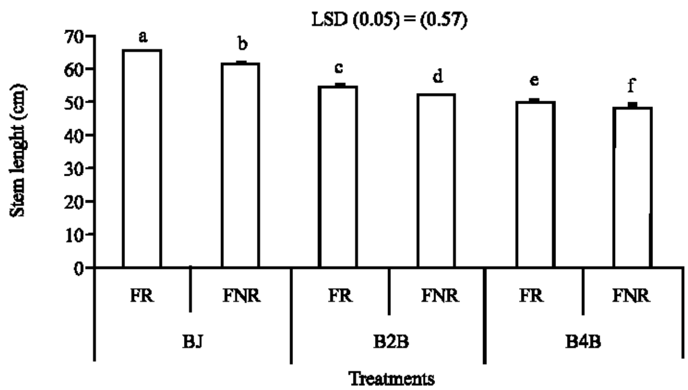

Fig. 1: Interaction between bending height and flower removal on stem length. Means followed by different letters are significantly different at the 5% level of probability, BJ: Bending at junction, B2B: Bending above 2 buds, B4B: Bending above 4 buds, FR: Flower bud removal from bent stem, FNR: Flower bud retention on bent stem, LSD: Least significant difference

Table 1: Effect of bending stage on stem length

Effect and levels	Stem length (cm)
Bending stage	
BP	55.71[b]
BC	56.64[a]
LSD (0.05)	0.54

Means followed by different letters are significantly different at the 5% level of probability, BP: Bending when the bud is at pea size stage, BC: Bending when the bud shows color, LSD: Least significant difference

Table 2: Effect of bending height, bending stage and flower bud removal on stem thickness

Effects and levels	Stem thickness (mm)
Bending height	
BJ	10.01[a]
B2B	7.86[b]
B4B	6.03[c]
LSD (0.05)	0.2244
Bending stage	
BP	7.42[b]
BC	8.52[a]
LSD(0.05)	0.1833
Flower removal	
FR	8.06
FNR	7.88
LSD (0.05)	ns

Means followed by different letters are significantly different at the 5% level of probability, BJ: Bending at junction, B2B: Bending above 2 buds, B4B: Bending above 4 buds, BP: Bending when the bud is at pea size stage, BC: Bending when the bud shows color, FR: Flower bud removal from bent stem, FNR: Flower bud retention on bent stem, LSD: Least significant difference

Effect on bud length: The interaction effects of bending height and flower bud removal were detected highly significant ($p<0.01$). Furthermore, the combined effects between bending stage and flower bud removal were found statistically significant ($p<0.05$). Accordingly, the maximum bud length (40.13 mm) was obtained when the stems were bent at junction and when the flower bud was removed from the bent stem (Fig. 2). In contrast the smallest bud length resulted from the bending height above 4 buds with the retained flower buds on the bent shoot.

On the other hand, a longer bud length (35.31 mm) was obtained as the flower bud removal acts with the bending stage at which the flower bud showed color (Fig. 3). Whereas, bending at pea size without the removal of flower buds was resulted in the smallest bud length (31.58 mm).

Effect on bud width: Variation ($p<0.01$) was observed among the different bending heights, bending stages and flower bud removal treatments with respect to bud width. The removal of flower

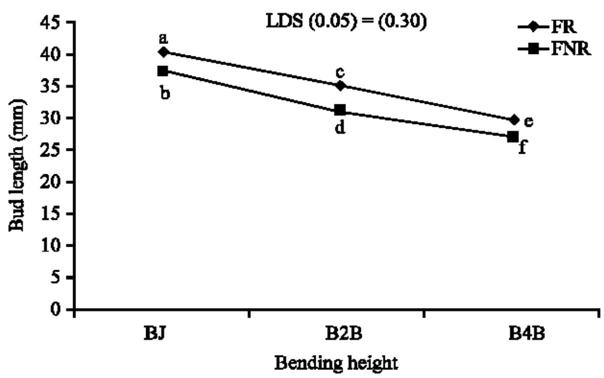

Fig. 2: Interaction between bending height and flower bud removal on bud length. Means followed by different letters are significantly different at the 5% level of probability, BJ: Bending at junction, B2B: Bending above 2 buds, B4B: Bending above 4 buds, FR: Flower bud removal from bent stem, FNR: Flower bud retention on bent stem, LSD: Least significant difference

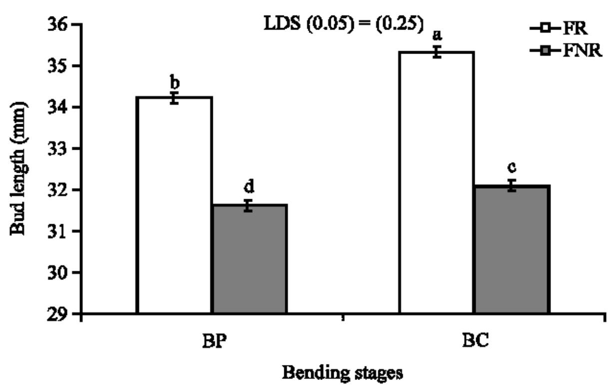

Fig. 3: Interaction between bending stage and flower bud removal on bud length. Means followed by different letters are significantly different at the 5% level of probability, BP: Bending when the bud is at pea size stage, BC: Bending when the bud shows color, FR: Flower bud removal from bent stem, FNR: Flower bud retention on bent stem, LSD: Least significant difference

buds from the bent shoot resulted in the maximum bud width (34.75 mm). In relation to bending height, highest bud width was recorded when bending was done at the junction (30.63 mm). On the contrary the bud width obtained from bending above four buds was appeared to be the least (28.86 mm) (Table 3).

With regard to bending stage effect, the lower width of flower bud was obtained when bending was done at pea size stage (29.54 mm). Maximum bud width (30.20 mm) was exhibited from later stage bending, i.e., bending when the flower bud shows color.

Effect on vase life: The flower bud removal and the bending height treatments were revealed a highly significant variation ($p<0.01$) on vase life. Consequently, highest number of days (16.08) was recorded from the bending height of above two buds, though statistically at par with the mean value of bending at the junction (16.00) (Table 4). On the contrary, bending the shoots

Table 3: Effect of bending height, bending stage and flower removal on bud width

Effects and levels	Bud width (mm)
Bending height	
BJ	30.63[a]
B2B	30.12[a]
B4B	28.86[b]
LSD	0.5094
Bending stage	
BP	29.54[b]
BC	30.20[a]
LSD	0.4159
Flower removal	
FR	34.75[a]
FNR	31.84[b]
LSD	0.4159

Means followed by different letters are significantly different at the 5% level of probability, BJ: Bending at junction, B2B: Bending above 2 buds, B4B: Bending above 4 buds, BP: Bending when the bud is at pea size stage, BC: Bending when the bud shows color, FR: Flower bud removal from bent stem, FNR: Flower bud retention on bent stem, LSD: Least significant difference

Table 4: Effect of bending height, bending stage and flower bud removal on vase life

Effects and levels	Vase life (days)
Bending height	
BJ	16.00[a]
B2B	16.08[a]
B4B	15.33[b]
LSD	0.4147
Bending stage	
BP	15.89
BC	15.72
LSD	ns
Flower removal	
FR	16.28[a]
FNR	15.33[b]
LSD	0.3386

Means followed by different letters are significantly different at the 5% level of probability, BJ: Bending at junction, B2B: Bending above 2 buds, B4B: Bending above 4 buds, BP: Bending when the bud is at pea size stage, BC: Bending when the bud shows color, FR: Flower bud removal from bent stem, FNR: Flower bud retention on bent stem, LSD: Least significant difference

Table 5: Bi-variate correlation coefficients among parameters

	SL	BL	BW	ST	VL
SL	-	0.94**	0.45	0.86**	0.50**
BL		-	0.55**	0.92**	0.53**
BW			-	0.33	0.69**
ST				-	0.33*

**,*: Statistically significant difference at 1 and 5% probability level, respectively. MY: Marketable Yield, BB: No. of Bottom Breaks, SL: Cut Rose stem length (cm), BL: Bud length (mm), BW: Bud width (mm), ST: Stem thickness (mm), VL: Vase life

above 4 buds revealed weakest vase life (15.33) as compared to the other two treatments. Besides the above stated results, longer vase life was traced (16.28 days) when flower buds being removed from the bent stem. In contrast, the retaining of the flower buds over the bent stem resulted in decreased vase life (15.33 days).

Correlation among quality parameters: Stem length was positively and highly correlated with bud length (r = 0.94), stem thickness (r = 0.86) and vase life (r = 0.50). Moreover, bud length was highly significantly and positively correlated with bud width (r = 55), stem thickness (r = 0.92) and vase life (r = 0.53). Bud width showed a highly significant and positive correlation with vase life (r = 0.69). Stem thickness was significantly and positively correlated with vase life (r = 0.33) (Table 5).

DISCUSSION

Understanding the effect of production techniques like bending on the quality of rose cut flower cultivars is mandatory to be competitive in the global market. For good quality cut flower production, best cultivars that suit to agro-climate conditions of the area and have high market demand must be selected to get maximum yield (Khan *et al*., 2004). The findings of this experiment reveal significant variations among the means of the different parameters used to evaluate the quality of cut rose cultivar 'Lovely Jewel'.

From the conducted experiment it was observed when bending height and flower bud removal from the bent stem influences the length of stem. This fact can be linked with the accessibility and accumulation of more carbohydrates in basal shoots to promote the rate of development of the newly initiated bud growth. Basal nodes may form numerous photosynthesizing leaves than nodes just below the flower. Rahman *et al*. (2000) stated that the more number of leaves manufacture more photosynthates which result in increasing plant height and produce more number of branches per plant. Similarly, Kim and Lieth (2004) reported that the success of applying bending to cut-rose production has been generally attributed to the possibility of bent shoots acting as a source of carbohydrates. Furthermore, in commercial practice it is believed that the removal of the flower bud from the bent shoot would redirect assimilates from the bent shoots to newly developing flowering shoots rather than investing them on unusable flower buds. Parvez *et al*. (2000) reported that removal of reproductive parts change the speed of growth by altering the source sink balance of the plant and hasten vegetative growth eventually increase the number of flowers. Likewise, Kim and Lieth (2004) stated that a developing flower bud is an active sink of carbohydrates and its removal may cause an imbalance in the source/sink relations of a shoot there by altering photosynthetic capacity.

Apart from the above mentioned results, stem length was also found to be affected by bending stage. This finding supports the facts explained by Kool and Lenssen (1997). As per their statements, delayed bending has generally promoted the rate of development and enlarged the diameter and weight of basal shoots and therefore affirmed strongly that the primary shoot should not be bent too early.

The occurrence of variation in stem thickness due to change in bending heights and bending stages might be due to the higher number of pith cells at the lower buds as compared to the buds located at higher position. Contradictory result was reported by Somkuwar and Ramteke (2008) based on their findings on effect of shoot orientation on growth of grapes. According to their statement, the maximum shoot length and higher shoot diameter were recorded at upward positioned shoot as compared to downward shoot positioned.

On the other hand, delay bending may be allowed the bent stem to form abundant photosynthesizing leaves enough to supply extra assimilates to the increment of the thickness of the newly originated growth. This finding is being supported by previous reports of De Hoog (2001) and Sarkka (2004).

The possible reasons for the interaction effects of bending height and flower bud removal as well as bending stage and flower bud removal on bud length can be explained in similar manner as being stated for stem length. The translocation of photosynthates from source to sink is very important for the development of economic part (Amanullah *et al*., 2010). Moreover, the variation observed among the different bending heights, bending stages and flower bud removal treatments with respect to bud width has analogous justification. This finding goes hand in hand with the findings of Kim and Lieth (2004).

In the present study, the vase life of the tested cultivar was clearly increased when flower bud was removed from the bent stems and bending was performed at junction and lower buds. This truth may be attributed due to the presence of higher amount of assimilates in the bottom portion of the shoots that would ensure vigorous growth and development of the newly emerged stems. Dole and Wilkins (2005) stated that the carbohydrate status of the crop should be high to maximize post harvest life of cut flower. The observed results suggest once again the importance of redirecting the reserved food sources to newly developing flowering shoots rather than investing them on unusable flower (Anonymous, 2009). Likewise, Parvez *et al*. (2000) reported that removal of floral buds resulted in highly significant increase in accumulation dry matter. Similar explanations were also given by Halevy and Mayak (1974) and Van Doorn *et al*. (1991).

Overall, bending at junction from the main stem when the flower bud showed color with flower removal practice from the bent stem exhibited best results for most of the considered responses. Consequently, the combinations can be used by growers who have desire in cultivating rose cultivar 'Lovely Jewel' to enhance major quality parameters. However, further studies in line with economic and yield issues would need to be conducted for realistic recommendation.

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