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Influence of Growth Retardant Chemicals on Stock Plant Growth and Subsequent Rooting of Verbena (*Verbena X hybrida*) Cuttings

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Abstract: Two phases greenhouse experiment was conducted at Florensis Ethiopia plc with the objective of determining the growth response of stock plants and subsequent rooting of cuttings of Verbena X hybrida cultivar 'Vegas Scarlet' to individual and combined application of Cycocel (CCC) and Alar. The experiment was laid down as 4x4 factorial experiment involving two different growth retardants as factor, with four levels in a complete randomized design (CRD) with three replications. On stock plants it was vividly observed that interaction of Alar and Cycocel considerably affected most of the evaluated parameters except the number of cuttings. Accordingly, the maximum number of main branches was obtained from the combination of 1ml L^{-1} CCC and 2g L^{-1} Alar. Moreover, the combined application of 1.5ml L^{-1} CCC and 3g L^{-1} Alar notably reduced internode length, stem length, root fresh weight, root dry weight, shoot fresh weight and dry weight. The maximum number of cuttings was achieved at concentration 1ml L^{-1} CCC. The combination of 1.5ml L^{-1} CCC and 3g L^{-1} resulted in maximum stem diameter. As far as the persistent effect of the treatments on subsequent rooting is concerned, the maximum number of roots per cutting was recorded from cuttings of stock plants treated with 0.5ml L^{-1} CCC and 2g L^{-1} Alar. Overall, the investigation entails that Alar and Cycocel can influence growth of Verbena hybrida and cutting yield thereof without significantly reducing rooting performance of cuttings. From commercial grower point of view, obtaining large number of quality cuttings is crucial. Hence, application of $1ml^{-1}L$ Cycocel, which demonstrated positive influence on cutting production, can be recommended for use by commercial growers in Ethiopia.

Key words: Verbena X hybrida · Growth Retardant · Stock plant · Cutting · Cycocel (CCC) · Alar

INTRODUCTION

In Ethiopia, floriculture is becoming one of the very promising business opportunities and is growing very fast owing to the existence of the favorable investment environment and exuberant natural resources [1]. At present, five cuttings propagating farms exist in Ethiopia producing pot and bedding plants cuttings which covers about 20% of the production area of the floriculture industry [2].

Many of the cultivated bedding and potted plants reveal undesirable stretch growth habits. To keep them shorter, compact and branchier, growth regulation is important. Growth retardants such as Cycocel are known to inhibit the gibberellin synthesis originating internally [3].

One way of controlling excessive plant growth is treating plants with chemical growth retardants. Growth retardant substances found to lower cell mass growth at higher concentrations compared with lesser once [4]. Chemical growth retardants are very useful tools for not only controlling the height of bedding and potted plants but also for better branching and flower induction [5]. For many species and cultivars of bedding and potted plants height control using chemical growth retardants seems an obligatory commercial procedure. Growth retardants commonly used and effective in controlling growth of numerous pot and bedding plants include Bonzi®, Sumagic®, Alar®, Cycocel®, Alar®/Cycocel® mixed use and Ethephon® [6, 7, 8].

Growth retardant chemicals are highly specific. There is no obvious correlation between taxonomic

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classification and plant response to a particular compound. Even different cultivars of the same species may vary greatly in the responsiveness to applied chemicals [9]. Scientific literatures referring to the effect of different growth retardants on growth of bedding plants are often divergent mainly with regard to retardant concentration as well as the time and frequency of application [10].

Plant growth retardants are justified having persistence effect on growth and quality of bedding plants [11]. The residual effects of these chemicals can influence adventitious root formation and can even last until the plants become fully established [12]. Most studies with chemical growth retardants in greenhouse crops are primarily concerned with effects on the stock plants during production. However, plants followed through the marketing channels or post-production are rarely tested on residual or carry over effects from plant growth retardants [13].

Verbena X hybrida is one of the very important bedding plants in plug production system [14]. Its cultivars are some of the most popular herbaceous bedding plants in the landscape due to their floriferous and long-lasting nature [6]. However, Verbenas can quickly grow up and often require repeated pruning or transplanting to a larger pot for maintenance in greenhouse environment. For greenhouse grower, excessive growth of verbena can lead to blow-over, plants outgrowing their pots, excessive drying between irrigations, leggy and less branched plants [6]. It is why these production problems commonly solved by the application of growth retardants because these compounds often offer effective alternative as compared to other means.

One of the limitations of chemical growth retardants is misapplications leading to catastrophic results, which in turn lower plant quality and yield. Common consequences include phytotoxicity, delayed flowering, ruined growth habit and stunted growth [15]. Hence, growers should adjust application of growth retardants to the existing conditions. In the absence of specific recommendations the grower must run a trial [16].

Plant growth regulators are widely used in cutting producing farms in Ethiopia without any scientifically justified concentration levels for Ethiopian condition. Among the many growth retardants Cycocel (CCC), Alar (B-Nine) and Ethephon are extensively used in the country's floriculture industry. Effects of growth retardants on Verbena X hybrida have not been previously studied in Ethiopia. As a result, growers frequently receive complaints from their clients on matters pertaining to the product quality which includes poor rooting performance and stretching of growth during propagation. Determining the effect of growth retarding chemicals on the growth responses of stock plants and subsequent rooting performance of cuttings obtained from the respective stock plants of Verbena hybrida and establishing the optimum application rate would be therefore mandatory to be competitive in the global market. Moreover, the availability of such knowledge will apparently encourage other investors to join this emerging business. Thus, this study was initiated to determine the effect of individual and combined applications of Cycocel and Alar on growth of stock plants and subsequent rooting ability of cuttings of Verbena X hybrida cultivar 'Vegas Scarlet'.

MATERIALS AND METHODS

Study Area: The study was conducted under greenhouse condition at Florensis Ethiopia plc, located at Koka town, South-Central Ethiopia 110 km away from the capital city Addis Ababa. Geographically, the area is situated at 8°, 26'N latitude and 39°, 02' E longitude at an altitude of 1595 meters above sea level (The temperature and relative humidity within the greenhouse were kept in the range of 18 to 30°C and 55 to 70%, respectively. In the propagation unit temperature and relative humidity were maintained in the range of 24 to 29°C and 75 to 85%, respectively using a computerized system (Priva Greenhouse Systems).

Materials: Stock plants used for the study were established from rooted cuttings of Verbena (Verbena X hybrida) cultivar 'Vegas Scarlet' released by Florensis Breeding Department which is located in Quedlinburg, Germany. Cultivar 'Vegas Scarlet' is well known for its vigorous growth and popular red flower color. At present, this cultivar covers the majority of the export volume of Florensis Ethiopia plc. The two plant growth retardants used for the experiment were Cycocel® (Chlormequat chloride) (BASF Asia Pacific Pvt. Ltd) and Alar® (Daminozide) (Chemtura Chemical Co.).

Experimental Design and Treatments: The experiment was executed in two phases. The first phase of the experiment was laid out in a 4x4 factorial arrangement with a complete randomized design (CRD) consisting of three replications. The treatments consisted of two different

growth retardants (each with four different levels). Accordingly, Alar (Daminozide) was leveled at concentrations of 0g/L, 1g/L, 2g/L and 3g/L and Cycocel (Chlormequat chloride) at concentrations of 0ml/L, 0.5ml/L, 1ml/L and 1.5ml/ L. Then the treatment combinations were randomly assigned to the experimental plots and replicated three times.

During the first phase experiment, rooted cuttings of the selected cultivar were planted in round plastic pots having a capacity of 1.5L filled with growing media. Application of the treatments to the stock plant was commenced when the rooted cuttings developed sufficient foliage and when the leaves fully expanded to the edge of the pot (Six weeks after planting) using hand sprayers. Each plot was sprayed uniformly with respective treatments until the foliage of the plants became sufficiently wet. This was done early in the morning at a week interval for eight consecutive weeks as per the recommendations of [17]. Other management practices and follow-ups were implemented uniformly to all the stock plants as per the operational procedures of the farm at Florensis Ethiopia plc.

Soon after completion of all observations on stock plants, the second phase of the experiment was launched with twenty cuttings consisting of one pair of leaves collected from each plot. The size of the cuttings was determined to be 2 cm long as per the export standard of the farm. The cuttings were subsequently rooted under mist in a propagation house using rooting flat tray filled with peat moss. This experiment was done with the same design and layout used for phase one of the experiment. Evaluation of the rooting performance of the cuttings was carried out when all cuttings had well developed shoots with three pairs of leaves.

During the planning and execution of the study due care was provided to the esthetical and safety issue related with the use of the chemicals. To this end, the study was conducted with full approval of the ethical committee of JUCAVM and all safety and ethical procedures were taken into consideration at each and every stage of the experiment.

Methods

First Phase Experiment: Two weeks after the last spray, data were recorded from randomly sampled six stock plants on parameters pertaining to growth and cutting yield. Accordingly, internode lengths were recorded by measuring the distance between the adjacent nodes of the main stem. In addition, the main stem length of stock plants was measured from the crown to the uppermost point of the stem. Lengths of both parameters were measured using a standard ruler. Stem diameter of the main stems of the sampled stock plants was measured starting 5cm above the surface of the media using standard (digital) Verneir Caliper. Number of main branches on the main stem of stock plants was counted.

Stock plants were uprooted and the roots thoroughly washed with clean water to determine the shoot and root fresh weight of the respective stock plants using digital sensitive balance (EX-2000 with maximum precision level of 0.1mg). Then after, the samples were placed into an oven (70°C) for 24 hours to dry them to a constant weight. Cuttings were collected from the remaining ten stock plants in each experimental plot at weekly interval (four times) and the total number of harvested cuttings per stock plant was recorded.

Second Phase Experiment: Evaluation of the rooting performance of the cuttings was carried out when all the cuttings formed well developed shoots with three pairs of leaves. Subsequently, the total number of adventitious roots per cutting was counted. Root fresh weight of the cuttings was measured using digital sensitive balance and their dry weight was recorded after placing them into an oven (70°C) for 24 hours to dry them to a constant weight. The mean root length of the cuttings was measured starting from the point of attachment on the cutting to the final tip of the roots and the resulting values were averaged for recording. In order to determine the mean percentage of the rooted cuttings, the number of cuttings that rooted was divided by the total number of cuttings struck for rooting and the resulting value was multiplied by 100 to arrive at the percentage of rooted cuttings.

Statistical Analysis: The data of all parameters considered in the study were subjected to the Analysis of Variance (ANOVA) and estimation of correlation using SAS version 9.2 computer software [18]. LSD procedures at 0.05 probability level of significance were used to find out differences between treatment means whenever the treatment effects were found to be significant.

RESULTS

First Phase Experiment

Internode Length: A highly significant ($P<0.01$) interaction effect among different concentrations of Alar and Cycocel was observed on internode length of stock plants. Consequently, the shortest internode length (3.88cm) was observed from the combined application of

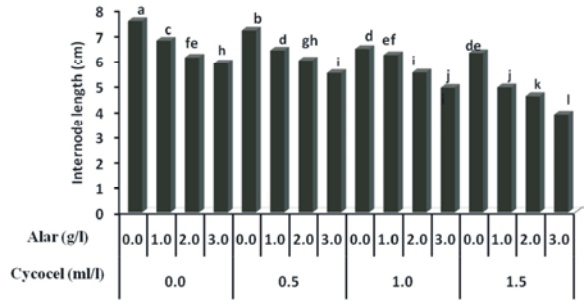

Fig. 1: Interaction effect of Cycocel and Alar on internode length of stock plants. Means followed by different letters are significantly different at the 5 % level of probability

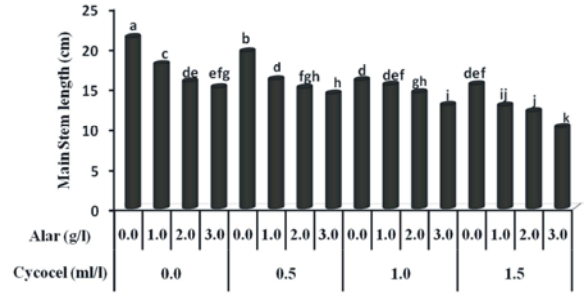

Fig. 2: Interaction effect of Cycocel and Alar on main stem length of stock plants. Means followed by different letters are significantly different at the 5 % level of probability

1.5 ml L^{-1} CCC and 3 g L^{-1} Alar. Conversely, the longest internode length (7.56cm) was recorded from non treated stock plants. Furthermore, an increase in either of the growth retardants concentration resulted in decreasing the mean length of stem internode of the treated stock plants (Fig. 1)

Main Stem Length: This study also revealed that the interaction effect of Cycocel and Alar on main stem length was highly significant ($P<0.01$). A similar scenario was observed for internode length wherein treatment combination of higher concentration of Cycocel and Alar produced the minimum main stem length (10.15cm) while non treated stock plants resulted in the maximum main stem length (21.35cm) (Fig. 2).

Stem Diameter: Irrespective of the concentration of Alar, treatment with Cycocel resulted in highly significant ($P<0.01$) variation in respect of stem diameter. Regarding the effect of Alar on stem diameter of stock plants, a significant variation ($P<0.05$) was noticed among the different concentrations. However, the interaction effect between Cycocel and Alar was not statistically significant

Table 1: Effect Cycocel and Alar on stem diameter

Factors and Levels	Mean
Alar	
0 g L^{-1}	1.37^{b}
1 g L^{-1}	1.37^{b}
2 g L^{-1}	1.38^{ab}
3 g L^{-1}	1.40^{a}
Cycocel	
0 ml L^{-1}	1.27^{c}
0.5 ml L^{-1}	1.36^{b}
1ml L^{-1}	1.43^{a}
1.5ml L^{-1}	1.45^{a}
LSD	0.0214
SE (±)	0.007
CV (%)	1.86

Means followed by different letters are significantly different at the 5% level of probability; ml=milliliter; g=gram; SE=Standard Error; CV=Coefficient of variation

($P>0.05$) in respect of stem diameter. As a trend, stem diameter was found to be directly proportional to the concentration of both Cycocel and Alar. In other words, with higher concentrations, higher stem diameter was obtained. Among concentrations of Cycocel, application of 1.5 ml L^{-1} produced significantly the maximum stem diameter (1.45mm) which however was at par with 1ml L^{-1} (1.43 mm). Stock plants with no application of Cycocel, on the other hand, resulted in significantly minimum stem diameter (1.27mm) followed by application of 0.5 ml L^{-1} (1.36mm). In case of Alar, application of 3 g L^{-1} was revealed significantly higher stem diameter (1.40 cm) which nevertheless was not statistically different from application of 2 g L^{-1} (Table 1).

Number of Main Branches: With regard to the effect of growth retardants on branching of stock plants, A highly significant ($P<0.01$) interaction effect was detected among the different concentrations of Cycocel and Alar. Subsequently, the maximum number of branches (14.35) was observed from treatment combination of 1 ml L^{-1} CCC and 2 g L^{-1} Alar, which however was not significantly different from combined application of 1 ml L^{-1} CCC and 1 gL^{-1} Alar. As indicated in Figure 3, the number of branches per plant followed an increasing trend with each additional levels of application of the two growth retardants, however, the number of branches trended to e decline beyond the treatment combination of 1 ml L^{-1} CCC X 2g L^{-1} Alar.

Root Fresh Weight: A highly significant ($P<0.01$) interaction effect among the different concentrations of Alar and Cycocel was observed on root fresh weight.

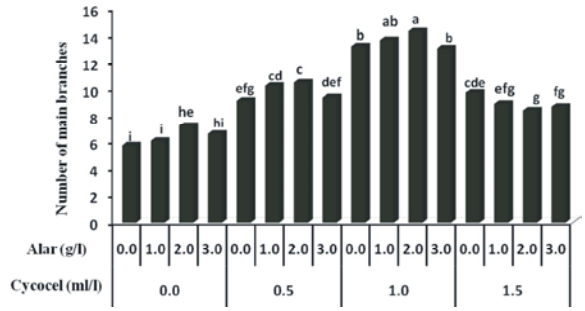

Fig. 3: Interaction effect of Cycocel and Alar on number of main branches of stock plants. Means followed by different letters are significantly different at the 5% level of probability

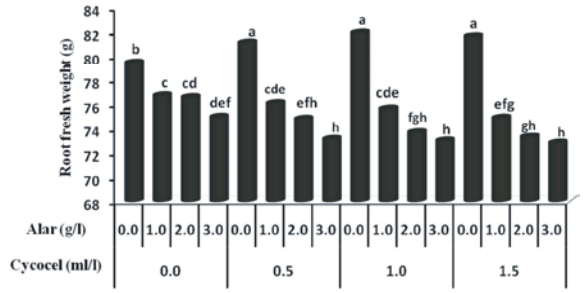

Fig. 4: Interaction effect of Cycocel and Alar on root fresh weight of stock plants. Means followed by different letters are significantly different at the 5% level of probability

The maximum root fresh weight (82.01g) was obtained from application of 1ml L^{-1} CCC X 0g L^{-1}Alar. However, this result was at par with the effect of applying 1.5ml L^{-1} CCC X 0g L^{-1} Alar (81.70g) and 0.5ml L^{-1} CCC X 0g L^{-1} Alar (81.20g). Whereas, significantly the minimum root fresh weight (72.86g) was obtained from the combined application of 1.5 ml L^{-1} CCC and 3 g L^{-1} Alar, which was still not significantly different from result obtained owing to the application 0.5 ml L^{-1} CCC X 3 g L^{-1} Alar (73.17g), 1ml L^{-1} CCC X 2g L^{-1} Alar (73.74g), 1ml L^{-1} CCC X 3g L^{-1} Alar (73.04g) and 1.5ml L^{-1} CCC X 2g L^{-1} Alar (73.35g) (Fig. 4).

Root Dry Weight: The interaction effect among the different concentrations of Cycocel and Alar on root dry weight was found to be significant ($P<0.05$). As depicted in Figure 5, the maximum root dry weight (16.17g) was obtained from the application of 1.5ml L^{-1} CCC X 0g L^{-1} Alar. However, it was still statically identical with untreated stock plants (15.94g), 0.5ml L^{-1} CCC X 0g L^{-1} Alar (16.01g) and 1ml L^{-1} CCC X 0g L^{-1} Alar (15.91g). On the other hand, the minimum value was registered from

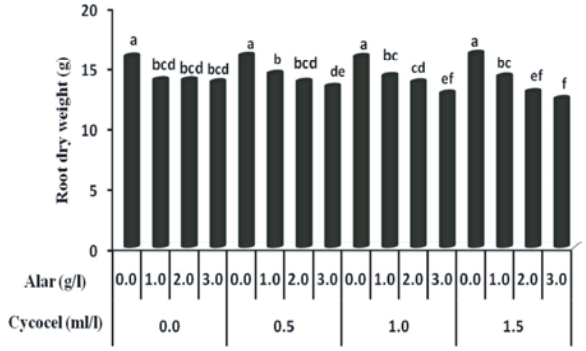

Fig. 5: Interaction effect of Cycocel and Alar on root dry weight of stock plants. Means followed by different letters are significantly different at the 5% level of probability

plants that received combined application of 1.5 ml L^{-1} CCC and 3 g L^{-1} Alar (12.39 g) which however was not significantly different from the combined treatments of 1.5ml L^{-1} CCC X 2g L^{-1} Alar (12.97g) and 1ml L^{-1} CCC X 3g L^{-1} Alar (12.84g).

Shoot Fresh Weight: There was a significant interaction effect between Cycocel and Alar in terms of shoot fresh weight of stock plants ($P<0.05$). In this regard, the maximum shoot fresh weight (229.80g) was recorded from the non treated stock plants while the minimum shoot fresh weight (196.74g) was observed from the combined application of 1.5ml L^{-1} CCC and 3g L^{-1} Alar which nevertheless was not significantly different from result imparted by the application of 1.5ml L^{-1} CCC X 2g L^{-1} Alar (198.48g) and 1.5ml L^{-1} CCC X 1g L^{-1} Alar (200.44g). The results of this study confirmed that shoot fresh weight was inversely proportional to the concentration of both Cycocel and Alar. Each additional amount of Alar and Cycocel applied resulted in an additional reduction of shoot fresh weight (Fig. 6).

Shoot Dry Weight: There was a highly significant ($P<0.01$) interaction effect between the different concentrations of Alar and Cycocel on shoot dry weight. Subsequently, the untreated stock plants attained significant superiority from the rest of the treatments by exhibiting the maximum shoot dry weight (57.84g). In contrast, the minimum shoot dry weight was obtained from the combination of 1.5ml L^{-1} CCC and 3g L^{-1} Alar (35.81g) which however was statically comparable results obtained with application of 1.5ml L^{-1} CCC X 2g L^{-1} Alar (36.87g) and 1.5 ml L^{-1} CCC X 2 g L^{-1} Alar (37.15 g) (Fig. 7).

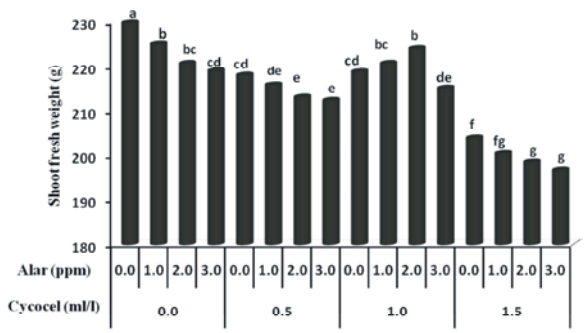

Fig. 6: Interaction effect of Cycocel and Alar on shoot fresh weight. Means followed by different letters are significantly different at the 5% level of probability

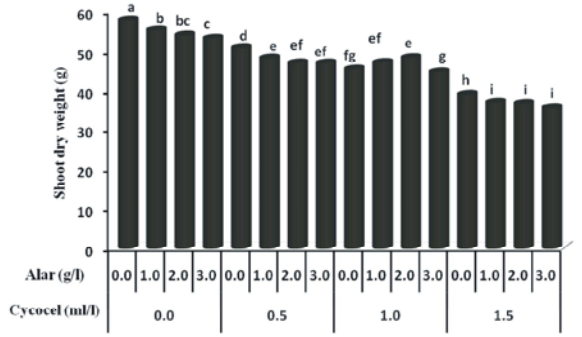

Fig. 7: Interaction effect of Cycocel and Alar on shoot dry weight. Means followed by different letters are significantly different at the 5% level of probability

Table 2: Effect of Cycocel and Alar on number of cuttings per stock plant

Factors and Levels	Mean
Alar	
0 g L^{-1}	69.4^{b}
1 g L^{-1}	69.9^{ab}
2 g L^{-1}	70.4^{a}
3 g L^{-1}	69.6^{b}
Cycocel	
0 ml L^{-1}	66.2^{c}
0.5 ml L^{-1}	68.7^{b}
1ml L^{-1}	75.0^{a}
1.5ml L^{-1}	69.2^{b}
LSD	0.7325
SE (±)	0.25
CV (%)	1.26

Means followed by different letters are significantly different at the 5% level of probability; ml=milliliter; g=gram; SE=Standard Error; CV=Coefficient of variation

Number of Cuttings: With regard to the total number of harvestable cuttings per stock plant a highly significant (P<0.01) difference was observed among the different concentrations of Cycocel regardless of the concentrations of Alar. Similarly, independent of Cycocel concentrations, spraying of stock plants with different concentrations of Alar resulted in a significant (P<0.05) variation in the number of cuttings harvested from each plant. On the contrary, there was no significant (P>0.05) interaction effect between Cycocel and Alar in respect of the number of cuttings produced per stock plant.

The results in Table 2 depict that among concentrations of Cycocel significantly maximum number of cuttings was obtained from stock plants treated with 1ml L^{-1} CCC (75.0) followed by 1.5 ml L^{-1} CCC (69.2). On the other hand, stock plants that received no CCC (0ml L^{-1}) produced significantly the minimum number of cuttings (66.2). Concerning Alar, significantly the maximum number of cuttings acquired by spraying plants with 2g L^{-1} (70.4) which however was at par with effect caused by 1g L^{-1} (69.9). Similar to that of Cycocel, the minimum number of cuttings per plant (69.4) was obtained from treatments without Alar (0g L^{-1}). Though the number of cuttings showed a trend of increment with increasing concentration of both retardants, no further rise was achieved with rates greater than 1 ml L^{-1} CCC and 2 g L^{-1} Alar.

Correlation among Evaluated Parameters: The present study unveiled that number of main branches was highly significant and positively correlated with number of cuttings and stem diameter (r=0.93** and r= 0.65**, respectively). On the other hand, e a significantly negative correlation was noticed between stem length (r = -0.29*) and shoot dry weight (r = -0.31*). Stem length demonstrated a highly significant and positive correlation with internode length (r = 0.96**), shoot fresh weight (r = 0.75**), shoot dry weight (r = 0.78**), root fresh weight (r = 0.66**) and root dry weight (r = 0.71**). Conversely, it exhibited a highly significant but negative correlation with stem diameter (r = -0.69**). Likewise, it had a significant and yet negative correlation with number of cuttings (r=-0.34*). Moreover, root dry weight was highly significantly and positively associated with internode length and root fresh weight (r = 0.77** and 0.90**, respectively). Apparently, a significant positive correlation was noticed between root fresh weight and shoot fresh weight having a correlation coefficient of r =0.30* (Table 3).

Second Phase Experiment

Subsequent Rooting Performance: The treatment of stock plants with growth retardants bore a significant effect on

Table 3: Bi-variate correlation coefficients among evaluated parameters

	IL	NB	SD	SL	RDW	RFW	SDW	SFW	NC
IL	-								
NB	-0.19	-							
SD	-0.66**	0.65**	-						
SL	0.96**	-0.29*	-0.69**	-					
RDW	0.77**	-0.03	-0.26	0.71**	-				
RFW	0.73**	-0.08	-0.26	0.66**	0.90**	-			
SDW	0.75**	-0.31*	-0.84**	0.78**	0.28	0.26	-		
SFW	0.73**	0.03	-0.61**	0.75**	0.34*	0.30*	0.90**	-	
NC	-0.26	0.93**	0.65**	-0.34*	-0.08	-0.11	-0.32*	0.02	-

**,* = statistically significant difference at 1% and 5% probability level, respectively. IL=Internode length (cm); NB=Number of main branches; SD=Stem diameter (mm); SL=Stem length (mm); RDW=Root dry weight (g); RFW=Root fresh weight (g); SDW=Shoot dry weight (g); SFW=Shoot fresh weight (g); NC=number of cuttings per stock plant

Table 4: Interaction effects of Cycocel and Alar on number of roots, root volume, percentage of rooted cuttings, root fresh weight, root dry weight and root length

	Mean				
Treatment combinations	NR	PR (%)	RL (cm)	RFW (g)	RDW (g)
0 ml^{-1} L CCC X 0 g^{-1} L Alar	7.80f	92.80	7.20	1.550	0.039
0 ml^{-1} L CCC X 1 g^{-1} L Alar	8.27ef	90.27	7.42	1.540	0.041
0 ml^{-1} L CCC X 2 g^{-1} L Alar	8.97abc	93.33	7.56	1.557	0.042
0 ml^{-1} L CCC X 3 g^{-1} L Alar	9.13abc	92.70	7.17	1.573	0.041
0.5 ml^{-1} L CCC X 0 g^{-1} L Alar	8.43de	90.00	7.61	1.503	0.039
0.5 ml^{-1} L CCC X 1 g^{-1} L Alar	8.80bcd	93.10	7.17	1.560	0.039
0.5 ml^{-1} L CCC X 2 g^{-1} L Alar	9.37a	93.23	7.58	1.560	0.040
0.5 ml^{-1} L CCC X 3 g^{-1} L Alar	9.13abc	92.00	7.31	1.580	0.040
1 ml^{-1} L CCC X 0 g^{-1} L Alar	8.47de	92.10	7.43	1.560	0.040
1 ml^{-1} L CCC X 1 g^{-1} L Alar	8.67cde	93.30	7.48	1.557	0.041
1 ml^{-1} L CCC X 2 g^{-1} L Alar	9.17ab	94.13	7.17	1.597	0.041
1 ml^{-1} L CCC X 3 g^{-1} L Alar	8.87bcd	93.33	7.62	1.573	0.041
1.5 ml^{-1} L CCC X 0 g^{-1} L Alar	8.83bcd	92.67	7.28	1.583	0.040
1.5 ml^{-1} L CCC X 1 g^{-1} L Alar	8.73bcde	90.83	7.44	1.567	0.041
1.5 ml^{-1} L CCC X 2 g^{-1} L Alar	9.07abc	92.03	7.49	1.593	0.041
1.5 ml^{-1} L CCC X 3 g^{-1} L Alar	8.83bcd	93.23	7.43	1.573	0.041
S.E±	0.16	0.88	0.14	0.02	0.001
LSD	0.175	ns	ns	ns	ns

Means followed by different letters are significantly different at the 5% level of probability; ml=milliliter; g=gram; SE=Standard Error; CV=Coefficient of variation; LSD=Least significant difference; NR=Number of roots per cutting; RFW=Root fresh weight; RDW=Root dry weight; RL=Mean Root length; PR=Percentage of rooted cuttings; RV=Root volume

the subsequent rooting performance of cuttings. Concomitantly, there was a significant ($P<0.05$) interaction effect among different concentrations of Alar and Cycocel on the number of roots per cutting. The maximum number of roots per cutting (9.37) was obtained from cuttings that were collected from stock plants treated with 0.5ml L^{-1} CCC X 2g L^{-1} Alar which however was not significantly different from those treated with 0ml L^{-1} CCC X 3g L^{-1} Alar (9.13), 0ml L^{-1} CCC X 2g L^{-1} Alar (8.97), 0.5ml L^{-1} CCC X 3g L^{-1} Alar (9.13), 1ml L^{-1} CCC X 2g L^{-1} Alar (9.17) and 1.5ml L^{-1} CCC X 2g L^{-1} Alar (9.07) (Table 4).

DISCUSION

Like several bedding plants, Verbena may begin to stretch, developing long, thin, spindly stems after transplanting which forces growers to use some sort of growth retardation to reduce plant height of bedding, potted and woody ornamentals [19]. Chemical growth retardations are broadly used to control the height plants in the greenhouse during production of cuttings here in Ethiopia. However, the effectiveness of chemical growth retardants usually varies with location, type of chemicals, application methods, plant species and even varieties.

Based on results of the present study it has been observed that different concentrations of Cycocel and Alar influence the internode and main stem length of stock plants. The findings are in line with the effect already observed in Erysimum marshallii [19].

Elongation of both internode and stem length are based on two cellular processes: cell division (based on cell number) and cell expansion or elongation which are mainly driven by gibberellins [7, 20, 21]. Growth retardants such as Cycocel are known to inhibit gibberellins biosynthesis in the cell [22].

The occurrence of variation in stem diameter due to the influence of Alar and Cycocel might be attributed to the stimulation of cell production in the cambium, accompanied by a delay in cell differentiation and to an increase in cell volume of the parenchymatous cortical cells [33]. This is in agreement with the results obtained by [24] in chrysanthemum using Alar. The authors justified that an increase in stem diameter might be due to the transverse cell expansion and division in the sub-apical tissues which deviates from the custom orientation of plants cells during cell expansion.

The substantial influence of the combined applications of the two chemical growth retardants on the number of main branches might be attributed to the synergetic effects of the two growth retardants in checking the apical dominance through reduced levels of endogenous production of auxins which in turn might have induced the sprouting of vegetative buds. Plant growth retardants work by interrupting cell division in the sub-apical meristem of the shoot which result in activating lateral buds to grow and fill in with more number of main branches [4]. Under normal circumstances, apical dominance from the shoot apex can prevent lateral bud growth. Such possible explanation was also forwarded by other authors [25, 26, 27]. Irrespective of concentrations, CCC was found to increase significantly number of branches per plant even under salt stresses [28].

The reduction of root fresh and dry weight due to the combined application of the two growth retardants could be associated with their synergic influences on the alteration of endogenous auxin level which causes the restricted growth of root system and subsequently limited production of carbohydrate [29]. According to [30], the rooting ability of cuttings is highly dependent on the accessibility of stored carbohydrate and the level of auxin which plays an important role in its mobilization. Despite the above mentioned explanations, contradictory reports have also been mentioned. For instance, according to [31] root growth is less affected, or slightly promoted with main roots often longer and thicker by growth retardants application. Such discrepancies in respect of the effect of growth retardants on root fresh and dry weight might be associated with the level concentrations, type, frequency and time of application.

Similarly, the stock plants treated with different concentrations of mixed retardants exhibited reductions in both shoot fresh and dry weights. These might be attributed due to the reduced stem length and thickness and moreover to less biomass accumulation in the plant tissue. Correspondingly, these results are coherent with previous reports of [32, 29].

The maximum number of harvestable cuttings obtained from the stock plants treated with 1 ml L^{-1} CCC might have resulted from the increased branching response of the stock plants to Cycocel. As the number of branches increases, a rise in the number of cuttings would be obvious. [33] similarly reported an enhancement in the number of branches per plant by increasing the concentration of Cycocel up to 250 µg mL^{-1}.

CONCLUSION

The results in the present study contribute to the booming floriculture industry in Ethiopia in enhancing the production of cuttings by promoting more branching stock plants. This could be achieved through treatment of stock plants with optimum concentration of Cycocel and Alar without detracting the rooting quality of the cuttings thereof. One of the main prerequisites for successful production of cuttings is the creation of quality cuttings which subsequently can grow with more branches and compaction habits. Cognizant with the findings of this study, combined applications of Alar and Cycocel have shown valid influence on most of evaluated growth parameters and cuttings yield of the stock plants without causing a significant reduction on subsequent rooting performance of cuttings. From commercial growers' point of view, obtaining the maximum number of quality cuttings is the main concern as it can determine the sustainability of business. To this effect application of 1mlL^{-1} Cycocel, which demonstrated positive influence on cuttings production, can be recommended for use by commercial growers. Among the mixed applications, 1mlL^{-1} CCC and 2g L^{-1} Alar can be considered as a better performing treatment owing to its superiority in respect of increasing the number of main branches.

Moreover, the combined application of Alar and Cycocel which showed a potential influence should be comprehensively studied to come up with a pertinent

recommendation by including other factors like varieties, stage of stock plant for treatment, method and frequency of application and economic feasibilities.

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